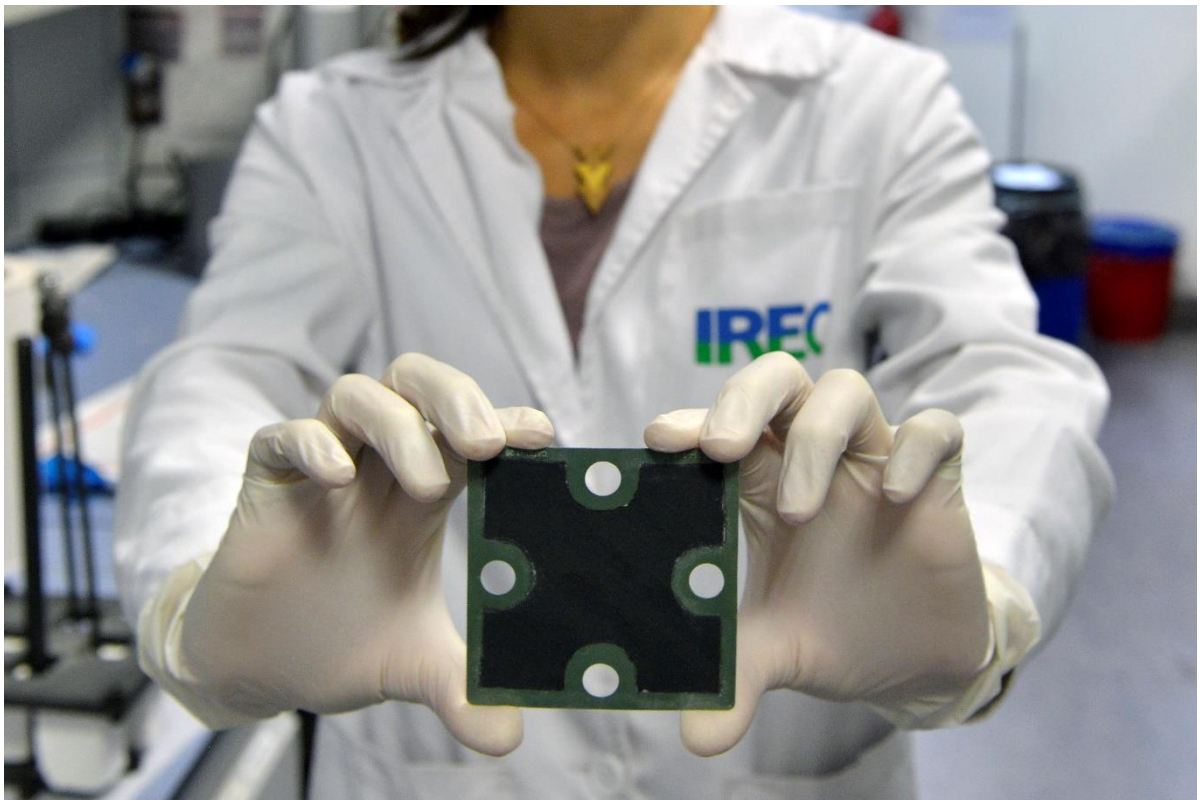
Shaping Energy for a Sustainable Future



Annual Report 2019

IREC, a centre of excellence in applied energy research

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1. LETTER FROM THE DIRECTOR

"Our centre's main objective is to develop disruptive energy solutions and bring them to society"

Prof. Dr. Joan Ramon Morante

Director of IREC

Energy transition is our core activity. We understand that we live in a fast-paced and ever changing world, in which the large-scale provision of sustainable, affordable and clean energy has never been more important.

To play its role as a reference center in the energy transition in our country, IREC is carrying out an intensive quality research program focused on supporting useful technological developments to provide alternatives and solutions to changes and modifications in the existing energy models.

This Research Program established scientific and technological priorities which should address three "Grand Challenges": Energy and Environment, Energy Storage and Smart Energy Management which are today essential for our society and on the basis of which the existence and presence of IREC in our country is relevant and necessary, translating the progress obtained in the generation of knowledge towards new products and technologies for the energy markets and, at the same time, giving support to the public authorities for the definition of regulations and regulation in the energy sector in front of the incessant changes in it.

To address the activities associated with these three grand challenges, IREC has 7 research groups framed in a support structure coordinated by the technology transfer and corporate image group. Likewise, this structure includes participation in special programs and actions as well as the participation in platforms and networks for services in the energy sector.

The objective of fostering new research ideas through interdisciplinary collaborations has been strongly encouraged in our program. IREC has confirmed its ability to generate many new outstanding competitive projects, mainly at European and industrial level, and based on this, IREC has also been able to attract talent in the category of young scientists and technologists as well as at the level of post-doc's. In particular, IREC coordinates, apart from national projects and industrial contracts, 12 European Union projects or other international actions. During 2019, IREC participated in 30 EU projects and coordinated the RIS3CAT energy community in Catalonia and the Energy for Society network.

Overall, at the end of 2019 a total of 68 projects were alive which provide to IREC a total accumulative income budget of 7,6 million euros. Actually, in 2019 we had an 80% of our

budget on competitive funding. Within of these quantities, 60% came from European Union calls or international sources and 18% from the industry, corroborating our progress in the success of attracting competitive funds, enhancing our international visibility and strengthening our ability to attract talent.

At the end of 2019, we had 26 PhD fellows (most of them from abroad), together with 12 undergraduates and master students. These numbers are a clear evidence of our activity and actions for enhanced attractiveness as an excellent and reference center, although it is limited by the available laboratories and office spaces of our provisional site and facilities.

The scientific and technological production of researchers continues to be diverse and of high quality. The outputs of the performed activities reveal that the institute is characterized by excellent research outcomes. IREC at the end of 2019, after 6 years of having finished its laboratories in 2013, counted 1093 publications and more than 27000 citations with an average ratio of about 25 citations per paper and a total h index of 77.
In 2019 IREC researchers published 83 articles in international scientific journals with impact factor, with an average impact factor of 8.25. The 98.80% of the papers were in first quartile (Q1) journals, and 32% were published in journals with impact factor above 10 and 37% above IF=8.
We continue to increase the total number of citations and our researchers are widely selected to lecture in international conferences as reference key note speakers. They cover contributions from novel materials, methodologies, devices, systems, technologies, applications and field evaluation oriented to deploy the energy transition (solar cells, thermoelectric, batteries, energy storage, fuel cell, hydrogen, CO2, synthetic fuels, smart grids, smart cities, efficient buildings, living lab, energy communities, smart energy managements, power electronics among others).

In addition, IREC activities have also led to the strengthening of technology transfer, having participated in industrial projects, having increased the number of patents, having developed and participated in diverses initiatives for the valorization of research results with the collaboration of KIC Innoenergy and also of the CERCA Ginjol program, and having supported the spin-offs born during the last years Ledmotive and Eolos as well as promoting new initiatives in this field. Likewise, IREC has collaborated in differents actions of our administration to increase the dissemination and social awareness of energy issues, having contributed to the PROENCAT program of the Generalitat de Catalunya.

So, you will also find in this report a thorough description of our new efforts to invigorate the communication, outreach and technology transfer actions, including at all steps our efforts to implement an effective gender action plan and a human resources career program. On the other hand, during this year, IREC has intensified the coordination actions with other subjects of the RDI organizations and industrial clusters to enhance the collaboration program in the energy sector.
In conclusion, we are very proud that the IREC, has increased its vibrant vitality, both concerning the scientific and technological activities strengthening its international position as reference and excellent center as well as its position at the national level increasing too its role with the energy enterprises enhancing its technology transfer capabilities. I'm sure that you will feel the IREC environment and enthusiasm all through this report.

Enjoy the development of science and technology in the field of the energy through our activities!

J.R. Morante
IREC Director

2. ORGANIZATION

HISTORICAL BACKGROUND

The Catalonia Institute for Energy Research, IREC (Institut de Recerca en Energia de Catalunya), was funded in July 2008, and began its R+D activities in January 2009.

After finishing the organization of the laboratories and infraestuctures in 2011-2012, in 2013 the Catalan Institute for Energy Research could achieve consolidation in both European and industrial projects. Since 2011 IREC has built a stable team of valuable individuals who are committed to the scientific and technological growth of the centre, resulting in cuttingedge research and a constantly increasing flow of income.
This was the result of the policy of the Generalitat de Catalunya - Ministry of Business and Knowledge- to promote research of quality in the energy sector and to strengthen the positive impact of technological developments on energy in the society through the creation of a center in its CERCA network of research institutes coordinanting its research, industrial and energy policy.
This action have the support from the CIEMAT (Research Centre for Energy, Environment and Technology) within Ministry of Science and Innovation- , from the IDAE (Institute for the Diversification and Saving of Energy) within Ministry for the Ecological Transition and the Demographic Challenge. Also with the support of the University of Barcelona, Universitat Politècnica de Catalunya · BarcelonaTech (UPC) and Universitat Rovira i Virgili (URV), and from the private sector with the contribution from ENDESA, ENAGAS and NATURGY, to launch together the reasearch and development activities of this specialized center on energy and its impacts on the economy, society and productive sector besides to enhance the disruptive creation in this area.

MISSION

Our mission is to contribute to the sustainable development of society with greater industrial competitiveness, by generating research of excellence, building new technologies to address current and future energy-related issues, and ensuring universal access to abundant, inexpensive and sustainable energy.

VISION

Our vision is to become a center of excellence and an international point of reference in the field of energy through research, development and innovation, and to work in a coordinated way with administration, industry and universities.

ORIENTATION

The Institute is developing its activities launching energy topics at short, medium and large term covering different approximations considering the time to market assessment:

» Technological researches which are focused on collaboration with Industry and Administration to create, in the short and medium-term, new products, solutions and services.

» Applied and technological researches which is aimed at generating novel flashing and exciting knowledges within groups of the Institute, with a medium or long-term application in mind for opening new transfer paths from science and technology to end users.

The Institute's orientation is defined by the balance and interaction between these two approaches.

ESTRATEGIC GOALS

» To spearhead the generation of disruptive scientific and technological knowledge aimed at providing industry with innovative and sustainable medium- and long-term energy solutions.

» To promote the continuous transfer of knowledge to the market and society, by collaborating directly with companies, and providing an environment that empowers spin-offs and supports the generation and licensing of patents.

» To expand our network in the field of energy, both at a local and international level, and to become a leading voice that inspires innovative, scientific and sustainable thinking across the sector.

ORGANIZATION CHART

BOARD OF TRUSTEES

THE IREC BOARD OF TRUSTEES HAS THE FOLLOWING MEMBERS

(updated December 2019)

CATALAN MINISTRY OF BUSINESS AND KNOWLEDGE, Catalonian Government
(Generalitat de Catalunya)
From Generalitat de Catalunya, Departament d'Empresa i Coneixement

Maria Àngels Chacón
Catalonian Minister of Business and Knowledge

Joaquim Ferrer
Secretary for Business and Competitiveness of the Catalonian Ministry of Business and Knowledge.

Francesc Xavier Grau
Secretary for Universities and Research of the Catalonian Ministry of Business and Knowledge.

Pere Palacín i Farré
General Director of Energy, Mines and Industrial Safety of the Catalonian Ministry of Business and Knowledge.

Joan Gómez Pallarés
General Director for Research of the Catalonian Ministry of Business and Knowledge.

Manel Torrent Aixa
Director of the Catalan Institute of Energy (ICAEN) of the Ministry of Business and Knowledge.

CIEMAT - Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas - (Research Centre for Energy, Environment and Technology)
Organization of the Spanish Ministry of Science and Innovation

Rafael Rodrigo Montero
Chairman of CIEMAT and General Secretary of Scientific Policy Coordination

Carlos Alejaldre Losilla
Director of CIEMAT

José Ignacio Cruz
Head of Wind Energy Unit

IDAE - Instituto Diversificación Ahorro Energético - (Institute for the Diversification and Saving of Energy)
Organization of the Spanish Ministry for the Ecological Transition and the Demographic Challenge

Sara Aagesen
Secretary of State for Energy - Organization of the Spanish Ministry for Ecological Transition and Demographic Challenge.
Chairman of IDAE

Joan Groizard Payeras
Director of IDAE

Consuelo Lozano
Area Director of Companies and Participated Companies

UB - Universitat de Barcelona - (University of Barcelona)
Joan Elias
Chancellor

UPC - Universitat Politècnica de Catalunya- (Polytechnic University of Catalonia)
Francesc Torres
Chancellor

URV - Universitat Rovira i Virgili - (Rovira i Virgili University)
María José Figueras

Chancellor

ENDESA Servicios S.L.
Isabel Buesa
Director of Innovation and Technology of ENDESA SA in Catalonia

Naturgy, S.A.
Mireia Ribot Rodulfo
Director of Gas Network, Energy Efficiency & Renewables

ENAGÁS, S.A.
Juan Andrés Díez de Ulzurrun Moreno
Engineering, Technology and Purchasing General Manager

IREC is one of the 42 research centres of Catalonia, especifically focused on energy research at Catalonia. IREC is a member of the CERCA Institution, the Catalan institution created by the Catalan Government to supervise, support and facilitate research to the Catalan research centres:

IREC is one the research Institutes with the TECNIO accreditation, awarded in 2016 by ACCIÓ, the agency from the Generalitat of Catalonia responsible for competitiveness and internationalization:

IREC is one of the 30 research centres of Catalonia, which were awarded by the European Comission with the acreditation "Human Resources Excellence in Research", to the R+D entities that implement the strategy "Human Resources Strategy for Researchers:

3. FINANCES - IREC IN NUMBERS

BREAKDOWN OF ACCOUNTS

2019 has been a year of financial stability regarding the ordinary operating R+D income, largely due to the strength of IREC's research initiatives.

Income from R+D activities increased significantly in competitive projects and also increased in industrial projects.

The increase in basal funding from Generalitat de Catalunya as trustee of the foundation, over previous years, affected positively the financial closing of the year 2019.

In 2019, the Institute achieved a positive exploitation balance, with an EBIT near to 0.4 million euros and a Net Profit of 0.055 million euros, due to the positive effects of the operational restructuring carried out in 2018, with a significant increase in income from R+D activities in competitive projects.

The tax contingency with respect to deductibility of the incurred value added taxes, which affected significantly both the economic results and equity from 2014 to 2016, is still waiting for resolution from the Regional Economic-Administrative Court. The recent resolutions of this Court to identical appeals from other research centres and also the judgments of the Spanish Supreme Court from 2016 and 2017, added to the judgments of the Central Economic-Administrative Court, have been clearly favourable to the precepts of universities and research centres. These resolutions state that the activity of scientific and technological research should be considered an economic activity, so, a subject activity to the value added taxes and not exempt from them, with full right to the refund of input value added taxes. This scenario determines the very high predictability, that the claim made by the IREC in front of the Court will be estimated.

	Audited P&L	Audited P&L	Audited P&L	Audited P&L	Audited P&L
PROFIT AND LOSS ACCOUNT ('000)	2015	2016	2017	2018	2019
TOTAL REVENUE	**9,778**	**7,892**	**7,395**	**7,842**	**8,288**
INCOME FROM R+D ACTIVITIES	5,227	4,316	4,144	4,272	5,198
TRUSTEES FUNDING	1,710	1,454	1,505	2,000	2,000
GRANT ASSETS ASSIGNED	2,795	2,098	1,721	1,552	1,044
OTHER INCOME	46	24	24	18	45
TOTAL OPERATING EXPENSES	**6,946**	**6,805**	**5,824**	**5,736**	**6,683**
PERSONNEL EXPENSES	4,331	4,360	3,929	3,743	4,364
OTHER OPERATING EXPENSES	2,615	2,445	1,896	1,993	2,320
EBITDA	2,831	1,087	1,570	2,106	1,604
AMORTIZATIONS	3,053	2,294	1,773	1,642	1,234
EBIT	- 221	- 1,207	- 203	464	371
FINANCIAL RESULT	- 446	- 419	- 375	- 343	- 326
EXCEPTIONAL RESULT		1,923	1,705	- 0.5	9.5
PROFITS	**- 667**	**296**	**1,127**	**120**	**55**

IREC'S 2019 PERFORMANCE

2019 has been a year of consolidation in the R+D activities, with significant increase in income from European and National competitive projects. Income from industrial projects also increased.

Overall total income budget increases 5,7%, due to a significant increase in European coordinated projects and consolidation in income from all competitive projects.

	European Competitive Projects	National Competitive Projects	Industrial Services	Researchers Grants	Subtotal R & D Activities Income	Trustees Funding	Total Operation Budget	Capital Grants	Total Income
2018	2.297.877	955.400	768.887	267.926	4.290.089	2.000.000	6.290.089	1.551.692	7.841.782
2019	2.662.528	1.372.471	910.743	297.532	5.243.274	2.000.000	7.243.274	1.044.400	8.287.674
Variation 2019/2018	15,9%	43,7%	18,4%	11,1%	22,2%	0,0%	15,2%	-32,7%	5,7%

INFRASTRUCTURE FUNDING

The IREC's scientific and technological infrastructures have been funded by the following public administrations through the annual calls for tender listed below:

» ERDF funding within the "Programa Operatiu Catalunya 2007-2013"; € 4,202,998.15 granted to finance the IREC's Barcelona infrastructures, and € 1,853,449.83 granted to finance the IREC's Tarragona infrastructures.

» ERDF funding within the "Fondo Tecnológico Ministerio de Ciencia e Innovación"; € 304,490 awarded to finance the infrastructures of the IREC's offshore wind energy test station in Tarragona, advanced through the program Innplanta 2010-2012 from "Parques Científicos y Tecnológicos del Ministerio de Ciencia e Innovación".

» "Infraestructuras Científico-Tecnológicas", from the Spanish Ministry of Science and Innovation, funded with loan and ERDF funding, within the "Fondo Tecnológico Ministerio de Ciencia e Innovación", with a € 402,425.78 grant to finance laboratory equipment in Barcelona.

» Funding of 2 million euros for IREC infrastructures in the 2009-2011 period from the 2009 Spanish State budget, pursuant to section 32 in the third additional ruling of the Statute of Autonomy, through the call made by the Spanish Ministry of Science and Innovation, with the support of the Ministry of Innovation, Universities and Enterprise of the Government of Catalonia.

» Funding of 3.1 million euros for IREC infrastructures in the 2010-2012 period from the 2010 Spanish State budget, pursuant to section 32 in the third additional ruling of the Statute of Autonomy, through the call made by the Spanish Ministry of Science and Innovation, with the support of the Catalan Ministry of Economy and Finance.

» Funding of 1 million euros for the IREC's offshore wind energy test station in Tarragona in the 2010-2012 period, from the 2010 Spanish State budget, pursuant to section 32 in the third additional ruling of the Statute of Autonomy, through the call made by the Spanish Ministry of Industry, Tourism and Commerce.

» Pluriannual funding of 7 million euros awarded by the Generalitat de Catalunya to fund 5 million € of the IREC's infrastructures in the period 2010-2014, plus interests.

» Nominal subsidy of € 100,000 from 2010 within a programme for cooperation between the state administration and the autonomous communities, awarded by the Spanish Ministry of Science and Innovation.

» Loans totalling € 13,963,966 through the calls Acteparq 2009 and Innplanta 2010-2012, both funding schemes from "Parques Científicos y Tecnológicos del Ministerio de Ciencia e Innovación", for the financing of the IREC's scientific and technological infrastructures at its Barcelona and Tarragona headquarters.

IREC PERSONNEL

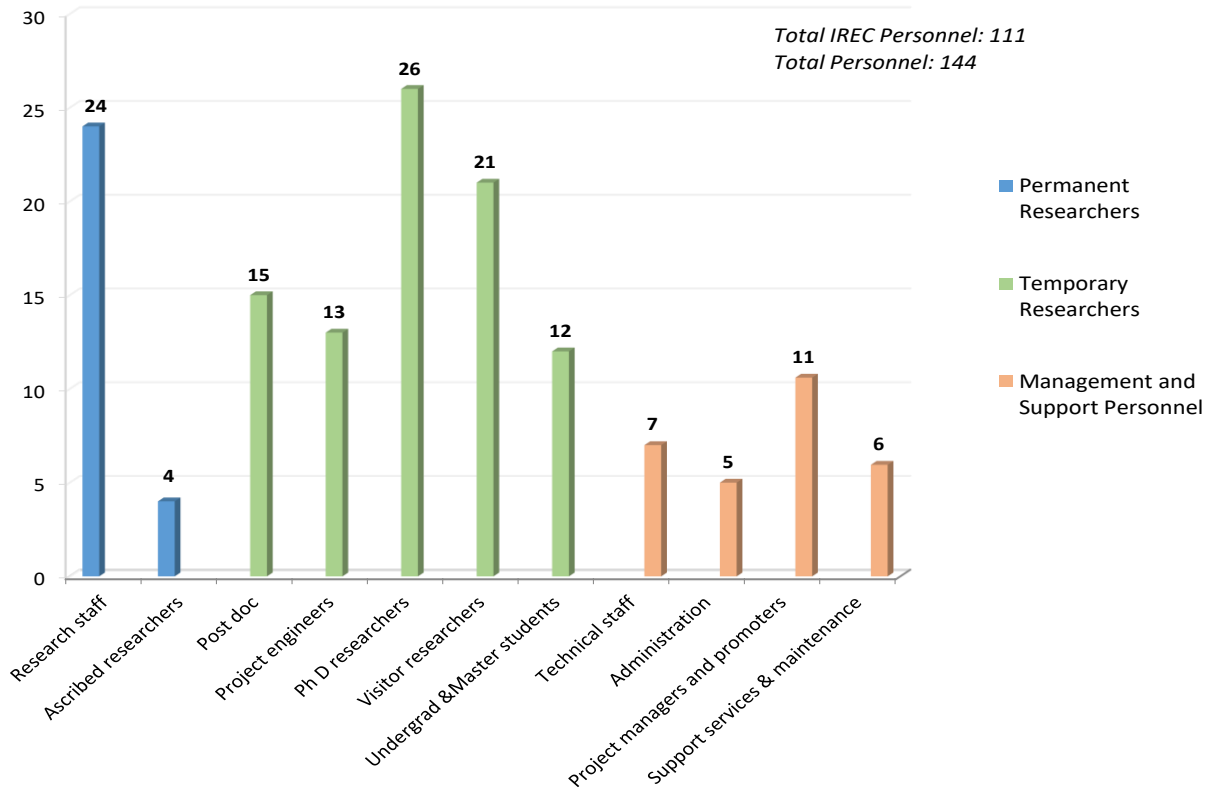
The Institute currently has more than 110 members from all over the world, including 7 research groups organised around two research areas -Advanced Materials and Systems for Energy Area and Energy Efficiency in Systems, Buildings and Communities Area- and one research programme -Program for Fusion Technology Development-. This IREC research is underpinned, protected and promoted by a comprehensive set of management and support services. All of them form the IREC Team.

IREC strives to provide a supportive and international working environment. The institute recognises the power of a diverse community and encourages applications from individuals with varied experiences, perspectives and backgrounds, and it is committed to promoting gender diversity among faculty. With this aim, IREC adopts family-friendly policies, adheres to state-of-the-art guidelines for advancing gender equality and women´s leadership in science.

IREC endorses the Requirements and Principles of the European Charter for Researchers, the Code of Conduct for the Recruitment of Researchers, and Open, Transparent, Merit-based recruitment promoted by the European Commission and follows Equal Opportunities policies.

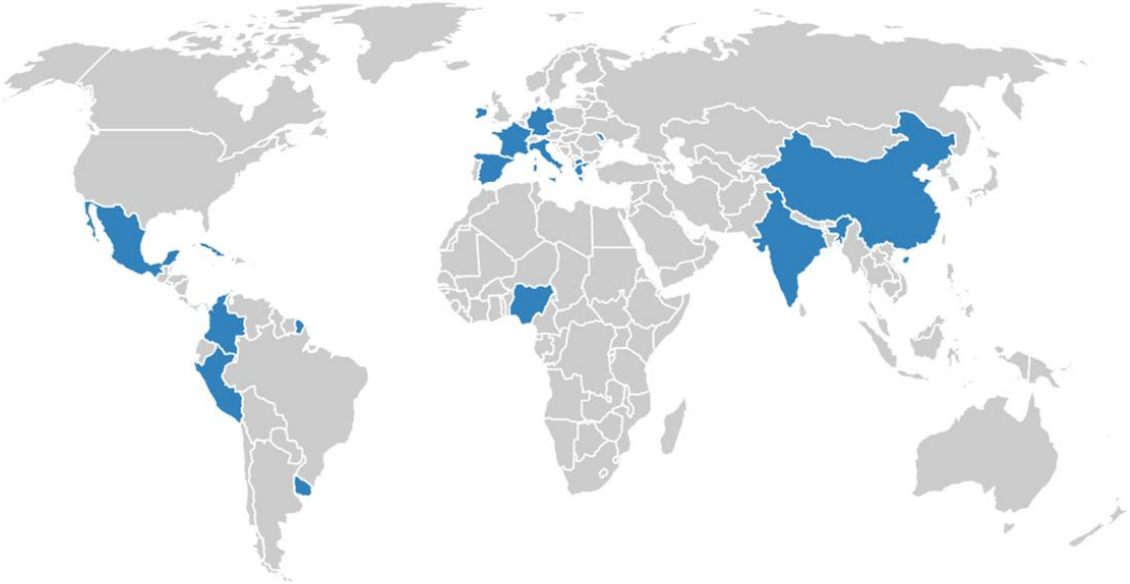
On December 2017, IREC was awarded the 'HR Excellence in Research' logo. This recognition reflects the commitment of the Institute to the continuous improvement of its human resources policies.

