European Cooperation in the field of Scientific and Technical Research
- COST -

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COST 094/14

MEMORANDUM OF UNDERSTANDING

Subject :	Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action ES1408: European network for algal-bioproducts (EUALGAE)

Delegations will find attached the Memorandum of Understanding for COST Action ES1408 as approved by the COST Committee of Senior Officials (CSO) at its 191th meeting on 12-13 November 2014.

MEMORANDUM OF UNDERSTANDING

For the implementation of a European Concerted Research Action designated as

COST Action ES1408
EUROPEAN NETWORK FOR ALGAL-BIOPRODUCTS (EUALGAE)

The Parties to this Memorandum of Understanding, declaring their common intention to participate in the concerted Action referred to above and described in the technical Annex to the Memorandum, have reached the following understanding:

1. The Action will be carried out in accordance with the provisions of document COST 4114/13 "COST Action Management" and document 4112/13 "Rules for Participation in and Implementation of COST Activities", or in any new document amending or replacing them, the contents of which the Parties are fully aware of.

2. The main objective of the Action is to generate a synergistic approach for utilization of microalgae biomass for sustainable fuels and chemicals.

3. 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 44 million in 2014 prices.

4. The Memorandum of Understanding will take effect on being accepted by at least five Parties.

5. The Memorandum of Understanding will remain in force for a period of 4 years, calculated from the date of the first meeting of the Management Committee, unless the duration of the Action is modified according to the provisions of Section *2. Changes to a COST Action* in the document COST 4114/13.

A. ABSTRACT AND KEYWORDS

Fossil fuel covers the majority of our energetic and chemical needs. However, fossil fuels are limited and the petrochemical industry has a negative impact on the environment. Biomass, as a renewable source, is attracting worldwide attention to satisfy this demand in the so-called bioeconomy. Conventional biomass feedstocks remain controversial due to the limited land availability and competition with food and feed production. Microalgae represent a promising alternative renewable source since they can be cultivated on non-arable land. Furthermore, microalgae remove and recycle nutrients from wastewater and flue-gases, thus providing additional environmental benefits. Investigating the production of non-fuel products could play a major role in turning economic and energy balances more favorable. Microalgae offer interesting applications in the nutrition field being high in antioxidants, pigments, polyunsaturated fatty acids and proteins. This COST Action proposes the establishment of a European network sharing a common goal: development of an economical feasible model for the commercialization of algae-based bioproducts. EUALGAE is created to stimulate not only interaction among research groups across Europe but also to foster cooperation between academia and industry. This scientific platform will generate a synergistic approach for utilization of microalgae biomass for sustainable fuels and fine chemical products.

Keywords: Microalgae, bioproducts, biofuel, harvesting, photobioreactor

B. BACKGROUND

B.1 General background

Renewable bioproducts are needed to replace fossil-derived compounds, which contribute to global warming and are of limited availability. Several advantages make microalgae an attractive feedstock for generation of bioproducts: high areal productivity, minimal competition with conventional agriculture, utilization of different water sources and recycle of carbon dioxide emissions. Additionally, components of microalgae can be separated and transformed in different valuable products. Microalgae offer interesting applications in the field of nutrition being high in antioxidants and pigments (carotenoids like fucoxanthin, astaxanthin and betacarotene and phycobiliproteins as phycocyanins), long-chain polyunsaturated fatty acids (EPA, DHA, and AA) and proteins (essential amino acids methionine, threonine and tryptophan). Likewise, microalgae

can become an important source for bioplastics which can be obtained as a by-product of algae biofuel production. The economic viability of algae based products and biofuels still needs to be reached. Investigating the production of non-fuel products, such as specialty chemicals, could play a major role in turning economic and energy balances more favourable.

Overall, microalgae could potentially provide an appropriate response to the worldwide biofuel demand by supporting different energetic forms and value-added products while coping with some other environmental issues such as water streams bioremediation and carbon dioxide mitigation. All these strategies are a priority all over the world and thus several research programs have been launched. In the USA and Australia, many companies (Aurora, Algae.Tec, ExxonMobil, Sapphire, Solazyme, DSM, Alltech) are involved in microalgae research programs. In the European Union context, algae research projects are also promoted but still needs further support. The EUALGAE seeks to stimulate and inspire the development of cross-cutting algal research activities. This COST Action dealing with the utilization of microalgae biomass for sustainable biofuel and bioproducts generation will provide a mechanism to strongly coordinate the research of leading-edge academic groups within Europe. Participants will focus on the targeted areas of activity rather than the normal fragmented approach. The involvement of both industrial partners and research groups will promote technology transfer and will grow a critical mass interested on algal based bioproducts. In this context, COST is the most appropriate framework to develop this highly required networking among partners, since research activities will be conducted by the participants that have their own financial support.

