Brussels, 24 March 2020

COST 026/20

DECISION

Subject: **Memorandum of Understanding for the implementation of the COST Action "Protection, Resilience, Rehabilitation of damaged environment" (PHOENIX) CA19123**

The COST Member Countries and/or the COST Cooperating State will find attached the Memorandum of Understanding for the COST Action Protection, Resilience, Rehabilitation of damaged environment 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 CA19123
PROTECTION, RESILIENCE, REHABILITATION OF DAMAGED ENVIRONMENT (PHOENIX)

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 demonstrate the effectiveness of Bio-electrochemical systems for exploiting the biological activity of live organisms for pollutants reduction, recycling of useful elements, synthesis of new products, production of electricity. PHOENIX also aims at evaluating the socio-economics and educational aspect of environmental technology, like BES, for a sustainable-city making process.. 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 36 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.

TECHNICAL ANNEX

OVERVIEW

Summary

Humanity faces unprecedented challenges: global warming, overuse of fossil fuel energy and rapidly growing urbanisation. While the development, validation and cost-efficiency improvement of energy-aware and limited-complexity solutions are becoming increasingly time-consuming, microorganisms represent one realistic hope. For millennia microbes have tirelessly been shaping the Earth's ecosystems and with the right approach, they can help re-introduce environmental equilibrium. PHOENIX aims to demonstrate the effectiveness of Bio-electrochemical systems (BESs); BESs are low environmental impact systems that exploit the biological activity of live organisms for pollutant reduction, recycling of useful elements, synthesis of new products and production of electricity, in the case of microbial fuel cells (MFC). Recent advances in the field of low power electronics enable the exploitation of these sustainable and environmentally-friendly technologies. The activities of PHOENIX will be related to the characterization of BESs technologies and their implementation as bio-remediator, bio-sensors, and bio-reactors connected to sustainable urban planning, educational and socio-economic aspects. The integration of bio-technologies in the urban context is a key priority for appropriate rational urban planning and minimum environmental impact.

Areas of Expertise Relevant for the Action	**Keywords**
● Electrical engineering, electronic engineering, Information engineering: Energy aspects of electrical and electronic engineering ● Environmental biotechnology: Environmental biotechnology, e.g. bioremediation, biodegradation ● Social and economic geography: Socio-economic aspects of environmental sciences ● Electrical engineering, electronic engineering, Information engineering: Sensors and sensor systems ● Educational sciences: Education: training, pedagogy, didactics	● bio-electrochemical system - microbial fuel cell - depollution ● educational and socio-economics aspect of environmental science ● low power electronics - energy harvesting ● wireless sensor network ● sustainable city planning

Specific Objectives

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

Research Coordination

- Identify valorisation possibilities of electroremediation, bioremediation, biosensing and biodegradation technologies;
- Identify the possibilities of enhancing BESs based applications and social response;
- Identify valorisation possibilities of iInteractions between microbial biofilm, biocompatible substrates and electromagnetic fields;
- Identify potentiality of increasing MFCs power density and MFCs stack efficiency;
- Support advancements on surface science related to BESs;
- Stimulate gene regulatory networks kinetic modelling for the design of optimal bioprocesses in biological systems connecting the inter- and intra-regulatory mechanisms focused on added-value products formation;
- Optimization of hardware platform for autonomous WSN and sensing innovations;
- Integration of biotechnology in political decision-making process and city planning for environment preservation and waste recycling. Identification of knowledge gap between science, politics and citizens

Capacity Building

- improve access to knowledge and career formation for students and researchers; producing high-end open access publications and position papers
- enhance dissemination of knowledge between sciences, public institutions, citizens associations

● improve personnel skills, experience and competence, especially for PhD students and ESRs; consortium members will host PhD students and ESRs for knowledge exchange
● promote collaboration and access to established worldwide research infrastructure networks;
● set the scientific objectives for creating opportunities among different domains
● encourage the communication and dissemination of research results with various instruments
● bridge the gaps between research and productive sector, translation into business models;
● foster the uptake of research results, especially by industry and SMEs;

TECHNICAL ANNEX

1 S&T EXCELLENCE

1.1 SOUNDNESS OF THE CHALLENGE

1.1.1 DESCRIPTION OF THE STATE-OF-THE-ART

The protection and rehabilitation activities of environments require a real-time detection of pollutants in the environment and immediate response for remediation. The activity of ecological resilience requires the search for tools based on natural elements to be integrated into the environment, so that a self-repairing process can be established allowing the ecological system to return to its original state. Furthermore, the social impact that follows the application of a technology, as well as the need to probe sustainable and more easily acceptable architectural alternatives to the people, who will benefit the remediation of the environment is critical [Battisti, C., Dodaro, G., & Fanelli, G. (2017). Paradoxical environmental conservation: Failure of an unplanned urban development as a driver of passive ecological restoration. *Environmental Development*, *24*, 179-186]. Wireless sensor network (WSN) constitutes a method of environmental observation and control that offers ample space for research and innovation, from architecture of the network, to specialized and miniaturized sensors, to autonomous power systems (energy harvesting), to transceivers with the lowest consumption but with proper uplink energy management. In order to pursue the above-mentioned goals, it is necessary to integrate research for technological advance with relevant scientific disciplines related to the environment and the society (e.g. territorial and urban planning, environmental engineering, natural sciences, social science and humanities).

We have identified environments and ecosystems that need to be protected, monitored and rehabilitated as examples of areas for intervention. One is a natural lake ecosystem located in the Rome city-centre as an example of ecosystems damaged by urbanization, flawed urban planning and even corruption in the urban design process (Fig. 1). In the lake area, a factory opened in 1922, which ended its activities in 1954 and remains abandoned for decades. In 1992, a natural lake emerged in the area, due to the illegal attempt of the property to build a large shopping centre. During the foundation work, the land was excavated more than 10 metres deep, intercepting the aquifer.

Fig. 1: *Natural lake in Rome as an example of wrong city planning process*

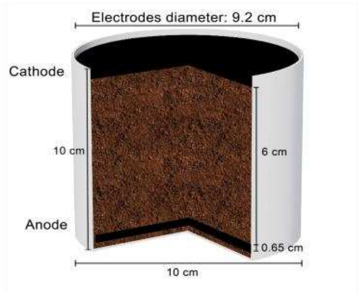
The municipality of Rome, stimulated by the active citizen Committees ("Associazione culturale S.N.I.A."), has expropriated part of the area to realize the "park of energies" and its facilities, that today host local groups of inhabitants and self-managed public services.

This represents an excellent location for in-field scientific experiments, monitoring and evaluation of the technology as well as of course dissemination of all the activities, in cooperation with the public as well as local schools and associations.