Following, a distribution of IREC's personnel by permanent and temporary, identifying research, technician and management team:

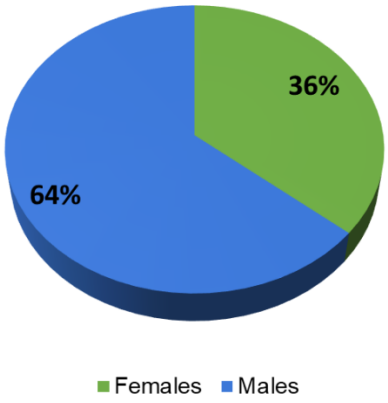


INTERNATIONALITY

In 2019 IREC had staff and researchers from different nationalities: Andorra, China, Colombia, Cuba, England, France, Germany, Greece, India, Ireland, Italy, Luxembourg, Macedonia, Mexico, Moldova, Nigeria, Peru, Spain, Ucraine and Uruguay.



BREAKDOWN OF IREC PERSONNEL BY GENDER



TECHNICAL STAFF

Research at IREC is supported by specific laboratory technicians and scientific and technological platforms and facilities running by specialized personnel that provide shared access to specialized and cross cutting equipment, services and expertise for the advanced technological preparation, characterization and assessments for all kinds of materials and energetic systems at different levels. These are open to external uses either from academia and industry, with precise conditions tailored to meet customer technology demands via our knowledge&technology transfer unit.

The IREC community in the Barcelona headquarters

4. FACILITIES AND EQUIPMENT

The IREC facilities are located in Barcelona and Tarragona. Our laboratories are equipped with state-of-the-art tools to conduct research of excellence in the two areas of the institute:

1) Advanced Materials and Systems for Energy
2) Energy Efficiency in Systems, Buildings and Communities

Both IREC laboratories are equipped with cutting-edge technology comprising systems for the generation, storage and smart management of the energy.

IREC hosts:
- 7 research laboratories
- 1 general research support laboratory
- 1 general common facilities lab for characterization and analysis of materials, components and energy systems.
- 2 simulation and testing facilities that can operate jointly

5. RESEARCH LINES

IREC research activities are aligned with **three pillars**:

1) **Energy and environment**

With an increased demand for energy comes an increased responsibility to protect the natural environment. At IREC, we are innovating towards a cleaner energy future.

2) **Energy storage**

To ensure that future energy needs are met, the transition towards renewable technologies must be accompanied by effective methods for large-scale energy storage.

3) **Smart energy management**

We are committed to making the energy efficient cities of tomorrow a reality. This requires a holistic approach that considers the economy, the environment, and the people who live in it.

IREC research lines are aligned with the European policy targets as well as with the energy industry aims of the energy strategy approved by the industrial and governmental members of the IREC Trustees Board.

In this framework, the European Strategic Energy Technology Plan (SET-Plan) as well as the forensen objectives included in the preparation of the Pacte Nacional per la Transició Energètica a Catalunya (PNTE), establishes a first references about the strategic energy technology policy for Europe and its adaptation to Catalunya. It is addressed to accelerate the development and the deployment of cost-effective low, even zero, carbon technologies and new energy generation, specially renewal ones, transport, distribution and end-users models as well as the smart energy management systems and related services considering the contributions from novel options as energy storage, internet of thing and big data alternatives.

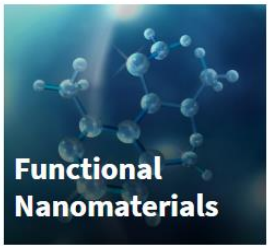
The proposed strategic map emphasizes the importance of promoting the quality of basic and applied science as a way of making progress for deployment emerging emerging technologies and their set-ups. The action plan also includes measures related to planning, implementation, resources and international cooperation in the field of energy technology, innovation and services as key elements for new energy business models and their acceptance and interaction with the society.

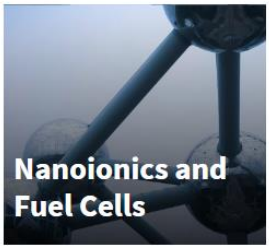
Under these boundaries, the most interesting topics, where European research should be the most effective for improving the industrial competitiveness, are about basic materials science for developing new functional sytems and device components, physical chemistry of processes, heat and mass transfer phenomena, advanced electronic and electrical power, dedicated powerful tools to assess energy set-up, especially, on large scale facilities.

Likewise, emphasis must be addressed on engineering capabilities for transferring knowledge and understanding to disruptive innovations, smart energy management and intelligent services increasing efficiency of the used energy.

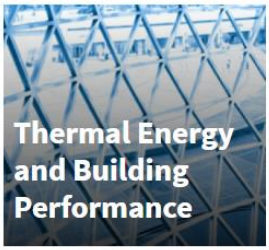
6. RESEARCH UNITS

Advanced Materials and Systems for Energy Area





Energy Efficiency in Systems, Buildings and Communities Area



6.1. ADVANCED MATERIALS AND SYSTEMS FOR ENERGY AREA

The area of Advanced Materials and Systems for Energy is a unit of research and technological development focused on materials and devices for implementing system for energy conversion and storage. Its activities involve the understanding, development and implementation of elements suitable for scientific and technological knowledge transfer to industry and offers, at the same time, technological support for addressing innovations in this field. These activities are strongly related with activities of research and technology development performed in other areas of the Institute, where projects are boosted through collaboration.

Regarding energy conversion, the work of the Advanced Materials and Devices for Energy area addresses major effort on solar energy and fuel cells, including also different options for the direct conversion of solar energy into electrical and/or chemical energy, in the context of artificial photosynthesis processes.

In this context, activities are centered on thin layer II-VI technology and the use of new concepts in nanomaterials to increase efficiency and or reduce cost considering its potential as building integration photovoltaic element. At the same time, our capacity to synthesize and or grow new nanostructured materials as well as new catalysts is addressed to new concepts of photoelectrochemical systems for the direct conversion of solar energy into chemical energy. Objectives are to obtain hydrogen and reduce CO2 to develop a C1 economy with special attention on the storage of chemical energy and the development of solar refinery. These activities are also guided by new results in the field of nanoionics for the advancement of electrochemical systems such as fuel cells and their reversible use as electrolyzers.

Nanoionic properties are being studied for developing advanced new electrochemical systems such as; integrated and intermediate temperature fuel cell and electrolyzers, while nanocatalyts are being implemented for new energy conversion systems.

Relevant advances in nanoelectrochemistry are being used for improved energy storage cells implementing new energy storage cells and systems as components of a pilote line. New 3D electrodes based on advanced nanomaterials and the use of catalysts, membranes and new formulations of liquid electrolytes are being applied to the development of new technologies for electrical storage beyond the present battery technology. This also includes new

methodologies for the diagnosis and prognosis of energy storage systems needed for smart energy management. Special attention is being laid on flow redox based batteries as an alternative to contemporary lithium ion cells. The above activities are converged for the development of integrated systems, their control, and development of testing tools and performance assessment procedures. Their control by means of sensors and the use of harvesting tools allows us to guarantee sustainable autonomy and potential effects on energy management criteria.

The Advanced Materials and Devices for Energy sector is organized in five interrelated laboratories and a general laboratory of common services and facilities. These laboratories are respectively focused on the following activities:

6.1.1. ENERGY STORAGE, HARVESTING AND CATALYSIS

6.1.2. FUNCTIONAL NANOMATERIALS

6.1.3. NANOIONIC AND FUEL CELLS

6.1.4. SOLAR ENERGY MATERIALS AND SYSTEMS

6.1.1. ENERGY STORAGE, HARVESTING AND CATALYSIS

The Team

(permanent and temporary positions, tenure tracks and fellowships)

Prof. Dr. Joan Ramón Morante, Group Leader of Energy Storage, Harvesting and Catalysis
Dr. Teresa Andreu, Deputy Group Leader of Energy Storage, Harvesting and Catalysis
Dr. Sebastián Murcia, Staff Scientist (Joan de la Cierva)
Dr. Jordi Jacas, Staff Scientist
Dr. Nina Carretero, Staff Scientist
Dr. Jordi Guilera, Postdoctoral Researcher
Dr. Zahilia Caban Postdoctoral Researcher (Tecniosping program)
Dr. Elias Martinez, Postdoctoral Researcher
Mr. Martí Biset, Laboratory Support
Dr. Carles Ros, Laboratory Support
Dr. Hemesh Avireddy, Postdoctoral Researcher
Mr. Arturo Javier Pajares, Predoctoral Student
Ms. Andreina Alarcón, Visiting Predoctoral Student
Mr. José Miguel Delgado, Visiting Predoctoral Student
Ms. Monalisa Chakraborty, Predoctoral Student
Ms. Viktoriia Holovanova, Predoctoral Student
Ms. Ting Zhang, Visiting Predoctoral Student
Mr. Venkata Siva Rama Krishma Tandava, Predoctoral Student
Mr. Marcelo Eduardo Chavez, Predoctoral Student
Mr. Paolo Lamagni, Postdoctoral Researcher (DFF grant)
Prof. Dr. Narcis Homs. Associated Professor, UB

The Energy Storage, Harvesting and Catalysis group investigates, establishes and assesses new processes, mechanisms and systems for storing energy, as well as develop high performance catalysts to enhance the involved energy conversion processes. Likewise, we investigate new methods in harvesting and energy storage for fully autonomous systems.

We cover a diverse range of multidisciplinary activities, including:

- The physics and chemistry of materials for their synthesis, processing and characterization.
- Electro (photo) chemistry
- Catalysis
- Thermoconversion, electroconverssion and artificial photosynthesis.
- CO_2 valorizationand Power to Gas or Liquids
- Renewable gases (hydrogen, methane,…), synthetic fuels and added value chemical's
- The development of knowledge and technology in lithium ion, redox flow, metal air batteries as well as in capacitor's. Harvesting and storage for autonomous systems.

The activities of the group have led to the development of new technological approaches that have allowed us to obtain competitive prototypes of flow systems based on vanadium or organic electrolytes with very high performance with high values of energy efficiency and applied current density that demonstrate its feasibility at the industrial level. Likewise, we have obtained significant records in the performances of the new generation of LiS batteries working in regimes from 0.1C to 5C and new catalysts have been implemented for new outstanding releases of metal air batteries and photobatteries. The latter have become a disruptive alternative for electrical energy storage combined with self-consumption.

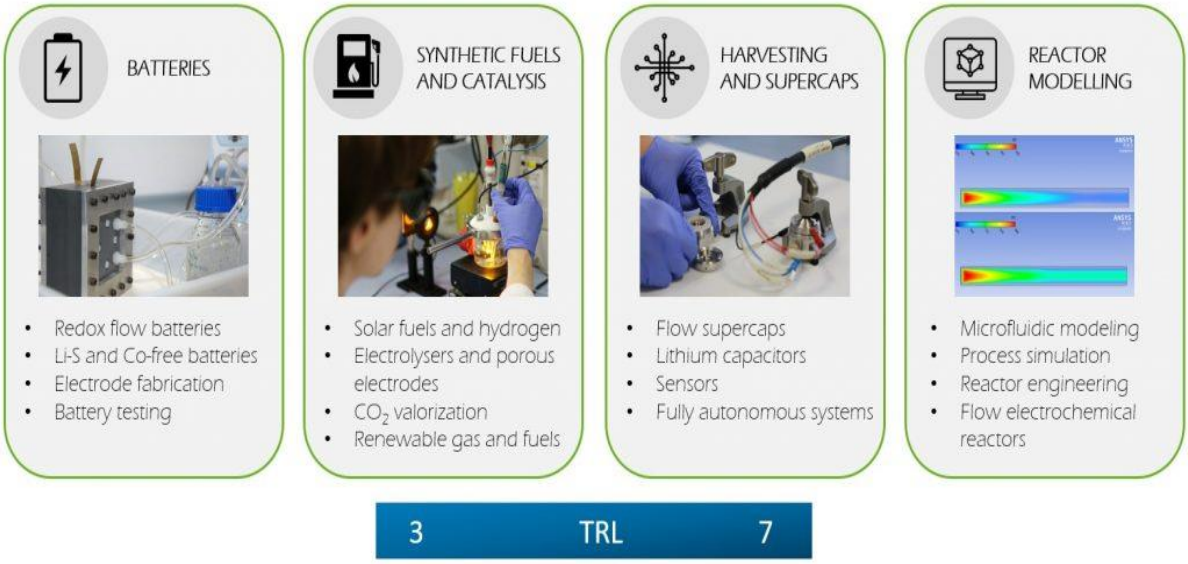
On the other hand, with the goal of building a decarbonized society based on a feasible energy transition in the industrial sectors, we are investigating the chemical storage of energy, the production of renewable fuels and the obtaining high value-added chemical products through sustainable procedures. So, based on the research carried out, new technological routes have been proposed for the efficient production of synthetic fuels in a high degree of efficiency, especially based on solar energy., The proposed technology route allow to achieve values of solar efficiency to hydrogen higher than 18% and solar to fuels greater than 15%. Likewise, activities are driven to the production of renewable gases (hydrogen, methane) at pilot plan level considering different sources of the required feedstock's. Complementary work is being performed using thermoconversion processes based on the use of plasmas and new catalysts.

Our research activities are distributed across three major axes:

- Electrochemical batteries, with a focus on redox flow batteries – vanadium, organics, supercaps, lithium sulphur, advanced lithium ion and metal air batteries.
- Thermoconversion, electroconversion, bioconversion and photoconversion (artificial photosynthesis) technologies as new alternatives for the sustainable fuel production.

- Fully autonomous systems with reliable capacity for energy storage, essential for achieving smart energy management systems.

The Energy Storage, Harvesting and Catalysis group conducts cutting edge research in emergent technologies to facilitate the energy transition: from materials to reactors of disruptive electrochemical and chemical energy storage devices contributing to the society descarbonization by reducing CO2 emissions or reusing CO2.



CAPABILITIES

- Battery fabrication, assembly and testing (ageing, degradation, climate tests...)
- Electrochemical testing (potentiostats, electrochemical impedance spectroscopy, rotating disk electrode, photoelectrochemistry, solar simulators, IPCE)
- Thermo-, photo- and plasma-catalytic reactors
- Heterogeneous catalyst characterization (BET, chemisorption-MS, TG-DSC, DRIFTS-MS)
- Electrode/catalyst fabrication and thin film deposition (ALD, electrospinning, hydrothermal, electro-deposition, wet impregnation, mesoporous materials, doctor Blade deposition, spin coating...)
- Reactor modelling (CFD)

HIGHLIGHTS

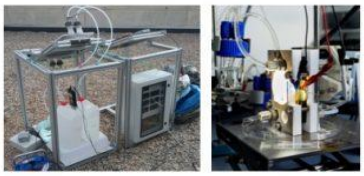
COSIN — **PILOT PLANT**

Methanation unit at the water treatment plant EDAR Riu-Sec, Sabadell

REDOX 2015 — **PILOT PLANT**

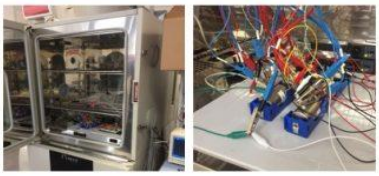
Collaboration in the Project for a Vanadium Redox Flow Battery pilot plant in EDP Energía (Gijón, Spain)

SOLAR FUELS — **PILOT PLANT**



Solar hydrogen demonstrator plant for an industrial project

HELIS — **DEMONSTRATOR**



New pouch cell based on LiS battery implemented

PROJECTS

Title: High energy lithium sulphur cells and batteries
Acronym: Helis
Description: Lithium sulphur batteries (LSB) are viable candidate for commercialisation among all post Li-ion battery technologies due to their high theoretical energy density and cost effectiveness. Despites many efforts, there are remaining issues that need to be solved and this will provide final direction of LSB technological development. Some of technological aspects, like development of host matrices, interactions of host matrix with polysulphides and interactions between sulphur and electrolyte have been successfully developed within Eurolis project. Open porosity of the cathode, interactions between host matrices and polysulphides and proper solvatation of polysulphides turned to be important for complete utilisation of sulphur, however with this approach didn't result long term cycling. Additionally, we showed that effective separation between electrodes enables stable cycling with excellent coulombic efficiency. The remaining issues are mainly connected with a stability of lithium anode during cycling, with engineering of complete cell and with questions about LSB cells implementation into commercial products (ageing, safety, recycling, battery packs). Instability of lithium metal in most of conventional electrolytes and formation of dendrites due to uneven distribution of lithium upon the deposition cause several difficulties. Safety problems connected with dendrites and low coulombic efficiency with a constant increase of inner resistance due to electrolyte degradation represents main technological challenges. From this point of view, stabilisation of lithium metal will have an impact on safety issues. Stabilised interface layer is important from view of engineering of cathode composite and separator porosity since this is important parameter for electrolyte accommodation and volume expansion

adjustment. Finally, the mechanism of LSB ageing can determine the practical applicability of LSB in different applications.
Funding: H2020
Project ID: 666221
Type: Competitive EU
IREC Role: Partner
Partners: Kemijski Institut (SAFT SAS), Centre National De La Recherche Scientifique (CNRS), SOLVIONIC SA, Chalmers Tekniska Hoegskola AB, Fraunhofer Gesellschaft Zur Forderung Der Angewandten Forschung Ev, Picosun OY, Westfaelische Wilhelms-Universitaet Muenster (WWU), Max Planck Gesellschaft Zur Foerderung Der Wissenschaften, E.V. (MPG), Fundació Institut de Recerca en Energia de Catalunya (IREC), Accurec-Recycling Gmbh (AC GMBH), Tel Aviv University (TAU), Institut National De L Environnement Et Des Risques (INERIS), Peugeot Citroen Automobiles S.A. (PSA)
Date: 6/1/2015 - 5/31/2019
Group: Energy Storage, Energy Harvesting and Catalysis
P.I: Prof. Joan Ramón Morante
Other groups: Power Systems-Dr.José Luis Domínguez García / Energy Systems Analitics-Dr.Cristina Corchero
URL: https://www.helis-project.eu/,https://drive.google.com/open?id=1U7ghYtZPjPpTpH77ki9eXDr_ID70L1Rt

Title: Combustibles sintétics,
Acronym: CoSin
Description: El projecte està orientat a desenvolupar aquelles accions necessàries per convertir-se en una referència internacional científica, tecnològica i industrial en combustibles sintètics a partir de carboni d'origen biogènic i aigua. El projecte pretén cobrir la fonamental necessitat dels sistemes energètics actuals i futurs de poder emmagatzemar energia com a energia química tot resolent la problemàtica de com emmagatzemar energies renovables a gran escala. La prioritat en usar el carboni d'origen biogènic emmarca aquestes accions dins d'una economia circular a l'entorn del CO2 contribuint a les millores medi ambientals i a la disminució de les emissions de CO2. Es contempla la possible utilització de fonts de carboni com la biomassa forestal, purins o fangs de depuradores que aporten un valor social i mediambiental afegit.
Encara que la producció de biogas és relativament ben coneguda a partir de la digestió anaeròbia, tecnològicament resten obert molts aspectes relatius a la seva optimització i control, especialment relatius a les etapes de filtratge per l'eliminació d'impureses del biogas i la possibilitat de poder separar el CO2 y el CH4 . Així mateix la hidrogenació del CO2 separat o del propi biogas ens porta a la síntesis de metà que constitueix la principal fita per aquest projecte si bé l'obtenció d'altres productes com metanol, combustibles líquids, també és contempla. L'objectiu del projecte és anar més enllà del present estat de l'art desenvolupant noves formes de separació i control de tot el sistema que constitueix un important valor afegit a l'actual tecnologia.
Funding: Ris3Cat
Project ID: COMRDI15-1-0037-01
Type: Competitive Nationals

Partners: Gas Natural SDG SA, Labaqua SA, Centre Tecnològic De L'aigua Fundació Privada (CETAQUA), Fundació Institut de Recerca en Energia de Catalunya (IREC), Francisco Albero SA (FAE), Aleaciones De Metales Sinterizados SA (AMES), Universitar Politècnica De Catalunya (UPC).
Date: 1/1/2016-12/31/2019
Group: Energy Storage, Energy Harvesting and Catalysis
P.I: Teresa Andreu Arbella
Other groups: Nanoionic and Fuel Cells-Dr. Albert Tarancón Rubio.

Title: Calcogenide-based photoelectrodes for efficient solar energy storage,
Acronym: WINCOST
Description: WINCOST proposes a breakthrough in the development of high efficiency and low cost energy systems based on wide band gap chalcogenide technologies. The project includes both electricity generation via advanced photovoltaic devices and the development of new concepts for energy storage, considering the implementation of specific solutions that meet the different needs in these applications, based on the use of semiconductors with different band gaps (Eg): 1.- Eg =1.4-1.5 eV, for the development of high efficiency photovoltaic devices with Voc >0.9 V and low current, in order to reduce potential efficiency losses related to window layer. This will allow resolving one of the current problems for the up-scaling of these technologies at module level, minimizing the effects related to the window layer inhomogeneities which are one of the main origins of the efficiency loss in the industrial photovoltaic modules;
2.- Eg = 1.6-1.8 eV, for the development of cells suitable for their integration as top cell in tandem structures of very high efficiency (>25%), and for the development of high efficiency photoelectrochemical devices for solar energy storage. The optimization of these devices that involve the integration of both the solar energy conversion and the storage in the same system, requires for devices configurations compatible with working voltages V > 1.3 V; 3.- Eg = 2.0-2.5 eV for the development of new semitransparent photovoltaic devices suitable for building integration (BIPV), with the aim to answer to the increasing demand in this sector for semitransparent devices with higher efficiencies and different colors with the requirements of both high aesthetic quality and high uniformity together with high stability and good durability.
The project involves the development of solutions based on the use of Cu(In,Ga)(S,Se)2 chalcopyrites that are compatible with processes already established at an industrial production level, and includes also the development of solutions based on emergent technologies with kesterites based Cu2ZnSn(S,Se)4 compounds and related alloys. Kesterites have potential interest as future replacement of chalcopyrites, being more compatible with a sustainable upscaling of the production to industrial mass production levels, avoiding the use of critical raw materials (Ga, In). In all the cases, the viability of different technological strategies for the development of competitive solutions compatible with their implementation at industrial level will be evaluated.
WINCOST is based in the strong experience and background of the groups participating in the proposal in these technologies. This has been acquired within the development of different research projects that included both national and European relevant projects on these topics. Most of the European projects where coordinated by the groups participating in this proposal (SCALENANO, KESTCELLS, PVICOKEST, INDUCIS). These projects involve the main world leading groups and reference centers in these technologies, and have

allowed the groups involved in WINCOST to achieve a deep knowledge on the fundamental properties of these materials and on the development of processes for high efficiency devices fabrication, positioning the WINCOST groups among the reference ones in these technologies in Europe. In this subproject, it will be developed the photoelectrochemical devices for solar energy storage.
Funding: Retos Investigació
Project ID: ENE2016-80788-C5-5-R
Type: Competitive Nationals
Partner: Fundació Institut de Recerca en Energia de Catalunya (IREC), Universidad De Barcelona (UB), Universidad Autonoma de Madrid (UAM), UNIVERSITAT JAUME I (UJI).
Date: 12/30/2016-12/31/2020
Group: Energy Storage, Energy Harvesting and Catalysis
P. I: Dr. Teresa Andreu Arbella.

Title: Biorefinery combining HTL and FT to convert wet and solid organic, industrial wastes into 2nd generation biofuels with highest efficiency"
Acronym: HtF
Description: Heat-to-Fuel will deliver the next generation of biofuel production technologies towards the de-carbonisation of the transportation sector. Heat-to-fuel will achieve competitive prices for biofuel technologies (<1€/l) while delivering higher fuel qualities and significantly reduced life-cycle GHG reductions. Heat-to-fuel will result in increased Energy production savings (>20%) and enhanced EU's energy security by the use of local feedstocks which in turn ensured local jobs are preserved and increased. The benefit of combining technologies like in Heat-to-Fuel is, that the drawbacks of the single technologies are balanced. FT and APR are promising technologies for the efficient production of 2nd generation fuels. But currently the economic border conditions don't allow the implementation, similar to many other biofuel technologies. The radical innovation of combining an APR with a FT reactor is the basis to overcome this barrier. The large organic wastes (from HTL or other streams) can be conveniently treated with APR to produce H2. Both dry and wet organic wastes can be integrated, with mutual advantages, i.e. steam production for gasification, HTL and APR preheating; FT heat cooling without external utilities. Using the synergies between these technologies maximizes the total process efficiency. Heat-to-fuel aims will be met thanks to the diversification of the feedstock for biofuels production, reducing the supply costs and upgrading the efficiencies of promising and flexible conversion.
Funding: H2020
Project ID: 764675
Type: Competitive EU
Partner: Gussing Energy Technologies Gmbh (GET), Fundació Institut de Recerca en Energia de Catalunya (IREC), Consorzio per La Ricerca e la Dimostrazione sulle Energie Rinnovabili (RE-CORD), Commissariat a l'Energie Atomique et aux Energies Alternatives (CEA), Johnson Matthey PLC (JM), Skupina Fabrika Raziskave In Razvoj Doo (SF), Politecnico di Torino (POLITO), Technische Universitaet Wien (TU WIEN), Bioenergy 2020+ GMBH (BE2020), Instytut Chemicznej Przerobki Wegla (ICHPW), Beta Renewables SPA (Beta), Atmostat (ATM), Centro Ricerche Fiat SCPA (CRF), R2M Solution Spain SL (R2M)
Date: 9/1/2017-5/31/2021

Group: Energy Storage, Energy Harvesting and Catalysis
P.I: Dr. Teresa Andreu Arbella
URL:
https://www.heattofuel.eu/,https://drive.google.com/open?id=1YWSvUPNFrbu_4Se5jGiND5-Rru6z6wam

Title: 3d anodes in full pec Device for h2 generation,
Acronym: AnoDHyGen
Descripction: The preparation of single and modified Bi2WO6-based materials was carried out, as alternative to TiO2 in photocatalytic processes under visible light. Initially, the Bi2WO6 synthesis was optimized and 3D-hierarchical superstructures were obtained. Besides, given the inherent limitations of this material, several modification alternatives were proposed. Thus, Bi2WO6/TiO2 heterostructures and activated carbon- or metal-Bi2WO6/TiO2 systems were studied. This way, the improved charge separation mechanisms led to better photocatalytic responses in several reactions. Besides photodegradation of organic compounds, other ""green chemistry"" processes were studied with these materials, including selective oxidation of alcohols, propylene epoxidation and CO2 photoreduction.
Funding: Accio
Project ID: TECSPR16-1-0084
Type: Competitive Nationals
Partners: Fundacio Institut de Recerca en Energia de Catalunya (IREC), Universidad De Barcelona (UB), Universidad Autonoma de Madrid (UAM), Universitat Jaume I (UJI).
Date: 2/21/2018-2/20/2020
Group: Energy Storage, Energy Harvesting and Catalysis
P.I: Dr.Sebastián Murcia López.

