GreenCarbon-ETN
Innovative Training Network (Marie Sklodowska Curie Action) Advanced Carbon Materials from Biowaste: Sustainable Pathways to Drive Innovative Green Technologies

Materiales carbonosos a partir de biomasa: estrategías para el impulso de tecnologías sostenibles e innovadoras.

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Resumen

GreenCarbon, proyecto financiado por la UE en el marco de H2020 Marie Skłodowska Curie Actions - Innovative Training Networks, ofrece desarrollo profesional y oportunidades de formación a 14 investigadores los cuales se encuentran en los primeros 4 años de sus carreras investigadoras. El objetivo principal de GreenCarbon es el desarrollo de nuevo conocimiento científico, capacidades, tecnología y productos comerciales para carbones obtenidos a partir de biomasa (BC); de esta manera se pretende estimular la innovación en este tipo de materiales a nivel europeo. Su programa de investigación abarca todos los aspectos, desde los precursores (naturaleza de la biomasa) hasta su procesamiento (conversión termoquímica, desarrollo de porosidad, funcionalización química) y sus aplicaciones (p. Ej., Captura de CO_2, catálisis heterogénea y productos químicos a partir de biomasa), permitiendo un único diseño de materiales sostenibles a partir de biomasa.

Abstract

GreenCarbon, a project funded by the EU in the framework of the H2020 Marie Skłodowska Curie Actions – Innovative Training Networks, provides career development and training opportunities for 14 researchers who are in the first 4 years of their research careers. The main objective of GreenCarbon is to develop new scientific knowledge, capability, technology, and commercial products for biomass-derived carbons (BCs); thus impacting the way that Europe uses and innovates with sustainable carbon materials. Its research programme covers all aspects from precursors (the nature of biomass) to processing (thermochemical conversion, porosity development, chemical functionalisation) and application (e.g., CO_2 capture, heterogeneous catalysis and chemicals from biomass) enabling a unique design of engineered sustainable BC materials.

1. Motivation

The energy crisis, environmental pollution and global warming are serious problems that are of great concern throughout the world. World´s current energy consumption is estimated to 500 EJ/year out of which around 40% is dedicated to the production of materials and chemicals. Materials and chemicals as today are mostly derived from fossil fuels and so is the global energy [1]. These materials need to be simple to synthesise, as cost effective as possible and ideally based on renewable resources as we are running out of certain key elements such as Pt, Ir, Ru, Rh, etc [2]. These high-performance materials should have specific characteristics and be designed for performing specific functions in the fields of energy and environment.

Carbon materials are ideal candidates for performing many of these functions. Carbon can be found in a wide variety of allotropes, from crystalline (diamond and graphite) to amorphous (carbon black, activated carbon, etc.). In the past decade, the nanostructured forms of crystalline carbon (fullerenes, carbon nanotubes and graphene) have received the most attention due to remarkable and unusual physicochemical properties. However, the main disadvantage of using these crystalline nanocarbons for energy and environmental related application is their high production costs. Alternatively, carbon materials derived from renewable resources (e.g., lignocellulosic biomass) will play a very powerful role in this direction in the near future. So far, excluding activated carbons [3], relatively little research has been conducted on the synthesis and characterisation of carbon materials based on natural resources.

Biochar [4] has gained significant interest worldwide. Converting widely available and abundant biomass into charcoal captures CO_2 from biomass into solid carbon which can then be used as soil amendment with long term CO_2 storage [5]. Biochar is produced through the thermochemical conversion of biomass in an oxygen-limited environment [6]. Nevertheless, the effects of biochar and the requirements on its properties for soil amendment and carbon sequestration purposes have not fully been established [7].

The economic feasibility of current biochar systems for agronomic benefits depends on numerous factors including the biomass feedstock selection, transportation requirements, carbon sequestration abilities, effects on soil, etc.

In other words, there is increasing uncertainty about the potential of such systems for commercial exploitation. Thus, developing biomass-derived carbon (BC) materials for alternative uses other than soil amendment can increase the value of biomass and products and generate new technologies for biomass/biowaste upcycling and interactions with other industries.

2. Objectives

The main objective of our proposed Innovative Training Network is to develop new scientific knowledge, capability, technology, and commercial products for biomass-derived carbons; thus impacting the way that Europe uses and innovates with sustainable carbon materials. This will be accomplished through a rigorous training programme for fourteen early-stage researchers (ESRs) enhancing the European knowledge economy and closing loops on agricultural waste utilisation while creating new bridges between various sectors (i.e., agriculture-chemical and materials industries). GreenCarbon will train a new generation of scientists capable of not only scientific rigour, but also entrepreneurship allowing for itinerant deployment of themselves and their knowledge into the real world.