Bio-Electrochemical Systems (BESs) are a cost-effective biotechnology that could be used as bio-remediator, biosensor and bioreactor. PHOENIX will join researchers from different countries that work in the field of BES technology and its applications in order to develop standards and approaches for the design, construction, deployment and monitoring of BESs. BESs are exploited in multiple fields, for example Microbial Fuel Cells (MFCs) as bio-electrochemical converters for rendering organic waste into a useful resource that is transformed in energy and nutrients. A stack of MFCs is able to empower a node of a Wireless sensor network (WSN), also, it can be directly used as biosensing device due to the inherent ability of the constituent microbes to directly respond to environmental perturbations. Moreover, BESs (Fig 2.) can be applied as:

- **Electro-remediation technologies** for seawater desalination and purification of wastewater with organic and heavy metals content;
- **Biodegradability** of different types of materials;
- **Electrochemical and bio-electrochemical sensors** for medical applications and environmental contaminants monitoring;
- **Bioremediation** of wastewater, also using antibiotic resistant bacteria**;**
- **Bioresources valorisation** by coupling biogas and biofuels systems with algal-based wastewaters bioremediation;
- **Electro-fermentation**: BESs for production of valuable compounds;


MFC boxes



Lab-scale TMFC section


Experimental model of a capacitive desalination system

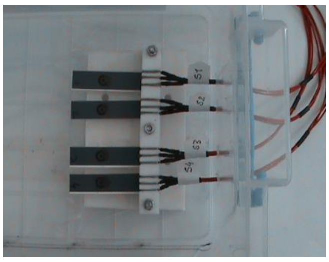

Functional model of an electrochemical biosensor for pesticides detection

Fig. 2: *Examples of different typologies of BESs systems*

BESs can be applied for drilling wastewater biodegradation that allows to produce biosurfactants and bio-plastics. Safe disposal of drilling waste (DW) currently poses important waste management and environmental problems to the O&G (Oil and Gas) industry mainly due to the DW vast quantities generated and the high content of contaminants. The drilling waste bioremediation may efficiently contribute to drilling waste disposal. Furthermore, inexpensive drilling waste bioconversion to high added-value compounds, such as biosurfactants (BS), is an environmentally friendly and sustainable process. Thus, a sustainable, practical and cost-effective solution for accurate prediction of the response of complex industrially-relevant biological systems met in bioprocesses and biological treatment plants could be the development of mathematical models; thus, optimising bioprocess design and control leading to efficient large-scale applicability. A gene regulatory modelling can be useful for the design of optimal bioprocesses. A Kinetic gene regulatory modelling can be used to predict microbial growth kinetics (Fig. 3) during microbial degradation of drilling waste. [Tsipa A., Koutinas M., Usaku C., Mantalaris A. (2018). Optimal bioprocess design through a gene regulatory network – growth kinetic hybrid model: Towards replacing Monod Kinetics, *Metabolic Engineering*, 48, 129- 137.]. However, large-scale application and production of BS are currently limited due to high production cost and narrow understanding of inter- and intra-cellular complicated communication [Banat I. M., et Al. (2000). Potential commercial applications of microbial surfactants, *Applied Microbiology and Biotechnology,* 53, 495–

508]. Kinetic gene regulatory network modelling can be applied to understand and decipher the complicated regulatory mechanisms. Further, as plastics constitute a major pollution source imposing emerging danger to the environment, bioplastics production using BESs and using drilling waste constitutes an interesting aspect of bioremediation.

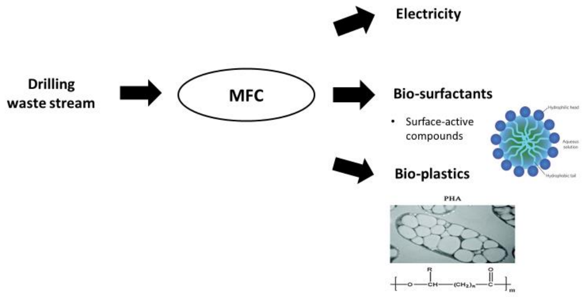


Fig. 3: State of the art: potential of MFCs to produce added-value compounds by drilling waste.

Another aspect of a bioremediation strategy relies on the capacity of natural microbial communities to degrade xenobiotics such as persistent organic pollutants and pharmaceuticals (Fig. 4). The role of microorganisms in transforming and mineralizing xenobiotics can be shown by the chemical determinations of a contaminant and the characterization of the microbial populations involved in its degradation. For this purpose, innovative molecular biology methods need to be applied for an unequivocal identification of bacterial species involved in bio-electrochemical transformations of persistent contaminants such as DDE (Dichlorodiphenyldichloroethylene) and PCBs (polychlorinated biphenyl) [Aimola G, et Al. 2019. MFCs for promoting DDE degradation. In: SETAC (Ed.) *One Environment. One Health. Sustainable Societies*. SETAC Europe 29th Annual Meeting, 26−30 May 2019, Helsinki, Finland Abstract Book ISSN 2309-803: 143].

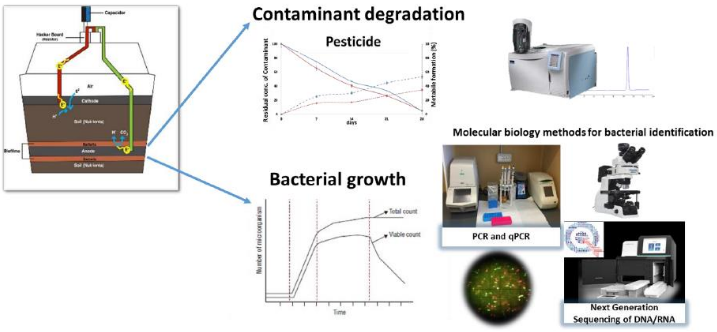


Fig.4: Contaminant degradation and bacterial growth in BES

The bioenergy recovered by MFCs systems can be used for many applications ranging from monitoring environments, lighting, charging of cell phones to even powering robots. There are many kinds of MFC typology, such as Terrestrial Microbial Fuel Cell (TMFC), Wastewater Microbial Fuel Cell (WWMFC) and Benthic Microbial Fuel Cell (BMFC). Among the most advanced MFCs systems, the PeePower® technology, where urine is used to feed the system as a fuel rich in organic content, has been used at the Glastonbury Music Festival since 2015, with the most recent installation running between the 26-30 June 2019 (Fig. 5). There, a stack of 15 MFC modules powered directly LED lights constantly (24/7) whilst treating 300 L of urine per day, reaching 851 mW at 2.75 V (roughly 288 Wh). The rest of the MFC modules directly powered 2 Gameboys and other regulated LED lighting displays. Field tests and in settings such as Glastonbury and the lake in Rome, will be important outlet & outreach activities, adding value to the range of PHOENIX activities that will enhance the experience of participants, in particular for PhD students and ESRs. To date, PeePower® systems have been used in Uganda (Seseme Girls School), Kenya (Brainhouse Academy) and South Africa (Thandanani township). A different, yet equally exciting application of MFCs is the possibility to power autonomous robots. The most advanced miniature MFCs that have been tested aboard one of the EcoBot family of robots, are small-scale (6.25 mL) 3D-printed MFCs that produced 26.5 mW/m^2. These MFCs enabled “EcoBot-II” (2018 edition) to charge its capacitors in only 64 seconds (Fig. 6) compared to its predecessor (“EcoBot-II” 2006, requiring 900 seconds).

Fig. 5: Pee Power® technology application, urinal assembled for energy recovery ready to be tested in a huge festival

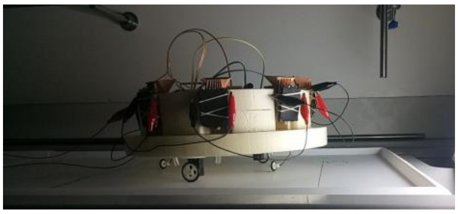


Fig. 6: EcoBot-II (2018) performing phototaxis with 8 x 6.25mL MFCs

Since the XXIst century wireless Sensor Networks (WSN) are a promising field for ambient intelligence. As one of the main architectures of Internet of Things, WSN has grown into an active field of research in the last decade. With a high constraint on fundamental energy, WSNs are a field of embedded systems where low power and energy harvesting are major stakes. Hence, in communicating embedded systems where all the hardware parts are kept to their most simple configuration (limited power computation, small memory, scarce Radio Frequency (RF) communications, small footprint) every hardware and software choice are critical (Fig. 7). State of the art in the field of autonomous WSN deals with hardware platforms that consume less than 1 mA with RF transceivers consumption at about 20 mA [F. Karray, et Al., « A comprehensive survey on wireless sensor node hardware platforms », *Computer Networks*, vol. 144, p. 89-110, 2018]. On the harvesting side, power availability from ambient sources can reach hundreds of micro-watts under favourable conditions [X. Tang, et Al., « Energy Harvesting Technologies for Achieving Self-Powered Wireless Sensor Networks in Machine Condition Monitoring: A Review », *Sensors*, vol. 18, nº 12, 2018]. From an “Operating Systems” point of view, numerous challenges in IoT are emerging, especially if historical operating systems (TinyOS, Contiki) are still used. In this context, research works show that a shift from centralized paradigm to distributed paradigm so as to lower RF consumption and optimize local power computation can enhance both performance of WSN and lifetime of deployed networks [M. Zielinski, et Al., A Distributed Active Vibration Control System Based on the Wireless Sensor Network for Automotive Applications, in *Advances in Network Systems*, Ed. Springer International Publishing, 2017, p. 235-253]. This approach coupled with MFC as both supply and monitoring source opens new perspectives in both ambient intelligence systems with reduced carbon footprint as well as autonomous self-monitoring networked systems for rehabilitation of ecosystems. Some bottlenecks yet need to be overcome such as global power capacity, fast regeneration, ability to adapt to dynamic WSN nodes whose computation needs can strongly vary.

