EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

Brussels, 24 March 2020

COST 021/20

DECISION

Subject: **Memorandum of Understanding for the implementation of the COST Action "High-performance Carbon-based composites with Smart properties for Advanced Sensing Applications" (EsSENce) CA19118**

The COST Member Countries and/or the COST Cooperating State will find attached the Memorandum of Understanding for the COST Action High-performance Carbon-based composites with Smart properties for Advanced Sensing Applications approved by the Committee of Senior Officials through written procedure on 24 March 2020.

MEMORANDUM OF UNDERSTANDING

For the implementation of a COST Action designated as

COST Action CA19118
HIGH-PERFORMANCE CARBON-BASED COMPOSITES WITH SMART PROPERTIES FOR ADVANCED SENSING APPLICATIONS (EsSENce)

The COST Member Countries and/or the COST Cooperating State, accepting the present Memorandum of Understanding (MoU) wish to undertake joint activities of mutual interest and declare their common intention to participate in the COST Action (the Action), referred to above and described in the Technical Annex of this MoU.

The Action will be carried out in accordance with the set of COST Implementation Rules approved by the Committee of Senior Officials (CSO), or any new document amending or replacing them:

a. "Rules for Participation in and Implementation of COST Activities" (COST 132/14 REV2);
b. "COST Action Proposal Submission, Evaluation, Selection and Approval" (COST 133/14 REV);
c. "COST Action Management, Monitoring and Final Assessment" (COST 134/14 REV2);
d. "COST International Cooperation and Specific Organisations Participation" (COST 135/14 REV).

The main aim and objective of the Action is to develop an innovation science and technology hub at European and International level, on advanced composite materials reinforced with CNMs for sensing applications. Main focus is to combine manufacturing technologies with innovative nano-enabled composite materials for fabrication of smart devices with new functionalities. This will be achieved through the specific objectives detailed in the Technical Annex.

The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at EUR 124 million in 2019.

The MoU will enter into force once at least seven (7) COST Member Countries and/or COST Cooperating State have accepted it, and the corresponding Management Committee Members have been appointed, as described in the CSO Decision COST 134/14 REV2.

The COST Action will start from the date of the first Management Committee meeting and shall be implemented for a period of four (4) years, unless an extension is approved by the CSO following the procedure described in the CSO Decision COST 134/14 REV2.

OVERVIEW

Summary

The goal of EsSENce is to develop an innovation scientific hub at European and International level, focusing on advanced composite materials reinforced with Carbon based (nano)materials (CNMs). The sharing of ideas and results will boost the development of high-performance composites with sensing properties. Special focus will be given in the utilisation of these materials for the introduction of smart properties to the final composites and their application in the field of sensors development. The aim of EsSENce hub, defined as a collaborative community, is to gather together scientific partners, research groups, technology providers and industrial key players aiming to enhance creativity and collaboration among them, by positioning the entrepreneurial individuals at the centre. Indeed, by building a community with diversity both in the broad sense (gender, ethnicity) and with regards to heterogeneous knowledge, the emergence of novel ideas and practices is fostered thus leading to unique and viable innovations. EsSENce activities will focus on the promotion of the successful results from the involved partners and the utilization of the synergistic effect to improve exploitation and dissemination of knowledge. Dissemination and management actions will be organised to attract the interest of research and industry for higher awareness. The intention is to enable as many groups as possible to participate in a highly integrated innovation environment, which will develop Workgroups, will organize Workshops and Conferences, as well as Training Schools and Seminars. EsSENce will promote mobility among researchers, junior scientists and students working on these fields, while promoting contacts with related industries.

Areas of Expertise Relevant for the Action	**Keywords**
● Materials engineering: Nanophysics for materials engineering applications ● Nano-technology: Nano-materials and nano-structures ● Materials engineering: Characterization methods of materials for material engineering applications ● Nano-technology: Particle physics for nano-technology applications	● Carbon-based nanomaterials ● Advanced Composites ● Smart Properties ● Sensing ● Mutli-functionality

Specific Objectives

To achieve the main objective described in this MoU, the following specific objectives shall be accomplished:

Research Coordination

● Development of a competitive network, consisting of specialized Working Groups, for the production and assessment of CNMs and advanced composites for sensing applications.
● Establishment of strong liaisons with international business networks through linking and sharing of information to identify current industrial market needs.
● Dissemination of the hub objectives, challenges and results both to specific sector audience (scientific and industrial) and to the large audience through e-platforms and social media.
● Promotion of EU groups contribution to the emergence of new value chains and the aim to take a leading position globally, supporting internationalisation towards third countries beyond Europe.
● Networking and communication with other relevant networks to promote multidisciplinarity and cooperation in the production of CNMs and nanocomposites through dedicated web forum.
● Improved global competitiveness and independence for the EU in the production and commercialization of carbon-based multi-functional products.

Capacity Building

● To promote interdisciplinary work streams using synergies between the participating groups for an efficient exchange of knowledge by taking advantage of the different COST Action tools.
● To contribute to human resources training in new technologies for high-performance nanocomposite

materials with sensing capabilities, favouring the mobility of researchers and promoting the organization of Training STSMs, Workshops and periodic seminars.

● To increase the soundness and visibility of Action's outputs via specific dissemination activities, such as: creating and updating a dedicated website, creating video footage of the most important achievements, publishing joint scientific and technical articles, preparing newsletters, inviting industry to workshops and organizing material technology showrooms.

● To bridge networks with international bodies and associations, such as the European Materials Modelling Council, the Carbon Fibres and Advanced High-Performance Cluster or conferences on overlapping topics (GOCarbon, JEC forum, EU Conference on Composite Materials, ECCM, etc.)

● To connect at national and international level with projects (including H2020 and Horizon Europe) dealing with this topic and to consolidate the Consortium of research groups with complementary skills and know-how in order to increase the success rate in future EC funded proposals.

TECHNICAL ANNEX

1 S&T EXCELLENCE

1.1 SOUNDNESS OF THE CHALLENGE

1.1.1 DESCRIPTION OF THE STATE-OF-THE-ART

Carbon-based nanomaterials (CNMs) such as carbon nanotubes (CNTs), carbon nanofibres (CNFs), nanodiamonds, carbon dots, graphene and its derivatives, have attracted the large interest of the scientific community because they can act as an additional and multifunctional reinforcement, due to their intrinsic mechanical, electrical, thermal, optical and chemical properties. Major research areas are those related to the development of nanocomposites with high thermal and electrical conductivity, electromagnetic interference, shielding ability, flexibility and transparency, as well as low coefficient thermal expansion, which are complemented by excellent mechanical properties. However, earlier contributions on this subject reveal that the improvements imparted from nanomaterials (NMs) are severely restricted either by the dispersion level or by the interfacial bonding, remaining lower than theoretical predictions. Therefore, the optimization of the mixing and processing conditions is of paramount importance to avoid the presence of undesirable agglomerates and to delay reagglomeration phenomena. The dispersion of CNMs is a critical issue that has hindered their industrial application, requiring the incorporation of higher loadings of fillers than those that would be anticipated. In pristine state, NMs tend to form agglomerates with strong cohesive strength, promoted by van der Walls forces or additional π-π stacking between separately layered structures. Remaining agglomerates reduce the fraction of NMs available for the formation of continuous conductive pathways and can act as microcenters of stress concentration. Another important bottleneck refers to the inherent difficulty in recycling and reusing CNMs-based composite, due to:

1. most nanocomposites are still based on thermosets resins
2. nanocomposites are multiscale materials
3. integrated devices including nanocomposites are difficult to be recycled.