B.2 Current state of knowledge

Value addition into the microalgae production-downstream chain has now moved beyond biofuels to also produce high value products for a wide range of applications. The high metabolic versatility of microalgae and cyanobacteria metabolisms supports the cost-effective production of therapeutic products, proteins, biofertilizers, colorants, antiobiotics and bioplastics, which is gradually opening up immense growth opportunities in the global algae business. Microalgae also exhibit a valuable potential in environmental biotechnology, allowing for a sustainable and efficient wastewater treatment and CO_2 capture from flue gases along with the generation of huge amounts of biomass that could potentially serve as a feedstock for the production of high-added value commodities for the industry. In fact, the most relevant governmental projects carried out to date in the areas of photosynthetic CO_2 capture and biofuel production (*Aquatic Research Program 1978-1996* in the United States and the Research *Institute of Innovative Technology for the Earth 1990-2004* in

Japan) concluded that only the co-production of high added value products could eventually off-set the high production costs of microalgae cultivation and support a microalgae-based bioeconomy. Today, most of the references in the field indicate that the production of biofuels requires the coupling between microalgae production and wastes removal to be economically and environmentally sustainable.

Although microalgae biotechnology dates back to the Second World War, today the number of microalgae cultivated for mass production purposes is mostly restricted to genera such as *Chlorella, Spirulina, Dunaliella, Haematoccocus* and *Scenedesmus*, with more than 90% of this production being carried out in open raceway ponds. The intensive research conducted over the past decade in the design and operation of enclosed photobioreactors is gradually increasing the microalgae spectra with potential for mass cultivation. In addition, the funding launched over the past years all over the world in the research field of microalgae has significantly increased the spectra of high added value metabolites potentially synthesizable by microalgae. The isolation of extremophile microalgae (e.g., strains thriving high salinity water, high pH) with potential biotechnological applications will also increase the number of candidates cultivable in open raceways ponds. Research fields such as molecular biology, systems biology and synthetic biology, traditionally focused to bacteria and yeast, are yielding promising results in terms of molecular microalgae manipulation oriented to increase photosynthetic efficiency and over expression of novel products of interests. However, the development of a cost-efficient and sustainable microalgae-based bioeconomy still requires overcoming several technological and microbiological limitations and the fulfilment of several knowledge gaps. Most microalgae-related R&D projects are currently addressing the following research niches

i) Increased microalgae biomass and high-added value product productivity at decreasing operating cost. The real challenge to be overcome involves the achievement of year round photosynthetic efficiencies over 5 % (solar light basis), which would support microalgae productivities high enough to make microalgae biodiesel economically viable in low cost open photobioreactors.

ii) Development of cost-effective microalgae harvesting. The fact that most microalgae and cyanobacteria grow as free-living cells, exhibiting poor sedimentation characteristics, limits their harvesting by conventional sedimentation and entails the need for costly centrifugation or filtration separations. The understanding of the mechanisms underlying microalgae autoflocculation or a symbiotic cultivation of microalgae with bacteria capable of excreting bioflocculants have emerged as promising low-cost alternatives to enhance microalgae harvesting (a critical step that can represent up to 30% of the operating cost of microalgae production). Operational strategies based

on biomass recycling and membrane separation also deserve further investigation.
iii) Development of smart biorefinery platforms. The potential accumulation of multiple high-added value products in microalgae along with the need to recycle nutrients back to the cultivation stage (in order to decrease both the operating costs and the overall GHG footprint of the process) require the development of smart sequential extraction/separation strategies. Most biorefinery concepts proposed to date consider the anaerobic digestion of the microalgae residues (after the sequential extraction of the target products) to recover the remaining carbon and energy in the form of biogas, and the nutrients in the form of soluble ammonium and phosphate. The recycling of CO_2, directly from biogas or indirectly from the exhaust gases derived from the combustion of this biogas, will play a key role on the sustainability of the process, since a microalgae-based bioeconomy should never depend on the availability of CO_2 from fossil fuel combustion.
iv) Holistic and sustainable evaluation of microalgae cultivation producing high-added value. Issues such a water footprint (fresh water availability) in desertic areas or N_2O emissions from wastewater-based microalgae cultivation will be central to guarantee the environmental sustainability of the process based on the huge amounts of microalgae to be cultivated to sustain a microalgae-based bioeconomy.
Over the last 50 years microalgae biotechnology has developed for several commercial applications, including: aquaculture (feed), source of nutritional supplements and source of cosmetic ingredients. For innovative products (immunoenhancing properties compounds, plastics or biofuels value chain (not yet commercially deployed)), applied research and development still deserve further investigation in order to comply with EU sustainability targets. The Action EUALGAE will represent a unique platform in Europe to discuss and integrate the most recent technologies advances in the field over the past decade in order to assess the potential and sustainability of a microalgae-based bioeconomy. This forum will help identifying, coordinating and filling in future research niches and will maximize valorisation of valuable research resources by joining individual research efforts and minimizing parallel research.