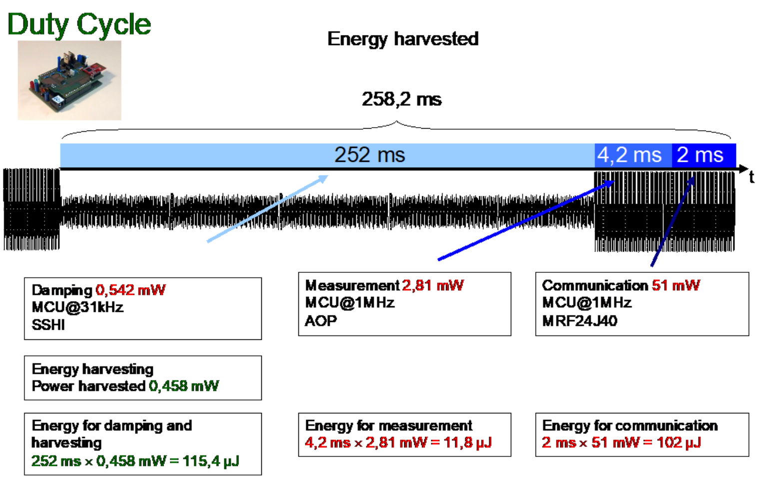


Fig. 7: Communications feature for design of WSN empowered by energy harvesting techniques

Miniaturized sensors inserted in system-on-glass for lab-on-chip implementation, is the next exciting area of research related to the protection and monitoring of environments. This type of sensors can allow *in-situ* and real-time detection for small quantities of substances to be examined (Fig 8), anticipating and replacing the analysis results normally performed offline in specialized laboratories [G. Petrucci, et Al., Multifunctional System-on-glass for lab-on-chip applications, Biosensors and Bioelectronics, 93, pp. 315-321, 2017].

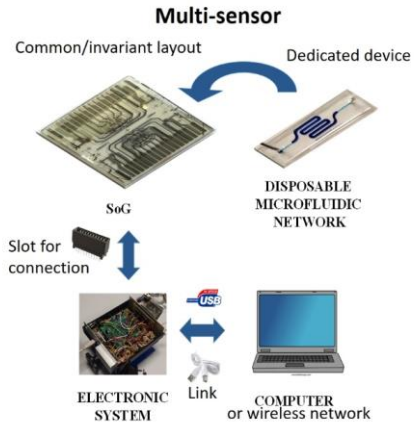


Fig. 8: Lab-on-Chip are miniaturized systems able to perform biomolecular analysis in shorter time and with lower reagent consumption than a standard laboratory. Their miniaturization interferes with the multiple functions that the biochemical procedures require.

1.1.2 DESCRIPTION OF THE CHALLENGE (MAIN AIM)

Humanity faces unprecedented challenges: global warming, limitation of fossil energy, with increasing urbanisation and its consequent demands. While solutions are becoming increasingly limited, microorganisms represent a realistic hope. For millennia, microorganisms have shaped the Earth's ecosystems. With this approach, they will enable us to recover and re-introduce environmental equilibria. PHOENIX aims at demonstrating the effectiveness of Bio-electrochemical systems (BESs) for exploiting the biological activity of live organisms for pollutants reduction, recycling of useful elements, synthesis of new products and, in the case of MFC, direct production of electricity. In recent years, the advancement in the field of low power electronics opens up a new way to exploit these environmental technologies. Activities will be related to the characterization of BES technologies and the application as bioremediator, biosensor, bioenergy source, in strict connection with sustainable urban planning and socio-economic aspects. Society had excessive interference with the natural environment [Sanchez-Bayo *et al.* Biological Conservation, 232, 8-27; Guardian, Sunday 10 February 2019], and although there is built-in natural resilience in our environment, continuous interference simply prevents natural recovery and repair. Over the last 20 years, there has been an exponential increase in literature corpus [Santoro *et al.* Power Sources, 356, 225-244] describing the different attributes of BES technology, from energy generation and waste and wastewater treatment, to pathogen killing, nutrient synthesis, bio-electrolysis and bio-sensing. BESs are particularly suitable for the treatment of waste with high organic content. It is therefore aligned with the OECD Environmental Outlook [OECD, 2012; DOI:10.1787/9789264122246-en], which establishes the Climate change, biodiversity, freshwater and health impacts of pollution to 2050 recommendations. The proposal addresses the four-key environmental ("Red Light") challenges requiring urgent attention. PHOENIX will generate and provide different activities and products (e.g. conferences, media coverage, multi-language materials, training courses for PhD students) in order to pursue an aggressive widespread dissemination. The project mainly aims to affirm the validity of a method of sensitization and social approval, aimed at changing the citizens' approach to the common good and subsequently to the rehabilitation of the local environment. In addition, the project will utilise central locations (as Park of Energies in Italy, Glastonbury Festival in UK), as dissemination "Hubs", which will maximise public engagement, including activities with the local schools, public debates, exhibitions, interactive sessions and more. BES technology is very extremely appealing in the classroom: a biological process that can couple sustainable energy production with waste treatment has innate appeal for students, as an effective educational tool to capture interest. It can serve as an ideal STEM (Science, Technology, Engineering and Math) platform for motivating students at all levels to understand complex concepts of cell respiration, microbial ecology, engineering, electronics, electrochemistry, natural environment importance inside urban fabric.

1.2 PROGRESS BEYOND THE STATE-OF-THE-ART

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

From a carbon cycle or circular economy perspective, the naturally occurring process in BESs is currently missing from the human-nature cycle of food production → consumption → waste management. One of the ambitions of this project is to demonstrate that BESs can represent an alternative method for wastewater treatment. As an example, in the treatment of agro-industry waste, home waste disposal and drilling waste. Moreover, BESs can be used for the protection and restoration of urbanised areas as well as ecosystem environments with the concomitant generation of clean energy. A second ambition is to demonstrate the benefits of powering WSNs with BES, to communities and local authorities, directly with readable data on environment pollution. A third ambition is to improve the quality of life by offering safety, security and comfort to communities in remote locations whilst preserving their culture and their social fabric. BESs highly rely on advancements of surface science [M. Picot, et al., Graphite anode surface modification with controlled reduction of specific aryl diazonium salts for improved microbial fuel cells power output, *Biosens. Bioelectron*, 2011]. The structural materials of MFCs affects their performance and susceptibility for biological and electrochemical reactions, as well as durability of the system. Activities will be performed to increase the understanding of the biological activities and to improve MFC structural materials. The startup of MFC systems represents an important stage, the biofilm attaches to the surface of the electrode and develops a stable structure that is directly related to its performance. It is therefore crucial to determine the most fundamental aspects of the MFC interface between biological and abiotic MFC components. Studies will be performed on the surface properties of the carbon-based electrodes. In order to increase the biofilm attachment and improve performance, chemical alterations of these materials will be tested coupled with the controlling of anodic potential.