The objectives of the research programme are: (i) developing engineered thermochemical processes (based on pyrolysis and hydrothermal carbonisation from dry and wet biomass sources, respectively) to produce tailor-made biomass-derived carbons (BCs); (ii) developing novel low-cost carbon materials from BCs through a unique set of functionalisation protocols; (iii) using the resulting carbon materials in advanced applications in heterogeneous catalysis for renewable energy as well as pollutants removal; (iv) analysing the feasibility of using BCs as soil enhancers and CO_2 capture and sequestration agents; and finally, and, most powerfully in the long term; (v) strengthening synergies by focusing on multidisciplinary research in order to close the bioeconomy loop in a circular fashion and stimulate the link of the bioeconomy sector with other industrial sectors such as energy, waste management, advanced materials manufacturing, etc. Fig. 1 illustrates a basic overview of the research programme.

Our proposed research programme is feasible given the varied expertise and knowledge of the academic and industrial participants. The project is highly multidisciplinary involving engineering (large scale BC production and development of demonstrable models and prototypes), chemistry (BC functionalisation), materials (porosity and nanostructuring), catalysis (development of new catalysts supported on biomorphic carbons), adsorption (pollutants removal), and soil science (biochar stability and soil functional attributes). GreenCarbon is also highly intersectoral involving a high number of wide range of industrial partners working in different sectors from materials characterisation to waste management and renewable energy. Within GreenCarbon, the next generation of young scientists will be trained through a network-based, highly interdisciplinary training programme comprising several scientific and technological fields, experimentation at different scales (from laboratory to pilot-plant devices) and complementary skills, and following a training-through-research philosophy. Research methods include the currently most advanced experimental approaches, numerical models, high-technology instruments and state-of-the-art research tools. The research programme also includes joint technological developments with private-sector partners, who are motivated to deploy the research results.

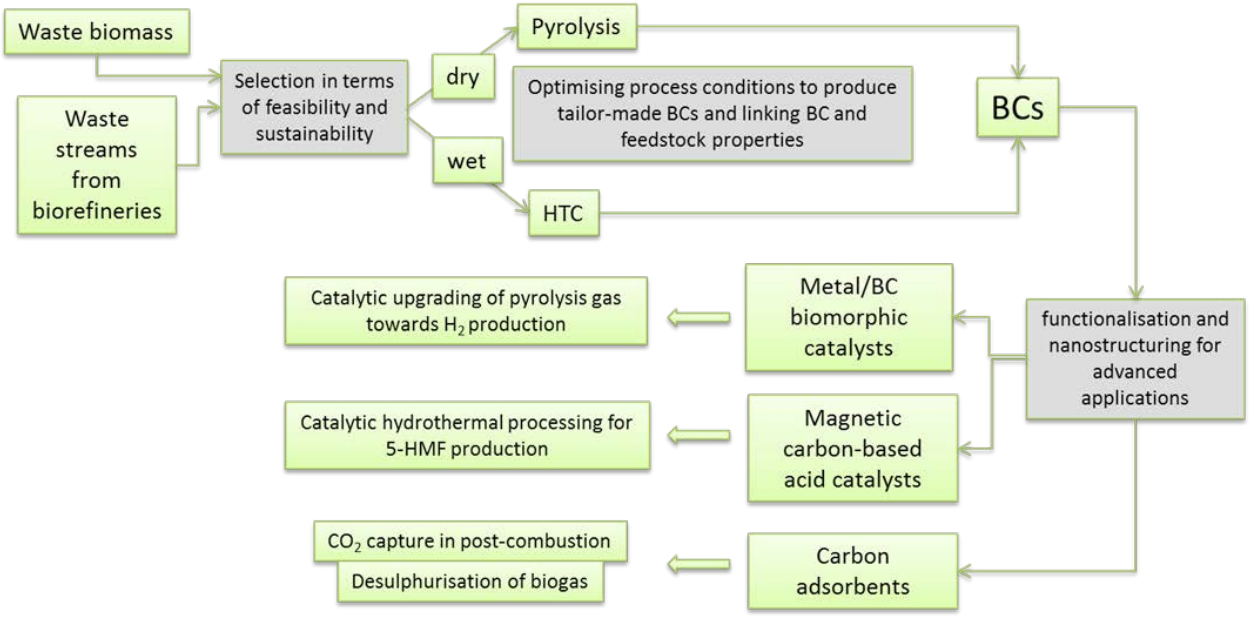

Figure 1. Simplified block diagram of the research programme.

Figura 1. Diagrama simplificado del programa de investigación.

Programme

The research programme of GreenCarbon consists of four strongly interconnected and interdependent work packages (WPs) 4–7.

WP 4 – Pyrolysis Conversion Routes for Dry Feedstocks

Objective: developing engineered pyrolysis processes –that can be taken to market– from dry biowaste sources with the view to produce tailor-made BCs.

Main tasks:

- Selection of several dry waste biomass samples in terms of potential sustainability.
- Setting the most appropriate slow pyrolysis process conditions (e.g., pressure, peak temperature, residence time of the vapour phase).
- Continuous intermediate pyrolysis: assessing the effect of the operating conditions on the properties of the produced BCs.
- Simultaneous production of BC and bio-oil by fast pyrolysis: establishing the best set of operating conditions.
- Development and validation of a comprehensive pyrolysis/carbonisation model.