Title: Materials, processes and components for a solar refinery
Acronym: RESOL
Description: The direct conversion of solar energy into a chemical, hydrogen or reduced products from CO2, is a difficult challenge, as it must exceed the range of efficiencies in the order of 8-10% (STF, Solar-To-Fuel) just to be energy-efficient compared to other indirect pathways. In addition, it should offer lifetimes, scalability and costs that make this option feasible as a preferred technology. For this, it is necessary to delve into the knowledge of the energy transfer processes of the photon to the charge carriers and from these ones to the chemical species via suitable catalysts to be able to design and to implement fotoelectrochemical cells with low cell voltages allowing configurations bias free. On the other hand, the development of these photoelectrochemical cells without bias, only with the contribution of solar energy, opens numerous capacities to implement oxidation treatments and / or reduction of components in industrial, agricultural or even urban

residual liquids for their treatment with excellent energy balances which constitutes a real disruptive challenge.
RESOL, is aimed at the study, knowledge, modeling and implementation of the different constituents of the photoelectrochemical system to construct prototypes that allow to evaluate both water oxidation processes and CO2 reduction processes with their transformation to added value chemicals as well as processes of oxidation of organic molecules. To this end, appropriate catalysts will be synthesized for each application, the procedures for their application being developed with the electrodes and photoelectrodes used in each of the PEC cell configurations that will be proposed for each of the objectives. Photoactive structures based on photovoltaic devices will also be used, combining junctions or developing tandem structures, in silicon or thin layer technology of chalcogenides or photoactive materials on transparent substrates or other emerging technologies implemented in the consortium to have enough photogenerated voltage to ensure bias free systems (artificial leaves). It will work in configurations of two compartments, anode and cathode, separated by selected membrane to minimize cell voltages. The catalysts will be explored based on their use in 3D structures to increase their specific surface active, trying to minimize voltage drops, maximizing their catalytic activity and minimizing their degradation. For this, their behavior will be studied at nano scale. Finally, RESOL will address the issues of stability, scalability and, based on the prototypes implemented, the potential uses for both the production of solar fuels based on a circular CO2 economy and for the decontamination of fluids at low costs will be evaluated.
Funding: Retos Investigació
Project ID: ENE2017-85087-C3-2-R
Type: Competitive Nationals
Partners: Universitat Jaume I (UJI), Fundacio Institut de Recerca en Energia de Catalunya (IREC), Fundació Institut Català de Nanociència i Nanotecnologia (ICN2)
Date: 1/1/2018-12/31/2020
Group: Energy Storage, Energy Harvesting and Catalysis
P.I: Prof. Dr.Joan Ramón Morante.

Title: M2E SGR 2017-2019,
Acronym: M2E SGR 2017-2019
Description: Electronic materials and M2E power. This consolidated research group carries out activities related to electronic materials and power.
Funding: SGR,2017
Project ID: SGR 1246
Type: Competitive Nationals
Partners: Fundacio Institut de Recerca en Energia de Catalunya (IREC), Universidad De Barcelona (UB), Universidad Autonoma de Madrid (UAM), Universitat Jaume I (UJI).
Date: 1/1/2018-12/31/2020
Group: Energy Storage, Energy Harvesting and Catalysis
P.I: Prof. Joan Ramón Morante
Other groups: Funtional Nanomaterials-Dr. Andreu Cabot.

Title: Towards High Energy All Solid State Lithium Batteries,
Acronym: SOLBAT
Description: All-solid-state Li-ion batteries in thin-film format are currently the most promising concept for the energy storage needs of miniature electronic devices. Using 3D substrates, the effective surface area and thus the energy density could be increased. Atomic layer deposition (ALD) is one of the few methods capable in producing conformal layers on such complex structures. The basic research on new ALD processes for Li-containing thin films is only in early stage. The aim of this project was to advance the field with the introduction of novel deposition processes for each of the active components of a thin-film Li-ion battery. An ultimate goal was to manufacture a fully functional all-solid-state thin-film battery.
Funding: Accio
Project ID: TECSPR18-1-0049
Type: Competitive Nationals
Partners: Fundacio Institut de Rerecerca en Energia de Catalunya (IREC)
Date: 2/1/2019-1/31/2021
Group: Energy Storage, Energy Harvesting and Catalysis
P.I: Zahilia Caban Huertas.

Title: Escalat del procés de fabricació de catalitzadors avançats per obtenir gas natural renovable,
Acronym: Escalat del procés de fabricació de catalitzadors avançats per obtenir gas natural renovable,"The circular economy of carbon dioxide is a field in permanent growth. Among the differentstrategies, the conversion of carbon dioxide to renewable natural gas allows i) the chemicalstorage of renewable energies in which production cannot be adjusted to the demand, ii) the reduction of the greenhouse gases though its capture and conversion and iii) reductionof the importation of fossil fuels, specifically of natural gas. Currently, there are severalnumber of pilot plants in operation in Europe, the most known is placed in Wertle, Germany, property of Audi and at MW scale. As regards the Catalan scenario, there is a 37 kWmethane pilot plant at EDAR Riu Sec Sabadell, owned by Gas Natural Fenosa andoperated by the Catalan Energy Research Institute.Based on the experiences from Sabadell, it has been detected that commercial catalysts donot meet the standards necessary to work in decentralized plants such as wastewatertreatment plants. These emerging facilities are of a much lower capacity than conventionalenergy plants and the European trend is to use structured modular reactors, instead ofbuilding high-volume chemical reactors. Examples of this technology can be found incompanies such as Atmostat (France) and Ineratec (Germany). In order to meet these newstandards, IREC has synthesized 50g of a material that meets the standards of thesesreactors because the commercial options could not be used directly. The firts result showthat the catalyst is more active and stable than commercial ones. The objective of this project is to scale-up the catalyst manufacturing process to quantitieslarger than 1 kg of material. At this quantity level, it is possible the market entry of a familyof tailor made catalysts for the structured reactors, which allow the intensification of catalyticprocesses. It is considered that the scientific stage (composition, formulation, preparationmethod) is completed and now the problem becomes engineering adaptation of themanufacturing process to

industrial ones. The project consists of an adaptation stage of thecurrent method of manufacture by wet impregnation to dry one. The preparation method isadapted to the process that could be carried externally by industrial catalyst manufacturingcompanies. In this step, the optimal synthesis variables must be modified (temperature, pressure, rotation, dissolution process). In order to assess the influence of theseparameters, the catalyst activity of each 25g batch will be evaluated in a catalytic micro-plant at T=300ºC, P=5bar, GHSV=40.000h-1, ratio H2:CO2=4. The expected catalyticactivity must be equal to or greater than the current wet impregnation method. Once the optimum manufacturing variables will be obtained, the process will be scale-up bya factor of 10, to produce 250g in each batch. In this way it will be possible to synthesizethe desired 1 kg in a period of 2 days to one week. In this second scale-up, the catalyticactivity would be evaluated again in order to evaluate any catalytic activity lost in therelation to 25g. Once the desired catalyst activity is obtained in 1kg, the industrial scale-upto large quantity will be explored. Within the targets of the project is the definition of thequality control parameters for the product, by avoiding the catalytic test in each batch. Thistechnique is expensive and it requires high experimental time. Some potentialcharacterization techniques are apparent density, colorimetry, BET area, H2-TPR, SEM-EDX and XRD. These will be related to the catalytic activity to propose the mostrepresentative and effective technique to carry out the quality control in the future and theelaboration of the technical and safety data sheet of the product. Finally, marked potentialcustomers will be explored. At the present, there is an interest on the members of theKopernikus project (https://www.kopernikus-projekte.de/en/home) to test our product in apilot plant with more capacity than the Sabadell one.
Funding: AGAUR
Project ID: LLAV 2018 00066
Type: Competitive Nationals
Partners: Fundacio Institut de Recerca en Energia de Catalunya (IREC)
Date: 6/1/2019-11/30/2019
Group: Energy Storage, Energy Harvesting and Catalysis
P.I: Dr.Teresa Andreu Arbella.

Title: Catalonia GraphCAT comunity,
Acronym: GRAPHCAT-Autograph
Description: The ultimate vision of the GraphCAT community is to make Catalonia a world leader in the development of advanced graphene applications; GraphCAT aims to promote and accelerate the transfer of technology based on graphene to the Catalan industry (existing or emerging) with interest in strategic industrial sectors that can benefit from the integration of graphene technologies (biomedicine, energy, graphene production and compounds, optoelectronics), offering a great competitive advantage in the global market. The mission of GraphCAT is to create a community in Catalonia that generates synergies to lead the development and technological innovations of graphene or graphene-based technologies; to grow and strengthen the links of the international community between graphene researchers and the local industrial landscape to develop and apply graphene technologies; facilitate the transfer of technology to the existing industry and support the creation of new industry through technological spin-offs.

The main objectives of GraphCAT are:
1.- To consolidate the excellence and the critical mass in R + D in graphene.
2.- To stimulate and enhance the development of graphene and prototyping technologies.
3.- To stimulate industrial investment in R + D in graphene.
To achieve these objectives, a portfolio of technological projects grouped into four thematic clusters will be developed and classified based on their level of TRL (technology readiness level): proof of concept (TRL> 2), prototype (TRL 4-6) and product or service (TRL 7-9).
GraphCAT will disseminate and communicate the technological developments of the community, organizing industrial round tables and dissemination events aimed at the most appropriate public to give visibility of scientific advances and opportunities for the Catalan industrial fabric. GraphCAT will also be present in relevant industrial forums, such as the Mobile World Congress for ICT, Beyond Building, Barcelona Construmat for Materials, etc. During the course of these events, funding instruments, access to research infrastructures and innovation platforms will be disseminated among Catalan companies"
Funding: Emergents
Project ID: IU16-011569
Type: Competitive Nationals
Partners: Fundació Institut Català de Nanociència i Nanotecnologia (ICN2), Institut de Ciència Fotònica (ICFO), Fundació Institut de Recerca en Energia de Catalunya (IREC), Institut de Física d'Altes Energies (IFAE), Universitat Autònoma de Barcelona/ Ingeniería Electrónica/Instituto de Neurociencias (UAB), Consorci Institut d'Investigacions Biomèdiques August Pi i Sunyer / Systems Neuroscience Group (IDIBAPS), Fundació EURECAT (EURECAT), Institut de Microelectrònica de Barcelona de la Agencia Estatal Consejo Superior de Investigaciones Científicas (IMB-CNM-CSIC), Instituto Hospital del Mar de Investigaciones Médicas (IMIM), Barcelona Institute of Science and Technology (BIST)
Date: 7/1/2019-6/30/2021
Group: Energy Storage, Energy Harvesting and Catalysis
P.I: Dr.Teresa Andreu Arbella.

Title: Catalonia GraphCAT comunity,
Acronym: GRAPHCAT-Integro
Description: The ultimate vision of the GraphCAT community is to make Catalonia a world leader in the development of advanced graphene applications; GraphCAT aims to promote and accelerate the transfer of technology based on graphene to the Catalan industry (existing or emerging) with interest in strategic industrial sectors that can benefit from the integration of graphene technologies (biomedicine, energy, graphene production and compounds, optoelectronics), offering a great competitive advantage in the global market. The mission of GraphCAT is to create a community in Catalonia that generates synergies to lead the development and technological innovations of graphene or graphene-based technologies; to grow and strengthen the links of the international community between graphene researchers and the local industrial landscape to develop and apply graphene technologies; facilitate the transfer of technology to the existing industry and support the creation of new industry through technological spin-offs.

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Funding: Emergents
Project ID: IU16-011569
Type: Competitive Nationals
Partners: Fundació Institut Català de Nanociència i Nanotecnologia (ICN2), Institut de Ciència Fotònica(ICFO), Fundació Institut de Recerca en Energia de Catalunya (IREC), Institut de Física d'Altes Energies (IFAE),Universitat Autònoma de Barcelona/ Ingeniería Electrónica/Instituto de Neurociencias (UAB), Consorci Institut d'Investigacions Biomèdiques August Pi i Sunyer / Systems Neuroscience Group (IDIBAPS), Fundació EURECAT (EURECAT), Institut de Microelectrònica de Barcelona de la Agencia Estatal Consejo Superior de Investigaciones Científicas (IMB-CNM-CSIC), Instituto Hospital del Mar de Investigaciones Médicas (IMIM), Barcelona Institute of Science and Technology (BIST)
Date: 7/1/2019-6/30/2021
Group: Energy Storage, Energy Harvesting and Catalysis.
I.P: Prof. Joan Ramón Morante.

Title: Interfacial engineering of nano-catalysts on gas diffusion electrodes for continuous CO2 photoelectroconversion to methanol,
Acronym: DFF-International Postdoctoral Grant
Description: Conversion of CO2 may be a key-player in defining new resources to produce chemical commodities and advanced materials, and to store chemical energy, especially when combined with renewable energy sources like wind and solar.
This project aims at the development of efficient catalytic systems for the realisation of scalable photo-assisted flow-reactors for CO2-to-MeOH photoelectroconversion. MeOH is of large industrial interest, being a key component in hundreds of chemicals and an attractive emerging fuel.
The first goal is designing novel catalysts merging together metal-organic frameworks and porous matrices, to form finely tailored gas diffusion electrodes. MOF nano-particles will be synthesised in situ within the pores of conductive templating layers, thus maximising the contact area with CO2 permeating through the hierarchical pores of the composite MOF catalyst-loaded layer. On top of this, a

porous photocatalyst driving OER will provide extra electrons and protons for CO2RR.
Funding: DFF-IPD
Project ID: 9059-00008B
Type: Competitive Nationals
Partners: Fundació Institut de Recerca en Energia de Catalunya (IREC)
Date: 11/4/2019-5/2/2021
Group: Energy Storage, Energy Harvesting and Catalysis
P.I: Dr. Teresa Andreu Arbella.

Title: Design of catalysts based on transition metal carbides efficient for H2 production processes and for selective CO2 activation.
Acronym: CD&HYCATS
Description: In this project new catalysts based on transition metal carbides (TMC of 5 and 6 groups) will be developed. Two processes are contemplated, the alternative H2 production using biomass derived resources and the chemical recycling of CO2 through its conversion to methanol. Different preparation methods including the use of microwaves and ultrasounds will be used for the preparation of the catalytic materials based on CMT (M= Mo, W, V, Nb, Ta). Catalysts based on CMT/ZnO-CeO2, CMT/CeO2-ZrO2 and M/CMT (M= Cu, Co, Ni) will be prepared and studied in the catalytic steam reforming of C1-C3 oxygenates, methanol, ethanol and acetone. The photocatalytic H2 production using methanol as sacrificial agent will be also carried out. For this end, nanostructured-CMT/TiO2 and CMT/ZnO will be prepared and characterized. For the CO2 hydrogenation to methanol new systems based on CMT/ZnOGa2O3ZrO2 and M/CMT (M= Cu, Ni) will be developed. In all cases, catalytic materials will be deeply characterized before and after reaction. The stability of representative systems will be analyzed. Appropriate relationships between the catalytic behavior and the characteristics of the catalysts will be stablished. It is expected the determination of the fundamental characteristics of this type of materials, which are necessary for carry out the catalytic processes studied.
Funding: Redes Excelencia
Project ID: MAT2017-87500-P
Type: Competitive Nationals
Partners: Fundació Institut de Recerca en Energia de Catalunya (IREC)
Date: 1/1/2018-12/31/2020
Group: Energy Storage, Energy Harvesting and Catalysis
P.I: Narcís Homs

PUBLICATIONS

Articles and Journals from ISI Database

Ros C., Carretero N.M., David J., Arbiol J., Andreu T., Morante J.R."**Insight into the Degradation Mechanisms of Atomic Layer Deposited TiO2 as Photoanode Protective**

Layer", 2019, ACS Applied Materials and Interfaces, 11,33,29725,29735,1,10.1021/acsami.9b05724, Article. IF:8.456.

Hermans Y., Murcia-López S., Klein A., Jaegermann W."**BiVO4 Surface Reduction upon Water Exposure"**, 2019, ACS Energy Letters, 4,10,2522,2528,1,10.1021/acsenergylett.9b01667, Article. IF: 16.331.

Tang P.-Y., Han L.-J., Hegner F.S., Paciok P., Biset-Peiró M., Du H.-C., Wei X.-K., Jin L., Xie H.-B., Shi Q., Andreu T., Lira-Cantú M., Heggen M., Dunin-Borkowski R.E., López N., Galán-Mascarós J.R., Morante J.R., Arbiol J. **"Boosting Photoelectrochemical Water Oxidation of Hematite in Acidic Electrolytes by Surface State Modification"**, 2019, Advanced Energy Materials, 9,34,1901836,1,10.1002/aenm.201901836, Article. IF:24.884.

Ibupoto Z.H., Tahira A., Tang P., Liu X., Morante J.R., Fahlman M., Arbiol J., Vagin M., Vomiero A.**"MoS x @NiO Composite Nanostructures: An Advanced Nonprecious Catalyst for Hydrogen Evolution Reaction in Alkaline Media"**, 2019, Advanced Functional Materials, 29,7,1807562,11,10.1002/adfm.201807562, Article. IF:15.621.

Biset-Peiró M., Guilera J., Zhang T., Arbiol J., Andreu T.**"On the role of ceria in Ni-Al2O3 catalyst for CO2 plasma methanation"**, 2019, Applied Catalysis A: General, 575,223,229,2, 10.1016/j.apcata.2019.02.028, Article. IF:4.63.

Shaposhnik A.V., Shaposhnik D.A., Turishchev S.Y., Chuvenkova O.A., Ryabtsev S.V., Vasiliev A.A., Vilanova X., Hernandez-Ramirez F., Morante J.R.**"Gas sensing properties of individual SnO2 nanowires and SnO2 sol-gel nanocomposites"**, 2019, Beilstein Journal of Nanotechnology, 10,1380,1390,10.3762/bjnano.10.136, Article, Open Access. IF: 2.269.

Vázquez-Galván J., Flox C., Jervis J.R., Jorge A.B., Shearing P.R., Morante J.R.**"High-power nitrided TiO 2 carbon felt as the negative electrode for all-vanadium redox flow batteries"**, 2019, Carbon, 148,91,104,1, 10.1016/j.carbon.2019.01.067, Article. IF:7.466.

Garayrodríguez L.F., López S.M., Andreu T., Moctezuma E., Torres Martínez L.M., Morante J.R.**"Photocatalytic hydrogen evolution using bi-metallic (Ni/pt) na 2 ti 3 o 7 whiskers: Effect of the deposition order"**, 2019, Catalysts, 9,3,285,1,10.3390/catal9030285, Article, Open Access. IF:3.444.

Urbain F., Tang P., Smirnov V., Welter K., Andreu T., Finger F., Arbiol J., Morante J.R.**"Multilayered Hematite Nanowires with Thin-Film Silicon Photovoltaics in an All-Earth-Abundant Hybrid Tandem Device for Solar Water Splitting"**, 2019, ChemSusChem, 12,7,1428,1436,3,10.1002/cssc.201802845, Article. IF:7.804.

Lacroix R., Biendicho J.J., Mulder G., Sanz L., Flox C., Morante J.R., Da Silva S.**"Modelling the rheology and electrochemical performance of Li 4 Ti 5 O 12 and LiNi 1/3 Co 1/3 Mn 1/3 O 2 based suspensions for semi-solid flow batteries"**, 2019, Electrochimica Acta, 304,146,157,2, 10.1016/j.electacta.2019.02.107, Article. IF:5.383.

Zhang X., Luo J., Lin H.-F., Tang P., Morante J.R., Arbiol J., Wan K., Mao B.-W., Liu L.-M., Fransaer J.**"Tailor-made metal-nitrogen-carbon bifunctional electrocatalysts for rechargeable Zn-air batteries via controllable MOF units"**, 2019, Energy Storage Materials, 17,46,61,8, 10.1016/j.ensm.2018.11.034, Article. IF:15.09.

Alarcón A., Guilera J., Díaz J.A., Andreu T.**"Optimization of nickel and ceria catalyst content for synthetic natural gas production through CO2 methanation"**, 2019, Fuel Processing Technology, 193,114,122,4, 10.1016/j.fuproc.2019.05.008, Article. IF:4.507.

Elias K.F.M., Bednarczuk L., Assaf E.M., Ramírez de la Piscina P., Homs N.**"Study of Ni/CeO2–ZnO catalysts in the production of H2 from acetone steam reforming"**, 2019, International Journal of Hydrogen Energy, 44,25,12628,12635, 10.1016/j.ijhydene.2018.10.191, Article. IF:4.084.

Guilera J., Del Valle J., Alarcón A., Díaz J.A., Andreu T.**"Metal-oxide promoted Ni/Al 2 O 3 as CO 2 methanation micro-size catalysts"**, 2019, Journal of CO2 Utilization, 30,11,17,11, 10.1016/j.jcou.2019.01.003, Article. IF:5.189.

Ros C., Andreu T., David J., Arbiol J., Morante J.R.**"Degradation and regeneration mechanisms of NiO protective layers deposited by ALD on photoanodes"**, 2019, Journal of Materials Chemistry A, 7,38,21892,21902,10.1039/c9ta08638b, Article. IF:10.733.

Zhang X., Luo J., Wan K., Plessers D., Sels B., Song J., Chen L., Zhang T., Tang P., Morante J.R., Arbiol J., Fransaer J.**"From rational design of a new bimetallic MOF family with tunable linkers to OER catalysts"**, 2019, Journal of Materials Chemistry A, 7,4,1616,1628,8,10.1039/c8ta08508k, Article. IF:10.733.

Urbain F., Murcia-López S., Nembhard N., Vázquez-Galván J., Flox C., Smirnov V., Welter K., Andreu T., Finger F., Morante J.R.**"Solar vanadium redox-flow battery powered by thin-film silicon photovoltaics for efficient photoelectrochemical energy storage"**, 2019, Journal of Physics D: Applied Physics,52,4,44001,6,10.1088/1361-6463/aaeab9, Article. IF:2.829.

Avireddy H., Byles B.W., Pinto D., Delgado Galindo J.M., Biendicho J.J., Wang X., Flox C., Crosnier O., Brousse T., Pomerantseva E., Morante J.R., Gogotsi Y.**"Stable high-voltage aqueous pseudocapacitive energy storage device with slow self-discharge"**, 2019, Nano Energy, 64,103961, 10.1016/j.nanoen.2019.103961, Article. IF:15.548.

Hermans Y., Murcia-López S., Klein A., Van De Krol R., Andreu T., Morante J.R., Toupance T., Jaegermann W.**"Analysis of the interfacial characteristics of BiVO 4 /metal oxide heterostructures and its implication on their junction properties"**, 2019, Physical Chemistry Chemical Physics, 21,9,5086,5096,6,10.1039/c8cp07483f, Article. IF:3.567.

Amin S., Tahira A., Solangi A., Beni V., Morante J.R., Liu X., Falhman M., Mazzaro R., Ibupoto Z.H., Vomiero A.**"A practical non-enzymatic urea sensor based on NiCo2O4 nanoneedles"**, 2019, RSC Advances, 9,25,14443,14451,1,10.1039/c9ra00909d, Article, Open Access. IF:3.049.

Finger F., Welter K., Urbain F., Smirnov V., Kaiser B., Jaegermann W.**"Photoelectrochemical Water Splitting using Adapted Silicon Based Multi-Junction Solar Cell Structures: Development of Solar Cells and Catalysts, Upscaling of Combined Photovoltaic-Electrochemical Devices and Performance Stability"**, 2019, Zeitschrift fur Physikalische Chemie,0.975,10.1515/zpch-2019-1453, Article,

H. Xie, Y. Sanchez, P. Tang, M. Espindola-Rodriguez, M. Guc, L. Calvo-Barrio, S. Lopez-Marino, Y. Liu, J.R. Morante, A. Cabot, V. **Izquierdo-Roca, J. Arbiol, A. Perez-Rodriguez, E. Saucedo "Enhanced Hetero-Junction Quality and Performance ofKesterite Solar Cells by Aluminum Hydroxide Nanolayersand Efficiency Limitation Revealed by Atomic-resolutionScanning Transmission Electron Microscopy"**, 2019, Solar RRL,3,1800279,10.1002/solr.201800279, Article,

Grau S., Giraldo S., Saucedo E., Morante J.R., Llobet A., Gimbert-Suriñach C**."Multi-layered photocathodes based on Cu2ZnSnSe4 absorber and MoS2 catalyst for the hydrogen evolution reaction"**, 2019, Journal of Materials Chemistry A, 7,42,24320,24327,10.1039/c9ta08818k, Article. IF:10.733.