Among the areas addressed to progress on BESs during activities:

- Investigation on biodegradability of various types of materials (textiles, leather, plastics, paints and polymers), usually tested using various strains of fungi. The most used species are: *Aspergillus Niger, Penicillium funiculosum, Paecilomyces variotii, Trichoderma viride and Chaetomium globosum*. Starting from a collection of over 40 different species of fungi, research will be performed to advance in the comprehension of their action in respect to biodegradability of different materials.
- study of the influence of electromagnetic field on the biofilms and microalgae will be conducted, in order to investigate the effect of a low-voltage disruptive field and its ability to stimulate or inhibit the cellular growth.
- innovative methods for identifying electrochemically bacteria involved in xenobiotic degradation
- advanced research in defining the biomethane potential for a wide range of organic wastes to design innovative concepts towards increasing the value chains in bioresources management; combined pre-treatment techniques for algal and lignocellulosic biomass to improve the waste-to-energy conversion; interdisciplinary approach by experimental and theoretical simulation of the biochemical processes for developing waste and wastewaters treatment sustainable solutions.
- advancements in research into water purification for sewage and leachates using MFC
- improvement on reduction of hazard contaminants with BESs: looking at different types of bacteria to treat contaminants. Investigate innovative techniques for incorporating plastic degrading into MFC to reduce Polyethylene Terephthalate (PET) pollution by means of bacteria (*Ideonella Sakaiensis*) for plastic degradation.

BESs can be also exploited in the agribusiness sector for wastewater treatment and energy recovery. As an example, the coffee business is generating a large volume of wastewater, unsuitable for a second usage in agriculture if pollution is not removed and BESs represent a cost-effective technology to achieve the natural treatment of agroindustry wastewater. Laboratories experiments will advance from the state of the art to reduce organic pollutant to a safe threshold within 1 week. Safe threshold for water agricultural reuse is for Chemical Oxygen Demand (COD) 100 mg O_2/dm^3 [Jörg E. Drewes et al. Characterization of unplanned water reuse in the EU (Final Report 2017)]. Valuable MFCs outputs are sufficiently-clean water for an immediate local usage and electricity for autonomous operation of the system (and more).

Furthermore, advancements will be performed in drilling waste biodegradation. MFCs will be tested upon use of DW as carbon and energy source to produce electricity and added-value compounds such as biosurfactants and bioplastics (i.e. PHAs). Further, a sustainable, practical and cost-effective solution for accurate prediction of the response of complex industrially-relevant biological systems such as that of MFCs could be the development of mathematical models using kinetic gene regulatory network modelling to understand and interpret inter and intra cellular communication of microbial communities of MFCs. Regarding kinetic models of gene regulatory networks could be extremely complicated leading to high parameter uncertainty and complication of parameter estimation. For this purpose, a reduction approach will be employed to exclude mechanisms/equations which are not necessary/complementary to explain the combined transcriptional regulation. Further, gene identification which are responsible for DW biodegradation and/or production of biosurfactants and/or bioplastics may be complicated. Collaboration between different research groups, which use advanced molecular techniques for species identification and genomes, will enhance specific genes identification.

Among advancements on MFC technology, activities will focus in miniaturising MFCs and increasing power density to be used in self-sustainable autonomous robotic systems other than biosensing and wireless monitoring systems. The advancements on the MFC capacity of energy conversion will enable to supply regular light for illumination, that can turn in an incredible added value for remote villages, urban areas and communities where electricity or illumination is not stable, durable or even present. Moreover, advancements will be performed on MFC catholyte production for use as fertiliser (as a PeePower® by-product).

Moreover, an advancement from the state-of-the-art on low power communication and the exploit of MFCs energy recovered will be related to the optimization of hardware platform, operating systems and MFC configuration for several scenarios. In particular, the dynamic variation on WSN configuration according to MFC availability and health and MFC regeneratively monitoring. An innovative sector of strong interest in the activities of environmental monitoring are sensors inserted in system-on-glass for lab-on-chip that allow in-situ and real-time detection with small quantities of substances to be examined; an original acid rain sensor built on lab-on-chip technology will be investigated.

1.2.2 OBJECTIVES

1.2.2.1 Research Coordination Objectives

- ❑ Identify valorisation possibilities of electroremediation, bioremediation, biosensing and biodegradation technologies;
- ❑ Identify the possibilities of enhancing BESs based applications and social response;
- ❑ Identify valorisation possibilities of interactions between microbial biofilm, biocompatible substrates and electromagnetic fields;
- ❑ Identify potentiality of increasing MFCs power density and MFCs stack efficiency;
- ❑ Support advancements on surface science related to BESs;
- ❑ Stimulate gene regulatory networks kinetic modelling for the design of optimal bioprocesses in biological systems connecting the inter- and intra-regulatory mechanisms focused on added-value products formation;
- ❑ Optimization of hardware platform for autonomous WSN and sensing innovations;
- ❑ Integration of biotechnology in political decision-making process and city planning for environment preservation and waste recycling. Identification of knowledge gaps between science, politics and citizens;

Support activities for achieving the objectives:

- ❑ Valorisation of electro-remediation technologies and bioremediation treatment for wastewater and their receiving environments, seawater desalinization; Bioresource valorisation;
- ❑ Optimization of biodegradability of materials for different species of fungi used. The species are chosen for each type of material individually, according to usual standards;
- ❑ Defining the biomethane production potential for a wide range of organic wastes;
- ❑ Valorisation of drilling waste biodegradation, biosurfactants and bio-plastics production by drilling waste biodegradation and potential of MFCs use;
- ❑ Identify valorisation possibilities of transcriptional kinetics and gene expression during microbial degradation of drilling waste focused on genes responsible for electricity, and added-value compound production;
- ❑ Support Advancements on biocompatible nanostructured carbon and conducting polymers supports for catalysts and electrodes in bio-electrochemical systems;
- ❑ Decreasing with BESs the extremely high levels of COD (Chemical Oxygen Demand) to safe threshold (100 mg O_2/L) for agricultural water reuse; Reducing the polluting load of the residues;