Apart from these, NMs have opened a new horizon for high-performance composites with smart properties for advanced sensing applications. A new way to monitor composite components arose from the integration of sensors directly into the materials and a lot of damage monitoring concepts have already been developed. In addition, some pilot applications already exist especially in the automotive, aerospace and wind energy sector. The used monitoring approaches include measurement methods such as integrated strain gauges, continuous fibre-optic sensors, integrated acceleration sensors, sensor networks, Carbon Fibre (CF) based sensors and lamb wave measurement concepts. The research carried out so far on nanocomposites containing CNTs and graphene has shown that an enhanced piezoresistive sensitivity can be attained by i) using hybrid nanofiller systems (combining CNTs with GnPs), ii) changing the aspect ratio of nanofillers, iii) modifying mixing and processing conditions, and iv) improving matrix-filler interactions. The influence of these parameters on the piezoresistive behaviour has been widely investigated for thermoplastic polyurethanes (TPU) nanocomposites. However, an overview of the literature reveals that only a few number of studies dealing with CNMs, as neuron sensory networks, for advanced composites are available. A considerable gap between laboratory successes and real industrial applications can also be found. Therefore, the integration of electrically conductive nanofillers in advanced composites is a promising route for in-service health monitoring and damage sensing, avoiding complex downtime inspection, improving lifetime and efficiency, and reducing costs. Finally, various technologies, employing functionalized magnetic nanoparticles (MNPs) in an operational synergy with CNTs, have been developed for on-off /

in-chip detection of organic pollutants and showed great potential for environmental monitoring applications. Additionally, a wide range of biosensors, such as antibody-based biosensors (i.e. electrochemical and optical immunosensors), enzymatic-based biosensors (i.e. voltammetric detection) and DNA biosensors (i.e. optical/magnetic/ fluorescent tag biosensors) have been reported using ink-jet and screen-printing technologies.

Going forward, it is clear that realising the potential of CNMs for sensing applications and theis widespread integration into sensing devices, necessitates the continued efforts in the areas of size selective synthesis, purification and separation of CNMs and upgrading of the existing manufacturing processes.

1.1.2 DESCRIPTION OF THE CHALLENGE (MAIN AIM)

The goal of EsSENce is to develop an innovation scientific & technological (S&T) hub at European and International level, focusing on advanced composite materials reinforced with CNMs for sensing applications. The demand for advanced composites that have been reinforced through the addition of carbon-based materials (CMs) and CNMs, as for example CNTs and/or graphene nanoplates (GnPs), is steadily increasing during the last five years and it is estimated to be continuously rising by at least 10% per year until 2025. This steadily increased industrial demand is driven mostly by aerospace and defence sector, followed by automotive, civil engineering, marine, electronic devices, renewable energy, medical sector and sport equipment business. Most of the forecasts about NMs agree on a market growth that is expected for the next years, with overall CAGR values between 12–25% while the nanocomposites market size is expected to exhibit a CAGR of 24.2% over 2019-2025. Regarding CNMs fillers, graphene is identified as one of the systems with the highest commercialization potential and thus many companies are seeking for mass/low cost manufacturing methods. For CNTs, the CAGR expected for the 2015-2023 period is around 22%. However, the expenditure of production of high quality CNMs is still high and one of the current challenges for the industrial up-take is the cost and the scalability.

The main focus of the scientific community is to combine advances in manufacturing technologies with the development of innovative nano-enabled composite materials for the fabrication of lightweight smart devices with structural performance and improved and/or added new functionalities including sensing and detection. The advent of sensors in many different applications, like environmental monitoring, monitoring constituents in food products, security, gas sensing as well as diagnostics and human health monitoring, has led to the ever-growing modification of existing processing and manufacturing routes by incorporating advanced carbon-based reinforced composites offering multi-functionality. Among the applications of CNMs composites, lightweight and smart sensors which will provide highly accurate and real-time monitoring functions in different equipment and devices without the cost of structural integration, is the area that is particularly focused on EsSENce. The main challenges to be addressed for a more resource- and cost-efficient as well as sustainable industrial implementation of CNMs composite sensors, demand the cooperation of R&D forces to shorten innovation cycles for the targeted applications.

Exploitation of CNMs, in terms of sensing, is identified in various user cases: strains sensors, biosensors, chemical sensors (as gas detectors), structural sensors and optical sensors, just to name a few. Overall, CNMs may allow the production of flexible sensors with superior sensitivity. The CNMs are also able to detect damage in advanced smart composites, avoiding the influence on the mechanical performance of composites promoted by large stress perturbations, occurred during conventional testing. However, the production of CNMs still faces a certain number of defects, which will lead to varied materials quality thus influencing the performance and stability of resulting sensors; high quality production processes need to be considered with the consequent impact in terms of costs. On the other hand, due to their high sensitivity, the effect of temperature and humidity on the sensor's response is generally relevant, which constitute an additional challenge for these technologies. New opportunities have arisen with the emergence of nanotechnologies and NMs for developing the next generation of integrated sensors for either in-service damage sensing or structural health monitoring (SHM) of advanced composites. Since continuous conductive networks comprising ultralow contents of nanofillers are susceptible to external mechanical stimuli, these NMs have been exploited as promising *in-situ* strain sensors with both tunable sensitivity and strain range. Self-sensing concepts, based on conductive nanofillers, allow the highly sensitive detection of defects even at the early stage just when they are initiated. Meanwhile, by enhancing the properties of matrix-rich or -dominated regions, which are the 'Achilles heel' in composites, catastrophic failure can be avoided. For all the above reasons,

CNMs have gained great interest in a wide range of industrial markets, and, therefore, will be the focus of attention for the members of the EsSENce network. Technical challenges need to be addressed, from the filler's functionalization to the development of robust and versatile CNMs; passing through characterization and modelling techniques and material design methodologies. EsSENce aims to leverage the knowledge of a wide network of experts, consisting of SMEs, research Institutes and Industries, for establishing new scientific and technological routes and be able to confront the increasing competition to spread and successfully enter new market opportunities.

The aim of EsSENce hub, which is defined as a collaborative community, is hence to gather together scientific partners, research groups, technology providers and industrial key players to enhance sharing of ideas and collaboration among them, by positioning the entrepreneurial individuals at the centre. The EsSENce hub is expected to lead and guide the S&T development in the targeted field; furthermore, provide continuously R&D resources for the advancement in this field. Indeed, by building a community with diversity both in the broad sense (gender, ethnicity etc.), as well as with regards to heterogeneous knowledge that different community members will bring in, the emergence of novel ideas and practices is fostered thus leading to unique and viable innovations. **Dissemination and management actions** will be creatively organised and effectively promoted to engage a variety of groups to participate in a highly integrated innovation environment, acting with specific activities: Working Groups (WGs), Workshops, Conferences dedicated to smart CNMs composite manufacturing, characterisation and applications, Short Term Scientific Missions (STSMs), Training Schools and Seminars. Mobility among established researchers, junior scientists and students working in the relevant fields will be promoted, while also enhancing their contact with the related industry. Cross-fertilization between different disciplines and research streams will be created by taking advantage of COST Network tools.

The **uniqueness of EsSENce hub** lays on the fact that the developed Network will:

- Serve as a most efficient intelligence tank with abundant S&T results, know-how and experience, which can be circulated in a most effective way.
- Provide the most accurate and fasted help for both academia and industry in the related area(s). Update the progress, S&T as well as industrialization, most efficiently.
- Constitute a campaign that most relevant researchers/developers and potential professionals can learn from and contribute fairly to both academia and industry.
- Assist local, regional, national and international policy, rules or roadmap making.

The hub will be a unique opportunity for all the involved people to share ideas about innovative solutions and joint efforts to create new composite materials that are particularly applicable in specific uses, which were previously not possible due to the use of conventional monolithic materials, such as polymers/plastics, metals, glass, and ceramics. This hub will provide a platform to combine existing knowledge and to identify common issues and problems derived from industrial needs as specified from the industrial COST Network partners. Novel processes and new, lighter high-performance composite materials with smart and tailored properties will be used in highly demanding and emerging industries in order to introduce sensing properties for their applications. EsSENce will contribute to a shared vision and effort to positioning Europe as world-leader in implementing innovative solutions in vibrant and strategic sectors for the European industry giving support to the further industrial exploitation of NMs.