Zhang C., Biendicho J.J., Zhang T., Du R., Li J., Yang X., Arbiol J., Zhou Y., Morante J.R., Cabot A**."Combined High Catalytic Activity and Efficient Polar Tubular Nanostructure in Urchin-Like Metallic NiCo2Se4 for High-Performance Lithium–Sulfur Batteries"**, 2019, Advanced Functional Materials, 29,34,1903842,3,10.1002/adfm.201903842, Article. IF:15.621.

Urbain F., Du R., Tang P., Smirnov V., Andreu T., Finger F., Jimenez Divins N., Llorca J., Arbiol J., Cabot A., Morante J.R.**"Upscaling high activity oxygen evolution catalysts based on CoFe2O4 nanoparticles supported on nickel foam for power-to-gas electrochemical conversion with energy efficiencies above 80%"**, 2019, Applied Catalysis B: Environmental, 259,118055,1, 10.1016/j.apcatb.2019.118055, Article. IF:14.229.

Yu X., Zhang C., Luo Z., Zhang T., Liu J., Li J., Zuo Y., Biendicho J.J., Llorca J., Arbiol J., Morante J.R., Cabot A.**"A low temperature solid state reaction to produce hollow MnxFe3-xO4 nanoparticles as anode for lithium-ion batteries"**, 2019, Nano Energy, 66,104199, 10.1016/j.nanoen.2019.104199, Article. IF:15.548.

DOCTORAL THESES

Presented Theses:

PhD graduate: Francisco Javier Vázquez Galván
PhD supervisor: Dr. Joan Ramon Morante, Dr. Cristina Flox
Title: Redox Flow Batteries: From Vanadium to Earth abundant organic molecules (Quinones)
Presented date: 1/11/2019

PhD graduate: Hemesh Avireddy
PhD supervisor: Dr. Joan Ramon Morante, Dr. Cristina Flox
Title: Enhancing electrochemical performances of supercapacitors
Presented date: 7/11/2019

PhD graduate: Carles Ros Figueras
PhD supervisor: Dr. Joan Ramon Morante, Dr. Teresa Andreu
Title: Stable and efficient photoelectrodes for solar fuels production
Presented date: 30/10/2019

Ongoing theses:

PhD student: Venkata Siva Rama Krishma Tandava (H2020-MSCA-COFUND-2016)
PhD supervisor: Dr. Joan Ramon Morante, Dr. Sebastián Murcia López
Title: Advanced Catalyst Materials and Systems for Electro-Conversion of CO2
Starting date: 01/10/2019

PhD student: Marcelo Eduardo Chavez
PhD supervisor: Dr. Joan Ramon Morante, Dr. Sebastián Murcia López
Title: Synthesis of Value-Added Products through Advanced Photo-Electrocatalytic Systems
Starting date: 01/11/2019

PhD student: Monalisa Chakraborty (H2020-MSCA-COFUND-2016)
PhD supervisor: Dr. Teresa Andreu Arbella, Dr. Sebastian Murcia-López
Title: Advanced photoelectrodes for next generation of solar energy storage: Photobatteries
Starting date: 01/11/2018

PhD student: Monalisa Chakraborty (H2020-MSCA-COFUND-2016)
PhD supervisor: Dr. Teresa Andreu Arbella, Dr. Sebastian Murcia-López
Title: Advanced photoelectrodes for next generation of solar energy storage: Photobatteries
Starting date: 01/11/2018

PhD student: Viktoria Holovanova (H2020-MSCA-COFUND-2016)
PhD supervisor: Dr. Joan R. Morante Lleonart, Dr. Teresa Andreu Arbella
Title: Development of catalysts for solar based fuels
Starting date: 01/09/2018

PhD student: Andreina Alarcón (visiting researcher ESPOL)
PhD supervisor: Dr. Teresa Andreu Arbella, Dr. Jordi Guilera Sala
Title: Synthetic fuels production for the chemical energy storage and the carbon dioxide circular economy

PhD student: Miguel Angel Delgado
PhD supervisor: Dr. Joan Ramon Morante
Title: Degradation studies in electrochemical storage systems without lithium

PhD student: Martí Biset Peiró
PhD supervisor: Dr. Teresa Andreu Arbella
Title: Plasma-catalytic conversion of carbon dioxide
Starting date: 01/10/2016

PhD student: Chaoqi Zhang
PhD supervisor: Dr. J.R. Morante, Dr. Andreu Cabot
Title: New nanomaterials for Li-S batteries
Starting date: 01/10/2017

PhD student: *Ting Zhang*
PhD supervisor: Dr. J.R. Morante, Dr. Jordi Arbiol
Title: MOF – OER/ORR / CO2 red
Starting date: 01/10/2017

PATENTS

Title: Gas sensor, equipped with threadlike nanostructures, network of sensors and measurement method using said sensor.
Inventors: Prades García, Juan Daniel; Hernández Ramírez, Francisco De Paula; Morante Lleonart, Joan Ramon; Cirera Hernández, Albert; Romano Rodríguez, Alberto
Applicants: Universitat de Barcelona (UB); Institut de Recerca en Energia de Catalunya (IREC); Prades García, Juan Daniel; Hernández Ramírez, Francisco De Paula; Morante Lleonart;, Joan Ramon; Cirera Hernández, Albert; Romano Rodríguez, Alberto
Date of application: 2010-02-01
Application number: WO2010EP51206
Publication date: 2010-08-05
Publication number: WO2010086450 (A2); WO2010086450 (A3) / EP2391885 (A2)

Title: Characterization of the composition of a deposited layer of an alloy of type I-(III',III'')-(VI'-VI'')
Inventors: Bermúdez Benito, Verónica; Saucedo Silva, Edgardo; Salvador Jaime-Ferrer Jesús; Pérez Rodríguez, Alejandro; Morante Lleonart, Joan Ramon; Fontané Sánchez, Javier; Izquierdo Roca, Víctor; Álvarez García, Jacobo
Applicants: Nexcis; Institut de Recerca en Energia de Catalunya (IREC); Universitat de Barcelona (UB) (UB); Bermúdez Benito, Verónica; Saucedo Silva, Edgardo; Salvador Jaime-

Ferrer, Jesús; Pérez Rodríguez, Alejandro; Morante Lleonart, Joan Ramon; Fontané Sánchez, Javier; Izquierdo Roca, Víctor; Álvarez García, Jacobo
Date of application: 2011-05-20
Application number: WO2011FR51157
Publication date: 2011-12-01
Publication number: WO2011148084 (A1)

Title: Method of monitoring and control of processes of chemical or electrochemical deposition of thin layers and device to carry it out
Inventors: Bermúdez Benito, Verónica; Jaime Ferrer, Jesús Salvador; Saucedo Silva, Edgardo; Pérez Rodríguez, Alejandro; Morante Lleonart, Joan Ramon; Fontané Sánchez, Javier; Izquierdo Roca, Víctor; Álvarez García, Jacobo
Applicants: Nexcis; Universitat de Barcelona (UB); Institut de Recerca en Energia de Catalunya (IREC)
Date of application: 2011-06-20
Application number: WO2011IB52691
Publication date: 2011-12-22
Publication number: WO2011158223 (A1) / ES2371841 (B1); ES2371841 (A1)

Title: Sensor electroquímico de estado sólido y procedimiento para su fabricación
Inventors: Morata García, Alejandro; Garbayo Senosiain Iñigo; Tarancón Rubio, Albert; Sabaté Vizcarra, María De Les Neus; Fonseca Chacharo, Luis; Salleras Freixes, Marc; Morante Lleonart, Joan Ramon
Applicants: Institut de Recerca en Energia de Catalunya (IREC); Consejo Superior Investigación; Universitat de Barcelona (UB)
Date of application: 2013-12-05
Application number: ES20130031791
Publication date: 2015-06-09
Publication number: ES2537587 (A1); ES2537587 (B1)

Title: Electrolyte formulations for use in redox flow batteries
Inventors: Rubio García, Javier; Skoumal I Canals, Marcel; Flox Donoso, Cristina; Morante Lleonart, Joan Ramon
Applicants: Institut de Recerca en Energia de Catalunya (IREC)
Date of application: 2013-02-26
Application number: EP20130156754
Publication date: 2014-08-27
Publication number: EP2770568 (A1)

Title: Fluid detector and method for detecting fluids
Inventors: Shen Hao; Mathur Sanjay; Hoffmann Martin Wolfgang Georg; Gad Alaa Eldin Abd Eltawab Mohamed; Prades García, Juan Daniel; Hernández-Ramírez, Francisco
Applicants: University Zu Koeln; Universitat de Barcelona (UB); Institut de Recerca en Energia de Catalunya (IREC)

Date of application: 2011-09-01
Application number: EP20110179783
Publication date: 2013-03-06
Publication number: EP2565645 (A1)

Title: Electrical generator for exploiting heat reservoirs using a ring-based themoelectric system
Inventors: Noriega Mosquera, Francisco German; Canandell Estrada, Alberto; Lopez Martinez, Antonio; Cabot, Andreu; Morante Lleonart, Joan Ramon; Revirand, Pascal; Niarchos Dimitris; Platzek Dieter
Applicants: Noriega Mosquera, Francisco German; Marquina Garrote, Maria Almudena
Date of application: 2012-06-15
Application number: ES20120030939
Publication date: 2014-01-17
Publication number: ES2438619 (A1); ES2438619 (B1)

Title: Substrate-electrode (SE) interface lluminated photoelectrodes and photoelectrochemical cells
Inventors: Penelas Pérez, Germán; Hernández Alonso, María Dolores; Andreu, Teresa; Morante, Joan Ramon
Applicants: Repsol, S.A.
Date of application: 2015-12-23
Application number: EP15382658.1 - 1360
Publication date:
Publication number: 15382658.1 - 1360

Title: Photoelectrochemical cell
Inventors: David Hernández-Alonso; G. Penelas; Teresa Andreu; Erdem Irtem; Andrés Parra; Morante, Joan Ramon
Applicants: Repsol, S.A.
Date of application: 2014-12-19
Application number: 14382541.2 - 1360
Publication date:
Publication number:

Title: Process for the carbon dioxide reduction to methane by bdb plasma activaded catalyst
Inventors: T. Andreu; J. R. Morante; J. Amoroux; S. Cavadias; M. Nizio; S. Ognier; C. Henriques; J. Lopes; I. Graça; M. Ribeiro; M. Rey.
Applicants: IREC Universitat de Barcelona (UB); University Pierre and Marie CURIE (UPMC); Ist
Date of application:
Application number:
Publication date: 2015/01/28
Publication number: P201530109

Title: Filter-press photoelectrochemical water oxidation and co2 reduction cell
Inventors: Hernandez Alonso María Dolores; Penelas Perez Germán; Andreu Teresa; Irtem Erdem; Parra Andrés; Fabrega Cristián; Morante Juan Ramón
Applicant: Repsol SA
Publicatoin number: ES2685279
Also published as: CN107406993 (A) DK3234224 (T3) EP3234224 (A1) EP3234224 (B1) US2018023203 (A1) WO2016097247 (A1)
Priority date: 19/12/2014

Title: Photovoltaic-electrochemical (PV-EC) system
Inventors: Penelas Pérez Germán; Hernández Alonso María Dolores; Andreu Teresa; Morante Juan Ramón; Carretero González Nina Magali
Applicant: Repsol SA
Publicatoin number: EP18382257
Priority date: 17/04/2018

OUTREACH

- Participation in the European Researchers' Night event at Brussels, "Science is Wonder-ful", organized by Marie Skłodowska-Curie Actions, on 25/09/2018 and 26/09/2018. During this event, we had a stand with the title "Catching the Light to Split Water". (S. Murcia, N.M. Carretero)

- Participation in the European Researchers' Night event in Barcelona, Cosmocaixa, about solar water splitting and Photocatalysts, organized by Marie Skłodowska-Curie Actions, on 28/09/2018. (T. Andreu, N.M. Carretero)

- Participation in Vermut amb bona energia: Les energies del futur" organized by Ajuntament de Barcelona and IREC. (F. Urbain)

- Visiting stay at Prof. Yury Gogotsi´s group. Drexel University- Philadelphia, USA. (Feb-May, 2018) Topic: 2-D high density transition metal carbides as electrode materials for high volummetric supercapacitors. Student: Hemmesh Avireddy.

- Participation in the European Researchers' Night event at Brussels, "Science is Wonder-ful", organized by Marie Skłodowska-Curie Actions, on 25/09/2018 and 26/09/2018. During this event, we had a stand with the title "Catching the Light to Split Water". (S. Murcia, N.M. Carretero)
- Participation in the European Researchers' Night event in Barcelona, Cosmocaixa, about solar water splitting and Photocatalysts, organized by Marie Skłodowska-Curie Actions, on 28/09/2018. (T. Andreu, N.M. Carretero)

- Participation in Vermut amb bona energia: Les energies del futur" organized by Ajuntament de Barcelona and IREC. (F. Urbain)

- Visiting stay at Prof. Yury Gogotsi´s group. Drexel University- Philadelphia, USA. (Feb-May, 2018) Topic: 2-D high density transition metal carbides as electrode materials for high volummetric supercapacitors. Student: Hemmesh Avireddy

- Seminar: Captura i conversió del CO2: Combustibles sintètics baixos en carboni Organising entity: S3 Chem seminar, ACCIÓ (Catalonia Trade & Investment Agency) End date: 28/11/2018 (T. Andreu)

- Workshop/round table: Producció de gas natural renovablea partir de biogas. City of activity: Vic, Spain Organising entity: 1r Salo del Biogas i tractament de purins. Fira de Vic. End date: 19/10/2018 (T. Andreu)

- Invited Seminar: Towards the energy transition: how to turn carbon dioxide and water to carbon-neutral synthetic fuels City of activity: Aarhus, Denmark Organising entity: iMAT Aarhus University Centre for Integrated Materials End date: 26/06/2018 (T. Andreu)

- Invited seminar: Design of photoelectrochemical cells. FOTOFUEL Summer School. City of activity: Almeria, Spain Organising entity: FOTOFUEL (Excellence network) End date: 04/06/2018 (T. Andreu)

- Taller: Autoconsumo Energético. Exposición: "Despues del fin del mundo" City of activity: Barcelona, Spain Organising entity: CCCB-Centro de Cultura Contemporánea de Barcelona End date: 29/04/2018 (T. Andreu)

- Taller: Hidrogen solar i conversio fotocatalítica. Festival de Nanociència i Nanotecnologia City of activity: Barcelona, Organising entity: 10 a la menos 9 End date: 12/04/2018

- Seminar: Nanocatalitzadors per a la síntesis de combustibles sintètics baixos en carboni. Festival de Nanociència i Nanotecnologia City of activity: Barcelona, Organising entity: 10 a la menos 9 End date: 11/04/2018 (T. Andreu)

- Organizer of Workshop and kick off meeting Young European Materials Research Society (Y-EMRS), Strasbourg, France, 17/06/2018. (T. Andreu)

- B-MRS Newsletter: Which materials can play an important role in circular economy of the CO2?

- B-MRS Newsletter: We want to know your work a little more. Choose your favorite scientific contribution and describe it briefly, in addition to sharing the reference.

- B-MRS Newsletter: Choose also a technological contribution that you have participated in: a case of transfer to the industry or a patent, for example, and make a brief description.

- Development of sensors and energy storage capacitites for fully autonomous systems
  J.R.Morante
  Chip in the Pampa Bento Gonçalves, RS, Brazil, August 27-31, 2018

https://wp.ufpel.edu.br/chipinthepampa2018/
keynote speaker.

- Catalyst materials for solar refineries, synthetic fuels and procedures for a circular economy of the CO2 J
  Brazil Materials Research Society meeting, BMRS, Natal (Brazil) 16-20 September 2018
  https://www.sbpmat.org.br/17encontro/home/
  keynote speaker

- Solar refineries as a CO2 circular economy tools.
  Alternative Energy Sources, Materials & Technologies (AESMT'18) Plovdiv Bulgaria, May 14-16 2018.
  https://www.aesmt.lima-city.de/Home_AESMT_18.html
  Keynote speaker

- Insight into ALD-TiO2 protective transparent layers of electrodes for solar fuels production and photobatteries
  J.R.Morante
  TCM 2018 7th International Symposium on Transparent on Conductive Materials. Minoan Palace Hotel, Platanias, Chania, Crete, Greece, October 14 - 18 2018.
  http://www.tcm2018.org/
  Keynote speaker

- Bias-free water splitting using advanced hematite photoanodes and thin-film silicon photocathodes in an all-earth-abundant hybrid tandem device
  J.R.Morante
  E-MRS & MRS-J BILATERAL SYMPOSIUM, Chania, Crete, Greece, October 13-14 2018
  http://www.tcm2018.org/
  Invited talk

- Energy and environmental friendly materials research for sustainable chemical energy storage
  J.R.Morante
  International Conference on Renewable Energy, ICREN, Barcelona (Spain) April 25-27, 2018
  https://premc.org/conferences/icren2018/
  Chairman& plenary keynote.

- EL GAS RENOVABLE: RETOS Y OPORTUNIDADES. Casos prácticos de aprovechamiento del gas renovable
  J.R.Morante
  El gas renovable. Jornadas Fundación Naturgy. Logroño (Spain) October 2, 2018
  http://www.fundacionnaturgy.org/wp-content/uploads/2018/09/Logro%C3%B1o-02.10.18.v13.pdf
  Keynote.

- FROM SOLAR PHOTONS TO ELECTRICAL AND CHEMICAL ENERGIES: A CHALLENGE FOR NEW ENERGY MODELS IN OUR SOCIETY
  J.R.Morante
  Vers la transition énergétique - WTE2018 Université paris Saclay paris (France) November 6th
  https://www.universite-paris-saclay.fr/fr/evenement/vers-la-transition-energetique-wte2018-0#workshop-scientifique-7401
  Keynote.

- Catalyst materials for enhancing the circular economy of CO2 (Transformation of CO2 to chemical fuels)
  2018 International Energy Forum (国际能源论坛), to be held at the Shanghai Talent Entrepreneurship Park (Jiashan County), from October 24 to 26, 2018.
  Keynote

- Functional analysis of ALD protective layers on photoelectrodes for solar fuels production and photobatteries.
  J. R. Morante
  12th International Conference on Ceramic Materials and Components for Energy and Environmental Applications 2018 (CMCEE 2018) Singapore July 22-27, 2018
  http://www.cmcee2018.org/
  keynote

- Seminari sobre Emmagatzematge Electric per l'Agència Nacional de Gestió de l'Energia de Tunísia Tunis (Tunísia) October 7-10
  Keynote.

- NEW BOOK : Thermoelectric thin films: materials and devices"
  Authors/Editors full name/s: Paolo Mele, Dario Narducci, Michihiro Ohta, Kaniskha Biswas, Juan R. Morante, Shrikant Saini, Tamio Endo
  Springer Science (2019)

- Debate y articulo "La Energía renovable a contrarreloj" publicado en El Periódico el 28 diciembre de 2018ç

- Autumm School Flow Batteries, 12 th and 13th November, 2018 In collaboration of Leitat.

OTHERS

- PhD jury member (T. Andreu). Candidate: Ana M. Escobar. Thesis title: "Hidrofobicitat en metalls modificats superficialment" University of Barcelona, Spain, 04/12/2018

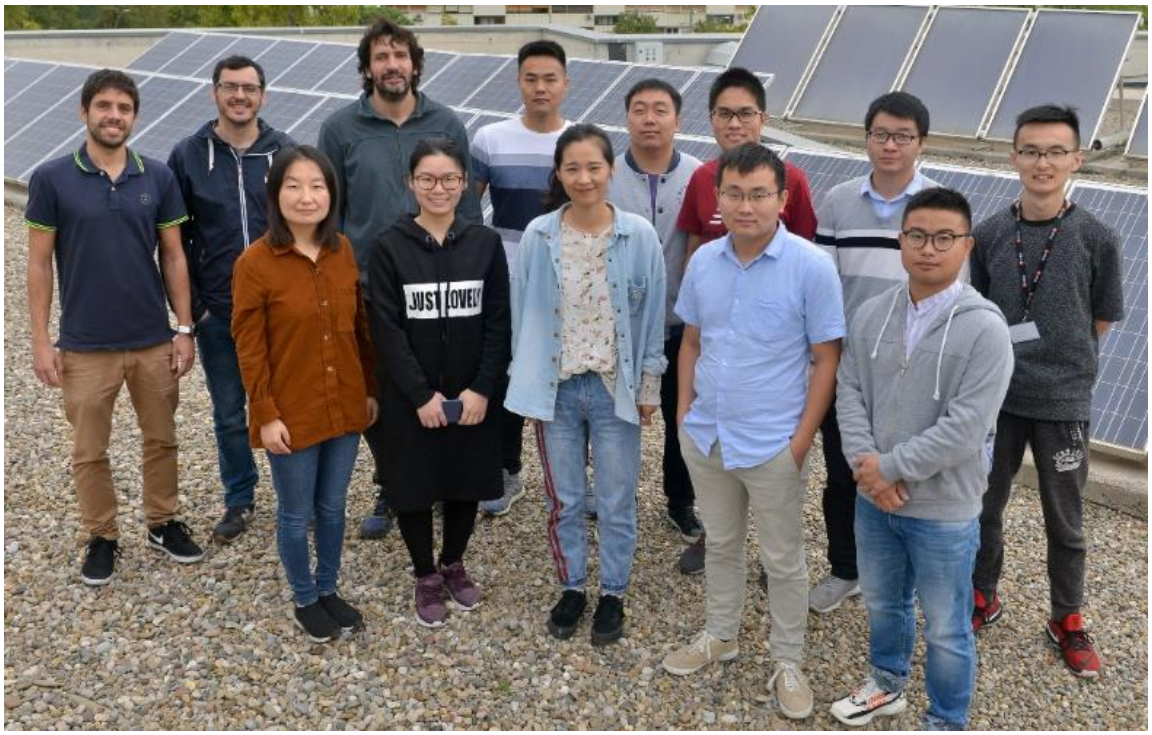
- PhD assessment committee (T. Andreu). Candidate: Kristina Wedege . Thesis title: "Aqueous flow batteries based on organic redox couples and their application in photoelectrochemical energy storage cells"Aarhus University, Denmark, 26/06/2018

6.1.2. FUNCTIONAL NANOMATERIALS

The Team

(permanent and temporary positions, tenure tracks and fellowships)

Prof. Andreu Cabot, ICREA research professor and Group Leader
Dr. Pablo Guardia, Postdoctoral Researcher
Ievgenii Liashenko, Predoctoral Student
Alberto Ramon, Predoctoral Student
Yu Zhang, Predoctoral Student
Yong Zuo, Predoctoral Student
Ruifeng Du, Predoctoral Student
Xiaoting Yu, Predoctoral Student
Chaoqi Zhang, Predoctoral Student
Concong Xing, Predoctoral Student
Xiang Wang, Predoctoral Student
Yang Dawei, Predoctoral Student
Mengyao Li, Predoctoral Student ent
Zhifu Liang, Predoctoral Student
Marcos Batista, Predoctoral Student
Ke Xiao, Predoctoral Student



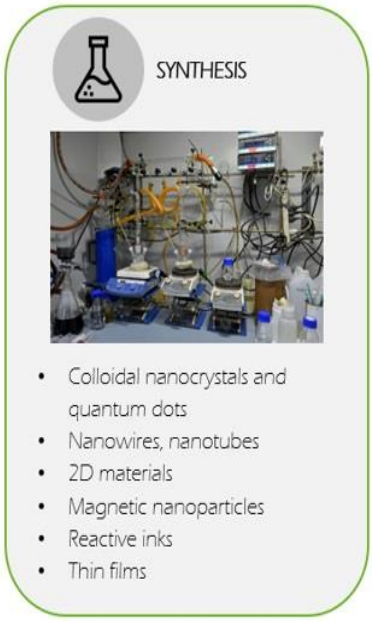
The Functional Nanomaterials group (FNG) designs and engineers nanomaterials to be applied in energy technologies, particularly in the fields of thermoelectrics, batteries and fuel cells.

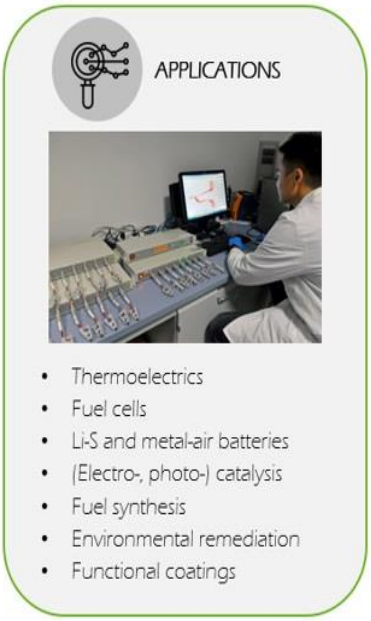
Our efforts are mainly focused on the synthesis of colloidal nanoparticles, and their assembly and use in different energy conversion technologies. In particular, we have pioneered strategies to produce complex multinary chalcogenides, phosphides and oxides and on their application in thermoelectric energy conversion, Li-S batteries and electrocatalysis.

A major outcome of our work has been the production of bulk materials with world record ZT values, which would allow up to 60% higher energy conversion efficiencies than current commercial devices. We have also developed innovative techniques to manipulate the surface chemistry of colloidal nanocrystals and assemble them into clusters, thin films, gels and bulk nanocomposites.

Our laboratories are equipped with the all the necessary set-ups to undertake every stage in the development of nanomaterial-based energy conversion devices, including nanomaterials synthesis, manipulation and fabrication of macroscopic structures and devices, material functional characterization and device test.