- Improve the analysis of the influence of electromagnetic field on the biofilms of BESs;
- Assessment of most fundamental aspects of the MFC interface between biological and abiotic MFC components;
- Support advancements on surface properties of the carbon-based electrodes, evaluation of recent trends and progress in surface and biofilm interactions and attachment in MFC systems to improve MFCs performance;
- Identification of potentiality from the study of microbial-carbon material interactions in wastewater treatment, wastes valorisation and bioremediation processes;
- Miniaturising MFCs and increasing power density. Improving efficiency of MFCs stack;
- Identify valorisation possibilities of development of autonomous MFC WSN with high computation capacity able to adapt to environment capacity of energy harvesting; Sustainable efficient WSN design;
- Identify valorisation possibilities of small scale MFC for sewage and canal water purification;
- Support development of autonomous self-regulated WSN water quality test and check system supplied by MFC;
- Optimization of hardware platform, operating systems and MFC configuration for several scenarios: monitoring of environment, active control of vibrations, autonomous robot;
- Identify valorisation possibilities of dynamic variation on WSN configuration according to MFC availability and health. Monitoring of MFC health and biosensing capabilities;
- Identification of potentiality of plastic degradation pollution and treat hazardous contaminants with BESs;
- Support the development of innovative sensors like system-on-glass for lab-on-chip that allow in-situ and real-time detection of small quantities of substances, e.g. for acid rain evaluation;
- Support the development of innovative methods for identifying electrochemically bacteria involved in xenobiotic degradation;
- Support the study of different cases which rely on the capacity of natural microbial communities to degrade xenobiotics (e.g. persistent organic pollutants and pharmaceuticals);
- Identify valorisation possibilities of integrated MFC/micro-storage systems for feeding microbial electrolysis cells. Study of electrochemical activity of long-term sediment microbial fuel cells;
- Support the co-construction of socio-technical shared indicators, built on research bases and maintaining bi-directional communication with social actors and the community, in order to evaluate how the objectives of protection, resilience, and rehabilitation of damaged environments are implemented;
- Identify the advantage of involvement of users in the technological implementation (BES utilization in ecosystem): qualification and quantification of level of acceptance, ecosystem improvement (and/or disruption practices) and empowerment;
- Action-research activities, e.g. hybrid participative design / public dissemination workshops, expert participation in local networks of people interested in sustainable urban regeneration policies and practices, development and use of tools for 'citizen science', etc.;
- Support the integration of innovative technological means with well-established nature-based solutions and methodologies for ecological networks reparation (de-fragmentation) in urban contexts;
- Identify valorisation possibilities and increase social awareness of the opportunities for de-centralized and widespread energy production, generated with eco-sustainable techniques;
- Identify valorisation possibilities of potential impact of selected gas from CO_2 intensive industries such as sulphuric compounds on biocathode for methane production with BESs;
- COVID-19 – specific objectives: support study on filters charged with Ag and Cu nanostructured materials for water and air decontamination; identify potentiality of producing and delivering stable dispersed colloidal Ag and Cu/Au nanoparticles in polyvinylpyrrolidone (PVP); support the study of innovative method based on ionizing radiation - an eco-friendly method - which is a fast and one-step method, allows metal reduction in aqueous solutions. Support advancements on optical technologies for water and air decontamination: UV-C based bioreactors and robots may be designed with proper expertise.

1.2.2.2 Capacity-building Objectives

PHOENIX consists of a multidisciplinary network of experts linked by their mutual interest in biotechnology and BESs applications to reduce the urbanization and industrial impacts on the environment. The PHOENIX COST program can improve a shared research environment building a permanent network on a key domain to regulate the impact of urbanization on environment. Capacity is built on existing assets, such as human resources, institutional funds, facilities, laboratories and infrastructures, and the presence of stakeholders from Higher Education & Associated Organisations, National Institute for R&D and international organizations. Overall, PHOENIX will establish a permanent network to promote sustainable science and engineering research development by enhancing the abilities of individuals, institutions and organizations to successfully and efficiently undertake and disseminate of high-quality research. Specific capacity-building objectives are:

- improve access to knowledge and career formation for students and researchers; producing high-end open access publications and position papers
- enhance dissemination of knowledge between sciences, public institutions, citizens associations
- improve personnel skills, experience and competence, especially for PhD students and ESRs; consortium members will host PhD students and ESRs for knowledge exchange
- promote collaboration and access to established worldwide research infrastructure networks;
- create opportunities for dialogue among the different domains of scientific community to reduce distances and improve interdisciplinarity; a consortium meeting focus group to be arranged early in the project with a SOAR (state of art review agenda) to set the scientific objectives for creating opportunities among different domains
- encourage the communication and dissemination of research results with various instruments
- bridge the gaps between research and productive sector, translation into business models;
- foster the uptake of research results, especially by industry and SMEs;

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

Bio-Electrochemical Systems (BESs) have to play now a more important role with respect to depollution, remediation, sensing in the environment, electrical energy harvesting or valuable gas and added-value compounds production from waste biomass. BESs have been demonstrated in laboratory or at small scale. Time has come to demonstrate the benefits of BESs at proper scale to turn pollution and/or wastes into valuable richness. Many fields of engineering such as energy, electrical, electronics, information, computer science, chemical are called to collaborate with biotechnology fields, biology, chemistry, ecology, social and human sciences. Collaboration is the key asset to advance quickly in this sector but in strict relation with the strategies, applications, and future use of energies considering the urbanism domain and social impact for a correct city planning and circularity of resources (like water, soil and energy) with permanent recovery, reuse and correct management. Multi-disciplinary and inter-disciplinary networking is the necessary added-value for a consortium operating in the sector. Acting quickly to demonstrate the pertinence of business models in relation with usage of BESs is reinforced by climatic changes. Techniques of bio-degradation for depollution with recovery of energy are a perfect example of technologies to reduce human impacts on environment. Consortium networking on a regular and deep basis is a key enabler for that objective.

2.2 ADDED VALUE OF NETWORKING IN IMPACT

2.2.1 SECURING THE CRITICAL MASS AND EXPERTISE

Scientific actors are aware of the human forces available to lead scientifically a large-scale demonstration in more than one application field. However, in the absence of a structuring framework, advances are marginal and do not encompass all the necessary engineering fields, i.e. actors. Scientific and technology actors are not sufficient either, and contributors from human and social science are mandatory as well as political deciders, business developers, private associations, city councils, etc. A critical mass of the various actors needs to share information, knowledge and knowhow on a regular basis. Events dedicated to research, to exchange with industry partners or developers and with the contributors of the civil society should be organized and intertwined. Proficiency in impacts means developing a stable program of sharing results to spread the knowledge and pushing up the advancement not only in the scientific field but also sharing with other communities of contributors and having social science experts to guide the pertinence of advancements. A permanent share of recent advancements is required, unified with parallel programmed investigations. This can create an excellent organization level for research development. Yearly face-to-face meetings with scientific staff and constant exchange of researchers between labs will provide an added value. Dedicated symposia, workshops and training schools can increase the benefits and are an integral part of the organization of a permanent shared research program. Starting with a well-prepared strategy of actions is a key milestone. Issuing white-papers about grand objectives of practical demonstrations in the field is another important key milestone. The consortium that will benefit from the EU support to grow and attract visibility should disseminate knowledge and know-how but also dreams and hopes with respect to social challenges brought by climatic change. An important action concerns the collaboration between public research and educational institutions, from Europe and beyond. Europe's ambitions are to be an outstanding actor against climatic change or pollution remediation. The consortium ambitions are to attract interest across the world. Public research and education institutions will have a key role in the future of Europe's knowledge and technological level with regards to BESs. Their collaboration is essential, and this needs clear objectives and strategies. The project encompasses to support such objectives et strategies. Civil society is represented by many actors, from political leaders (at various hierarchy levels) to private actors in economy or public associations, for the defence of environment. A clear and strong connection with the civil society is also part of the strategy and the objectives of the consortium.

2.2.2 INVOLVEMENT OF STAKEHOLDERS

All participating groups have excellent research capacities, including highly trained staff, state-of-the-art equipment and a strong know-how. The members of the network come from various parts of Europe and around the world both from research institutions, international organizations and universities. A plan will be prepared to involve ESR, PhD and MSc candidates in different ways (STSMs, training schools, COST meetings etc.). STSMs will be dedicated to research activities in the network labs with a wide choice of opportunity in science activities, combining engineering, social science and natural science (see research clusters in figure 9). Moreover, STSMs will be dedicated to career prospection and carrier pursuing visits for students and ESRs, as well as for networking, lab visiting, double and joint-degree organization. Furthermore, citizens will be involved in dissemination events and participatory workshops, like the two in-field events in Glastonbury Festival and in the Natural Lake Park in Rome. The policy makers, as stakeholders, will have an important role in conferences and dissemination events.