B.3 Reasons for the Action

This Action proposes the establishment of a cluster composed of scientific groups and companies that share a common goal. Both research and engineering improvements are absolutely crucial for a successful implementation of any commercial algal-based production facility. According to the current scientific knowledge and the available technology, research carried out on algae biofuel production reached the same conclusion: unaffordability of a single product. In this line, the

biorefinery concept has been identified as the most promising option for a microalgae-based industry. An important argument for this COST Action is that microalgae biomass requires a completely new production process, with novel technologies for production, process control and automatization, harvesting and biomass processing. Therefore, large-scale production of microalgal biomass requires intensive collaboration and exchange of information between researchers working in different stages of the production process and value chain.

Over the last years, microalgae have shown their benefits in the context of nutrition, cosmetics and medical therapies. Nevertheless, microalgae biomass can offer a wide range of other added-value products and biofuels that still deserve further research and exchange of knowledge and experience is a must. The general objective of the EUALGAE is to promote mutual interchange and cooperation in biomass production and downstream biomass processing. EUALGAE participants cover different areas of research and have direct contact with industrial partners in the algae field. This COST action is created to foster synergies among all the partners involved and make algal-based bioproducts a reality. Moreover, the participants aim to apply the knowledge gained during the development of this Action in the industry and thus bring the microalgae field one step further towards commercialization.

B.4 Complementarity with other research programmes

EUALGAE is in line with strategic plan of the Seventh Framework Programme of the European Commission, the new Horizon 2020 and national programs developed in European countries. Likewise, the Algae-based biofuels and biomaterials are also the focus of other organizations such as the Biobased for Growth PPP, the European Energy Research Alliance, EUREKA, the European Biofuels Technology Platform, and the European Algae Biomass Association. Nevertheless, this COST Action does not overlap with previous initiatives since no other Action was found in this topic. The most related Action is CM0903, however the biomass employed in that Action is most likely lignocellulose biomass from wood and pulp industry.

C. OBJECTIVES AND BENEFITS

C.1 Aim

This COST Action aims at the establishment of a European network sharing a common goal: development of an economical feasible model for the commercialization of algae-based

bioproducts. EUALGAE is created to stimulate not only interaction among research groups across Europe but also to foster cooperation between academia and industry. EUALGAE is designed to establish a scientific platform to generate a synergistic approach for utilization of microalgae biomass for sustainable fuels and chemicals through cooperation between scientists from different member states and different areas and disciplines.

C.2 Objectives

The general objective is to create an EU cluster for a successful development of algae-based bioproducts. The goal will be addressing optimum overall energy and mass balances, to improve the reliability and robustness of the relevant bioproducts, lowering capital and operational costs. The different approaches and working areas of the participants are highly relevant to achieve that goal. Even though participants focus on a particular stage of the overall process, their interaction will clearly be a positive aspect to avoid research fragmentation. With this Action, participants will be given the opportunity to network, collaborate and exchange information which otherwise will be limited. This Actionattempts to gather European top scientists in the field and thus become an important pillar worldwide.
The deliverables will include periodical newsletters that will help to keep members informed and in touch with each other. This newsletter will describe the activities of the Action partners as well as reports that will be discussed in Working Group (WG) meetings. Likewise, some other outputs expected of this Action will be a website containing information of the partner's projects, Training Schools and Short Term Scientific Mission (STSM) for Early Stage Researchers (ESRs), scientific articles and annual workshops. Additionally, this Action will have once per year an "Open-day to microalgae facilities". This activity is a highly specific deliverable of this Action and is aimed to familiarize society with the benefits that microalgae can offer. An early stage contact with science and technology can be decisive for young students' future life path.
Finally, a summary of the scientific and technological results will be compiled in a book including guidelines and recommendations to be addressed for industrial partners.

C.3 How networking within the Action will yield the objectives?