WP 5 – Hydrothermal Carbonisation (HTC) Conversion Routes for Wet Feedstocks

Objective: developing engineered HTC processes from wet biowaste sources and lignin-containing streams with the view to produce tailor-made hydrochars; to explore the possibility to simultaneously obtain 5-HMF and other valuable platform chemicals.

Main tasks:

- Selection of several wet waste biomass samples (including lignin obtained within a lignocellulosic biorefinery framework) in terms of potential sustainability.
- Setting the most appropriate HTC process conditions in terms of BC quality and composition of the process liquid.
- Hydrothermal carbonisation and its integration with pyrolysis.

WP 6 – Refining of BCs and Advanced Applications

Objective: to ensure that the resulting BCs produced in WP 4 and WP 5 will be implemented in key industrial technologies adding thus value to biowaste, closing loops in biowaste utilisation and linking the biowaste sector with materials and chemical industries.

Main tasks:

- Development of low-cost BC-derived adsorbents for CO_2 capture in post-combustion.
- Development of low-cost BC-derived adsorbents for biogas desulphurisation.
- Development of novel metal/BC-supported catalysts for hydrogen production from pyrolysis gas.
- Development of novel magnetic catalysts for 5-HMF synthesis through HTC.

WP 7 – Sequential Biochar Systems

Objective: to integrate expertise across the network, focusing on identifying synergistic sequences for BC uses, spanning engineering, agricultural and horticultural applications, in order to maximise the added value and minimise carbon footprint across the whole chain.

Main tasks:

- Characterisation of BCs and BC-derived materials with the view of their final land use.
- Identifying opportunities for sequential uses of biochar.

Events

During its first year, several events were already organized within the GreenCarbon project. Regarding the meetings, the kick-off meeting of GreenCarbon, organised by the Management Team (MT), was hold in Huesca (Spain) the days 20-21st March. All the partners (beneficiaries and partner organisations) were invited to attend it as well as the first batch of ESR recruited. Besides, the vice-rector of Science Policy at the University of Zaragoza, the director of Escuela Politécnica Superior of Huesca and the director of European projects´ office at University of Zaragoza accepted also the invitation to attend the event. This meeting which was held successfully, was an opportunity for all the members of the consortium to meet for the first time and established the basis of the project.

More recently, the first annual meeting of this project organized by QMUL together the Management Team was hold in London the 12th December. All the participant institutions (beneficiaries and partner organisations) and the three members of the Advisory Board attended it as well as all the recruited researchers (ESRs).This meeting was a great opportunity for all the ESRs to present the work developed during this first year to the rest of the consortium.

Besides, during this meeting, each WP´s leader summarised the progress within that WP and future actions to be taken. In conclusion, this meeting was very useful to update the progress of the project between all the partners involved.

In other hand, within the GreenCarbon project, three Schools focused on topics related to the project and two workshops on complementary skills were organized at different nodes during this first year to contribute to the training of the ESRs. One more workshop will be held next September in Germany. Each of these events were the following:

- Research School 1: Thermochemical Biomass Conversion. Hold in UGent the days 3-4 July 2017.
- Research School 2: Refining of biomass-derived carbons. Hold in SU the days the days 13-14 September 2017.
- Reseach School 3: Applications of BC-derived materials. Hold in QMUL the days 13-14 December 2017.

Regarding the three workshops in complementary skills planned, the consortium got an agreement with the Careers Research and Advisory Centre (CRAC) Limited to support the GreenCarbon-ETN, through its Vitae programme, in providing complementary skills training to its ESRs, through an exclusive series of professional development workshops. Two of these workshops have already done; the first one was focused in personal skills. This was organised by Stockholm University (SU) in collaboration with the Management Team (MT) and given by the previously mentioned company “CRAC”. The event was hold in Stockholm (Sweden) the 15st September. Similarly, the second workshop, organized with the help of Queen Mary University of London (QMUL), was hold the same week as the School 3 and the first annual meeting in London (UK). The workshop was hold the 15st December and as the previous one developed by the company “CRAC”. Below, pictures of the attendees of the kick-off meeting hold in Huesca and all the ESRs during the school 2 organized in Stockholms in September.

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SUMMARY

Objective: To develop new scientific knowledge, capability, technology, and commercial products for biomass-derived carbons.

Financing: European Comission, Marie Sklodowska Curie actions, European Training Networks (ETN). Total EU contribution: 3.623.830 euros.

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Beneficiaries: University of Zaragoza (Spain), University of Ghent (Belgium), Aston University (United Kingdom), University of Hohenheim (Germany), Stockholms Universitet (Sweden), Queen Mary University of London (United Kingdom), University of Edimburg (United Kingdom) and Fraunhofer Center for Chemical-Biotechnological Processes (Germany).

Industrial Partners: Deutsches Biomasseforschungszentrum (Germany), Viridor Waste Management Ltd. (United Kingdom), PYREG GmbH (Germany), Biokol Sverige AB (Sweden), Surface Measurements Systems Ltd. (United Kingdom) and Freenland Horticulture Ltd. (United Kingdom).

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Website: greencarbon-ETN.eu

Coordinator: Dr. Joan J. Manyà, Associated Professor at the University of Zaragoza.