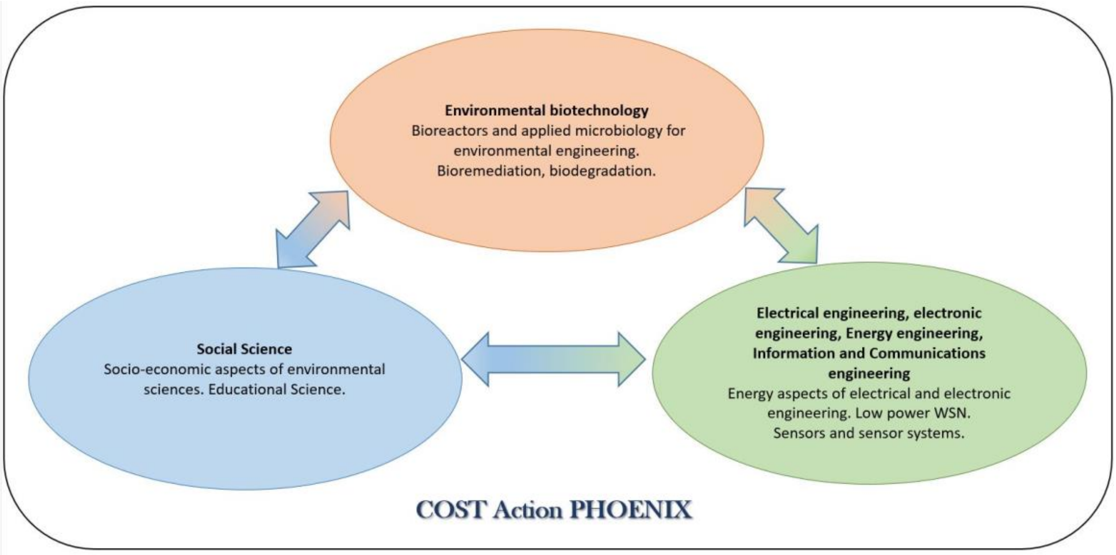


Fig 9: PHOENIX research clusters

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

By involving secondary proposers from around the world, state-of-the-art knowledge will be shared more efficiently. Such collaboration will allow faster progress in science, industrial applications and technology implementation, and thus offer global environmental benefits through the application of novel, clean and energy efficient technologies. To ensure a worldwide network, international organizations, companies and academic partners from different continents are involved, from New Zealand to Colombia. The relation with NNCs is strongly encouraged starting with the partnership with Russia and Jordan.

3 IMPACT

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

3.1.1 SCIENTIFIC, TECHNOLOGICAL, AND/OR SOCIO-ECONOMIC IMPACTS (INCLUDING POTENTIAL INNOVATIONS AND/OR BREAKTHROUGHS)

PHOENIX will contribute to the construction of a comprehensive “good practices” framework, achieving multi-directional relationships and finally, ensuring feedbacks and contributions to the project activities. The assessment of cost-effectiveness of the restoration measures will include aspects such as business focus for scaling, life-cycle of the materials and identification of potential risks & negative effects, as well as the main direct and indirect benefits, e.g. in terms of ecological services provided. Beneficiaries of this multi-disciplinary network are manifold:

- the wider academic community will benefit from the advances made both within the discrete fields of study but also from the connections made across disciplines and concomitant progress;
- the industrial sector in the field due to an enlarged collaboration and knowledge sharing between industrial and academic sector;
- the Consortium as a whole will benefit form the opportunity to advance this burgeoning research area through a collaborative period of activity;
- the European Community will benefit from the progress achieved in the technology and manufacturing readiness levels for bio-electrochemical systems and will remain at the forefront of this growing scientific field;
- the communities in which demonstrators will be tested (waste treatment, nutrient recycling, and electricity generation for useful applications); Scaling-up these technologies can result in a several added values for communities, policy maker and local government.
- any citizen aware of the environmental problems caused by pollution and wrong urban planning will benefit from the access to ready-to-use knowledge in order to make educated decisions at different levels (from pragmatic to political).

3.2 MEASURES TO MAXIMISE IMPACT

3.2.1 KNOWLEDGE CREATION, TRANSFER OF KNOWLEDGE AND CAREER DEVELOPMENT

PHOENIX offers a benevolent solution that comes from the very nature of the environment we attempt to repair and provides the network for natural remediation. The project is founded on previous successful examples and is designed to capitalise on these through collaboration in pursuit of the common objectives, demonstrating the overall feasibility of scaling through the relationship with the industrial partners. These interactions will be enriched by the previous experiences of civic society organizations directly addressing the problems of their homes and local institutions, especially regarding public policies in the different sectors related to environment. Among the goals of the action:

- ❑ Scientific exchange, in-field activities and motivating experience in COST events for advancement of the careers of doctorate students, postdocs and ESR
- ❑ Improving links with public institutions as state organizations for ecology, private actors or civil associations for transfer of knowledge and vision.
- ❑ Knowledge creation from large scientific exchange of recent progress and future desired objectives among stakeholders. This will be performed through annual meetings, dedicated conferences to improve sharing of scientific experiences, feedbacks and expression of needs.
- ❑ Thematic conferences dedicated to cover certain aspects of BESs technologies open to all the stakeholders to encourage advancement of scientific knowledge
- ❑ In-field activities are provided during conferences, short-term scientific missions (STSMs) and PhD training schools. As an example, open ambient festivals or natural ecosystems where technologies and research are tested, monitored and disseminated.

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

We will maintain constant dialogue with institutions and government representatives, networking between stakeholders of private and public sectors, and will inform and sensitize citizens and government representatives regarding environmental issues and benefits of BESs. Field tests and dissemination activities will be performed in proper places like the Glastonbury Festival and the natural lake in Rome. Moreover, a synergy with existing conferences and symposia near the fields of PHOENIX will be planned, starting from a collaboration with the MEEP (Microbial, Enzymatic & Bio-Photovoltaic Electrochemical Reactors) symposium (EFCF Conference) and others (JNRSE and ECS). A wide plan of dissemination strategy is targeted. WG1 covers activities to measure the level of acceptance of technologies, and the contribution of the project to Climate Change Actions. Moreover, WG1 covers the educational science aspect within the project. We will prepare a plan for dissemination activities directed to schools to be held during our events WG5 will develop and implement strategy and disseminations, taking into account the different sensibilities among stakeholders. The WG5 Leader will coordinate the dissemination of scientific knowledge. Each beneficiary will be invited and encouraged to contribute directly to the exploitation/dissemination activities.

4 IMPLEMENTATION

4.1 COHERENCE AND EFFECTIVENESS OF THE WORK PLAN

4.1.1 DESCRIPTION OF WORKING GROUPS, TASKS AND ACTIVITIES

A working group (WG) approach will be adopted to support the overall strategy and general description of the project. Despite the general division of groups, all WGs will work together to improve the technologies related to the fields of biotechnology, BESs and their applications. WGs will streamline efforts not only in restricted areas, but on a large scale. Circulation of knowledge will be encouraged considering its key role for highly interdisciplinary science sectors like the core fields of PHOENIX. Conferences and roundtable discussions dedicated to one aspect within the broad spectrum of the project's scientific fields will be among the deliverables, with the aim of sensitizing the different disciplines among themselves, increasing interdisciplinary collaboration and reducing distances in the scientific community.