1.2 PROGRESS BEYOND THE STATE-OF-THE-ART

1.2.1 APPROACH TO THE CHALLENGE AND PROGRESS BEYOND THE STATE-OF-THE-ART

The efforts of EsSENce participants will focus on combining their expertise, to speed up progress with increased synergies towards the generation of innovative research solutions and methodologies in order to fabricate high-performance nanocomposites with enhanced sensing properties for applications in various industrial sectors. An effective way to increase the properties of nanocomposite materials refers to the use of novel NMs such as metal nanoparticles, CNMs, quantum dots and polymer nanoparticles. Moving the current state-of-the-art a step further, EsSENce will study the synergetic effect of these NMs and how their combined attributes could lead towards the desired properties. Hybrid mechanisms, including combination of CNMs with other types of NMs, could lead to enhanced physicochemical properties in relation to final composite sensing performance. The transfer and exchange of relevant know-how will lead to the development of new strategies and technologies for the manufacturing and up-scaled production of such systems and fabrication techniques, mainly related with quality control. New developments are also ongoing, enabling greater energy efficiency on their manufacturing (due to easier processing, more automatic, shorter cycle times, and lower curing temperatures used)

considering strict requirements on health and safety. Aiming for higher resource- and cost-efficiency, methodologies for recycling and/or upcycling material streams along the process will be developed, identified and optimized. Long-term technological innovations and developments will focus on promoting recycling of nanocomposite wastes and identifying new value chains within EsSENce partners to achieve reusability of smart composite materials. Therefore, a more sustainable and circular flow in the R&D as well as production processes will be achieved, according to the Agenda 2030 for Sustainable Development.

COST offers by far the most appropriate framework for EsSENce, as it aims to bring together the existing expertise from different national initiatives in the larger EU-region to study the potential of CNM composites as lightweight, high-performance, multi-functional materials for a wide range of applications, with a special emphasis on those addressing the advent of novel smart devices with unprecedented sensing properties. An educational and coaching support strategy is foreseen, which will include preparation and review of training events, including practical and commercial value mentoring. Also, individual training in scientific and transferable skills, as well as training in complementary disciplines and entrepreneurship will be part of the training process. The training program will be designed to enhance the employability of diverse groups. It will include high quality training, taking into account gender diversity, through interdisciplinary knowledge transfer and research collaboration. Training on entrepreneurial skills and competences will empower young researchers with advanced knowledge, communication techniques, and support them to get familiar with business models. The EsSENce hub will act as a real "springboard" for all the groups involved, to help them gain access to global value chains and develop long-term strategic partnerships. They will benefit from specialised business support services, such as through the organisation of international study visits, STSMs, partnering or “matchmaking” missions that facilitate finding new partners outside their own region for research and prototyping as well as for bringing products and services to the market. This will also create new exciting opportunities of growth for SMEs and "spin-offs". The complexity of EsSENce requires a multi-technique approach: exchange of experience on the development of innovative and integrated methodologies for synthesis, functionalization, characterisation, advanced processing methodologies and engineering of carbon-based nanocomposites that will promote and implement new perspectives for science and technology. This Action will link European scientists and technology teams with expertise in the field of CNMs and advanced nanocomposites manufacturing, characterization and modelling as well as in the field of sensor development.

1.2.2 OBJECTIVES

1.2.2.1 Research Coordination Objectives

EsSENce, will bring together experts from different countries, either COST Member countries, COST Inclusiveness Target Countries (ITCs), Near Neighbour Countries (NNCs) and International Partner Countries (IPCs), to establish a business network of collaborations across borders and sectoral boundaries, to transfer and disseminate the existing knowledge and innovations on CNMs and nanocomposites for sensing applications. Without the proposed cooperation this is not easily to be achieved. Subsequently, the initial group will attract additional European and International research groups to fully explore the potential of CNM composite materials in a wide variety of engineering and technological areas, such as medical sector, automotive, constructions, aerospace and renewable energy.

EsSENce will also contribute to fostering the development of European Strategic Cluster Partnerships (i.e. European meta-clusters) by helping research institutes, SMEs and industries find easier access to global value chains and engage in long-term cooperation with strategic partners.

The main objectives are:

1. Development of a competitive network, consisting of specialized Working Groups, for the production and assessment of CNMs and advanced composites for sensing applications.
2. Establishment of strong liaisons with international business networks through linking and sharing of information to identify current industrial market needs.
3. Dissemination of the hub objectives, challenges and results both to specific sector audience (scientific and industrial) and to the large audience through e-platforms and social media.
4. Promotion of EU groups contribution to the emergence of new value chains and the aim to take a leading position globally, supporting internationalisation towards third countries beyond Europe.

5. Networking and communication with other relevant networks to promote multidisciplinarity and cooperation in the production of CNMs and nanocomposites through dedicated web forum.
6. Improved global competitiveness and independence for the EU in the production and commercialization of carbon-based multi-functional products.

1.2.2.2 Capacity-building Objectives

EsSENce has three general capacity-building objectives: i) synergizing a critical mass of scientists and research groups working in relevant fields; ii) training of potential professionals and young researchers; iiists) creating bridges to implement the proposed solutions together with the industrial stakeholders. This will be done in compliance with COST policies, e.g. assuring gender balance in Working Groups (WGs) and tasks with specific responsibilities and promoting ECI participation as independent researchers: trainers in Training Schools, Lecturers in Workshops, leaders of high-end research projects implemented in the frame of STSMs.

The following **specific objectives** are aimed to be achieved:

1. To promote interdisciplinary work streams using synergies between the participating groups for an efficient exchange of knowledge by taking advantage of the different COST Action tools.
2. To contribute to human resources training in new technologies for high-performance nanocomposite materials with sensing capabilities, favouring the mobility of researchers and promoting the organization of Training STSMs, Workshops and periodic seminars.
3. To increase the soundness and visibility of Action's outputs via specific dissemination activities, such as: creating and updating a dedicated website, creating video footage of the most important achievements, publishing joint scientific and technical articles, preparing newsletters, inviting industry to workshops and organizing material technology showrooms.
4. To bridge networks with international bodies and associations, such as the European Materials Modelling Council, the Carbon Fibres & Advanced High-Performance Cluster or conferences on overlapping topics (GOCarbon, JEC forum, EU Conference on Composite Materials, ECCM, etc.)
5. To connect at national and international level with projects (including H2020 and Horizon Europe) dealing with this topic and to consolidate the Consortium of research groups with complementary skills and know-how in order to increase the success rate in future EC funded proposals.

2 NETWORKING EXCELLENCE

2.1 ADDED VALUE OF NETWORKING IN S&T EXCELLENCE

2.1.1 ADDED VALUE IN RELATION TO EXISTING EFFORTS AT EUROPEAN AND/OR INTERNATIONAL LEVEL

EsSENce has a relevant added value in relation to some existing COST Actions (ended and running) in the areas of composite research, nanomedicine, high-resolution characterization, manufacturing (following list), but no Networks addressing advanced high-performance nanocomposites for sensing applications were identified. EsSENce intends to leverage the previous efforts of these past COST Actions towards a timely and efficient completion of the proposed objectives. To this end, EsSENce intends to organize at the onset of the project a workshop where representatives of this past Actions listed below are exposed to the planned developments. This event will play a fundamental role in bridging this effort with past or ongoing complementary endeavours, and in bridging distinct scientific communities with a shared interest in the development and use of novel carbon-based nanocomposite materials.

- CA15107| Multi-Functional Nano-Carbon Composite Materials Network (MultiComp), 2016-2020.
- CA18132| Functional Glyconanomaterials for the Development of Diagnostics and Targeted Therapeutic Probes, 2019-2023.
- CA17140| Cancer nanomedicine - from the bench to the bedside, 2018-2022.
- CM1302| European Network on Smart Inorganic Polymers, 2013-2017.
- MP1403| Nanoscale Quantum Optics, 2014-2019.
- MP1202| Rational design of hybrid organic-inorganic interfaces: the next step towards advanced functional materials, 2012-2016.