The network is composed of scientists working mainly in research and development at Universities and Technological Centers, but in contact with industry and real production processes. The Action

will enable experts from the COST countries to come together and share knowledge and experience in order to achieve the stated objectives. The experts are familiar with the state of the art of each of the tasks listed in the WGs. In this way, the participants know the actual challenges and what deserves further investigation, which means an effective start of results generation. The main resources (manpower, equipment, infrastructure) needed to achieve the goals of the Action are already available at the participating researchers institutions and thus, available for the development of this COST Action. The recognized expertise of the partners is ensuring the coverage of the scientific objectives while the networking activities will play a key role in accomplishing the Action´s objectives. This Action will support this cooperation and exchange of knowledge through several instruments that will help in the objectives achievement:

- initial workshop with cross-disciplinary sections to assess the current situation and establish targets and strategies to achieve the objectives
- mid-term workshops to ensure openness and flexibility of the Action and its structure in order to permit the inclusion, after the implementation stage, of perspectives and emerging issues not foreseen earlier
- establishing a web-based forum beyond the Action participants for continuous exchange of ideas, experience, solutions, needs…
- training visits (using STSMs) for the diffusion of knowledge and harmonization of methods and techniques between the different scientific communities
- closing conference to present the Action results and to propose further collaborations by integrating expertise and interdisciplinary teams of the networking partners. Support from COST will facilitate the preparation of proposals for research funding calls (Horizon 2020).
- collaboration with stakeholders in the organization of activities, definition of needs and data supply. Research partners will get first-hand information about industrial needs. Intensive cooperation with industry is foreseen since one of the Action goals is the transfer of knowledge.
- newsletter describing the activities of the partners that will be forwarded to researchers and stakeholders
- organization of Training Schools for Early Stage Researchers with different background and participation in the different WGs
- collaboration with International Partner Countries (IPC) to give the Action a relevant and up-to-date role at international level through scientific and dissemination activities.

C.4 Potential impact of the Action

This Action will benefit the research and development in the field of algae-based biofuel and biomaterials production by bringing together a diverse group of researchers. More specifically, this Action includes environmental, economic and societal impacts:

- Environmental benefits entail carbon dioxide abatement by CO_2 uptake for microalgae growth and wastewater bioremediation by nutrients recycling or removal. Additionally, the substitution of existing products by alternative ones that are safer may reduce negative environmental impact
- Economic benefits include minimizing land use for microalgae culture production and energy requirements since microalgae are sun-powered microorganisms
- Societal benefits include mitigation of negative impacts of current fuels. Furthermore, the development of algae bioproducts would raise the need to safeguard natural resources by elaborating public policies.

Likewise, additional benefits of the Action outcomes include:

- Partners interaction will positively impact research fragmentation by proving a holistic approach
- Coordination of research efforts, transfer of knowledge and critical analysis of data will lead to specific recommendations for policy support
- Improvements in the knowledge of microalgae biomass utilization for biochemical and biofuel productions
- Increase of European economy competitiveness by implementing new technologies and alternative bioproducts generation on small and medium enterprises

C.5 Target groups/end users

Results of the Action will not only impact on scientists researching on the different disciplines involved in the Action (biologist, chemists, biotechnologists, engineers…) but also on European policy makers who in view of the results will be able to launch new initiatives to further reduce Europe dependence on fossil fuels, and public in general, who are really concerned about energy problems and environmental issues. Having developed an extensive network of diverse experts and organizations, the Action will create links to all interested parties to disseminate the results and achieve maximum impact. The interest of this Action for end users will be demonstrated by the inclusion of industrial partners in the networking activities. It is a main aim of this Action to foster the transfer of innovative technologies to full-scale applications. Exploitation of results will be performed by companies dealing with the design, construction and management of microalgae biobased processes.

This COST Action on the utilization of microalgae biomass for bioproducts has potential economic,

environmental and societal benefits. From this point of view, results of the Action are expected to have far-reaching consequences at both industrial and societal benefits. Those benefits do not only concern the sustainable energy sector but positive effects will also be observed in many other industry segments, such as pharmacological, aquaculture, nutritional and chemical industry, and renewable energy.

D. SCIENTIFIC PROGRAMME

D.1 Scientific focus

Emerging economies and the growing population rely on the natural resources availability. The society focuses increasingly on sustainable technologies and therefore recycling of waste streams and efficient energy use is highly required. Due to their efficient sunlight utilization, the potential of microalgae for energy purposes and production of value-added products is widely recognized. Simple growth requirements of microalgae make them attractive for bioprocesses aimed at producing a wide variety of bioproducts. Historically the emphasis of fuel products from microalgae has been devoted to the high lipid content that can be converted into alcohol esters using conventional transesterification. Economic analyses have shown that algal biodiesel production requires further research and development to become economically viable. Same conclusion stands for other biofuels production. Technical advances combined with the several advantages that microalgae offer such as CO2 capture, wastewater bioremediation and value added-products extraction will rush algal bioproducts profitability.