WG1 – *Educational and socio-economics aspect of environmental science for sustainable city planning*

This WG supports the methodological and applicative aspects concerning the technology itself and the user's implications and impact qualification (in terms of costs vs gains) according to the deployment of technological devices, also focusing on the relationships between technological development, environment, urban planning and empowerment of local actors (groups of inhabitants, NGOs, etc.). Deliverables will be reviews, reports or papers on the relationship between education, technology and environment, as well as sustainable city planning. Also, a related conference is planned on social aspects and integration of biotechnology for an ecologically coherent urban planning and city-making process and sustainable city planning for resilient cities and environment protection. Furthermore, a deliverable in connection with WP5 will be an educational easy-to-use *handbook* *(D_{17})* available on-line (supported by three STSMs). Specific polling activities are envisaged as general studies of the opinion of particular groups of people and actors. Activities are related to:

- Implication of users in the technological implementation: qualification and quantification of level of acceptance, ecosystem improvement and empowerment (user-centred inquiries, participatory observation, trainings); Social impact and acceptance by local communities;
- Increase social awareness of the opportunities for fractioned and widespread energy production, realized with eco-sustainable techniques;
- Introduction of the technologies into educational processes
- Action-research activities, e.g. hybrid participative design / public dissemination workshops, expert participation in local networks of people interested in sustainable urban regeneration policies and practices, development and use of tools for 'citizen science', etc.;
- Co-construction of socio-technical shared indicators, built on research bases and with the population in order to predict and evaluate how the objectives of protection, resilience, recovery of damaged environments is implemented;

- Integration of innovative technological means with well-established nature-based solutions and methodologies for ecological networks reparation (de-fragmentation) in urban contexts;

WG1 is organized in two tasks:

-**WT_{11}** *Relation between education, technology and environment*; Deliverable 1 (D_1) will be the production of a scientific report on educational teaching, knowledge mediation and moving, with support of 2 STSMs and the organization of a dedicated conference on the relationship and links between technology, society, education, political decision-making and environment preservation.

-**WT_{12}** *Sustainable City Planning*; accountable to produce a joint paper on sustainable city planning for resilient cities and environment protection (D_{11} – Month 48), supported by 2 STSMs joint with the organisation of a dedicated conference.

WG2 - *Bio-Electrochemical Systems to reduce the environmental impact of pollutants and bioresource valorisation*

The WG2 programs concern aspects like bioremediation techniques and surface science related to BESs which can lead to environmental sustainability. Aspects that concern WG2 are electro remediation, bioremediation, bioprocesses, electromagnetic interactions on biofilm, BESs and electrodes materials, bioresource valorisation, electro-fermentation, biological interaction, water valorisation for coffee industry, drilling waste biodegradation, gene expression of microbial communities of MFCs, kinetic modelling of regulatory mechanisms of microbial communities involved in MFCs.

Some main scientific events will be organized by WG2 to spread the related knowledge and science progress and innovation among the consortium: a conference on Surface science in MFCs; a conference on microbial-functionalized electrodes interactions in BESs; a conference on BESs depollution capabilities; a conference on Hazardous contaminant treatment with BESs. A Working Task organization of WG2 comprehends:

-**WT_{21}**: *Surface science related to BESs and sensors.* This task includes a conference on surface science advancements for improving the performance and selectivity of microbial fuel cells for biosensor applications, and STSMs (e.g. short-term internships for PhD or MSc students) towards improved microbial metabolism in BESs. Knowledge exchange is planned with other WGs and the implementation will be concluded with D_2 as scientific report (Month 24).

-**WT_{22}**: *Drilling waste biodegradation, biosurfactants and bioplastic production potential and Gene regulatory networks modelling for optimal bioprocesses of BESs*: We will carry out activities on the production of biosurfactants and bioplastics, and to identify genes responsible for electrogenic activity, to build a gene regulatory network kinetic model built connecting the inter- and intra- regulatory mechanisms focused on added-value products formation, Knowledge exchange between partners will be supported by two STSMs dealing with environmental biotechnology. A dedicated conference will be organized among the dissemination activities. A scientific report (Month 24) on added-value compounds formation by MFCs using drilling waste will be written (D_{12}).

-**WT_{23}**: *Capacity of microbial communities to degrade hazardous contaminants*: this WT will focus on different case studies which rely on the capacity of natural microbial communities to degrade contaminants (e.g. persistent organic pollutants and pharmaceuticals) with BESs. Exchange of knowledge between partners will be performed with 3 STSMs dealing with natural microbial communities able to degrade contaminants in BESs and training innovative methods for identifying electrochemically bacteria involved in xenobiotic degradation. Moreover, a conference on Hazardous contaminant treatment with BESs will be organized. A common review paper on the knowledge gaps and research needs for the implementation of BESs used for contaminant degradation will be written (D9 – Month 42).

-**WT_{24}**: *Functionalized electrodes in BESs, Electro-fermentation, BESs for production of valuable compounds*: this WT will focus on the study and consolidation of knowledge in the production of valuable compounds with Electro-fermentation and functionalized electrodes in BES. Two scientific reports are expected to arise from these activities at Month 42 (D_3). For Knowledge sharing between partners, two STSM will be promoted, one to train a young researcher in the preparation and characterization of functionalized electrodes and another in Electro-fermentation for wastes valorisation. The organization of a conference on microbial-functionalized electrodes interactions in BESs is among the responsibilities of WT_{24}. Besides, Practical Workshops on BES technologies will be organized with the goal to disseminate this technology among secondary students.

-**WT_{25}**: *Wastewater depollution*: WT_{25} will use BES inoculated with native or artificial microbial communities to depollute urban and agro-industrial wastewater with high organic loads, and will construct low-cost devices employing recycled or re-purposed materials. Activities will involve STSMs for ECRs and PGRs training on BES construction using suitable alternative materials, and on applications of BES in wastewater depollution and re-use, either as self-standing systems or in combination with established technologies. WT_{26} includes the organization of a conference on BESs depollution capabilities, with participation of world-leading scientists and technologists, and involving an experimental section directed to non-experts, where the advances and developments made in the STSMs will be put into practice. Deliverable: Scientific report in Month 24 (D_6)

WG3 - *Environmental monitoring and sensing*

WG3 focuses on the activities of monitoring and sensing, evaluating and exploring the different patches to exploit the energy converted from BESs and its sensing capabilities, in synergy with the other WGs. In the context of low power communications activities will be focused on the development and testing of autonomous efficient WSN. Also, activities will be performed for evaluation of sensing capabilities of BESs, optimization of hardware platforms, operating systems and MFCs configuration for several scenarios. Furthermore, WG_3 takes part in the design of innovative sensors like system-on-glass for lab-on-chip that allow in-situ and real-time detection of small quantities of substances, like for acid rain evaluation. The activities of this WG include the organization of a conference on environmental monitoring applications for energy harvesting techniques like MFCs and on sensors.

-WT_{31}: *autonomous efficient WSN*; A scientific report will be delivered (D_4 – Month 36) on the following activities: monitoring of environments and sea (Benthic MFCs fabrication and testing); optimization of hardware platform, operating systems and MFC configuration for several scenarios; organization of a conference on environmental monitoring applications and a special session on BES (D_{16}) attached to the existing JNRSE (days of energy harvesting and storage - 2021). Support of two STSMs) on autonomous WSN systems.

-WT_{32}: *sensors for real-time detection*: research and development of sensors for real-time control with innovative methods like lab-on-chip systems; the activities will be supported by two STSMs; organization of a conference focused on Sensors; A scientific report (D_{10} – Month 48) will be delivered on development of environmental sensors integrated in lab-on-chip systems and powered by MFC cells and inserted in a detection network for pervasive and real time monitoring. Joint organization of in-field research activities and a practical seminar for kids (primary and secondary school) during training at natural lake/park school (D_8) with WG4.

WG4 - *Point-of-load*

WG4 will focus on the electrical management aspect of energy harvesting techniques with MFCs. Assuming as primary objective the improvement of electrical outputs performance and energy storage systems: develop MFC systems with higher than state-of-the-art power outputs, considering miniaturization of systems, increase in capacity and decrease in energy losses.