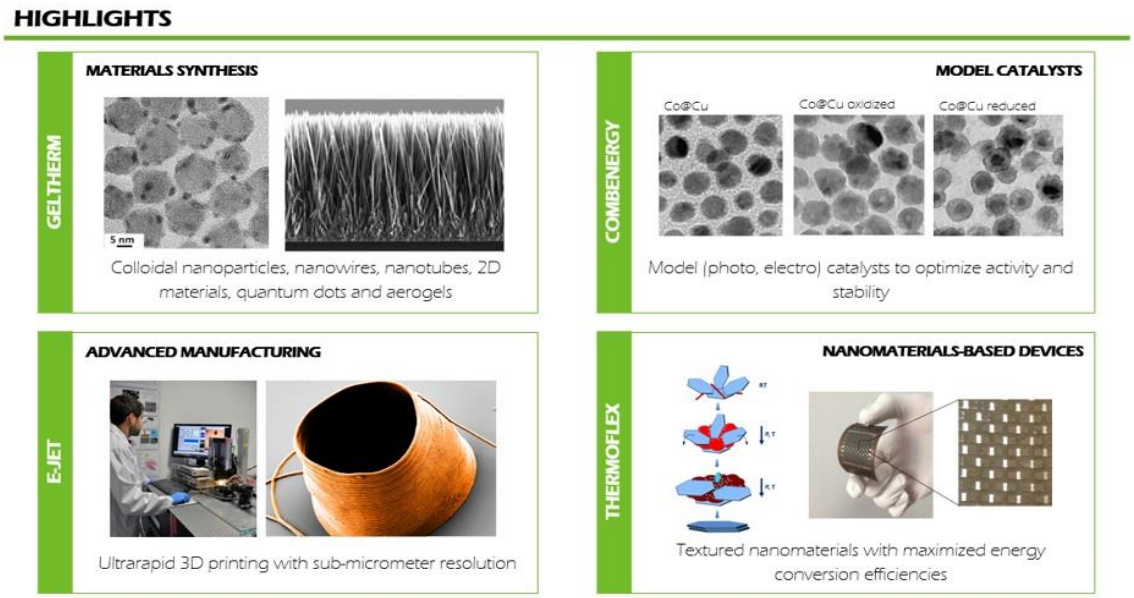
The Functional Nanomaterials Group designs and engineers nanomaterials with optimized functionalities and applies them in energy conversion, energy storage and environmental remediation technologies.





CAPABILITIES

- Nanoparticle synthesis (2-glove glovebox, 8 fume hoods for colloidal synthesis, hydrothermal synthesis, ball milling, etc.)
- Nanomaterial/nanocomposite preparation (16-glove gloveboxes, rapid hot press, induction ovens, vacuum infusion)
- Nanomaterial growth (dip coating, sputtering, chemical vapor deposition, evaporation, etc.)
- Surface functionalization (plasma cleaner, UV-vis spectroscopy, dynamic light scattering, zeta potential)
- (Hydro)gel and aerogel preparation (freeze drier, CO_2 and high temperature supercritical point driers)
- Ink-based high resolution 3D printing system
- Battery / fuel cell / (photo-, electro-) catalytic test (gas chromatography, potentiostats, solar-simulator, reactors, etc.)
- Thermoelectric characterization (thermal conductivity, Seebeck coefficient and electrical conductivity up to 600 °C)



PROJECTS

Title: Solar Energy Harvesting with Two-Photon Processes: Nanoparticle-based light sensitizers
Acronym: Sehtop-NP
Description: This project, joining effort from four groups, will apply to photovoltaic, photoelectrochemical, photocatalytic and photoluminescent systems a novel scheme of solar energy utilization which makes use of a wider interval of the solar spectrum than in usual systems by combining two electronic excitations produced by photons of relatively low energy to achieve the excitation of one electron by an energy larger than that of each of the two photons absorbed. This two-photon process (TPP) is similar to the one behind natural photosynthesis (the Z-scheme), but adds the possibility of achieving the complete excitation as well with only one photon having enough energy. In this way one obtains an important electric or chemical potential with a larger number of excited electrons than could be achieved with a traditionalsemiconductor. To this aim the project will use different materials, focussing in perovskites and composite sulphide/oxide systems, with partial substitution of their cations by transition elements which according to quantum calculations can produce an in-gap band allowing a TPP. These systems will be tested as thin film photovoltaic or photoelectrochemical cells, as powders in photocatalytic generation of hydrogen or as luminescent up-converters, their efficiency measured by rigorous methods and interpreted by a combined theoretical/experimental approach. The project aims at translating its results not only to scientific outputs but also to technologically oriented solutions advantageous for society using the already made connection with several companies interested in our approach. Within this joint project, the subproject SEHTOP-NP will address the synthesis of TPPenabled perovskites and sulphides in the form of nanoparticles and nanostructured layers in combination with high surface area titania. The synthesis of this materials and its application will be at all times

guided by the theoretical work developed in SEHTOP-QC and coordinated with the subprojects SEHTOP-HRM and SEHTOP-TF. Besides their use in photocatalysis in the SEHTOP-HRM subproject, TPP-enabled materials in nanoparticle form will be used in SEHTOP-NP to produce up-conversion luminescent solar concentrators. The advantage of TPP will be also demonstrated here with materials in the form of supported films in the fields of photoelectrochemical water splitting and semiconductor sensitized solar cells.
We foresee the results of this sub-project to have not only a significant scientific impact but also an economic and subsequently a social one, based on the development of more efficient technologies for the conversion of solar energy into electricity or readily usable chemical energy.
The research team that will carry out this subproject has extensive experience in the preparation of nanostructured materials and its application in various energy conversion technologies, including photovoltaics, photoelectrochemistry and luminescent conversion filters.
At the same time, IREC is equipped with state of the art laboratories enabling pursuing with the appropriate tools the project goals.
Funding: Retos Investigació
Project ID: ENE2016-77798-C4-3-R
Type: Competitive Nationals
Partners: Agencia Estatal Consejo Superior De Investigaciones Cientificas (CSIC), Universitat Politècnica De València (UPV), Universidad Politecnica De Madrid (UPM), Fundacio Institut de Recerca en Energia de Catalunya (IREC)
Date: 12/30/2016-12/29/2020
Gorup: Funtional Nanomaterials
P.I: Andreu Cabot.

Title: Smart nanoclusters for Photo-magnetic hyperthermia, SmartTherm
Acronym: SMARtTHERM
Description: Main objective is to produce magneto-plasmonic nanoparticle clusters (NPCs) for dual photo and magnetic hyperthermia for biobedicalapplications. The synergetic effect between plasmonic and magnetic nanoparticles will increase the hyperthermia, SERS and MRI performances of NPCs. The project addresses the current limitations of high closes and long-time treatments in cancer. The work plan involves interdisciplinary training and technology-transfer activities increasing overall fellow's expertise. The participation of renowned research institutions and companies ensures project's successful. At the end of the project, the fellow will be positioned at the forefront of nano-and bio-technology while enrolled in a young research center with a strong career projection.
Funding: Accio
Project ID: TECSPR16-1-0082
Type: Competitive Nationals
Partners: Fundacio Institut de Recerca en Energia de Catalunya (IREC)
Date: 9/1/2017-8/31/2019
Group: Funtional Nanomaterials
P.I: Pablo Guardia Giros.

Title: Gel-Nanocomposites for Magnetic-Mediated Heating Assited Water Purification
Acronym: GELTHERM
Description: The project GELTHERM addresses one of the greatest challenges of the 21st century defined in the Plan estatal de investigación científica y técnica y de innovación 2017-2020 (Reto 5): Providing water universally in a safe, reliable and affordable manner. This challenge is also included in the EU Horizon 2020 Work Program 2018-2020 Climate action, environment, resource efficiency and raw materials CE-SC5-04-2019. GELTHERM solution to this challenge is based on the development of novel materials and the application of novel strategies and technologies for water remediation. In particular, the project aims to develop magnetic-activated multifunctional nanocomposite gels as a platform for multiple activated water treatments: ion removal, dye degradation, oil spill clean-up and pathogen inactivation. As such, a unique absorbent material can be exploited to eliminate a range of pollutants, thus reducing the complexity and costs associated to traditional water purification systems. To achieve this ambitious goal, the project will exploit gelation processes to combine different nanoscaled building blocks (several types of nanoparticles and graphene oxide nanosheets) into highly porous structures (gels or aerogels). Multifunctionality will be provided by combining nanoparticles having photocatalytic activity, magnetic response, biocidal activity and selective adsorption capability. Embedding magnetic nanoparticles into gels will allow for magnetic mediated heating (MMH) and the use of hyperthermia for purification (i.e. pathogen inactivation or foulant degradation). MMH combined in standard purification procedures will boost the performances: Ion-absorption and desorption capacities, photocatalytic dye degradation and pathogen inactivation, absorption and desorption of oil spills and molecules, and biocidal release can be boosted well beyond the current-state-of-the-art through local increase of the temperature by MMH. Moreover, since MMH is a contactless process, it can be exploited for triggering each process thus providing both selectivity and remote control over the purification treatment. Finally, the magnetic response will provide magnetic extraction, improving the reuse of the absorbent material and limiting unintended release to the environment. The nanocomposite gels developed will be also exploited as sensing platforms for water pollutants in collaboration with external groups.
The technology developed during the project will be directly applied in a gravity filter prototype to be further implemented in a cartridge filter for a water purification pitcher. The final goal of the project is to provide a point-of-use water purification system for areas in which water security is scarce or water-supplying systems are inefficient. Outcomes of the project will find further applications in industrial, agriculture and urban wastewater management. As such, the project have a huge potential impact in society by: i) decreasing diseases and deaths related with contaminated water, ii) decreasing wastewater management costs through faster and efficient purification processes, iii) the restoration of aquatic ecosystems and iv) providing point-of-use water purification systems for undeveloped areas.
Funding: Retos Investigació
Project ID: RTI2018-102006-J-I00
Type: Competitive Nationals
Partners: Fundacio Institut de Recerca en Energia de Catalunya (IREC)
Date: 9/1/2019-8/31/2022
Group: Funtional Nanomaterials
P.I: Pablo Guardia Giros.

Title: Fabricació additiva d'alta velocitat i resolució mitjançant un nou sistema de control del posicionament del material addicional
Acronym: Fabricació additiva d'alta velocitat i resolució mitjançant un nou sistema de control del posicionament del material addicional.
Description: There is an ample consensus that the main challenges of 3D printing technologies is to increase their production speed, to improve their resolution and to increase the palette ofprinted materials, ideally making possible the fabrication of multi-material products. Amongthe different current and under development additive manufacturing technologies, thematerial injection in an ink form is the only one providing a true material versatility, makingpossible the fabrication of structures with any composition that can be formulated as ink, thus virtually any composition. However, the current 3D printing technologies based onmaterial jetting are severely limited both in terms of fabrication speed and in resolution, withthe intrinsic problem that when trying to improve resolution, fabrication speed is furtherreduced. At the basis of this limitation, there is the combination of a slow material injectionand a slow translation of the printing head. More specifically, the moderate acceleration thatmechanical stages are able to reach, due to their relatively high mass, strongly constrainsthe translation speed of the injector or support in the non-linear movement required tocreate predefined 3D structures. Best motorized stages move with maximum accelerationsclose to 20 m/s2 and are able to reach speeds close to 0.2 m/s. To overcome this intrinsiclimitation of additive manufacturing technologies based on material jetting, a revolutionarynew strategy to control the position of addition of material need to be developed. In the Nanomaterials Group, at the Catalonia Institute for Energy Research ¿ IREC, wehave demonstrated the possibility to move a jet with accelerations above 500,000 m/s2 andspeeds close to 10 m/s using electrostatic fields. We plan to use this concept to develop anew 3D printing technology that makes use of electrostatic fields to deflect the material jetand to control in this way the positioning of the added material. The use of a fast positioningwill further allow increasing the jet generation speed to 1-10 m/s. In the present project, wewill validate this new and revolutionary technological concept, which will allow printingspeeds over 100 times faster than current technologies based on material jetting. At thesame time, the use of charged jets potentially allows creating filaments with a thicknessdown to 100 nm, thus potentially providing sub-micrometer resolution. This technology willbe initially based on inks, which will allow creating 3D structures with any composition,including metals, semiconductors, oxides, and even proteins and biological material.The possibility of fabricating 3D structures with submicron resolution at high speed and withan unlimited material versatility, will allow to advantageously compete in a number of fieldswhere conventional additive technologies has been already entered and opening new blueocean markets for 3D printing strategies.To translate the formulated technological concept into a commercially exploitabletechnology, several challenges are yet to be overcome. The main 3 challenges are thecontrol of the jet start/stop, the improvement in the resolution of the initial positioning of thematerial addition and the probe of the concept with inorganic materials through developinginorganic inks, printing protocols and postdeposition treatments, since the basic concepthas been just probed with polymer-based inks. Additionally, a compact electronics and asoftware able to control the different system components need to be developed. These tasks will be carried out during this Llavor

project. Along with this experimental work, we will define applications, follow the competing technologies and market, define acommercialization route and a business model, study the commercial viability of ourtechnology, and partner with key players and end potential users of our new technology.
Funding: AGAUR
Project ID: 2018 LLAV 00044
Type: Competitive Nationals
Partners: FUNDACIO INSTITUT DE RECERCA DE L'ENERGIA DE CATALUNYA (IREC)
Date: 7/22/2019-1/21/2020
Group: Funtional Nanomaterials
P.I: Andreu Cabot.

Title: Solid-liquid thermoelectric sytems with uncorrelated properties
Acronym: UncorrelaTEd
Description: More than 60% of the global power is lost as waste heat. Thermoelectric (TE) materials can convert vast amounts of this waste heat into electricity and significantly contribute to the current energy challenge. Despite large efforts to identify better TE materials, still, the TE technology is limited by low efficiency. One of the two performance improvement routes, thermal conductivity reduction, has already reached its limit, which makes the other route, power factor (PF) improvements, crucial. Current strategies targeting PF enhancement have only reached modest improvements, mainly due to the adverse interdependence of the Seebeck coefficient (S) and the electrical conductivity (?), which produces a decrease in one of these properties if the other is increased. This is a serious obstacle to achieve the widespread application of the TE technology, since PF=?S^2. UncorrelaTEd will come true the dream of breaking the S-? correlation by introducing a new paradigm in thermoelectricity that comes from the connection of TEs and electrochemistry, using a properly designed hybrid system, formed by a porous TE solid permeated by a liquid electrolyte. The porous solid provides a low thermal conductivity, whereas the electrolyte tactically interacts with the solid to enlarge the PF. Unprecedented PF improvements (above 35 times) have already been observed by UncorrelaTEd members in this system using a material with modest TE properties. UncorrelaTEd aims at extending these improvements to different materials (bismuth telluride alloys, oxides, and polymers) with state-of-the-art TE properties, potentially leading to an extraordinarily powerful technology able to provide more than 4 times larger PF than state-of-the-art low-mid temperature (<150 ºC) materials and ZTs>3. This will enable the TE technology to be implemented in many areas, such as self-powered sensors, empowering the elimination of batteries, textiles, factories, power plants, and combustion engines.
Funding: H2020
Project ID: 863222
Type: Competitive EU
Partners: Universitat Jaume I De Castellon (UJI), Fundacio Institut de Recerca en Energia de Catalunya (IREC), Kungliga Tekniska Hoegskolan (KTH), The University of Warwick (Warwick), Solvionic, Intenanomat SL.
Date: 1/1/2020-12/31/2023
Group: Funtional Nanomaterials

P.I: Andreu Cabot

PUBLICATIONS

Articles and Journals from ISI Database

Zuo Y., Liu Y., Li J., Du R., Yu X., Xing C., Zhang T., Yao L., Arbiol J., Llorca J., Sivula K., Guijarro N., Cabot A.**"Solution-Processed Ultrathin SnS 2 -Pt Nanoplates for Photoelectrochemical Water Oxidation"**, 2019, ACS Applied Materials and Interfaces, 11,7,6918,6926,9,10.1021/acsami.8b17622, Article. IF:8.456.

Ibáñez M., Genç A., Hasler R., Liu Y., Dobrozhan O., Nazarenko O., De La Mata M., Arbiol J., Cabot A., Kovalenko M.V.**"Tuning transport properties in thermoelectric nanocomposites through inorganic ligands and heterostructured building blocks"**, 2019, ACS Nano, 13,6,6572,6580,1,10.1021/acsnano.9b00346, Article, Open Access. IF:13.903.

Ostovari Moghaddam A., Shokuhfar A., Zhang Y., Zhang T., Cadavid D., Arbiol J., Cabot A.**"Ge-Doped ZnSb/?-Zn4Sb3 Nanocomposites with High Thermoelectric Performance"**, 2019, Advanced Materials Interfaces, 6,18,1900467,10.1002/admi.201900467, Article. IF:4.713.

Liu J., Yu X., Du R., Zhang C., Zhang T., Llorca J., Arbiol J., Wang Y., Meyns M., Cabot A.**"Chromium phosphide CrP as highly active and stable electrocatalysts for oxygen electroreduction in alkaline media"**, 2019, Applied Catalysis B: Environmental, 256,117846, 10.1016/j.apcatb.2019.117846, Article. IF: 14.229.

Liu J., Luo Z., Li J., Yu X., Llorca J., Nasiou D., Arbiol J., Meyns M., Cabot A.**"Graphene-supported palladium phosphide PdP 2 nanocrystals for ethanol electrooxidation"**, 2019, Applied Catalysis B: Environmental, 242,258,266,17, 10.1016/j.apcatb.2018.09.105, Article. IF: 14.229.

Carvalhaes-Dias P., Morais F.J.O., Duarte L.F.C., Cabot A., Dias J.A.S.**"Autonomous soilwater content sensors based on bipolar transistors encapsulated in porous ceramic blocks"**, 2019, Applied Sciences (Switzerland), 9,6,1211,10.3390/app9061211, Article, Open Access. IF: 2.217.

Zuo Y., Liu Y., Li J., Du R., Han X., Zhang T., Arbiol J., Divins N.J., Llorca J., Guijarro N., Sivula K., Cabot A.**"In Situ Electrochemical Oxidation of Cu2S into CuO Nanowires as a Durable and Efficient Electrocatalyst for Oxygen Evolution Reaction"**, 2019, Chemistry of Materials, 31,18,7732,7743,2, 10.1021/acs.chemmater.9b02790, Article. IF: 10.159.

Li J., Xu X., Luo Z., Zhang C., Zuo Y., Zhang T., Tang P., Infante-Carrió M.F., Arbiol J., Llorca J., Liu J., Cabot A.**"Co–Sn Nanocrystalline Solid Solutions as Anode Materials in Lithium-Ion**

Batteries with High Pseudocapacitive Contribution", 2019, ChemSusChem, 12,7,1451,1458,4,10.1002/cssc.201802662, Article. IF:7.804.

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Li M., Liu Y., Zhang Y., Zuo Y., Li J., Lim K.H., Cadavid D., Ng K.M., Cabot A.**"Crystallographically textured SnSe nanomaterials produced from the liquid phase sintering of nanocrystals"**, 2019, Dalton Transactions, 48,11,3641,3647,10.1039/c8dt04414g, Article. IF:4.052.

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Yi M., Zhang C., Cao C., Xu C., Sa B., Cai D., Zhan H.**"MOF-Derived Hybrid Hollow Submicrospheres of Nitrogen-Doped Carbon-Encapsulated Bimetallic Ni-Co-S Nanoparticles for Supercapacitors and Lithium Ion Batteries"**, 2019, Inorganic Chemistry,5, 10.1021/acs.inorgchem.8b03594, Article. IF:4.85.

Caudillo-Flores U., Kubacka A., Berestok T., Zhang T., Llorca J., Arbiol J., Cabot A., Fernández-García M.**"Hydrogen photogeneration using ternary CuGaS2-TiO2-Pt nanocomposites"**, 2019, International Journal of Hydrogen Energy, 10.1016/j.ijhydene.2019.11.019, Article. IF:4.084.

A. Ostovari Moghaddam, A. Shokuhfar, A. Cabot**"Ball Milling and Post Annealing as an Effective Route to Synthesize Co1-xCuxSbS Paracostibite Thermoelectric Material"**, 2019, Iranian Journal of Materials Science & Engineering ,0.41,16,20,26,10.22068/ijmse.16.4.20, Article, Open Access.

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Lim K.H., Wong K.W., Liu Y., Zhang Y., Cadavid D., Cabot A., Ng K.M.**"Critical role of nanoinclusions in silver selenide nanocomposites as a promising room temperature thermoelectric material"**, 2019, Journal of Materials Chemistry C, 7,9,2646,2652,3,10.1039/c9tc00163h, Article. IF:6.641.

M. Ibañez, R. Hasler, A. Genç, Y. Liu, B. Kuster, M. Schuster, O. Dobrozhan, D. Cadavid, J. Arbiol, A. Cabot, M. V. Kovalenko **"Ligand-Mediated Band Engineering in Bottom-Up Assembled SnTe Nanocomposites for Thermoelectric Energy Conversion"**, 2019, Journal of the American Chemical Society, 140,20,8025,8029,10.1021/jacs.9b01394, Article, Open Access. IF:14.695.

H. Xie, Y. Sanchez, P. Tang, M. Espindola-Rodriguez, M. Guc, L. Calvo-Barrio, S. Lopez-Marino, Y. Liu, J.R. Morante, A. Cabot, V. Izquierdo-Roca, J. Arbiol, A. Perez-Rodriguez, E. Saucedo **"Enhanced Hetero-Junction Quality and Performance ofKesterite Solar Cells by Aluminum Hydroxide Nanolayersand Efficiency Limitation Revealed by Atomic-resolutionScanning Transmission Electron Microscopy"**, 2019, Solar RRL,3,1800279,10.1002/solr.201800279, Article,

Zhang C., Biendicho J.J., Zhang T., Du R., Li J., Yang X., Arbiol J., Zhou Y., Morante J.R., Cabot A**."Combined High Catalytic Activity and Efficient Polar Tubular Nanostructure in Urchin-Like Metallic NiCo2Se4 for High-Performance Lithium–Sulfur Batteries"**, 2019, Advanced Functional Materials, 29,34,1903842,3,10.1002/adfm.201903842, Article. IF:15.621.

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Yu X., Zhang C., Luo Z., Zhang T., Liu J., Li J., Zuo Y., Biendicho J.J., Llorca J., Arbiol J., Morante J.R., Cabot A.**"A low temperature solid state reaction to produce hollow MnxFe3-xO4 nanoparticles as anode for lithium-ion batteries"**, 2019, Nano Energy, 66,104199, 10.1016/j.nanoen.2019.104199, Article. IF:15.548.