Microalgae represent a very large untapped reservoir of novel compounds. For instance, microalgae can accumulate pigments and vitamins that can be used as food and feed additives and as health-promoting supplements. Likewise, these microorganisms can also synthetize polysaccharides that can be used as emulsion stabilizer or bioflocculants and polyhydroxyalkanoate which is used for the production ofbioplastics. In the near future, microalgae are projected as living-cell factories for the production of biofuels and various biochemicals.

Since microalgae are often grown in diluted solutions and require large areas and water volumes, the high cost associated with mixing and harvesting impact negatively the microalgae bioproducts profitability. Low cost algal harvesting options are currently under development. A significant research effort is needed to develop and prove out cost-effective algal harvesting techniques.

Major barriers have to be overcome in order to make algal bioproducts a commercial reality. The EUALGAE research and development efforts of the participants focus on all the above scientific and technological needs. Additionally, the Action will establish partnerships with stakeholders involved in the different stages required to obtain microalgae bioproducts in a sustainable manner.

D.2 Scientific work plan methods and means

Based on the EUALGAE framework, challenges to be addressed include the cultivation process, cells harvesting, cell wall disruption and downstream processing of microalgae biomass for the obtaining of different bioproducts. WGs have been defined as follows:

WG 1: Microalgae growth optimization and population dynamics. The aim of this WG is to address constraints related to microalgae productivity.

Task a) Photobioreactor (PBR) design (including hybrid configurations and floating systems). Algal production facilities employ open and closed cultivation systems. Photobioreactors have not been engineered to the extent of other bioreactors in commercial practice, and therefore there is certainly scope for cost reductions and increases in efficiency. Reactor construction materials, optimal cultivation (gases and nutrients dynamics), heating/cooling and nutrient supply have been explored to some degree, but more definitive answers are needed. There is no best PBR design that allows high productivity with minimum operational costs, since the choice of the most suitable PBR design depends on the cultivated species, the location, and the final targeted product. The new systems should present important advantages with respect to conventional culture systems (i.e. open ponds) such as the possibility to operate with ultra-dense cultures (thus facilitating harvesting and reducing the risk of pollution of the culture) and reduced energy demand for culture recirculation.

Task b) Nutrients source (synthetic vs wastewater) and nutrition modes. The availability of water and nutrients to promote microalgal growth are determinant for a feasible production of any bioproduct. In fact, based on the current technology, microalgal cultivation is economically viable only if wastewater is used as source of water and nutrients. Nevertheless, this option may be questionable when added value products, or products for food and feed are targeted. On the other hand, for biofuels and other low cost products coupling microalgae culture and wastewater treatment is nowadays seen as an appropriate and economic solution.

Culture medium prepared with conventional agricultural fertilizers will be also tested and compared with wastewater feeding in terms of microalgae biomass production and targeted bioproduct content. Ideally, the microalgae cultivation will be firstly carried out in the lab and thereafter evaluated again at outdoors conditions.

Task c) Interaction with other co-occurring microorganisms in the culture broth. An optimized algae cultivation does not only depend on the cultivation system but also on the development of strains and conditions for culture that allow rapid production of algal biomass while minimizing growth of competing microalgal strains, grazers and pathogens. Deep knowledge of co-existing bacterial and algal communities in semi-sterile algae cultivation systems is essential for successfully establishing phototrophic outdoor production cultivation. Within this Action, partners will perform intense data-mining in the field of meta-genomics to characterize community in an algal cultivation system. A deep understanding of this co-existence will help to improve culture media to assist co-cultivation of algal production strains with
symbiotic microbes and in parallel will help to control or even eliminate parasitic predators.

WG 2: Microalgae harvest and cell wall disruption.

WG2 should be given full attention since it will clearly affect downstream biomass processing. The objective of WG2 is to focus on the evaluation of innovative harvesting and cell disruption techniques in accordance to the targeted bioproduct.
Due to the low biomass concentration and small size of microalgae cells, harvesting of microalgae biomass is a major challenge. The main criteria for selecting the harvesting procedure are the quality of the product, the biomass concentration for the subsequent process and the cost associated. Biomass is usually harvested by sedimentation, centrifugation or filtration, sometimes requiring an additional flocculation step. However, those harvesting techniques may not be suitable for microalgae because it can result in bioproduct damage. Autoflocculation, bioflocculation and electro-flocculation are novel technologies that deserve further investigation since these methods do not need any chemicals addition and thus culture medium can be reused for culturing of microalgae without any extra cost.