- MP1302| NanoSpectroscopy, 2013-2017.
- MP1303| Understanding and Controlling Nano and Mesoscale Friction, 2013-2017.
- TD1204| Modelling Nanomaterial Toxicity, 2012-2012.
- MP1201| Nanoscale Superconductivity: Novel Functionalities through Optimized Confinement of Condensate and Fields, 2012-2016.
- TD1003| Bio-inspired nanotechnologies: from concepts to applications, 2010-2014.
- MP0903| Nanoalloys as advanced materials: from structure to properties and applications, 20102014.
- MP0901| Designing novel materials for nanodevices - from Theory to Practice, 2009-2013.
- MP1206| Electrospun nano-fibres for bio inspired composite materials and innovative industrial applications, 2013-2017.
- TU1207| Next Generation Design Guidelines for Composites in Construction, 2013-2017.
- MP0902| Composites of Inorganic Nanotubes and Polymers (COINAPO), 2009-2013.
- MP0701| Composites with Novel Functional and Structural Properties by Nanoscale Materials (Nano Composite Materials-NCM), 2008-2012.

EsSENce will also focus in building close ties with the Graphene FET flagship, whose aim is to bring together academic and industrial researchers to take graphene from the realm of academic laboratories into European society in the space of 10 years, thus generating economic growth, new jobs and new opportunities. Moreover, the collaboration with existing clusters, such as the Carbon Fibres & Advanced High Performance Cluster (CFPC), the European Technology Platform for Advanced Engineering Materials and Technologies (EuMAT), the Alliance for Materials (A4M), the Global Scientific *Association* on Advanced *Carbon Fibers* (GSAC) as well as other existing initiatives, will give the opportunity for future collaborations and enable interested teams to go forward to apply for joint research projects under the scope of the forthcoming Horizon Europe programme.

2.2 ADDED VALUE OF NETWORKING IN IMPACT

2.2.1 SECURING THE CRITICAL MASS AND EXPERTISE

The relevance of the proposed Network lays on the connection between high-quality research groups specialized in different aspects of the development and characterization of CNMs, advanced composites and end-users of structures and components with sensing functions. The synergies that occur between these stakeholders are essential for achieving innovative and sustainable solutions. The network comprises of leading scientists from all relevant fields involved with CNMs, while also includes universities, research institutes and industries spread over most of the European countries and over COST International Partner countries. EsSENce aims to create a structure of this network, ensuring balance between different research areas as well as between academic research and industrial use. Network is carefully composed in order to include all the expertise required and provide access to the facilities needed, in order to reach the ambitious aim of this Action.

EsSENce will gather together pre-existing specialist teams and networks, created informally through current and former EU research funded projects, which are listed below. These teams and networks mainly focus on research in nanocomposites and CNMs and will establish an overarching hub within which they can collaborate and distribute know-how and establish expertise towards the development of new understanding and applications of materials with sensing properties. The main goal is the coordination and the integration of the scientific achievements of the existing and completed funded R&D projects, in order to generate a broad knowledge-base for the entire field of carbon-based nanocomposites. This collaboration will foster the European research in this specific area and increase the competitiveness with USA and Asian countries where massive coordinated R&D programmes are currently being organised.

- H2020 (814588) | Recycling and Repurposing of Plastic Waste for Advanced 3D Printing Applications (REPAIR3D) | 2019– 2023.
- H2020 (760779) | Smart by Design and Intelligent by Architecture for turbine blade fan and structuralcomponents sys tems (SMARTFAN) | 2018– 2022.
- H2020 (685844) | Modified cost effective fibre based structures with improved multi-functionality and performance (MODCOMP) | 2017– 2020.
- H2020 (722626) | Fibre break models for designing novel composite microstructures and applications (FiBreMoD) | 2017 –2020.

- H2020 (690638) | Ecological and Multifunctional Composites for Application in Aircraft Interior and Secondary Structures (ECO-COMPASS) | 2016 –2019.
- ERASMUS+ | Improvement of innovative teaching methods in the fields of Technology and
- Chemical Engineering according to the best standards of the Bologna Process (InnoChem) | 2014-2017
- FP7 (246389) | Advanced materials enabling High-Volume road transport applications of lightweight structural Composite parts (HIVOCOMP) | 2010 – 2014.
- FP7 (314935) | Radio Frequency Sensing for Non-Destructive Testing of Carbon Fibre Reinforced Composite Materials for Structural Health Monitoring (COMP-HEALTH) | 2012 – 2014.
- FP7 (262355) | Development of energy efficient / lightweight composite parts and tooling based on Tailored Fibre Placement technology / self-heating technology (EMBROIDERY) | 2011 – 2012.

By engaging these specific partners to collaborate, new and existing knowledge related to CNMs will be combined, integrated and further exploited, in order to bridge existing gaps identified form the industrial partners. The composition of the Network, including groups with synergic expertise on NMs and/or sensor development, processing, characterisation and modelling, as well as dealing with complementary objectives and challenges, increases the possibilities for the Action's success and spans its impact over several streams of work. The formed Network will be open, and the goal is to continuously evolve over time by incorporating new partners, thus representing a gateway for scientists from respective countries to join the effort and participate in STSMs, ITC Conference Grants Competitions, etc.

2.2.2 INVOLVEMENT OF STAKEHOLDERS

The development of an open environment for knowledge and skills sharing is of high interest for companies related to the CNMs industry as well as sensing devices and indeed they have already shown strong interest in the hub proposed by EsSENce. The interest is high in (nano)composite producing companies as well as in sensing applications end-users which are distributed in many market segments. Relevant stakeholders will be involved in order to investigate new approaches or techniques. Industrial stakeholders will be invited to the activities of this hub in order to create synergies between the research and commercial parts of the topic. An additional type of relevant activities are workshops and material show-cases, involving researchers from the Network and relevant stakeholders (such as producers of CNMs and nanocomposites, or end-users of those materials), in order to disseminate the most practical aspects reached within this Action and to facilitate the application of these innovative materials both in existing and new market niches.

2.2.3 MUTUAL BENEFITS OF THE INVOLVEMENT OF SECONDARY PROPOSERS FROM NEAR NEIGHBOUR OR INTERNATIONAL PARTNER COUNTRIES OR INTERNATIONAL ORGANISATIONS

The initial EsSENce Network comprises of experts from 39 countries across the world, who expressed an interest to join this COST Action. This partnership includes 7 NNC countries distributed among Europe, Asia and Africa, as well as an International partner from America. The involvement of the aforementioned partners in EsSENce will empower the Network, since new insights and needs will be transferred from the out-Europe countries, both on a technological and an economical point of view. Several of the NCC partners are dealing with high-tech industrial sectors, such as aerospace/space industry, where the CNMs will play a crucial role with the sensing ability that they can offer. Additionally, there are partners from NCCs, who are experienced in the exploitation of natural resources and they can offer raw materials. NNC partners will be benefited from EsSENce, since they will find new funding opportunities, they will have access to advanced facilities and infrastructure and they will gain experience. Moreover, NCC partners will be able to find solutions to current needs, that were difficult to overcome, due to low funding or lack of experience. Due to the different mentality and the regional peculiarities, a multidisciplinary knowledge transfer can be achieved, adopting new educational and training strategies (online educational platforms, e-learning, etc). At the end, an international market of EsSENce outcomes will be set, that can be exploited in the future for expanding Europe's business and industrial activities.

3 IMPACT

3.1 IMPACT TO SCIENCE, SOCIETY AND COMPETITIVENESS, AND POTENTIAL FOR INNOVATION/BREAK-THROUGHS

3.1.1 SCIENTIFIC, TECHNOLOGICAL, AND/OR SOCIOECONOMIC IMPACTS (INCLUDING POTENTIAL INNOVATIONS AND/OR BREAKTHROUGHS)

It is widely accepted that CNMs and nanocomposites have penetrated many applications and EsSENce is expected to have significant impact on scientific, technological and socioeconomic level.