DOCTORAL THESES

Presented Theses:

PhD graduate: Junfeng Liu
PhD supervisor: A. Cabot, M. Menys
Title: Colloidal Metal Phosphide Nanocrystals for Electrochemical Energy Technologies
Presented date: 01/10/2019

PhD graduate: Junshan Li
PhD supervisor: Dr. Andreu Cabot
Title: Ni-Co-Sn Colloidal Nanoparticles for Electrochemical Energy Technologies
Presented date: 18/06/2019

Ongoing theses:

PhD student: Alberto Ramon
PhD supervisor: Dr. Andreu Cabot
Title: High electric fields to control jet deflection
Starting date: 01/10/2018

PhD student: Zhifu Liang
PhD supervisor: Dr. Andreu Cabot
Title: Single atom catalysts for CO2 conversion
Starting date: 01/10/2018

PhD student: Chaoqi Zhang
PhD supervisor: Dr. Andreu Cabot
Title: New nanomaterials for Li-S batteries
Starting date: 01/10/2017

PhD student: Ruifeng Du
PhD supervisor: Dr. Andreu Cabot
Title: 2-photon processes to improve photovoltaic and photocatalytic efficiency
Starting date: 01/10/2017

PhD student: Congcong Xing
PhD supervisor: Dr. Andreu Cabot
Title: Metal doping in graphene for electrocatalytic applications
Starting date: 01/10/2017

PhD student: Mengyao Li
PhD supervisor: Dr. Andreu Cabot
Title: Electronic doping in bottom-up engineered nanomaterials
Starting date: 01/10/2017

PhD student: Yang Dawei
PhD supervisor: Dr. Andreu Cabot
Title: Optimization of catalytic properties of metal chalcogenides toward polysulfides
Starting date: 01/10/2017

PhD student: Xiang Wang
PhD supervisor: Dr. Andreu Cabot
Title: Single atom catalysts for electrocatalytic fuel production
Starting date: 01/10/2017

PhD student: Yong Zuo
PhD supervisor: Dr. Andreu Cabot
Title: Precise Engineering of Interband Photocatalysts for Solar Fuels
Starting date: 01/10/2016

PhD student: Yu Zhang
PhD supervisor: Dr. Andreu Cabot

Title: Molecular precursors towards high performance inorganic functional materials
Starting date: 01/10/2016

PhD student: Ievgenii Liashenko
PhD supervisor: Dr. Andreu Cabot
Title: Electrohydrodynamic 3D printing
Starting date: 01/07/2015

PhD student: Xiaoting Yu
PhD supervisor: Dr. Andreu Cabot
Title: Colloidal nanoparticles for electrocatalytic energy conversion
Starting date: 30/09/2015

PhD student: Marcos Batista
PhD supervisor: Dr. Andreu Cabot
Title: Complex oxide nanostructures for photocatalytic applications
Starting date: 01/10/2015

PhD student: Guillen Montaña
PhD supervisor: Dr. Andreu Cabot
Title: Influence of external electric fields on thermocatalytic processes for the generation of solar fuels
Starting date: 01/10/2015

PATENTS

Title: Electrical generator for exploiting heat reservoirs using a ring-based themoelectric system
Publication number : ES2438619 (A1); ES2438619 (B1)
Publication date: 2014-01-17
Inventors: Noriega Mosquera, Francisco German; Canandell Estrada, Alberto; Lopez Martinez, Antonio; Cabot, Andreu; Morante Lleonart, Joan Ramon; Revirand, Pascal; Niarchos Dimitris; Platzek Dieter
Applicants: Universitat de Barcelona (UB)
International classification: H01L35/32
Cooperative Patent Classification: H01L35/30, H01L35/32
Application number: ES20120030939
Date of application: 2012/06/15
Priority numbers: ES20120030939 20120615

Title: Continuous flow process for the preparation of colloidal solutions of nanoparticles, colloidal solutions and uses thereof
Publication number : WO2012119779 (A3); WO2012119779 (A9); WO2012119779 (A2)
Publication date: 2012-09-13
Inventors: Cabot Codina, Andreu; Shavel Alexey; Ibanez Sabate, Maria
Applicants: Universitat de Barcelona (UB)

International classification: B22F9/24, B22F1/00, H01L31/0352, **Cooperative Patent Classification:** B22F1/0022, B22F9/24, B82Y30/00, H01L31/0326, H01L31/035218, Y02E10/50
Application number: WO2012EP01047
Date of application: 2012/03/09
Priority numbers: EP20110382064 20110310

OUTREACH

- Thermoelectrics workshop, Network of Excellence, Valencia, September 27-28th 2018, Invited talk
- ICREN 2018, Barcelona, April 25-27th 2018, Invited talk
- JICI-IV, Cordoba, February 7th 2018, Invited talk
- IST, Viena November 13th 2018, Invited talk
- FEMS Junior Euromat 2018, Budapest, July 8-14th 2018, poster
- NanoBio&Med2018 november 20-22, 2018 – Barcelona, poster and talk
- AEROGEL SEMINAR 2018, Hamburg Germany September 24-26th 2018, poster
- CHALLENGES & OPPORTUNITIES IN ENERGY RESEARCH, Winter School, Sion, Switzerland. March 5th-9th,2018, poster
- Scienza alla scuola / Scuola elementare Govi, genova, Italy/ 19/04/2018-20/042018
- 12è Festival de la Ciència, Barcelona /Barcelona, Spain / 10/06/2018
- Researchers night / Cosmocaixa, Barcelona, Spain / 28/09/2018

6.1.3. NANOIONIC AND FUEL CELLS

The Team

(permanent and temporary positions, tenure tracks and fellowships)

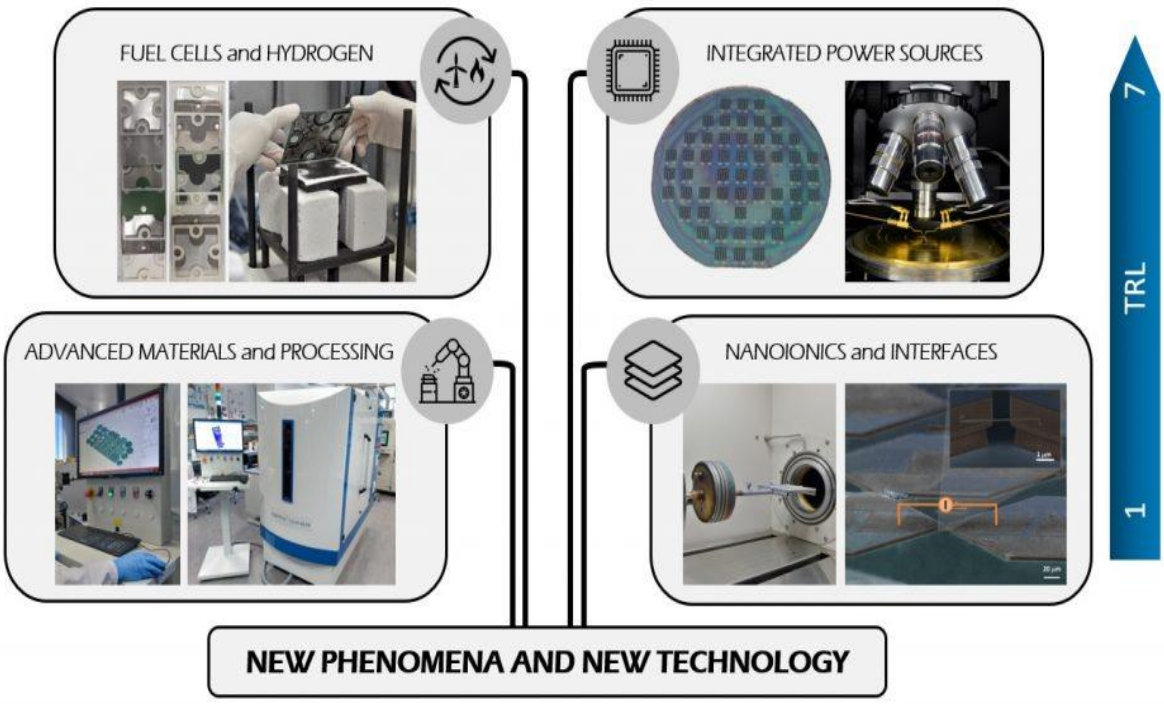
Prof. Albert Tarancón, ICREA Professor and Head of Group
Dr. Alex Morata, Staff Scientist
Dr. Marc Torrell, Staff Scientist
Dr. Marc Núñez, Laboratory Support
Dr. Nerea Alayo, Staff Scientist
Dr. Federico Baiutti, Staff Scientist
Dr. Aitor Hornes, Postdoctoral Researcher
Dr. Mercè Pacios, Postdoctoral researcher (Beatriu de Pinós Fellow)
Dr. Lucile Bernadet, Postdoctoral researcher
Dr. Julian Atilio Puszkiel, Postdoctoral Researcher (TecnioSpring Fellow)
Dr. Francesco Chiabrera, Postdoctoral Researcher
Mr. Gotzon Garcia, Project Engineer
Ms. Arianna Pesce, Predoctoral Student
Mr. Simone Anellli, Predoctoral Student
Ms. Valerie Siller, Predoctoral Student
Mr. Marco Bianchini, Predoctoral Student
Mr. Jose Sojo, Predoctoral Student
Ms. Yunqing Tang, Predoctoral Student
Ms. Maritta Meyrella Dos Santos, Predoctoral Student
Ms. Natalia Kostretsova, Predoctoral Student
Mr. Juan De Dios Sirvent, Predoctoral Student

The Nanoionics and Fuel Cells Group addresses the challenge of developing highly efficient and clean solid state energy conversion technologies to power a sustainable society. We use our knowledge in ionic, electronic and thermal transport combined with expertise in advanced manufacturing to develop new energy concepts from the microwatt to the kilowatt range.

In the microwatt range, we develop miniaturized energy sources for powering the Internet of Things (IoT). Using disruptive ideas from the emerging Nanoionics and Iontronics disciplines, which deal with the complex interplay between electrons and ions in the nanoscale, we develop new families of all-solid state micro-energy sources able to harvest and store energy at the same time. Together with ambitious high-tech companies, we look for the viability of a new paradigm of embedded energy.

In the kilowatt range, we develop advanced solid oxide fuel cells and electrolysers that will enable a hydrogen-based zero-emissions energy system. Through the innovative ceramic 3D printing of ionic conductors, we are working towards fabricating a new generation of enhanced solid oxide cells that will bring us closer to novel functionalities and improved performance by design. In our lab, we push for joint development of original concepts and more conventional technologies with the current leading industry.

The Nanoionics and Fuel Cells group focuses its research on the fundamental and applied research of ionic, electronic and mixed conductive materials for solid state energy conversion devices.



CAPABILITIES

- Nanostructures and thin films fabrication (large area PLD, CVD) and characterisation (operando ellypsometry/Raman, quantum efficiency, electroemission)
- Advanced materials fabrication (multimaterial ceramic 3D printer, Screen printing, 3D-controlled airbrush, Inkjet printing, DLP and FDM plastic printers) and characterisation (in-situ Raman, TGA)
- Electrochemistry and performance (micro-devices automatized electrochemical test stations, button cells and kW-stack scale test benches)

HIGHLIGHTS

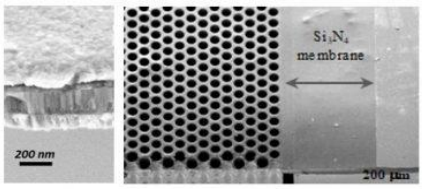
COSIN

DEMONSTRATOR

kW range co-electrolyser for CO_2 methanation, in a water treatment plant

ULTRASOFC

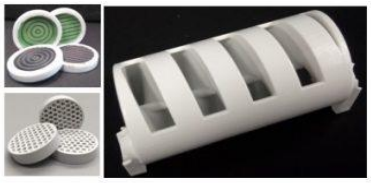
MICRO-DEVICES



Integrated micro-SOFC devices

CELL3DITOR

ADVANCED MANUFACTURING



Multimaterial ceramic 3D printing of enhanced energy devices

HARVESTORE

CUTTING-EDGE SCIENCE

Novel energy and harvesting concepts in the nanoscale

PROJECTS

Title: Breaking the temperature limits of Solid Oxide Fuel Cells: towards a new family of ultra-thin portablepower sources
Acronym: Ultra Sofc
Description: Solid Oxide Fuel Cells (SOFCs) are one of the most efficient and fuel flexible power generators. However, a greatlimitation on their applicability arises from temperature restrictions. Operation approaching room temperature (RT) isforbidden by the limited performance of known electrolytes and cathodes while typical high temperatures (HT) avoidtheir implementation in portable applications where quick start ups with low energy consumption are required.The ULTRASOFC project aims breaking these historical limits by taking advantage of the tremendous opportunitiesarising from novel fields in the domain of the nanoscale (nanoionics or nano photochemistry) and recent advances inthe marriage between micro and nanotechnologies. From the required interdisciplinary approach, the ULTRASOFCproject addresses materials challenges to (i) reduce the operation to RT and (ii) technological gaps to develop ultra-low-thermal mass structures able to reach high T with extremely low consumption and immediate start up. A unique SOFC technology fully integrated in ultrathin silicon will be developed to allow operation with hydrogenat room temperature and based on hydrocarbons at high

temperature. Stacking these SOFCs will bring a new familyof ultrathin power sources able to provide 100 mW at RT and 5W at high T in a size of a one-cent coin. A stand-alonedevice fuelled with methane at HT will be fabricated in the size of a dice. Apart from breaking the state-of-the-art of power portable generation, the ULTRASOFC project will cover the gapof knowledge existing for the migration of high T electrochemical devices to room temperature and MEMS to highT. Therefore, one should expect that ULTRASOFC will open up new horizons and opportunities for research inadjacent fields like electrochemical transducers or chemical sensors. Furthermore, new technological perspectives ofintegration of unconventional materials will allow exploring unknown devices and practical applications
Funding: ERC
Project ID: 681146
Type: Competitive EU Coordinator
Partners: Fundacio Institut de Recerca en Energia de Catalunya (IREC)
Date: 3/29/2016-3/28/2021
Group: Nanoionic and Fuel Cells
P.I: Albert Tarancón Rubio
URL:
http://www.ultrasofc.eu,https://drive.google.com/open?id=13WyZ2D9ph9q8sEV1UR-g_GKB1Ujt0RFX

Title: Efficient Co-Electrolyser for Efficient Renewable Energy Storage
Acronym: ECo
Description: The overall goal of ECo is to develop and validate a highly efficient co-electrolysis process for conversion of excessrenewable electricity into distributable and storable hydrocarbons via simultaneous electrolysis of steam and CO2through SOEC (Solid Oxide Electrolysis Cells) thus moving the technology from technology readiness level (TRL)3 to 5. In relation to the work program, ECo will specifically:
• Develop and prove improved solid oxide cells (SOEC)based on novel cell structure including electrode backbone structures and infiltration and design of electrolyte/electrode interfaces to achieve high performances and high efficiencies at ~100 oC lower operating temperatures thanstate-of-the-art in order to reduce thermally activated degradation processes, to improve integration with hydrocarbonproduction, and to reduce overall costs.
• Investigate durability under realistic co-electrolysis operating conditionsthat include dynamic electricity input from fluctuating sources with the aim to achieve degradation rates below1%/1000 h at stack level under relevant operating conditions.
• Design a plant to integrate the co-electrolysis withfluctuating electricity input and catalytic processes for hydrocarbon production, with special emphasis on methanation (considering both external and internal) and perform selected validation tests under the thus needed operatingconditions.
• Test a co-electrolysis system under realistic conditions for final validation of the obtained results at largerscale.
• Demonstrate economic viability for overall process efficiencies exceeding 60% using results obtained in theproject for the case of storage media such as methane and compare

to traditional technologies with the aim to identifycritical performance parameters that have to be improved. Perform a life cycle assessment with CO2 from differentsources (cement industry or biogas) and electricity from preferably renewable sources to prove the recycling potentialof the concept"
Funding: H2020
Project ID: 699892
Type: Competitive EU
Partner: Danmarks Tekniske Universitet (DTU), Commissariat a l' Energie Atomique et aux Energies Alternatives (CEA), Eifer Europaisches Institutfur Energieforschung Edf-Kit Ewiv (EIFER), Ecole Polytechnique Federale de Lausanne (EPFL), Fundacio Institut de Recerca en Energia de Catalunya (IREC), HTceramix SA (HTceramix SA),Belgisch Laboratorium Vande Elektriciteitsindustrie (LABORELEC), Enagas, S.A. (ENAGAS S.A.)
Date: 5/1/2016-4/30/2019
Group: Nanoionic and Fuel Cells
P.I: Albert Tarancón Rubio
Other group: Energy Systems Analitics-Dr. Cristina Corchero García
URL: http://www.eco-soec-project.eu/,https://drive.google.com/open?id=1RKn832eaSV2Me0viLVpq6lqhzzTtKkDA

Title: Cost-effective and flexible 3D printed SOFC stacks for commercial applications
Acronym: Cell3ditor
Description: A Solid Oxide Fuel Cell (SOFC) is a ceramic-based multilayer device that involves expensive and time-consuming multi-step manufacturing processes including tape casting, screen printing, firing, shaping and several hightemperature thermal treatments. In addition, these cells are manually assembled into stacks resulting in extra steps for joining and sealing that difficult the standardization and quality control of the final product while introducing weak parts likely to fail. Since current ceramics processing presents strong limitations in shape and extremely complex design for manufacturing (more than 100 steps), industrially fabricated SOFC cells and stacks are expensive and present low flexibility and long time to market. This is particularly relevant for the commercial segment of the stationary fuel cells market (5-400kW) that is highly heterogeneous in terms of the overall power and heat requirements and requires customization of the final product. The main goal of the Cell3Ditor project is to develop a 3D printing technology for the industrial production of SOFC stacks by covering research and innovation in all the stages of the industrial value chain (inks formulation, 3D printer development, ceramics consolidation and system integration). All-ceramic joint-free SOFC stacks with embedded fluidics and current collection will be fabricated in a two-step process (single-step printing and sintering) to reduce in energy, materials and assembly costs while simplifying the design for manufacturing and time to market. Compared to traditional ceramic processing, the Cell3Ditor manufacturing process presents a significantly shorter time to market (from years to months) and a cost reduction estimated in 63% with an initial investment below one third of an equivalent conventional manufacturing plant (production of 1000 units per year). The project is product-driven and involves SMEs (with proved technologies) in the entire value chain to ensure reaching TRL>6.
Funding: H2020
Project ID: 700266

Type: Competitive EU, Coordinator
Partners: Fundacio Institut de Recerca en Energia de Catalunya (IREC), Danmarks Tekniske Universitet (DTU), Francisco Albero SA (FAE), 3DCERAM (3DCERAM), Promethean Particles LTD (PROM), Universidad de la Laguna (ULL), SAAN Energi AB (SAAN), HyGear Fuel Cell Systems B.V. (HFCS)
Date: 7/1/2016-4/30/2020
Group: Nanoionic and Fuel Cells
P.I: Dr. Albert Tarancón Rubio
Other group: Energy Systems Analitics-Dr. Cristina Corchero García
URL:
http://www.cell3ditor.eu/,https://drive.google.com/open?id=1Tfc9RGe2Fyo1aTMU29njd_iP88WeavTb

Title: 3D- Printing MAterials and Devices for Energy Storage and Biofuels
Acronym: 3D Made
Descripction: The main goal of the 3D-MADE project is the optimization of different advanced ceramic 3D printing technologies for a cost-effective and time efficient fabrication of highly complex devices for energy conversion technologies. The focus of the proposal is put on i) development and optimization of 3D printing technologies for advanced ceramics and ii) the design, fabrication and performance evaluation of 3D printed devices and reactors for the energy market. In particular, the project will address major concepts in syngas production by high temperature electrolysis (Power-to-Fuel, P2F) and production of Solar Fuels and Biofuels. The development of these energy technologies contributes to reach the goal of Secure, clean and efficient energy production, defined in the Spanish and European Strategic Programmes, by implementing and deploying. The first major aim of the 3D-MADE project is to carry out a product-driven optimization of different ceramic 3D printing techniques, i.e. to optimize the printing parameters and ceramic precursor slurries/inks/filaments to reach the specific requirements (printable materials, accuracy, surface finishing, microstructure control, size, speed and cost) of each particular device or reactor. While the second major aim refers to the implementation of unique functionalities and unfair advantages of 3D printing in sustainable energy conversion devices for: i) improving their efficiency by surface maximization or increasing their specific power by designing complex geometries and ii) reducing the cost, energy consumption, environmental impact and waste material during fabrication. The 3D-MADE project represents a natural extension of the former R3DES project (ENE2013-47826-C4-4-1, 2013 RETOS Call). All the partners involved in the current proposal already participated in the previous project and, therefore, the whole set of results obtained
there are considered specific background and the initial set of hypotheses for facing the new challenges pursued here.
Funding: Retos Investigació
Project ID: ENE2016-74889-C4-1-R
Type: Competitive Nationals, Coordinator
Partners: Fundacio Institut de Recerca en Energia de Catalunya (IREC)
Date: 12/30/2016-12/31/2020
Group: Nanoionic and Fuel Cells
P.I: Albert Tarancón Rubio.

Title: Nanoestructuras de Silicio-Germanio para la Generación y Almacenamiento de Energía
Acronym: Siggnal
Description: The project pursues the exploitation of silicon and germanium-based materials holding a nanometric structure that provides them with extraordinary properties useful in the field of energy. With this aim, two approaches are proposed. The first uses micro-technology for arranging a matrix of silicon or silicon-germanium nanowires, in such a way that their exceptional thermoelectric properties are accessible. The second consists in the generation of sheets that can be handled at a macroscopic level formed by silicon or silicon-germanium nanotubes. The first approach aims to carry out the improvement of a micro machined thermoelectric generator that uses silicon or silicon-germanium nanowires as thermoelectric material with the objective of facilitating its introduction in the market. This technology will be designed to suit a model based in the internet of things (IoT), in which a net of autonomous sensors and actuators with an integrated Wi-Fi modulus are required to operate. The device must be able to provide enough energy to feed a RF antenna when situated on top of a hot surface. A micro-platform based on silicon, designed and fabricated by IMB-CNM will be provided. As the characteristics of the nanowires are essential for the performance of the device, the electrical and thermal conductivity will be matched to the system by means of controlling the density of the nanowire array, their doping and the composition of the silicon-germanium alloy. The second approach is based on a new material consisting on large area flexible sheets formed by silicon or silicon-germanium nanotubes. The fabrication method includes mature and industrially scalable techniques: chemical vapor deposition (CVD) an delectro spinning. The paper-like sheets present a thickness on the order of 100 ?m. The diameter of the nanotubes is 500 nm and their wall thickness is 70 nm. When situating the sheets in contact with a hot surface, important temperature differences are achieved, providing an electrical power in the range of mW/cm2. At this level of development, the most important improvements will come from the perfection of the electrical contacts, which currently suppose the major barrier for the exploitation of the outstanding properties of the material. Once this difficulty has been overcome, a matrix of alternating p-n sheets will be connected, generating a thermoelectric module. Simultaneously, a work devoted to the study, the improvement and the adjustment of the nanotube sheets to the device will be carried out. Finally, the proposal considers an extension of the use of this previous material to the field of the lithium batteries. The enormous lithium insertion capacity of silicon is well known, but its reduced stability hinders an implementation as electrode. Nevertheless, it has been shown that nanostructured silicon can hold an enhanced tolerance to cycling. After preliminary measurements with the proposed material, capacities close to the values exhibited by commercial batteries have been attained. Moreover, it has provided a noticeable, although still not sufficient, stability. For this reason, some strategies are suggested to be explored in order to achieve an improvement of the cyclability. Among other possibilities, it will be essayed the cover of the nanotubes with carbon and the introduction of an outer silicon oxide supporting layer.
Funding: Retos Investigació
Project ID: TEC2016-78284-C3-2-R

Type: Competitive Nationals
Partners: Agencia Estatal Consejo Superior de Investigaciones Cientificas (CSIC), Fundacio Institut de Recerca en Energia de Catalunya (IREC), Universidad De Barcelona (UB)
Date: 12/30/2016-12/29/2019
Group: Nanoionic and Fuel Cells
P.I: Alex Morata García.

Title: Fabrication of High efficiency electrolyser system for energy storage.
Acronym: FETENS
Description: The market of the renewable energies achieved a new global record in 2015 with $285 billion investment on this technology, exceeding the previous record of $278 billion on 2011. The use of renewable energy has many potential benefits, including a reduction in CO2 emissions, the diversification of energy supplies and a reduced dependency on fossil fuel markets. During the last decades a relevant effort has been done in Europe to promote this type of energy source. In 2014, 196 million tons of oil equivalent (toe) were produced, 73 % more than in 2004, and these numbers are expected to continue growing. Even though the high production of renewable energy, especially in our country, its consumption only reaches to the 12% of the total energy used. An important part of the production is wasted because it is produced during the low peaks of consumption and there is a lack of efficient method to store the energy produced by renewable sources. The most promising solution is the development of flexible power-to-gas processes for energy storage. The energy produced by renewable sources during the low spot energy prices periods would be used to reduce H2O (or H2O+CO2) to H2 (or synthetic gas) and smartly couple the two major energy infrastructures of our modern society, i. e. gas and electricity networks, while covering the necessities of the mobile sector. Most of the components that form the power-to-gas system are well established in the industry. FETENS will improve the performance and durability of electrolyzer cells, which is the bottle neck that prevents this technology from successing in the market.
In accordance with the objectives of the ongoing RIS3CAT program, we aim to produce a solid oxide electrolyzer cells (SOEC) stack with high efficiency and fuel flexibility to be integrated in a final power-to-gas system. The prototype will produce more than 1L H2/min cm2 with degradation rates below 3%-1000h and faradic efficiency > 90%; highly above the values of competitor technologies (PEMEC and AEC). The proof of concept of the proposed technology has been already successfully demonstrated, therefore the project activity is placed in TRL 5-7, based on technology demonstration with the fabricated prototype and the design of the final system. According to that the funding of this program will be used to fabricate the final prototype and design the balance of plant (BoP) of the system, as well as perform a comprehensive market research and customer discovery.
SOEC module is the core of proposed energy storage technology. The market penetration in the middle of the value chain will suppose an opportunity from different Catalan and European companies. SOEC module fabrication will produce a “push-pull effect” on each side of the value chain. Energy utilities have demonstrated their interest on SOEC system funding R+D projects in energy storage and CO2 revalorization on the last years.
Funding: AGAUR
Project ID: 2016 PROD 00028

Type: Competitive Nationals
Partners: Fundacio Institut de Recerca en Energia de Catalunya (IREC), Agencia Estatal Consejo Superior de Investigaciones Cientificas (CSIC), Universidad de Castilla-La Mancha (UCLM) Universidad de la Laguna (ULL).
Date: 7/18/2017-3/21/2019
Group: Nanoionic and Fuel Cells
P.I: Marc Torrell Faro.

Title: 2017 SGR NANOEN
Acronym: NANOEN
Funding: SGR
Project ID: 2017 SGR 1421
Type: Competitive Nationals
Partners: Fundacio Institut de Recerca en Energia de Catalunya (IREC), Agencia Estatal Consejo Superior de Investigaciones Cientificas (CSIC), Universidad de Castilla-La Mancha (UCLM), Universidad de la Laguna (ULL)
Date: 1/1/2018-12/31/2020
Group: Nanoionic and Fuel Cells
P.I: Albert Tarancón Rubio.

Title: 3D-printed u-reactors for green chemistry
Acronym: 3D4GREEN
Description: The 3D4GREEN project represents a cutting edge multidisciplinary approach aiming to convert emitted CO2 into valuable chemicals using electricity from renewable sources. Applying innovative 3D-printing of ceramics, a Micro-Structured Catalytic Reactor coupled to a Solid Oxide Electrolyser will be fabricated as a reliable CO2 re-use technology, directly impacting the RIS3CAT strategy on energy storage lead by IREC. Moreover, the future career of the candidate will be reinforced by complementing his background with expertise in a relevant Key Enabling Technology (KET), such as 3D-printing, applied to the crucial field of Energy Storage together and with new skills in technology transfer gained in the industrial secondment and the active participation in the KIC InnoEnergy initiative.
Funding: Accio
Project ID: TECSPR18-1-0046
Type: Competitive Nationals
Partners: Fundacio Institut de Recerca en Energia de Catalunya (IREC), Agencia Estatal Consejo Superior de Investigaciones Cientificas (CSIC), Universidad de Castilla-La Mancha (UCLM), Universidad de la Laguna (ULL)
Date: 2/1/2019-1/31/2021
Group: Nanoionic and Fuel Cells,
P.I: Julián Puszkiel.