Likewise, cell disruption is one of the important steps in the downstream processing of intracellular products from microorganisms. The cell disruption techniques have an important effect on the yields and quality of the intracellular compounds and the scale of operation restrict the type of

applications. The influence of different cell disruption processes in the recovery of microalgal biomaterials will be assessed. Lately, mild temperature cell lysis techniques are investigated since they allow regulating the energy input to avoid bioproduct damage.

WG 3. Refining of microalgae into its value components

This WG deals with the primary biorefinery processes with the objective of providing microalgae biobased products and building blocks. For downstream processing, primary processing will include fractionation and separation of microalgae into their basic components and isolation of specific high-value components. Microalgae can synthetize a number of metabolites of great commercial interest that need to be extracted in order to make the microalgae large scale cultivation a cost-effective process. Microalgae co-extraction of other high-value products (PUFAs, antioxidants and pigments) will be also evaluated. The activities undertaken by this WG will aim at identifying the various products of interest that can be obtained from different strains of microalgae as well as choosing the best strategy and techniques for the separation of the different compounds.

The main bottleneck of the biorefinery approach is to separate the different fractions without damaging other fractions. There is a need for mild, inexpensive and low energy consumption separation techniques to overcome this bottleneck. Some of the biorefinery techniques appropriate for metabolite separation and extraction are ionic liquids or surfactants. These techniques are relatively new and should therefore be studied thoroughly before commercial use is possible.

WG 4. Valorisation of intermediates and subproducts

The aim of this WG is the development of valorisation methods from intermediates and sub-products of microalgal biomass from previous valorisation processes. The WG will focus in the optimal valorisation process to obtain useful products as food and feed ingredients, chemicals, materials, as well as liquid and gaseous energy carriers. Integration of different processes will be analysed to maximize the products yield while minimizing the releasing of wastes.

For instance, aminoacids can be used as biofertilizers and promoters for higher plants growth while carbohydrates could be the basis for the production of agents for the stabilization of emulsions and bioflocculants. Regarding materials, the utilization of microalgae biomass and subproducts in the elaboration of materials with industrial applications as bioplastics will be evaluated. After the

extraction of added-value compounds, the waste biomass could also be used as feedstock for the production of biofuels. According to the composition of waste biomass, it could be used for the production of liquid biofuels (bioethanol, biodiesel, biobutanol, bio-oil) or gaseous biofuels (biomethane, biohydrogen, syngas etc.). Technology used to produce biofuels efficiently is not yet established, thus different biological and thermochemical processes will be studied.
WG5: Life Cycle Assessment (LCA)

The objective is to evaluate microalgae-based bioproduct selected chains from both an economic and an environmental perspective and to point out the environmental and economic challenges to overcome in the near future. In a first step, information on different/alternative technologies for cultivation, harvesting, cell wall disruption, and downstream processing (see WG 1 to WG 4), as well as on valorisation of intermediates and co-products needed for economic analysis and LCA will be collected. Comparative environmental analyses of different technologies at the same process step will provide guidance on selecting environmentally friendly technologies. Throughout the Action, information on the different technologies will be updated by interacting with partners from other WGs to update LCA inventory data. Besides LCA, economic analysis of the microalgae-based bioproduct chain(s) is important because it is of low value to select an environmentally friendly technology that is economically unviable. Finding the trade-off between economic benefits and low environmental impacts will be crucial for the successful development of microalgae-based bioproducts.

E. ORGANISATION

E.1 Coordination and organisation

The EU ALGAE is composed of senior and Early-Stage Researchers coping with the different areas tackled along the Working Groups (WGs). The Action will provide the means to coordinate the activities required for an effective collaboration. Research activities will be conducted by the participants that have their own financial support, while COST will provide the necessary funding for the networking activities.
The Management Committee (MC) will be responsible for the budget planning and allocation of funds. The MC will coordinate the activities of all WGs. Likewise, the MC will integrate these activities to reach the overall objectives of the Action. Efficient day-to-day management will be ensured by the Steering Committee (SC). The SC will be constituted by the Chair, Vice-Chair, the