Scientific: High impact can be expected in the scientific field, since strengthening the cooperation between first class EU and International Research and Technological Development Centres will accelerate the exchange of know-how and expertise across centres and countries. Moreover, this transnational perspective will enable the mobility of researchers among the involved research parties and facilitate shared access to the available facilities (e.g. pilot plants). This interactivity will also lead to the preparation of high-impact publications or even new advanced level IP (e.g. establishment of new patents), beyond the present state of science. The implementation of the described hub is expected to result in practically applicable solutions and methodologies, thus promoting the establishment of new collaborations and the launch of new joint research projects (e.g. in the forthcoming Horizon Europe), while also creating young research experts through joint training programs.

Technological: The initial intention is to enable the development of innovative CNMs while taking into consideration, the cost efficiency of the processes in combination with their environmental impact. Moreover, in order to improve the final properties of the produced carbon-based nanocomposite materials, innovative perspectives will be initialized as a result of the formed network, by employing novel precursors for the synthesis of these materials and novel surface functionalization approaches to improve matrix-fibre interactions. The know-how transfer will also impact on the establishment of advanced characterization tools (in-line probes, e.g. Raman, etc.) as well as the development of new nanocomposites and tailored products-by-design thanks to modelling tools. In this context, the main technological impact will enable the broadening of the field of applications of CNMs composites, which can be achieved through STSMs, between CNMs producers and composites manufacturers.

Socioeconomic: Market opportunities for European industries will be enhanced, by introducing new low-cost composites reinforced with CNMs. The prevention or the reduction of waste generation and the decreasing of production costs, will lead to lower product pricing and further expansion into previously unexploited markets. Another important asset will be the enhancement of the durability and performance of structures and components (cost reduction for maintenance and repair, improving consumer safety). Emphasis will be also given in the promotion of a sustainable industrial carbon-based production and resource efficiency. Finally, a recycling plan will be adopted towards the establishment of a circular economy in order to boost global competitiveness. New pathways for recycling of carbonbased nanocomposites for multiple processing life cycles will influence key industrial sectors, e.g. sports, automotive, medical, etc. and will reduce the landfill waste and the carbon footprint. This will increase Europe's competitiveness and lower overall product cost, which would represent a major economical breakthrough.

The **main breakthrough of EsSENce** will be the formation of a S&T hub and the subsequent establishment of a strong scientific network and a technology roadmap for synthesizing and processing of carbon-based nanocomposites with special focus on the introduction of sensing properties. EsSENce will tackle the main challenges that many researchers face across the world, such as lack of (experimental) infrastructure, insufficient experience with specific methods and techniques or inadequate funding and will pave the way for translating research discoveries and innovations to industrial applications. Consequently, the Action's strategy will focus on facilitating the transition of science-based information into a business context, highlighting the use of stakeholder dialogues and interferences in key value chains. This will require working with representatives of large and small industries from all parts of the world and with related stakeholders, ranging from consumers to nongovernmental organizations and research organisations. The engagement of all these experts in the proposed hub will effectively allow for the development of novel research ideas, the opportunity to enrich the involved laboratories with novel methodologies and thus further exchange knowledge and expertise, increase the number of publications and technological innovation, boosting European competitiveness in this strategic sector.

In this context, EsSENce will target the following issues:

- Enhancement of the international mobility of scientists among universities, research institutes, and industries through STSMs (at least 12 per year).
- Opportunities for new EU and International funded research programs, thus facilitating access to infrastructure and research data.
- Establishment of guidelines and Codes of good practices referring to the synthesis and characterization processes of carbon-based nanocomposites.
- Transfer technologies to industrial users and even encouraging the participating groups to get involved in the creation of spin-off companies.

3.2 MEASURES TO MAXIMISE IMPACT

3.2.1 KNOWLEDGE CREATION, TRANSFER OF KNOWLEDGE AND CAREER DEVELOPMENT

EsSENce will focus on the organisation of Training schools, Workshops, Seminars, Conferences, Roundtables and STSMs, in order to encourage the Network partners to engage in collective and mutually supportive Actions. Knowledge on innovation deployment and training for new skills are of importance in developing a critical mass of researchers and new career opportunities. Knowledge tranfer on using new techniques and materials is of equal significance. EsSENce activities will incorporate young researchers and new members, identified through the Network, involving training activities such as hands-on, online courses and STSMs. EsSENce will force the development of new business models as well as financing and funding schemes and engagement leading to economic growth. In this way, high-quality individualised training in scientific/transferable skills and network-level training in interdisciplinary skills will be ensured. Training will include preparation and review of educational events, including practical mentoring. Motivation for conferences participation from young researchers will be achieved through offering "Best Poster Awards", "Best Pitch Awards", etc.

Additionally, individual training in scientific and transferable skills, and training in complementary disciplines and entrepreneurship will be part of the training process. The training program will be designed to enhance employability. Trainees will receive a firm grounding in the skills needed to carry out their work, and a unique understanding of the interface between the different disciplines. Young researchers will have the opportunity to be actively involved and they will enable the transfer of knowledge through all the relevant training activities. The participants will be also able to contact other organizations soliciting their support and participation in dissemination activities. EsSENce will enable the dissemination of know-how as well as the development of activities to maximize the value of the project and lay the foundations for innovation in this field. Coaching will also include personal effectiveness courses (including assertiveness, creativity, design thinking, negotiation skills, networking), time management and effective planning, teamwork and will provide the steps for transition from a theoretical implementation to a market-oriented implementation. The training program will include:

- High quality, individualized training through a demanding research program and local-level academic and on-the-job training in scientific and transferable skills.
- Interdisciplinary knowledge and experience through research collaboration, training secondments sharing of and net-work level lectures and workshops.

Main activities will focus on the exploitation and diseemination of the successful results, know-how and experience from the involved partners, promotion of seamless communication between academia and industry as well as encouragement, education and training of other researchers and potential professionals. A key priority for the established Network will be the knowledge dissemination towards young scientists and researchers, striving for excellence, and their empowerment in order to exploit their full potential towards new S&T achievements. Last but not least, acknowledging gender differences as well as differences in motivation within the Network is important as a two-tier ecosystem is not sustainable.

3.2.2 PLAN FOR DISSEMINATION AND/OR EXPLOITATION AND DIALOGUE WITH THE GENERAL PUBLIC OR POLICY

The dissemination and exploitation measures and strategy to be implemented during the lifetime of this Action but also afterwards, are:

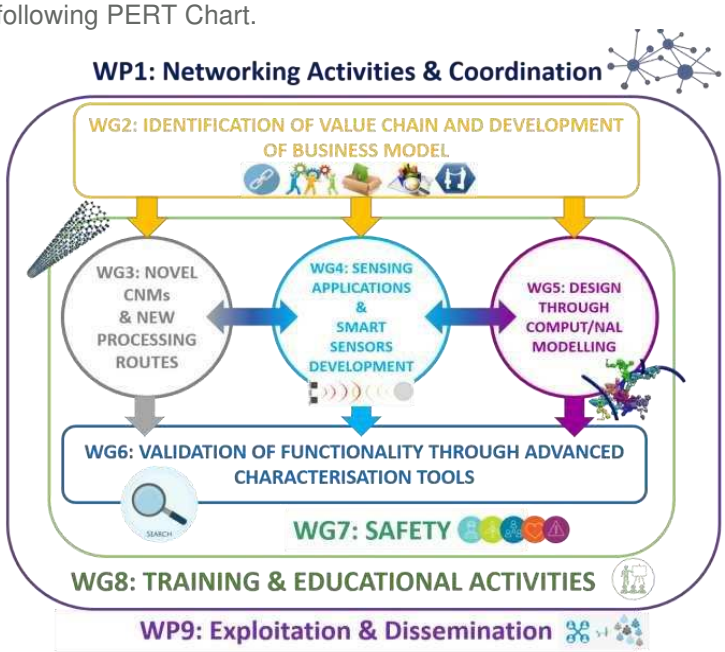
1. Project website with updated information of the progresses of each WG and optico-acoustic material of the most important achievements.
2. Annual Newsletters for the general public, companies, public entities, EC, etc and web forum to interact with relevant Networks.
3. Joint Review articles (at least 5) in high-quality scientific journals and technical magazines. 4. Participation of Early Career Investigators in relevant conferences via the COST ITC Conference Grants Program.
4. Social media networks participation (facebook, linkedin, etc.) to promote EsSENce activities.
5. Periodic workshops and seminars on local areas at least twice per year.
6. New annual conference with focus on CNMs.
7. Establishment of an Open Innovation Environment incorporating all the produced data in an Open Access Database to ensure that research data will be easily discoverable, accessible, assessable and intelligible, usable beyond the original purpose for which they were collected.
8. Sharing of well documented processing analysis tools, e.g. MATLAB scripts developed by researchers to process and analyse data.
9. Elaborate “white” or “position” papers which present recommendations and best practices on high-performance nanocomposites and their applications.