Title: Energy HarceStorers for Powering the Internet of Things
Acronym: HARVESTORE
Description: A breakthrough in micro-energy harvesting and storage technologies is required to cover the increasing demand of autonomous wireless sensor nodes (WSN) for the future Internet of Things (IoT), which is considered one of the five technologies that will change the world by connecting 27 billion devices and generating €2 trillion market by 2025. The HARVESTORE project aims to power these IoT nodes from ubiquitous heat and light sources by using nano-enabled micro-energy systems with a footprint below 1cm3. Using disruptive concepts from the emerging Nanoionics and Iontronics disciplines, which deal with the complex interplay between electrons and ions in the nanoscale, a radically new family of all-solid state micro-energy sources able to harvest and store energy at the same time will be developed. This new device will be called "harvestorers" (HS). In order to enable this science-totechnology breakthrough, our nano-enabled -HSs will be integrated in silicon technology. This will allow reaching the highly dense features and scalability required for a real miniaturization and massive deployment that will show their viability as a new technological paradigm of embedded energy. The HARVESTORE project addresses this challenging objective by building an interdisciplinary research consortium that includes consolidated and emergent leading researchers in modelling, microfabrication, materials science and energy together with high-tech pioneer SMEs with unique capabilities to develop and deploy IoT nodes for real applications. Moreover, the structure and communication strategy have been designed to make HARVESTORE a lighthouse project for boosting this novel micro-energy paradigm and building around an innovation ecosystem founded on emerging Nanoionics and Iontronics applied to energy.
Funding: H2020
Project ID: 824072
Type: Competitive EU, Coordinator
Partners: Fundacio Institut de Recerca en Energia de Catalunya (IREC), Danmarks Tekniske Universitet (DTU), Interuniversitair Micro-Electronica Centrum (IMEC), Agencia Estatal Consejo Superior de Investigaciones Cientificas (CSIC), Technische Universitaet Wien (TU WIEN), Imperial College of Science Technology and Medicine (Imperial), Centre National de la Recherche Scientifique CNRS (CNRS), Coventry University (COVU), Worldsensing SL (WSE), Horiba France SAS (HORIBA), Alternative Energy Innovations SL (AEInnova).
Date: 12/1/2018-11/30/2023
Group: Nanoionic and Fuel Cells
P.I: Albert Tarancón Rubio
URL:
http://www.harvestore.eu/,https://drive.google.com/open?id=1eaik0KB7gGKuz_VCyGUriyFUvxsSYzbA

Title: 3D-PRintable glass-based Electrolytes for all-Solid-State lithium batteries
Acronym: 3D-PRESS
Description: The main goal of the 3D-PRESS project is to advance in the 3D printing concepts for safer, cheaper andcustomizable all-solid state Li-ion batteries (LIB). More specifically, the project is focused on the design, production, characterization and testing of 3D printed NASICON-type glass-based electrolytes for 3D printed batteries. In 3D-PRESS,

glass-based compositions will be designed and synthesized in order to obtain printable glass-basedelectrolytes with superior conductivity and functional properties. The produced glasses will be thermally andelectrochemically characterized in order to investigate their sinter-crystallization behaviour (tailoring suitable sinteringtreatments) and electrochemical performances. The most promising electrolyte compositions will be selected to beprinted in free-form robust self-standing structures in order to obtain 3D batteries with high active area (allowing highspecific energy and power per unit volume).3D-PRESS represents a cutting edge multidisciplinary approach for the development of reliable and customizableall-solid state 3D LIBs, especially interesting for micro-power applications such as the ones for Internet of Things(IoT). The project will provide a new family of printable materials increasing the short list of available compositions, especially solid electrolytes, opening the door to the development of a new generation of fully printable all-solid state3D LIBs.A high impact on the future career of the candidate is expected by complementing his current background with newskills in one of the more relevant Key Enabling Technologies (KETs), 3D-printing, applied to the crucial field of theEnergy Storage. Moreover, the host institute will offer unique opportunities to re-enforce the technology transfercompetences of the candidate by carrying out an industrial secondment and by the involvement in the KIC Innoenergycommunity.
Funding: H2020
Project ID: 841937
Type: Competitive EU, Coordinator
Partners: Fundacio Institut de Recerca en Energia de Catalunya (IREC)
Date: 3/1/2020-2/28/2022
Group: Nanoionic and Fuel Cells
P.I: Albert Tarancón Rubio
URL: https://cordis.europa.eu/project/id/841937/es,NO

Title: Tecnologies de Làser i altra Llum
Acronym: LIGHT3D
Description: The final objective of Base3D is to accompany additive manufacturing technologies during a technological maturation process and to press as much as possible to achieve its tangible implantation in the industry, the operating theaters, companies and the Catalan classrooms. To achieve this goal, the different subprojects that are part of Base3D will be developed. This base will be generated through research and development in materials, simulation, design and development of prototypes, and testing and evaluation in laboratory and industrial environments.
First, Project1, Light3D and laser technologies and other light will develop systems for the formation of material for stimulation through the application of energy from radiated emission of light. This will be applicable to plastic and / or metal materials.
Secondly, Project2, Fus3D, which will consist of generating and improving parts forming systems for the deposition of hot materials in a semi-cast or pasty (plastic, metal or hybrid) to acquire pieces with new mechanical properties and / or Making it viable is processed through more efficient and sustainable methods. The fields of application are Bio-Health and Pharmaceutical, Food, Construction, Energy and Traditional.

The third project will be the Ink3D that will consist of the development of materials, the design of machinery and the simulation of processes that allow to respond in the short, medium and long term to the great technological challenges of the printing by deposition of continuous inks at room temperature.
Finally, the fourth project will be the Hybri3D which will consist of the development, optimization and integration of different manufacturing technologies in order to obtain a multimaterial hybrid manufacturing process.
Funding: Emergents
Project ID: IU16-011596
Type: Competitive Nationals
Partners: Centre d'innovació i tecnologia especialitzat en Tecnologies Avançades de la Producció i Fabricació Additiva/Impressió 3D.(CIM-UPC), Innovació en Materials i Enginyeria Molecular (IMEM), Institute of Chemical Research of Catalonia (ICIQ), Institut de Bioenginyeria de Catalunya (IBEC), Fundació EURECAT (EURECAT), Fundacio LEITAT (LEITAT), Fundacio Institut de Recerca en Energia de Catalunya (IREC), Centre d'innovació tecnològica de la UPC (CD6), Plàstics i Compòsits Ecològics (e-PLASCOM UPC), Centro Internacional de Métodos Numéricos en Ingeniería (CIMNE), Fundació Sant Joan de Déu (FSJD), Hospital Sant Joan de Déu (HSJD), Grupo de investigación en ingeniería de materiales (GEMAT), Grup de Recerca en Enginyeria de Producte, Procés i Producció (GREP), Centro de Diseño y Optimización de Procesos y Materiales (DIOPMA UB)
Grup de Recerca de Biomaterials, Biomecànica i Enginyeria de Teixits (BBT) UPC, Centro de Diseño de Aleaciones Ligeras y Tratamientos de Superficie (CDAL) UPC, Centre de Prototips i Solucions Hardware-Software (CEPHIS UAB), Centro de Integridad Estructural, Fiabilidad y Micromecànica de los Materiales (CIEFMA UPC), Centre Tecnològic de Transferència de Calor (CTTC) , UPC, IMEM UPC, NEMEN UPC, POLTEPO UPC, REMM UPC, TECNOFAB UPC, PROCOMAME.
Date: 1/1/2019-12/31/2021
Group: Nanoionic and Fuel Cells
P.I: Marc Torrell Faro.

Title: Infraestructures del Carrer Connectat
Acronym: FEM IoT P1
Description: Analitzant l'estat de l'art actual de les Ciutats Intel·ligents s'observa una notable fragmentació de les solucions existents en quant a infraestructura, ja que la majoria de proveïdors de serveis acaben desplegant nous equips i recursos (sensors, xarxa, gestió i emmagatzematge de dades) de manera aïllada i independent de la resta. S'han portat a terme algunes iniciatives, tals com City-OS o FIWARE, per trencar aquesta estructura basada en sitges ('Smart City silos') a nivell de plataforma de dades, però no existeix una solució consolidada per a integrar tota la infraestructura necessària en la ciutat del futur. Sumat a això, les futures infraestructures plantegen alguns reptes. Per una banda, s'hauran d'incorporar una gran quantitat de noves antenes i equips de la futura xarxa 5G que proporcionarà comunicacions d'ultra alta velocitat (eMBB), ultra fiables (URLLC) i tecnologies per a la comunicació massiva de dispositius (mMTC). Per altra banda, s'haurà de veure com el model de la infraestructura dona cabuda als requeriments de mobilitat i latència de nous casos d'ús de IoT relacionats amb els vehicles connectats i, més

endavant, amb els cotxes autònoms i drones. Així, el projecte té l'objectiu de contribuir a la definició, implementació i desenvolupament de les infraestructures de carrer a la ciutat intel·ligent del futur. Per tal de dissenyar una arquitectura global que pugui donar resposta a totes les necessitats de connectivitat i serveis d'un entorn urbà, la originalitat del projecte es centrarà en tres elements tecnològics: Una infraestructura ICT integrada, multi-tecnologia i flexible, que suporti el desplegament dinàmic de diferents serveis de ciutat intel·ligent de manera àgil i eficient. Les tecnologies IoT de baix consum, que son la base per connectar els milions de dispositius sensors que es desplegaran a les ciutats, i generaran les dades que permetran extreure decisions intel·ligents. Les comunicacions vehiculars, que son imprescindibles per tal d'integrar en la ciutat del futur un element tant disruptiu com és el futur cotxe autònom i connectat. Aquest projecte és singular en la mesura que posa de relleu diverses iniciatives de la ciutat de Barcelona com a capital del mòbil, l'existència d'interessos reals en la indústria de la mobilitat (Seat) i el consorci 5GBarcelona.
Funding: Emergents
Project ID: IU16-011655
Type: Competitive Nationals
Partners: Fundació Internet i Innovació Digital a Catalunya (i2CAT), Centre Tecnològic de Telecomunicacions de Catalunya (CTTC), Universitat Politècnica de Catalunya (UPC), Universitat Oberta de Catalunya (UOC), Universitat Rovira i Virgili (URV), Centre de Visió per Computador (CVC), Universitat Pompeu Fabra (UPF), Centre Tecnològic de Catalunya (Eurecat), condicionamiento Tarrassense (Leitat), Fundacio Institut de Recerca en Energia de Catalunya (IREC)
Date: 5/2/2019-4/30/2022
Group: Nanoionic and Fuel Cells
P.I: Alex Morata García.

PUBLICATIONS

Journals and articles, Peer review System

Chiabrera F., Garbayo I., López-Conesa L., Martín G., Ruiz-Caridad A., Walls M., Ruiz-González L., Kordatos A., Núñez M., Morata A., Estradé S., Chroneos A., Peiró F., Tarancón A.**"Engineering Transport in Manganites by Tuning Local Nonstoichiometry in Grain Boundaries"**, 2019, Advanced Materials,31,4,1805360,4,10.1002/adma.201805360, Article, Open Access. IF:25.809.

Tarancón A., Pryds N.**"Functional Oxide Thin Films for Advanced Energy and Information Technology", 2019, Advanced** Materials Interfaces, 6,15,1900990,10.1002/admi.201900990, Editorial, Open Access. IF:4.713.

Acosta M., Baiutti F., Tarancón A., MacManus-Driscoll J.L.**"Nanostructured Materials and Interfaces for Advanced Ionic Electronic Conducting Oxides", 2019, Advanced** Materials Interfaces, 6,15,1900462,2,10.1002/admi.201900462, Review. IF:4.713.

Chiabrera F., Garbayo I., Pla D., Burriel M., Wilhelm F., Rogalev A., Núñez M., Morata A., Tarancón A.**"Unraveling bulk and grain boundary electrical properties in La 0.8 Sr 0.2 Mn 1-y O 3± ? thin films", 2019,** APL Materials, 7,1,13205,10.1063/1.5054576, Article, Open Access. IF:4.296.

Anelli S., Baiutti F., Hornés A., Bernadet L., Torrell M., Tarancón A.**"Improved mesostructured oxygen electrodes for highly performing solid oxide cells for co-electrolysis of steam and carbon dioxide", 2019,** Journal of Materials Chemistry A, 7,48,27458,27468,10.1039/c9ta07373f, Article. IF:10.733.

Garbayo I., Chiabrera F., Alayo N., Santiso J., Morata A., Tarancón A.**"Thin film oxide-ion conducting electrolyte for near room temperature applications", 2019,** Journal of Materials Chemistry A, 7,45,25772,25778,10.1039/c9ta07632h, Article, Open Access. IF:10.733.

Donmez Noyan I., Dolcet M., Salleras M., Stranz A., Calaza C., Gadea G., Pacios M., Morata A., Tarancon A., Fonseca L.**"All-silicon thermoelectric micro/nanogenerator including a heat exchanger for harvesting applications", 2019,** Journal of Power Sources, 413,125,133,2, 10.1016/j.jpowsour.2018.12.029, Article, Open Access. IF:7.467.

Garbayo I., Baiutti F., Morata A., Tarancón A.**"Engineering mass transport properties in oxide ionic and mixed ionic-electronic thin film ceramic conductors for energy applications", 2019,** Journal of the European Ceramic Society, 39,43892,101,114,5, 10.1016/j.jeurceramsoc.2018.09.004, Article, Open Access. IF:4.029.

Masciandaro S., Torrell M., Leone P., Tarancón A.**"Three-dimensional printed yttria-stabilized zirconia self-supported electrolytes for solid oxide fuel cell applications"**, 2019, Journal of the European Ceramic Society, 39,1,9,16,8, 10.1016/j.jeurceramsoc.2017.11.033, Article. IF:4.029.

Shi Y., Fluri A., Garbayo I., Schwiedrzik J.J., Michler J., Pergolesi D., Lippert T., Rupp J.L.M.**"Zigzag or spiral-shaped nanostructures improve mechanical stability in yttria-stabilized zirconia membranes for micro-energy conversion devices"**, 2019, Nano Energy, 59,674,682,1, 10.1016/j.nanoen.2019.03.017, Article. IF:15.548.

Domnez Noyan I., Gadea G., Salleras M., Pacios M., Calaza C., Stranz A., Dolcet M., Morata A., Tarancon A., Fonseca L.**"SiGe nanowire arrays based thermoelectric microgenerator"**, 2019, Nano Energy, 57,492,499,6, 10.1016/j.nanoen.2018.12.050, Article, Open Access. IF:15.548.

Tarancón A.,**"Powering the IoT revolution with heat"**, 2019, Nature Electronics,2,7,270,271,1,10.1038/s41928-019-0276-4, Article.

Burriel M., Dittmann R., Tarancón A., Mebane D.S.**"Special issue for the 2018 E-MRS Spring Meeting Symposium R on solid state ionics"**, 2019, Solid State Ionics, 334,87, 10.1016/j.ssi.2019.01.040, Editorial. IF:2.886.

DOCTORAL THESES

Presented Theses:

PhD student: Valerie Siller
PhD supervisor: Dr. Albert Tarancon, Dr. Alex Morata
Title: Thin film all-solid-state lithium ion batteries

PhD student: Yunqing Tang
PhD supervisor: Francesco Maria Chiabrera, Alex Morata, Albert Tarancón
Title: Mixed ionic and electronic conduction in nanostructured materials for energy applications

PhD student: Simone Anelli
PhD supervisor: Albert Tarancón Rubio, Marc Torrell Faro, Federico Baiutti
Title: Advanced concepts for Solid Oxide Electroylzer Cells

PhD student: Arianna Pesce
PhD supervisor: Alex Morata, Albert Tarancón
Title: 3d printing of ceramic based energy conversion devices

Ongoing theses:

PhD graduate: Francesco Chiabrera
PhD supervisor: A. Tarancón, I. Garbayo
Title: Interface Engineering in Mixed Ionic Electronic Conductor Thin Films for Solid State Devices
Presented date: 28/6/2019

6.1.4. SOLAR ENERGY MATERIALS AND SYSTEMS

The Team

(permanent and temporary positions, tenure tracks and fellowships)

Prof. Dr. Alejandro Pérez-Rodríguez, Group Leader of Solar Materials and Systems
Dr. Edgardo Saucedo, Researcher, Deputy Group Leader of Solar Materials and Systems
Dr. Víctor Izquierdo-Roca, Staff Scientist
Dr. Marcel Placidi, Staff Scientist
Dr. Yudania Sánchez, Laboratory Support
Dr. Maxim Guc, Postdoctoral Researcher
Dr. Sergio Giraldo, Staff Scientist
Dr. Zacharie Jehl Li Kao, Postdoctoral Researcher
Dr. Kunal Jogendra Tiwari, Postdoctoral Researcher
Dr. Ignacio Becerril, Postdoctoral Researcher
Dr. Josep Oriol Blazquez Gomez, Postdoctoral Researcher
Jacob Andrade-Arvizu, Predoctoral Student
Pedro Vidal, Predoctoral Student
Mohamed Salem, Predoctoral Student
Alex López-García, Predoctoral Student
Robert Fonoll-Rubio, Predoctoral Student
Enric Grau, Predoctoral Student
Fabien Atlan, Predoctoral Student

Solar Materials and Systems group aims to design new materials and processes for advanced thin-film photovoltaic (PV) technologies. We investigate and develop novel solutions for industrial mass-production that are more affordable, efficient and sustainable.

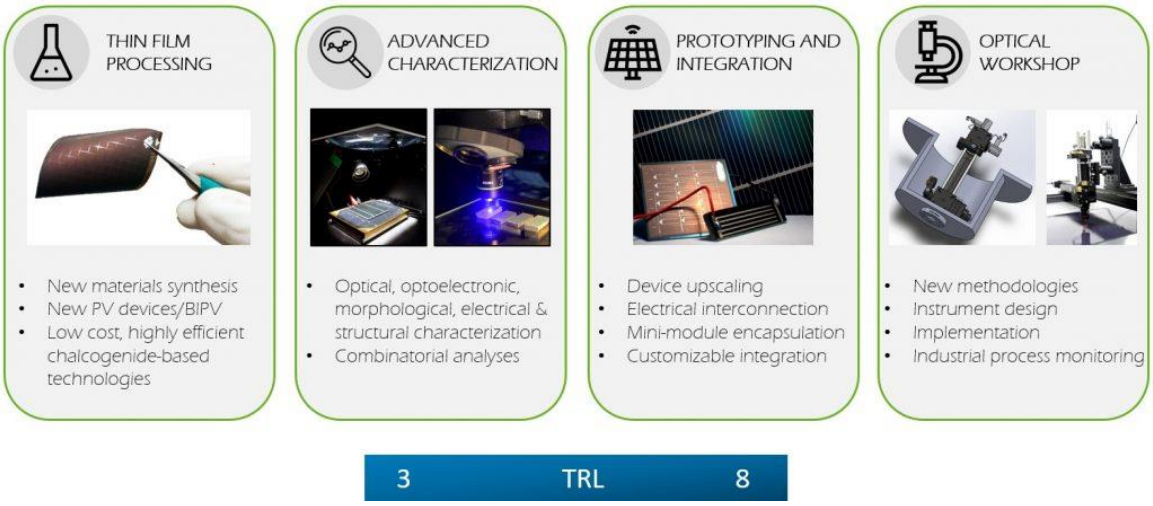
One of our major outcomes has been the development of new earth abundant PV baseline technologies scalable up to 10×10 cm2 substrates with efficiency values that are among the highest achieved in the world avoiding the use of scarce critical elements or toxic compounds.

Our research is about pushing innovative emerging technologies based on inorganic chalcogenide compounds to industry, with a focus on kesterites, chalcopyrites and low dimensional compounds. Our aim is to exploit the flexibility of these technologies for next generation PV integrated components and systems, to enable their use in all scenarios of human activity.

Our state-of-the-art laboratory is a global point of reference in the field and one of the few facilities in Spain that enables both the production and advanced characterisation of solar cell prototypes.

We work closely both with pioneer research groups from institutions across Europe and multinational companies in advanced characterization methodologies for quality control and process monitoring applications.

The Solar Materials and Systems group designs new materials and processes for advanced thin film photovoltaic technologies, developing new solutions for industrial mass-production that include thin film processing, solar cell prototypes, advanced characterization and industrial process monitoring.

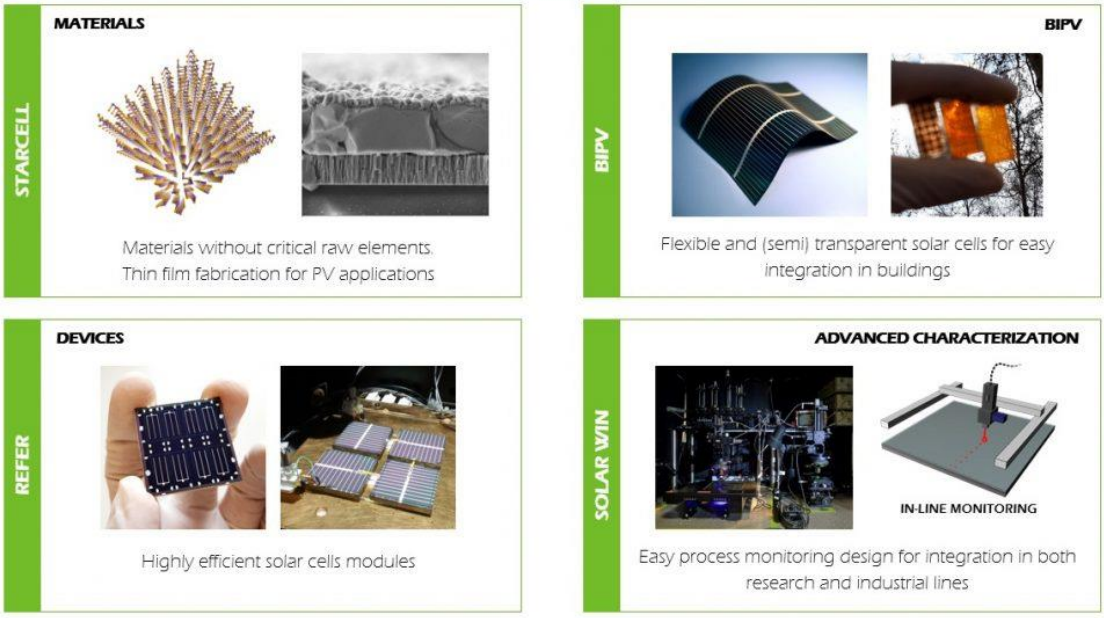


CAPABILITIES

- *Synthesis:* DC, DC pulse & RF sputtering, thermal & e-beam evaporator, ALD, chemical bath deposition, electrochemical workshop, spray pyrolysis, spin coating, screen printing, advanced chemical workshops, substrate washing machine, UV ozone cleaner, reactive CTP & RTP furnaces, mechanical scribing, ball-milling, electrical & module prototyping workshop.

- *Characterization:* solar simulator, EQE/IQE, XRF, 4-point probe, XRD, multi-wavelength Raman, industrial integrable & portable Raman, PL, EL, AFM, UV-Vis-IR, confocal-interferometric microscope, impedance system, helium cryostat, optical workshop, 3D prototyping platform, XY platform for optical characterization, industrial process monitoring workshop.

HIGHLIGHTS



PROJECTS

Title: SEMS SGR 2017-2019
Acronym: SEMS SGR 2017-2019
Description: SEMS group research activities are centred in the development and advanced characterisation of thin film chalcogenide devices and processes for next generation cost-efficient sustainable photovoltaic technologies, including chalcopyrite technologies (based on Cu(In,Ga)(S,Se)2 (CIGS) compounds) that have already started their transition to industrial production, as well as emerging technologies based on kesterites (Cu2ZnS(S,Se)4 (CZTS) compounds) that avoid the use of critical raw materials and highly toxic compounds. In these technologies, the group has developed an intense activity in the development of methodologies based on Raman Spectroscopy for advanced characterization of devices and their extension to Quality Control and Process Monitoring applications, being one of the reference groups at world level in this field. At technological level, the SEMS group is one of the pioneers in Europe in the development of kesterite technologies, having obtained a photovoltaic conversion efficiency of 11.8% which is among the best values reported at

world level using processes free of hazardous or explosive compounds (as hydrazine). The SEMS group has also been a pioneering group in the extension of these technologies to alternative substrates with relevant added value for building and product integration applications, as ceramic architectural substrates and poliyimide/steel foils for light weight and flexible modules.
Funding: SGR
Project ID: 2017 SGR 862
Type: Competitive Nationals
Partner: Fundacio Institut de Recerca en Energia de Catalunya (IREC), Universidad De Barcelona (UB), Universidad Autonoma de Madrid (UAM), Universitat Jaume I (UJI)
Date: 1/1/2018-12/31/2020
Group: Solar Energy Materials and Systems
P.I: Alejandro Pérez-Rodríguez.