Leaders of the 5 WG, Short-Term Scientific Mission (STSM) Coordinator, dissemination manager and a speaker for the Early-Stage Researcher (ESR). The ESR speaker will be responsible to communicate the young scientist´s concerns and opinions during the WG meetings.
The Action will start with the first MC meeting. The MC will be responsible to coordinate the networking activities such as meeting, workshops and Training Schools.
The MC will receive the information from all the participants regarding the activities carried out within the COST Action context. In this manner, the MC will provide the Dissemination Manager the appropriate information to maintain an updated website and the two newsletters per year. The newsletter will describe the activities of the participants as well as reports that will be discussed in the WG meeting.
Based on the EUALGAE framework, WG are clearly interrelated and should be closely coordinated. In this context, the two Training Schools will be devoted to all the WGs activities. The aim of these Training Schools is to facilitate cross-fertilization between WGs and cover the whole chain from biomass cultivation to bioproducts generation. The possibility of converting the biannual Training School in a specialized course for PhD students will be also evaluated.
To reduce costs and to improve direct communication across the EUALGAE participants, the MC meeting will be held one day later of the annual workshop to withdrawn the main conclusion of the workshops. WG meetings will be held in a yearly basis to gather the results of the different WGs involved in the Action. To monitor the Action progress, semiannual distance meetings will be also organized. During these meetings, the WG will set up and monitor the milestones of the Action. More specifically, those milestones include the organization of Workshops and Training Schools, undertake decisions after the first MC meeting, MC and WG meetings and annual-Workshops, selection of ESR for STSMs and evaluation of results and future steps.
To foster interinstitutional collaboration, the MC will support the STSM Coordinator. STSMs are aimed at increasing researcher mobility across Europe to share knowledge, instruments and techniques. Hopefully, in addition to the knowledge gained by the visitor, these STSMs will results on publications of several EUALGAE participants' authorship.
The SC will present the scientific aims of each WG during the Workshops. The meeting activities that will be conducted in the Action include:
1st year: First MC meeting and Workshop I
2nd year: Workshop II and Training School
3rd year: Workshop III
4th year: Workshop IV and Training School
At the end of the Action, a final congress will be held in which both the scientific and industrial

community will be invited. During this final congress, the book including guidelines and recommendations for stakeholders will be also presented.
Likewise, the participants will share responsibilities and will be involved equally in the success of this Action. In this context, as explained above, different transversal committees will coordinate the organization of Workshops, exchange of Early Stage Researchers, and elaboration of newsletter and website.

E.2 Working Groups

The Action will be structured into five Working Groups:
WG1: Microalgae growth and population dynamics
WG2: Microalgae harvest and cell wall disruption
WG3: Refining of microalgae into its value components
WG4: Valorisation of intermediates and sub-products
WG5: Economic analysis and Life Cycle Assessment (LCA)
The activities will be coordinated by the WG Leader and Vice-Leader. The WGs will meet in yearly basis, while additional meetings will be held through internet. More specifically, they will be in charge of: (i) setting up and monitoring the milestones of the WG, (ii) dissemination of the WG achievements on the Action s website through the dissemination manager, (iii) potential European project application, (iv) interaction possibilities with other WGs and organization of the WG meetings. Communication between WGs will be encouraged through combined Workshops in which industrial partner will be also invited to promote discussion.

E.3 Liaison and interaction with other research programmes

This Action will establish collaboration with other related Actions such as ES1202 (Conceiving Wastewater Treatment in 2020 - Energetic, environmental and economic challenges and CM1303 (Systems Biocatalysis). The SC and MC will explore opportunities for Joint workshops and participation in the Training Schools through inter-Actions lectures.
The Action deals with one of the innovative bioenergy value chains established in the Implementation Plan of European Industrial Bioenergy Initiative (EIBI). EIBI efforts have been focused in 7 selection technologies which are not yet commercially available, and which could bring significant contribution to the bioenergy markets by large scale deployment (large single units or larger number of smaller units), whilst complying with the current sustainability requirements set

in relevant EU legislation. Although EIBI recognize that energy carriers produced by photosynthetic microorganisms (algae or cyanobacteria) is less mature than other value chains at this moment, the potential to shift this dynamics through technical improvements exists and the learning rate is higher than that of other value chains. Additionally, it should also be stressed out that EUALGAE will be developed with the aim of continuing the research and amplify the activities within the European research framework given by the Horizon 2020 Programme. The knowledge will also be shared with top scientists of different countries that are regularly meeting within the European Energy Research Alliance programme.