4 IMPLEMENTATION

4.1 COHERENCE AND EFFECTIVENESS OF THE WORK PLAN

4.1.1 DESCRIPTION OF WORKING GROUPS, TASKS AND ACTIVITIES

The work plan is organized in nine complementary Working Groups (WG), each one devoted to a progressive development of synthesis, characterization, processing, integration and modelling aspects, development of smart materials with sensing applications, validation of their functionality, safety and standardisation, training, dissemination and communication. The interconnections between the WGs are presented in the following PERT Chart.



WG1: NETWORKING ACTIVITIES & COORDINATION

WG1 will strategically coordinate various network activities aiming to promote interdisciplinary communication, synergies, knowledge exchange, and access to COST Action tools. Annual Meetings will be organised, to gather all stakeholders and scientists of the different communities, by synchronising scientific sessions, WG meetings, courses, and end-user sessions. WG1 will also ensure that knowledge exchange is promoted through the Action’s events. WG1 will also work with the Management Committee (MC) to select candidates for local organisation of events and manage the applications for educational events. Moreover, the aim of WG1 is to promote the enrichment of the initial Network with

the engagement of new scientists and researchers either from the industrial or the academic field, by considering the gender balance and the empowerment of young researchers and innovators. Within this WG, S&T core groups will be established for each one of the following WGs.

WG2: IDENTIFICATION OF VALUE CHAIN AND DEVELOPMENT OF BUSINESS MODEL

WG2 will focus on the collection of all relevant data from the involved end-users and setting the key aspects and priorities that will define the backdrop for future commercial and policy developments. The main goal is to identify existing gaps in common industrial processes along with the main challenges that the industrial partners are currently facing towards technology advancements and the launch new smart products to the market. This information will shape the core S&T strategy to be adopted during implementation of EsSENce and define the ways to expand S&T fields by adding sensing properties. WG2 will work on innovative ways to involve and connect academia and industrial partners to practical sessions, where end-users and scientists/researchers will meet to discuss and identify commercial market gaps and industrial challenges that need to be tackled. Validation of S&T development strategy will be performed on the basis of new Business Models development and identification of new value chains in the relevant industrial sectors. For this, partners from industry will interact with academics/researchers to find cost-effective routes for large scale manufacturing.

WG3: NOVEL CNMs & NEW PROCESSING ROUTES

Within WG3, new processing routes for nanocomposites manufacturing will be investigated. Developing the processing–manufacturing technologies in terms of scale up and value for commercialization will be one of the biggest challenges. WG3 will try to overcome issues related with the processing of carbonbased nanocomposite materials, through intense knowledge exchange between different labs by organising STSMs and practical exercises in nanocomposites manufacturing. By this, the main challenges that are faced will be overcome; i.e. dispersion issues of nanoparticles or chemical compatibility with matrix materials, alignment of nanoparticles in the composite matrix that can be critical to maximize unidirectional properties such as strength, modulus, and toughness. This WG will also interact with WG5, to study the carbon nanofiber-matrix interfacial adhesion. Scale up is also needed to produce large quantities of NMs for manufacturing purposes, as well as to define the best practices for nanocomposites manufacturing in larger scale, for real applications. Due to the future changes in the guidelines for the disposal of NMs, which no longer permit landfill or incineration in waste incineration plants, it will be necessary to invest in the development of new recycling technologies that permit the establishment of closed material cycles. The value retention can be significantly increased by specifying the material flows in collaboration with industrial partners from different sectors.

WG4: SENSING APPLICATIONS & SMART SENSORS DEVELOPMENT

WG4 is seeking to explore properties of CNMs in sensing & smart sensors platforms. Research in the area of design and fabrication of sensors and/or composite materials with sensing properties as well as in actuators to enhance standard inspection techniques, has become of great interest to a variety of scientific communities ranging from biological and chemical sciences to engineering communities. Several tools and techniques for detection, based on the latest trends in NMs, and micro- and nanotechnologies are offering new opportunities for the development of composites with sensing properties. CNMs are emerging as reliable and powerful tools for sensing various compounds (e.g. heavy metals, phenolic compounds and pesticides) being offered at the same time as efficient destroying agents with interest for industrial applications. Moreover, CNMs with optical properties (e.g. carbon quantum dots) could be considered for smart sensing applications. Through EsSENce, knowledge will be exchanged between partners engaged in the NMs and nanocomposite synthesis and partners with expertise in sensors development. This integration will lead to sensing technologies with advantages such as high sensitivity and selectivity, rapidness, and cost efficiency.

WG5: DESIGN THROUGH COMPUTATIONAL MODELLING

WG5 is seeking to establish a community of European and International stakeholders in the process of developing and improving simulation tools in order to bring the development of CNMs and advanced high-performance composites into end products more successfully. It will stimulate the development and use of “standard” or widely agreed modelling protocols, particularly for those methods commonly used to characterise nanocomposite materials. It will provide a forum to identify the needs of the community considering both experimental characterisation and modelling points of view. EsSENce will place focus of attention in liaising with expert groups in the emerging field of Deep Learning, in the purpose of setting up collaboration avenues for the automated modelling of novel materials using advanced artificial intelligence methods. One of the goals of this WG is also to disseminate these design practices, to assess their applicability in industrial environments and to develop educational tools in order to spread

them as much as possible in the large community dealing with advanced highperformance carbon-based nanocomposites.

WG6: VALIDATION OF FUNCTIONALITY THROUGH ADVANCED CHARACTERISATION TOOLS

The specifics of an investigation technique can be suitable to explore specific structural, physical or chemical aspects, yet may exclude others. Furthermore, micro- and nano-scale data complement each other, and their consistent correlation can enable novel perspectives and open new research avenues in all research fields where carbon-based nanocomposites could play key roles, such as automotive, medicine, environment or electronics. One of the objectives of EsSENce in this WG is to design one or more multimodal prototypes that will incorporate a variety of techniques that rely on complementary contrast mechanisms and which operate at different scales, which are relevant for the characterization of CNMs composites and to evaluate their performance in various applications. This multimodal and correlative imaging platform(s) will result in novel characterization frameworks that can enable multiple paradigm shifts en route to dissolving current bottlenecks that impede answering important questions of material science. Such systems will potentially be implemented during the lifetime of the project depending on available financial provisions in the network and identified funding opportunities. Furthermore, an objective that is equally important will be to familiarize scientists conducting research in the synthesis and functionalization of CNMs and composited with latest hour characterization tools (e.g. imaging, spectroscopy, etc), by organizing periodic meetings between the parties involved in instrumentation development and the parties involved in materials science and application development. STSMs that will address the implementation of proof-of-concept experiments in terms of demonstrating the potential usefulness of a novel characterisation tool for carbon-based nanocomposites-oriented research will represent a major focus of attention. This will ensure a speedy penetration of novel valuable characterisation tools in this specific field of research and innovation, accelerating the progress in this connected area. This WG will be closely tied to the progress in WG5, in light of emerging Deep Learning methods for virtual cross-modality imaging.