Objectives of WP4 are the organization of activities in-field with interactive training sessions or schools programmed in a Festival (D_5) – in a Natural Lake/Park (D_8) and a conference on Environmental Biotechnologies and energy harvesting from waste and workshops on BESs in connection with existing conferences (D_{14}, D_{15}). Following the two working task descriptions:

-WT_{41}: *electrical performance of BESs*: this will cover all the electrical aspects of advancements on MFCs electrical efficiency and electrical management. It will be supported by a STSM and will be responsible for organising workshops in BES within Conferences such as ECS 2021 (D_{14}) and EFCF 2022 (D_{15}) as well as promoting the work through outreach activities available to the general public (such as science centres and festivals) and a training school in-lab.

-WT_{42}: *environmental biotechnologies and energy harvesting from waste*: this will focus on the relation between biological activities, waste degradation and electrical behaviour of BESs. Thus:

- selective technological solutions for biological treatment of wastewater, using bacterial cultures, will be tested. Two STSMs will be considered for this purpose, with regard to identification of the new species of microorganisms with valence in wastewater treatment, using a bacterial consortium as the source of microorganisms, with a high capacity to degrade different classes of chemical compounds from the hydrocarbons class;
- selective technological solutions for quaternary treatment of wastewater, using specific plants (Lemna sp., algae etc), will be tested. One STSM will be considered for this purpose, with regard

to identification and exploitation of the ability of some plant species to remove antibiotics and heavy metals;
- study of the potential impact of gaseous output from CO_2 intensive industries such as sulphuric compounds on biocathode for methane production with BESs; Study of microbial-carbon material interactions in wastewater treatment processes. An STSM will be considered to support these activities;
- waste water treatment using MFC with a focus on pure water formation on the cathode side via the oxygen reduction reaction, the support of an STSM will be considered;

Moreover, this task manages possible activities related on COVID-19 emergency. A conference on environmental biotechnologies and energy harvesting from waste will be organized, as well as a scientific report on combined selective eco-technologies for water protection, conservation and treatment (D_7 – Month 48).

- WT_{43}: *energy storage in MFCs*: A scientific report will be delivered (Month 24) on energy storage systems for MFCs using super capacitors or capacitive electrodes to continuously supply small devices (D_{13}). The recovered energy will be assessed for directly connecting to a microbial electrolysis cell to produce hydrogen; this is novel. The activities will be supported by STSMs in order to train two young researchers or PhD students in monitoring, characterisation and integration of the systems.

WG5 - *Dissemination*

The WG5 will prepare yearly dissemination and exploitation plans with the purposes of:

- boosting engineering, industrial and scientific research on BESs by sharing knowledge with scientific research communities and programming shared research programs;
- promoting private investments, levering on the innovative outputs of the Action and appealing emerging market;
- increasing biotechnology acceptance and spreading, networking between citizens, communities, academics, governments, integrating biotechnology and energy harvesting techniques in the urban texture, evaluating correct city planning

The production of materials and Open Educational Resources (OER) concern:

- Production of different types of content (scientific articles, handbooks, panels for parks, brochures, videos and other dissemination materials on the specific themes of the project and their framing in sustainable urbanization horizons); local dissemination, through specific appointments and projects (activities with schools, public debates, conferences, meetings, summer/winter PhD schools, etc.). Synergy and organization of shared events with pre-existing scientific conferences and symposia.

- An easy-to-use *handbook (D_{17})* for educational programs available on-line, merging all the scientific and historical aspects related to the protection and rehabilitation of environments and the correct city planning process as well as multimedia contents.

- Publication of pamphlets on the project and implementation of a dedicated website (D_{19}) and a YouTube channel. It will be established with updates on progress and with information about the project and its background. This website will attract wider attention and will be used to announce events and to disseminate results of high value to potential beneficiaries. This will include overall information about the project, the participants and their respective roles in the project, and specific information that requires regular updating, such as published scientific results, papers, conference presentations, as well as presentations to the general public in the form of public lectures, courses, seminars, radio and television appearances featuring the work, news clippings, film clips, etc.

- MOOCs (Massive Open Online Courses) and social media strategy diffusion (Research Gate, LinkedIn, Twitter, YouTube…)

4.1.2 DESCRIPTION OF DELIVERABLES AND TIMEFRAME

A first general meeting of founder members is foreseen in mid-2020 to define roles and start the organization of the actions. A dedicated website is considered the first deliverable (D_{19}) but will be constantly managed and updated for all the project timeline. Programmed Training school with in-field activities where the participation of PhDs students will be strongly encouraged like for D_5 (PhD school with in-field activities and testing in a large festival context) and D_8 (similar activities in a natural ecosystem degradation by urbanization). The production of joint scientific reports and papers, based on the activities of each Task, are the deliverables: D_1-D_2-D_3-D_4-D_6-D_7-D_9-D_{10}-D_{11}-D_{12}-D_{13}. D_{14}-D_{15}-D_{16} including output from workshops and special sessions organized jointly in existing conference (ECS 2021 - ECFC 2022 - JNRSE 2022). D_{17} is related to a core dissemination objective, the production of an easy-to-use handbook and its presentation in dissemination events (Month 42). A large final event D_{18} will be a conference which will join all the participants. A plan for the dissemination's objective will be defined by WG5 identifying annual and finals goals. Yearly STSMs will be organized in synergy between labs and in coherence with the main project aim.

4.1.3 RISK ANALYSIS AND CONTINGENCY PLANS

The major risks are related to the efficient management of a wide interdisciplinary network of scientists from different fields. The core consortium (Action chair and the Grant holder) have expertise in working with experts from different sectors. There will be a management structure implemented to enable appropriate governance; roles and responsibilities will be assigned at the first consortium meeting. Budget management: A strong and reliable back-office will be identified as Grant Holder. The Management Committee (MC) will decide on budget distribution and eventually necessary re-allocations among activities. Issues with performing research and innovation activities with own funds: although the research and innovation activities will be financed by leveraging activity from other projects, the networking activities of the Action offer the possibility to create competitive partnerships for European calls for grants (e.g. H2020, FP8), and to implement industry-research partnerships for translational and technological outputs. To ensure compliance with the deadline for deliverables: the correct planning and coordination of task activities will be managed not only by the Working Group Leaders (WGL) but also by additional Working Group Co-Leaders (vice-WGL) and Task Leaders (WTL). In case of workload underestimation or a change in the composition of the consortium, the Management Committee can strengthen the Working Groups with additional participants. Attract industrial investments on biotechnologies to reduce the impact of urbanization and industrialization on the environment: PHOENIX is designed to sensitize and stimulate private investments, also through an active participation of companies in the activities of the WGs. Moreover, the Action could implement strategies, such as dedicated workshops and training schools open to the companies, and the possibility for consortium partners to attend international business meetings and to participate in SME-Academia matchmaking and brokerage events organised by the European community.

4.1.4 GANTT DIAGRAM

Year	2021		2022		2023		2024	
Month	6	12	18	24	30	36	42	48
WG1 – *Educational and socio-economics aspect of environmental science for sustainable city planning*								
T1.1 Relation between education, technology and environment						D1		
T1.2 Sustainable city-planning								D11
WG2 - *Bioelectrochemical systems to reduce the environmental impact*								
T2.1 Surface science				D2				
T2.2 Drilling water				D12				
T2.3 Hazardous contaminants							D9	
T2.4 Funzionalized electrode in BES							D3	
T2.5 Depollution capabilities of BES				D6				
WG3 - *Environmental monitoring and sensing*								D16
T3.1 Autonomous WSN						D4		
T3.2 Sensors								D10
WG4 - *Point-of-load*				D14		D15		
T4.1 electrical performance of BESs				D5				D8
T4.2 environmental biotechnologies and energy harvesting from waste								D7
T4.3 energy storage in MFCs				D13				
WG5 - *Dissemination*		D19					D17	D18
MANAGEMENT	HY1	FY1	HY2	FY2	HY3	FY3	HY4	FY4