E.4 Gender balance and involvement of Early -Stage Researchers

To respect gender issues, a gender balance plan for the Action will be set up. The Action aims to achieve an appropriate gender representation in scientific and administrative activities and for this a quota of at least 30-40% of female members in the Working Groups would be attempted. The MC will encourage female activity by providing information of different research programs such as "L'Oréal - UNESCO "For Women in Science", Association for Woman in Science and any other national programs.
Early Stage Researchers will be supported according to the "COST Strategy towards increased support of Early Stage Researchers". In particular, the Training Schools, workshops and Short-Term Scientific Missions attempt to stimulate the participation of ESR. Furthermore, there will be a responsible of the EST within the SC which clearly reflects the willingness to involve young researchers. STSM for exchange of knowledge and collaboration will be particularly addressed to ESRs in order to allow them to create their international profile.

F. TIMETABLE

This Action will last for four years. Year 1 will include the MC meeting where Chair, Vice Chair, WG Leaders, STSM Coordinator and dissemination manager and speaker of young researchers are elected.
The first MC meeting: 1st quarter of year 1
MC meeting: 1st quarter of year 1 and 3rd quarter of year 1, 2, 3 and 4.
WG meeting: 1st and 3rd quarter of year 1, 2, 3 and 4.
EUALGAE website: available the 2nd quarter of year 1 until the end of the COST Action.

Action Workshop: 3rd quarter of year 1, 2, 3 and 4.

Training Schools: 2nd quarter of year 2 and 4.

STSMs: available from the 4th quarter of year 1 until the end of the COST Action.

Newsletter: 2nd and 4th quarter of year 1, 2, 3 and 4.

Final Congress and Book: last quarter of year 4

	First MC meeting	X															
MC meeting	X		X				X				X				X		
WG meeting	X		X		X		X		X		X		X		X		
EUALGAE website		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Action Workshop			X				X				X				X		
Training Schools						X								X			
STSMs				X	X	X	X	X	X	X	X	X	X	X	X		
Newsletter		X		X		X		X		X		X		X		X	
Final Congress and Book																X	

G. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: BE, DE, DK, EL, ES, FR, IT, NL, NO, PT, TR. On the basis of national estimates, the economic dimension of the activities to be carried out under the Action has been estimated at 44 Million € for the total duration of the Action. This estimate is valid under the assumption that all the countries mentioned above but no other countries will participate in the Action. Any departure from this will change the total cost accordingly.

H. DISSEMINATION PLAN

H.1 Who?

The target audience of this COST Action includes:

- Researchers in chemistry, biochemistry, biology and engineers from academia and industry. The immediate beneficiaries of the research activities are scientist and Early-Stage Researcher who participate in this Action.
- Industrial stakeholders working in the different fields that this Action tackles. Renewable resources, fine chemistry, green chemistry and wastewater industries are the secondary beneficiaries

of the research output and networking activities conducted under this COST Action
- European policy makers that outline strategies for the development of new research topics and technologies. Overall, the Action results will help profiling the European framework programs, and thus funding opportunities.
- Society is the general public that will be aware of the energy and bioproducts available from new resources such as microalgae

H.2 What?

All targeted audiences will find all the activities of the EUALGAE in the Action website. This website will be routinely updated by the dissemination manager. This website will contain:
- Description of the Action´s objectives
- Description of the work developed in each WG
- Events announcements (STSM, Action Workshops, and Training Schools)
- Information regarding interesting conferences within the investigation carried out under this Action and articles published by the Actions participants.
- Newsletters will be also posted on the website and additionally, an optional webmail list may be created for those interested in receiving the COST Action newsletter

The website will be public and thus, the COST Action information will be reachable by academia, industrial and policy makers community.
Scientific results will be published by standard means such as articles in peer-reviewed journal, review articles and books, presentation at scientific conferences and the annual workshops.
The general society will be addressed by public media such as science blogs, radio or TV interviews and divulgation articles.

H.3 How?

The dissemination of the results and networking activities will be addressed in MC meetings, annual workshops and final congress, STSM, Training Schools and newsletters. All these dissemination activities will be posted in the Action website. The EUALGAE website will be established for continuous update about the progress and developments of the WGs listed in the COST Action. Communication among Action members will be facilitated by electronic communication networks such as email lists and password protected website to exchange documents.

Members of the Action will publish in peer reviewed scientific and technical journals, and participate in meetings and conferences organized by the Action. . The expected impact is very high taking into consideration the scientific excellence of the network.. The participants will promote visibility of these Action activities by acknowledgments to COST support and, whenever possible, include both the Action acronym and COST logo. All the information concerning publications and conferences attended or organized by EUALGAE members will appear as well in the website. Representatives of the major stakeholders will liaise with the Action.