WG7: SAFETY & STANDARDS

WG7 is seeking to collect the necessary information about the standards that have been developed (such as ISO TC229 and IEC 113) for the synthesis and characterization of CNMs and their composites, as well as all the safety issues that arise during the employment of this type of materials. The standardization process facilitates the transfer of composite CNMs from lab to the market. The extended use of CNMs in both research and industrial environments also demanded the establishment of safety rules for handling them as well as the monomers and precursors employed for their production. The goal is to examine and gather all the health and environment risks posed by the use and the production of this type of materials and hence put safety concerns in perspective. Fundamentally, risk assessment will involve an estimation of the potential for exposure and characterization of hazards.

WG8: TRAINING & EDUCATIONAL ACTIVITIES

This WG will focus on training activities in order to contribute to professional development through advanced training of young researchers and other key staff, research managers, industrial executives, and potential users of the knowledge generated by EsSENce. Training is envisaged as that given by and for personnel working in the hub. Different training approaches will be adopted at various levels:

a) Organisation of four summer schools for high-degree students and young researchers of both academia and enterprises with well-defined focus:

- Summer school N.1 (Y1): Synthesis of innovative CNMs composites
- Summer school N.2 (Y2): Modelling and characterization of CNMs composites
- Summer school N.3 (Y3): Smart sensing applications
- Summer school N.4 (Y4): Business of high performance advanced composite applications

b) Thematic Seminars will be organised in the frame of relevant events and EU funded projects and clusters meetings, in order to further the information and dissemination potential, while optimising the use of the EC funds.

c) STSMs will be also organised in each of the technical WGs in order to provide the opportunity to young researchers to create contacts and establish partnerships with experts across the world.

WG9: EXPLOITATION AND DISSEMINATION

This WG is in charge of internal and external public relations, within and outside the hub. It is responsible for developing and maintaining the web page of this Action, the collection of information from the

scientific WGs in order to improve the exploitation and dissemination of knowledge from the academic society to the end-users. At the beginning of the Action, a dissemination plan will be drafted in order to ensure the adequate coordination between the different Actions and the tools used to implement them, both during and at the end of the Action. Particular focus will be given to the content of communication strategies so as to produce targeted information and to convey clear, simple and straightforward messages in order to ensure the dissemination of the results achieved at local, European and International level.

Meetings and events

National as well international Conferences, Workshops and other events will be attended from all partners in order to ensure wider dissemination of the outcomes. Dedicated Workshops will be also organized in correspondence with relevant events and by the end of the Action.

Publications

- Target audience publications: scientific publications, conference contributions (invited, oral, posters), technical magazines, general audience articles and others (CORDIS news), etc.
- Wide audience publications and development of specialist sessions at relevant Conferences
- Leaflets/brochures that will be distributed at topical events
- Audiovisual publications on electronic medias Periodic newsletters (one issue every year)

Media activities

- Advertisement in newspapers and radio: newspapers and local radio stations will be used to advertise this Action throughout its development. At the same time, radio messages will be broadcast so as to advertise it at a national and local level.
- Press conferences will be held before and after having reached the main Milestones, and before and after conferences and other key events, so as to disseminate the cultural approach of the Action as well as the state-of-the-art of good practices of environmental sustainability

4.1.2 DESCRIPTION OF DELIVERABLES AND TIMEFRAME

DELIVERABLES OF ESSENCE

WG1

D1.1: High-level roundtable discussion with representatives of past and existing relevant EU efforts complementary to this COST Action (**M3**)

WG2

D2.1: Survey and report on industrial needs and main challenges underpinning industrial processes (**M4**)
D2.2: Practical sessions between academia and industry (**M12, M24, M36, M48**)
D2.3: Technology report. Market Overview and Business Models on breakthroughs realised within this Action (**M48**)

WG3

D3.1: Guidelines and Codes of good practices referring to the manufacturing processes of CNM composites (**M12**)
D3.2: Feasibility study and business plan for upscaling the manufacturing technologies of CNM composites (**M36**)

WG4

D4.1: Selection and Report on CNMs nanocomposites for detection technologies and sensing applications (**M28**)
D4.2: Joint papers on advanced sensing applications (**M24, M36, M48**)
D4.3: Development of Open access analysis tools and relevant Platform with Simulation Tools (Beta versions) (**M30**)

WG5

D5.1: Open Access Database with initial and preliminary simulation results of CNM composites (**M10**)
D5.2: Report on simulation methodologies and methods for properties prediction of CNM composites (**M24**)

WG6

D6.1: Design of multimodal characterisation system(s) that incorporate complementary techniques relevant for carbon-based nanocomposites research (**M18**)

D6.2: Roadmap for translating latest hour characterisation technologies into ready to market systems that can assist carbon-based nanocomposite research (**M24**)

WG7
D7.1: Survey on standards for carbon-based nanocomposites (safety issues) and Sensing devices (**M6**)
D7.2: Safe-by design standards and Life Cycle Analysis of CNMs and composites (**M36**)

WG8
D8.1: Workshop on basic process for synthesis and characterization of CNMs (**M26**)
D8.2: Workshop on future trends and novel sensing applications of CNMs composites (**M42**)

WG9
D9.1: Action web-site creation with content for public access and yearly periodic update (**M2**)
D9.2: Dissemination Plan including Workshops, Summer Schools, Conferences, Trainings, STSMs, participation in events. (M5)
D9.3: Call for ITC Conference Grants for Early Careers Investigators in ITC countries conducting research in CNMs composites (**M1, M13, M25, M37**).

MILESTONES OF ESSENCE

M1: Report on requirements for future development in CNMs and composites (**M12**)
M2: Technology Roadmaps on the manufacturing of CNMs, composites and sensing devices (**M42**)
M3: Strategy on the interdisciplinary research programs on CNMs and composites (**M24**)
M4: Agreement on application requirements and trends for future development (**M36**)
M5: Submission of Roadmap on carbon-based nanocomposites for sensing applications (**M36**)
M6: EsSENce Annual Conference to specific sector audience and to the public (**M7, M19, M31, M43**)

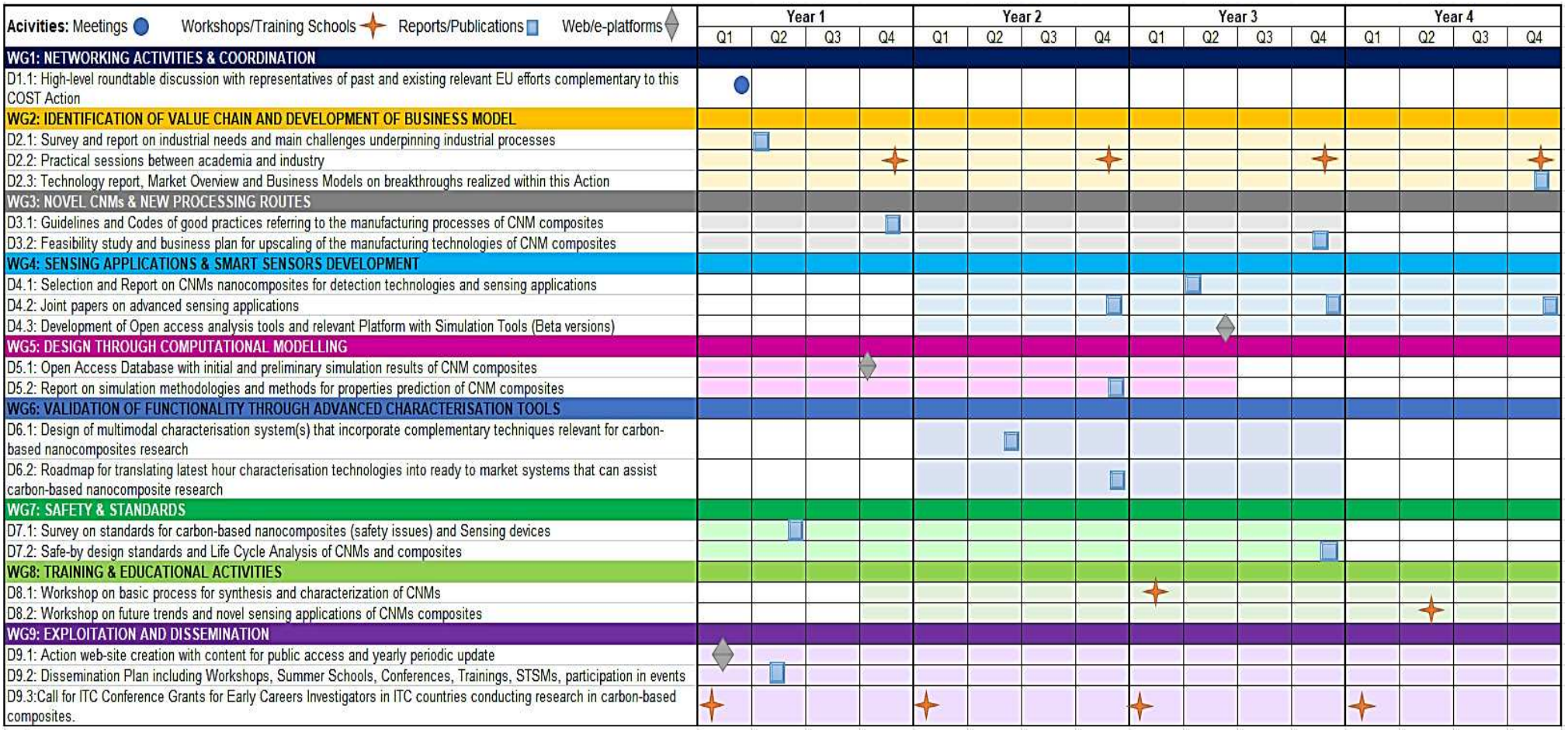
4.1.3 RISK ANALYSIS AND CONTINGENCY PLANS

EsSENce is based on very innovative technologies, thus there are potential risks to be taken into consideration and management will put contingency planning to maximize the effectiveness on the overall flow by determining in advance Actions that will occur during its timeframe. As the described hub involves a consortium of partners across Europe and COST International Partner countries, it guarantees the collaboration between basic research and industrial sectors focusing on the achievement of the Action's objectives. We also seek to publish any negative findings, since this is of importance for technology assessment and can also be of value for future applications. The proposed network is aware of these risk areas. The following table shows the contingency strategy matrix that was established at the outset of this Action.

Table 1. Critical risks for implementation

Description of risk	WGs	Probability	Proposed risk-mitigation measures
Time for the Action's progress/ objectives is underestimated	All	Low	The workflow could be delayed and lead to inconsistencies. Action Chair will be informed by the WGs leaders and take corrective Actions.
Coordination difficulties due to increased number of participants	1	High	Create subgroups and assign more participants to each task. Render decision-making processes simpler and faster.
Insufficient funds to implement the targeted number of STSMs	8	Med	Reduce the individual grant maximum allowance. Search for complementary external funding opportunities.
Multidisciplinary nature of the partners may lead to disciplines working separately	3-7	Low	Responsibilities of each partner have been distributed in a balanced way. This ensures that partners derived from different scientific areas will collaborate transferring the gained knowledge to each other.
Partners fail to communicate effectively	All	Med	This may cause partners to perform research not usable or is duplicated. Issues will be overcome by discussing the problem individually with the concerned partners. Coordinator will provide tools and utilities to facilitate successful communication and collaboration.
Lack of interest from young scientists to join the training schools	8	Med	Promotion of the initiative among participating universities. Correlation with other events to raise awareness.
Difficulties in involving industries in benchmarking due to IP issues	2	High	Provide to industrial partners the opportunity to exploit scientific results for product development towards commericialisation and standardization processes.

4.1.4 GANTT DIAGRAM



REFERENCES

1. Aragay, G.; et al. Recent Trends in Macro, Micro and Nanomaterials Based Tools and Strategies for Heavy Metals Detection, Chemical Reviews, 111 (5), 3433-3458, 2011.
2. Cataldi, P.; et al. Graphene Nanoplatelets-Based Advanced Materials and Recent Progress in Sustainable Applications. Appl. Sci. 2018, 8, 1438.
3. Das, S.; et al. Global Carbon Fibre Composites Supply Chain Competitiveness Analysis; ORNL/SR-2016/100 | NREL/TP-6A50-66071; CEMAC: N'Djamena, Chad, 2016.
4. Gharailou D. A Review of Market Studies in Different Fields of Nanotechnology, StatNano Publications, December 2018
5. Gupta, B.D.; et al. Carbon-Based Nanomaterials for Plasmonic Sensors: A Review, Sensors 2019, 19(16), 3536
6. Hung, P.-Y.; et al. Surface modification of carbon fibre using graphene-related materials for multifunctional composites. Compos. Part B Eng. 2018, 133, 240-257.
7. Koumoulos, E.P.; et al. Research and Development in Carbon Fibers and Advanced High-Performance Composites Supply Chain in Europe: A Roadmap for Challenges and the Industrial Uptake, Journal of Composites Science, 2019, 3(3), 86
8. Kumar, V.; et al. Review of Recent Advances in Nanoengineered Polymer Composites. Polymers2019, 11, 644.
9. Liu, W.-W.; et al. Synthesis and characterization of graphene and carbon nanotubes: A review on the past and recent developments. J. Ind. Eng. Chem. 2014, 20, 1171-1185.
10. Lorca, J.; et al. Multiscale Modeling of Composite Materials: A Roadmap Towards Virtual Testing. Adv. Mater. 2011, 23, 5130-5147.
11. McCrary-Dennis, M.C.L. and Okoli, O.I. A review of multiscale composite manufacturing and challenges. J. Reinf. Plast.Comp. 2012, 31, 1687-1711.
12. Pérez-López, B. and Merkoçi, A. Magnetic Nanoparticles Modified with Carbon Nanotubes for Electrocatalytic Magnetoswitchable Biosensing Applications", Advanced Functional Materials, 2011, 21, 255-260.
13. Punetha, V.D.; et al. Functionalization of carbon nanomaterials for advanced polymer nanocomposites: A comparison study between CNT and graphene. Prog. Polym. Sci. 2017, 67, 1-47.
14. Sahoo, N.G.; et al. Polymer nanocomposites based on functionalized carbon nanotubes. Prog. Polym. Sci. 2010, 35, 837-867.
15. Spitalsky, Z.; et al. Carbon nanotube-polymer composites: Chemistry, processing, mechanical and electrical properties. Prog. Polym. Sci. 2010, 35, 357-401.
16. Witten, E.; et al. Composites Market Report 2016, Market Developments, Trends, Outlook and Challenges; AVK: Frankfurt, Germany, 2016.
17. Yue, L.; et al. Epoxy composites with carbon nanotubes and graphene nanoplatelets-Dispersion and synergy effects. Carbon 2014, 78, 268-278.
18. Zhang, H.; et al. Improved fracture toughness and integrated damage sensing capability by spray coated CNTs on carbon fibre prepreg. Compos. Part A Appl. Sci. Manuf. 2015, 70, 102-110.
19. Zhang, Q.; et al. The Road for Nanomaterials Industry: A Review of Carbon Nanotube Production, Post-Treatment, and Bulk Applications for Composites and Energy Storage. Small 2013, 9, 1237-1265.
20. Zor, E.; et al. Graphene quantum dots-based photoluminescent sensor: a multifuncional composite for pesticide detection, Applied Materials & Interfaces, 2015.