Title: Advanced strategies for substitution of critical raw materials in photovoltaics, Starcell
Acronym: STARCELL
Description: proposes the substitution of CRM's in thin film PV by the development and demonstration of a cost effective solution based on kesterite CZTS (Cu2ZnSn(S,Se)4) materials. Kesterites are only formed by elements abundant in the earth crust with low toxicity offering a secure supply chain and minimizing recycling costs and risks, and are compatible with massive sustainable deployment of electricity production at TeraWatt levels. Optimisation of the kesterite bulk properties together with redesign and optimization of the device interfaces and the cell architecture will be developed for the achievement of a challenging increase in the device efficiency up to 18% at cell level and targeting 16% efficiency at mini-module level, in line with the efficiency targets established at the SET Plan for 2020. These efficiencies will allow initiating the transfer of kesterite based processes to pre-industrial stages.
These innovations will give to STARCELL the opportunity to demonstrate CRM free thin film PV devices with manufacturing costs 0.30 €/Wp, making first detailed studies on the stability and durability of the kesterite devices under accelerated test analysis conditions and developing suitable recycling processes for efficient re-use of material waste. The project will join for the first time the 3 leading research teams that have achieved the highest efficiencies for kesterite in Europe (EMPA, IMRA and IREC) together with the group of the world record holder David Mitzi (Duke University) and NREL (a reference research centre in renewable energies worldwide) in USA, and AIST (the most renewed Japanese research centre in Energy and Environment) in Japan. These groups have during the last years specialised in different aspects of the solar cell optimisation and build the forefront of kesterite research. The synergies of their joined efforts will allow raising the efficiency of kesterite solar cells and mini-modules to values never attained for this echnology
Funding: H2020
Project ID: 720907
Type: Competitive EU, Coordinator
Partners: Fundacio Institut de Recerca en Energia de Catalunya (IREC),Commissariat a l'Energie Atomique et aux Energies Alternatives (CEA), Eidgenossische Materialprufungs- und ForschungsanstalT (EMPA), Uppsala Universitet (UU), Imperial College Of Science

Technology And Medicine (ICL), Helmholtz-Zentrum Berlin fur Materialien und Energie GMBH (HZB), Martin-Luther-Universitaet Halle-Wittenberg (MLU), Imra Europe SAS (IMRA), Midsummer AB (MIDS), Weee International Recycling SL (WIREC), ACT Sistemas SL (AYESA), National Institute of Advanced Industrial Science and Technology (AIST), Duke University (UDUKE)
Date: 1/1/2017- 12/31/2019
Group: Solar Energy Materials and Systems
P.I: Edgardo Ademar Saucedo Silva
URL:
http://www.starcell.eu/,https://drive.google.com/open?id=1F9YaugA490FITgtWfb1gKAgYfuxsMrBR

Title: Wide band gap Chalcogenide Technologies for cost efficient solar energy applications
Acronym: Wincost
Description: WINCOST proposes a breakthrough in the development of high efficiency and low cost energy systems based on wide band gap chalcogenide technologies. The project includes both electricity generation via advanced photovoltaic devices and the development of new concepts for energy storage, considering the implementation of specific solutions that meet the different needs in these applications, based on the use of semiconductors with different band gaps (Eg):
1.- Eg =1.4-1.5 eV, for the development of high efficiency photovoltaic devices with Voc >0.9 V and low current, in order to reduce potential
efficiency losses related to window layer. This will allow resolving one of the current problems for the up-scaling of these technologies at
module level, minimizing the effects related to the window layer inhomogeneities which are one of the main origins of the efficiency loss in
the industrial photovoltaic modules;
2.- Eg = 1.6-1.8 eV, for the development of cells suitable for their integration as top cell in tandem structures of very high efficiency (>
25%), and for the development of high efficiency photoelectrochemical devices for solar energy storage. The optimization of these devices
that involve the integration of both the solar energy conversion and the storage in the same system, requires for devices configurations
compatible with working voltages V > 1.3 V;
3.- Eg = 2.0-2.5 eV for the development of new semitransparent photovoltaic devices suitable for building integration (BIPV), with the aim
to answer to the increasing demand in this sector for semitransparent devices with higher efficiencies and different colors with the
requirements of both high aesthetic quality and high uniformity together with high stability and good durability.
The project involves the development of solutions based on the use of Cu(In,Ga)(S,Se)2 chalcopyrites that are compatible with processes already established at an industrial production level, and includes also the development of solutions based on emergent technologies with kesterites based Cu2ZnSn(S,Se)4 compounds and related alloys. Kesterites have potential interest as future replacement of chalcopyrites, being more

compatible with a sustainable upscaling of the production to industrial mass production levels, avoiding the use of critical raw
materials (Ga, In). In all the cases, the viability of different technological strategies for the development of competitive solutions compatible with their implementation at industrial level will be evaluated.
WINCOST is based in the strong experience and background of the groups participating in the proposal in these technologies. This has been acquired within the development of different research projects that included both national and European relevant projects on these topics. Most of the European projects where coordinated by the groups participating in this proposal (SCALENANO, KESTCELLS, PVICOKEST, INDUCIS). These projects involve the main world leading groups and reference centers in these technologies, and have allowed the groups involved in WINCOST to achieve a deep knowledge on the fundamental properties of these materials and on the development of processes for high efficiency devices fabrication, positioning the WINCOST groups among the reference ones in these technologies in Europe.
Funding: Retos Investigació
Project ID: ENE2016-80788-C5-1-R
Type: Competitive Nationals, Coordinator
Partners: Fundacio Institut de Recerca en Energia de Catalunya (IREC), Universidad de Barcelona (UB), Universidad Autonoma de Madrid (UAM), Universitat Jaume I (UJI)
Date: 12/30/2016-12/31/2020
Group: Solar Energy Materials and Systems
P.I: Alejandro Pérez-Rodríguez.

Title: International cooperation for the development of cost-efficient kesterite/c-Si thin film next
Acronym: Infinite-Cell
Description: Photovoltaic (PV) is recognized as one of the main renewable energy solutions for fulfilling the targets defined bythe EU Energy Roadmap 2050 and the SET Plan. Most of the current commercial PV devices are formed by singlejunctions, and more complex device concepts allowing a significant increase in device efficiency (well beyond thetheoretical limit in the 30%-33% range) are still mostly limited to expensive III-V technologies. INFINITE-CELL proposes extending the very high efficiency tandem device concepts to emerging thin film PVtechnologies with high potential for reduction of costs and avoiding the use of critical raw materials. Within thiscontext, the aim is to establish and consolidate an International and Intersectoral Cooperation between 6 EC/ACAcademic Institutions (IREC, SINTEF, CNRS, UAM, IAP-ASM, HZB), 2 European Companies (SUNGA, MET), and 4 non EC/AC Academic Institutions (MASCIR, BSUIR, UM5, UWC), for the development of cost-efficientphotovoltaic tandem devices based in the combination of wide band-gap kesterite absorbers (Cu2Zn(Si,Ge,Sn)(S,Se)4)as top cell, and low cost c-Si thin film as bottom cell. Thanks to the combination of the know-how generated inprevious and successful FP7 projects (PVICOKEST (269167) and EUROSUNMED (608593)), INFINITE-CELLtargets to develop stacked and monolithically integrated kesterite/c-Si thin film devices with efficiencies of 15% and20% respectively, using only fully sustainable materials and processes.This will be possible through de definition of a very impacting Research Plan

and a very ambitious Plan ofSecondments, where 293 PMs will be exchanged among the partners. The seconded researchers will be immersed inan International and Intersectoral environment for the development and improvement of their networking, scientific,writing, effective communication, and time management skills, warranting the consolidation of a high level scientificcommunity in Advanced Tandem Solar Cell.
Funding: H2020
Project ID: 777968
Type: Competitive EU, Coordinator
Partners: Fundacio Institut de Recerca en Energia de Catalunya (IREC), Stiftelsen Sintef (SINTEF), Centre National de la Recherches Cientifique CNRS (CNRS), Universidad Autonoma de Madrid (UAM), Institute of Applied Physics of the Academy of Sciences of Moldova (IAP ASM), Helmholtz-Zentrum Berlin fur materialien und Energie GMBH (HZB), Societatea cu Raspundere Limitata Sunga S.R.L. (SunGa), UAB Modernios E-Technologijos (MET)
Date: 11/1/2017-10/31/2021
Group: Solar Energy Materials and Systems
P.I: Edgardo Ademar Saucedo Silva
URL: http://www.infinite-cell.eu/,https://drive.google.com/open?id=1X1RapvSKTtL7l0fSCvbTvl0sawrvwV9G

Title: Soluciones avanzadas de encapsulado de muy alta estabilidad para tecnologias
Acronym: Duracis
Description: Flexible photovoltaics based in thin film Cu(In,Ga)Se2 (CIGS) technologies can largely contribute to the fast penetration of solar energy production inresidential and low weight infrastructures applications. These flexible devices can reduce the weight of a conventional glass-glass solar panel in almostone order of magnitude, representing a clear advantage for their application in building integrated concepts. Nevertheless, for a cost-competitive fullmarket entry, flexible CIGS photovoltaic (PV) technologies require the availability of innovative encapsulation solutions with both, very low costs andexcellent barrier properties guaranteeing a long operating time of the devices, while keeping the lightweight characteristics. Even if there are alreadyexisting solutions with acceptable performance levels, costs remain a relevant issue that needs to be solved in order to keep the stringent cost reductiontargets established for these technologies. To solve these problems, DURACIS will explore new alternative encapsulation and optical glue materials andconcepts, compatible with their implementation into already existing industrial CIGS pilot lines and allowing a significant extension of the lifetime whilesubstantially reducing costs. To achieve this goal, transfer of concepts previously developed for organic technologies (with very stringent encapsulationrequirements) will be investigated. In particular, three innovative approaches will be fully developed and tested, including: i. Liquid encapsulant basedstrategies that have been previously developed and applied in OLED technologies; ii. Self-stratifying polymers concepts that have been developed forencapsulation of organic PV (OPV) devices; and iii. Alternative front sheet and Polyolefin embedding encapsulant concepts. The final goal of DURACIS is the development of a novel encapsulation technology with costs below 15 Euros/m2 and ensuring a durability higher than25 years for flexible CIGS devices. The project will adopt a global strategy including

solutions for the main industrial substrate technologies that havebeen developed for flexible CIGS (polyimide, steel substrates) and will also include the analysis of their transfer into industrial pilot lines available in theconsortium. The implications of the different kinds of substrates on these new encapsulation concepts will be specifically addressed aiming at thedevelopment of optimized cost efficient solutions compatible with very long term stability.The project will also include the development of advanced methodologies for the non-destructive monitoring of the encapsulation processes and layers.In particular, IREC will work in the development of optical methodologies (Raman scattering, photoluminescence, reflection based methodologies), toassess and provide fast and reliable tools for control and monitoring of the degradation of the different encapsulant solutions proposed in DURACIS. Thisinvolves both monitoring of the deposition processes as well as the definition of fast methodologies for detection of potential degradation effects affectingthe encapsulation and device lifetime.
Funding: APCIN
Project ID: PCIN-2017-041
Type: Competitive Nationals
Partners: Fundacio Institut de Recerca en Energia de Catalunya (IREC)
Date: 9/1/2017-8/31/2020
Group: Solar Energy Materials and Systems
P.I: Alejandro Pérez-Rodríguez.

Title: Soluciones innovadoras de bajo coste y alta eficiencia para la produccion de bipv semitransparente
Acronym: MASTER PV
Description: MasterPV proposes the development and demonstration of low cost innovative processes for cost efficient semi-transparent Cu(In,Ga)(S,Se)2 (CIGS)BIPV solutions. The project involves the replacement of the Mo back contact in the traditional CIGS device architecture by chemical vacuum-free basedTCO (Transparent Conductive Oxide) electrodes. This will allow achieving a significant improvement in the aesthetic quality of the semi-transparentdevices, with the elimination of the back mirror effect that is determined by the remaining Mo regions in the semi-transparent modules. Improvement of the aesthetic quality of CIGS ST devices is strongly relevant to ensure a higher level of acceptance of these solutions in the BIPVmarket. The proposed solutions will contribute to a more efficient exploitation of the potential of CIGS technologies for lowering of manufacturing costs,with the replacement of the vacuum-based Mo sputtering deposition processes by lower cost approaches that are based in low CAPEX vacuum-freechemical strategies.The main scientific challenge of the project is related to the development of optimal transparent contacts allowing for device efficiencies comparable tothe high efficiency values that have already been achieved with standard Mo based back contacts. This will imply a special effort in the optimization ofTCO based contacts suitable for high efficiency devices, which will be based in the development of surface contact configurations including nanometrictransition metal oxides (TMO) that have already been demonstrated as efficient hole transport layers in organic based technologies and are verypromising for optimization of the valence band alignment at the back contact/CIGS interface. The main technological challenge is related to theimplementation of low cost

vacuum-free processes for the growth of the optimal transparent back contact configurations and to the adaptation of theseprocesses for the fabrication of efficient semi-transparent CIGS modules. At commercial level, the improvement of the aesthetic quality of the STmodules and the decrease of their cost will contribute to the consolidation of CIGS as one of the main commercial technologies able to answer to theincreasing demand of cost-efficient and reliable semi-transparent products in the BIPV market. The project will contribute in a relevant way to theenhancement of the innovation capacity and integration of new knowledge in the European PV industry, with the development of innovative processesthat are also relevant for other advanced PV applications as bifacial solar cells and very high efficiency thin film tandem devices
Funding: APCIN
Project ID: PCI2018-092945
Type: Competitive Nationals
Partners: Fundacio Institut de Recerca en Energia de Catalunya (IREC)
Date: 9/1/2018-7/31/2021
Group: Solar Energy Materials and Systems
P.I: Víctor Izquierdo Roca.

Title: Dispositivos hibridos de silicio/calcogenuro de capa delgada para tecnologias fotovoltaicos sostenibles de bajo coste y muy alta eficiencia
Acronym: IGNITE
Description: IGNITE will explore a new concept in the development of high efficiency tandem photovoltaic technologies, based in the combination of c-Si and thin film technologies using earth abundant materials with excelent stability, low toxicity and proved sustainability. This will bepossible by combining for the first time, c-Si technology with interdigitated back contacts (IBC c-Si) prepared at low temperature (< 250 ºC)as bottom cell in a tandem configuration, and wide band-gap kesterite absorbers deposited onto semi-transparent substrates as top solarcell. The project proposes to introduce a fully new tandem concept, taking advantage of the intrinsic characteristics of the devices basedon IBC c-Si with the low cost potential of thin film technologies, allowing for the integration of the kesterite device in a monolithicconfiguration, and with the possiblitiy to fully and independently optimize the different electrical contacts. In the last years, the fastimprovement of new photovoltaic materials such as perovskites and kesterites, has open the posibility to develop for the first time highefficiency tandem solar cells using exclusivelly cost-efficient and earth abundant materials, by combining them with already stablished c-Sitechnologies. Nevertheless, the toxicity and stability issues related to perovskites, and the necesity of relatively high temperatureprocesses in kesterites for obtaining good efficiencies, has limited in a large extent this development. In this sense, and thanks to the fast improvements on the IBC c-Si technoloy, IGNITE will explore for the first time the possibility tointegrate these devices, with wide band-gap sustainable solar cells besed on kesterites. The most relevant idea behind IGNITE issupported by the fact that in the interdigitated technology, the electrical contacts of c-Si are placed in the same side of the waffer, makingpossible the compatibility with the independent development and optimization of the kesterite device in the other side of the wafer. This willallow to have monolithically integrated tandem devices, in 4 terminal connection configuration, in

which for the first time each of the 4electrical contacts can be independently optimized. This will suppose a clear technological advantage, reducing production costs, andallowing for the independent optimization of the fabrication processes for the two different devices.For solving the proposed challenges, IGNITE is formed by a multidisciplinary and complementary consortium, joining leading groups atSpanish and European level in the development of c-Si technologies (UPC), in thin film photovoltaic chalcogenides (IREC), and inchemical routes for synthesis of functionalized oxides (UJI), positioning these technologies towards a possiblie future industrialization. Atthe end of the project, IGNITE will demonstrate c-Si photovoltaic devices with interdigitated contacts fabricated at low temperature withefficiencies higher than 20%, wide-band gap and semi-transparent kesterite devices with efficiencies exceeding 14%, and combining both,a monolithic integrated tandem device with conversion efficiency > 25%, allowing to push the efficiency in IBC c-Si devices to valuescomparable with the current Si world record efficiency by the implementation of low cost thin film processes.
Funding: Retos Investigació
Project ID: ENE2017-87671-C3-1-R
Type: Competitive Nationals, Coordinator
Partners: Fundació Institut de Recerca en Energia de Catalunya (IREC), Universitat Politècnica de Catalunya (UPC), Universidad Jaume I de Castelló
Date: 1/1/2018-12/31/2020
Group: Solar Energy Materials and Systems
P.I: Edgardo Ademar Saucedo Silva.

Title: Semi-transparent back contacts for solar cells
Acronym: Semi-transparent back contacts for solar cells
Description: It was proposed to use the high aspect ratio of electrodeposited Zinc Oxide (ZnO) nanowires as a super hydrophobe surface for self-cleaning glass application. In collaboration with the leading glass French company Saint-Gobain, electrodeposited films with various nanowire geometries were developed. These films were coated with stearic acid to lower surface energy, and characterized by sessile drop wettability. It was found that the density of the nanowires was a critical aspect for optimization, while their verticality had very little influence on the surface wettability; however, verticality was still needed to obtain specular films in terms of optical transmission. By using a ZnO seed layer, electrodeposited at lower temperature and with a difference Zn concentration, it was possible to significantly increase the nanowires' density hence leading to an improvement of the super hydrophobicity of the films. Water drop contact angles showed a near perfect super hydrophobicity, and values above 175° were obtained in the course of this project.
Funding: Accio
Project ID: TECSPR17-1-0052
Type: Competitive Nationals
Partners: Fundació Institut de Recerca en Energia de Catalunya (IREC), Universidad de Barcelona (UB), Universidad Autonoma de Madrid (UAM), Universitat Jaume I (UJI)
Date: 8/12/2018-8/11/2020
Group: Solar Energy Materials and Systems

P.I: Zacharie Jehl.

Title: Nuevos procesos industriales sostenibles para la producción de dispositivos fotovoltaicos competitivos integrables en sensores y sistemas autónomos (FOTOSENS)
Acronym: FOTOSENS
Description: El objetivo principal del proyecto FOTOSENS es el desarrollo y demostración de nuevos procesos industriales para la fabricación de dispositivos fotovoltaicos avanzados para la alimentación de sistemas autónomos basados en la implementación de procesos sostenibles y de bajo impacto medio-ambiental que se caracterizan por presentar una elevada flexibilidad tecnológica, una relación coste-eficiencia adecuada y que son compatibles con su escalado para etapas de producción industrial en masa.
El proyecto propone un nuevo concepto basado en la integración de los dispositivos fotovoltaicos en los sistemas autónomos, para lo que se propone el desarrollo y demostración de tecnologías basadas en procesos de impresión y tratamiento térmico con láser que presentan un potencial muy elevado de reducción de costes y que son compatibles con el uso de diferentes tipos de sustratos, y con la realización de forma sencilla de diseños complejos sin la necesidad de integrar etapas costosas adicionales de ataque selectivo y/o grabados.
Funding: Retos Col·laboració
Project ID: RTC-2017-5857-3-P02
Type: Competitive Nationals
Partners: Francisco Albero SA (FAE), Fundació Institut de Recerca en Energia de Catalunya (IREC), Universidad De Zaragoza
Date: 10/1/2018-9/30/2021
Group: Solar Energy Materials and Systems
P.I: Marcel Placidi.

Title: Disruptive sustainable TECHnologies FOR next generation pvWINdows
Acronym: Tech4Win
Description: Tech4win proposes a very innovative transparent photovoltaic (PV) window concept that is based on the adoption of a tandem inspired structure combining an inorganic UV selective multifunctional coating (including UV filtering and UV selective PV functionalities), with an organic IR selective PV device. This will allow fully exploiting the IR efficiency and transparency potential of organic based solutions together with the robustness and stability of inorganic thin film concepts, combining sustainable and industrial compatible technologies with demonstrated potential for cost reduction, and avoiding the use of critical raw materials to ensure sustainable mass deployment. This "tandem inspired structure" will be able to generate on-site renewable energy (PCE 10%, with a long term goal 12%) guaranteeing a high-transparency degree (AVT 60% with a long term goal 70%, and CRI 70) and all by a competitive manufacturing costs. This novelty lies precisely in the capacity to protect the most active PV layer (IR selective organic solar cell) through the filtering of UV radiation, extending the lifetime of the PV hybrid device to 10 years (with a long term goal 25 years). To fulfil these objectives, a very well balanced multi-

sectorial consortium comprising reference Research Centers in the different PV technologies involved in the window concept, together with high-tech European Companies from different sectors including relevant stakeholders involved in the value chain (Organic materials, Industrial Equipment developers, PV module producers and BIPV system manufacturers). This scenario constitutes an excellent business opportunity to satisfy the growing BIPV market to commercialize a unique cost-effective solar window solution, fully feasible as an active product capable to reach a challenging combination of efficiency, transparency and lifetime, with the design of a "Tech4Win" roadmap to place on the market a robust solar window in approximately 10 years.
Funding: H2020
Project ID: 826002
Type: Competitive EU, Coordinator
Partners: Fundació Institut de Recerca en Energia de Catalunya (IREC), Onyx Solar Energy S.L (ONYX), Commissariat a l'Energie Atomique et aux Energies Alternatives (CEA), Interuniversitair Microelectronica Centrum (IMEC), Fundacion Tekniker (IK4-TEKNIKER), Armor SA, Advanced Energy Technologies (AE), Ereunas & Anaptyxis Ylikon, Proiontonananeosimon, Pigon Energeias & Synafon Symvouleftikon Y Piresion ADVEN, Kenosistec S.R.L.
Date: 1/1/2019-6/30/2022
Group: Solar Energy Materials and Systems
P.I: Alejandro Pérez-Rodríguez
Other group: Thermal Energy & Building Performance-Dr. Jaume Salom Tormo
URL:
http://www.tech4win.eu/,https://drive.google.com/open?id=1HWddM4WyNQn1ryzOofACNKyCqCkkdyUq

Title: New in-line process monitoring in advanced PV
Acronym: MONICIS
Description: MONICIS aims to develop and demonstrate (at module level) new optical methodologies for the in-line monitoring of cost-efficient encapsulation processes in CIGS industrial flexible photovoltaic (PV) technologies. The project proposes the design of an optical multifunctional probe based in Raman, PL and trans-reflectance techniques for the non-destructive assessment of innovative cost-efficient encapsulant and barrier layers that are being developed in these technologies, in order to ensure a successful transfer of these highly innovative encapsulation concepts from the cell (lab) level to the module (industrial) level. This implies the need for high sensitivity methodologies for the advanced assessment at in-line monitoring levelof the uniformity of the processes.
Funding: Accio
Project ID: TECSPR18-1-0048
Type: Competitive Nationals
Partners: Fundació Institut de Recerca en Energia de Catalunya (IREC)
Date: 2/1/2019-1/31/2021
Group: Solar Energy Materials and Systems
P.I: Maxim Guc.

Title: Next generation transparent solar windows based on customised integrated photovoltaics
Acronym: SOLAR-WIN
Description: The main goal of Solar-Win is the industrial scale-up, validation under real-world operation conditions (TRL8) and commercialisation of next generation transparent and non-intrusive photovoltaic (PV) windows. The project will result in a unique transparent and electricity-generating window that merges the functionality of a PV module and a window in one, allowing a strong increase in the surface available in the building for generation of PV electricity. Solar-Win will revolutionize the Building Integrated PV (BIPV) and the architectural sectors, by providing a PV window solution featuring a unique set of characteristics, namely: (1) transparent and visually non-intrusive windows (with controlled visible transparency from 40% to 75%) able to generate up to 60 W/m2 of green electricity; (2) full compatibility with existing window manufacturing technologies; (3) lifespan equivalent to standard windows (20 years); and (4) cost effectiveness (cost increase of just 30% with respect to a standard window). To achieve these goals, Solar-Win involves two Technology-based SMEs (PHYSEE and SUNPLUGGED from the Smart Window and PV sectors, respectively) coordinated by a flagship RTD organisation with a strong experience and background in technology transfer and optimisation of advanced PV technologies (IREC) and a leader constrution company (ACCIONA) which is the main costumer segment. The Project concept relies on the solar window patented technology developed by PHYSEE at TRL6, and on the highly flexible PV technology of SUNPLUGGED, which will be further optimised and customised for Solar-Win application. Solar-Win will overcome a major barrier that presently limits a further deployment of BIPV solutions, which relates to its intrusive character. Moreover, Solar-Win will allow achieving a disruptive advance extending drastically the possibilities for integration of PV solutions to virtually any kind of buildings, just by installing and/or replacing building windows.
Funding: H2020
Project ID: 870004
Type: Competitive EU, Coordinator
Partners: Fundació Institut de Recerca en Energia de Catalunya (IREC), Physee Group BV, Sunplugged – Solare Energiesysteme GMBH, ACCIONA Construccion SA,
Date: 10/1/2019-9/30/2021
Group: Solar Energy Materials and Systems
P.I: Víctor Izquierdo Roca
URL:https://www.physee.eu/solarwin,https://drive.google.com/open?id=1Q5Uu2yfCPRNyxZ2ZgnxIQUyEP-Yu0YNt

PUBLICATIONS

Articles and Journals from ISI Database

Pedro Vidal-Fuentes, Maxim Guc, Xavier Alcobe, Tariq Jawhari, Marcel Placidi, Alejandro Pérez-Rodríguez, Edgardo Saucedo, Victor Izquierdo Roca,**"Multiwavelength excitation Raman scattering study of Sb2Se3 compound: fundamental vibrational properties and secondary phases detection",** 2019**,**2D Materials,343,6,4,45054,1,2053-1583/ab4029, Article, Open Access.IF:7

Andrade-Arvizu J., Izquierdo-Roca V., Becerril-Romero I., Vidal-Fuentes P., Fonoll-Rubio R., Sánchez Y., Placidi M., Calvo-Barrio L., Vigil-Galán O., Saucedo E.**"Is It Possible to Develop Complex S-Se Graded Band Gap Profiles in Kesterite-Based Solar Cells?"**,2019, ACS Applied Materials and Interfaces, 456,11,36,32945,32956,10.1021/acsami.9b09813, Article. IF:8.

Lie S., Leow S.W., Bishop D.M., Guc M., Izquierdo-Roca V., Gunawan O., Wong L.H.**"Improving Carrier-Transport Properties of CZTS by Mg Incorporation with Spray Pyrolysis",**2019**,** ACS Applied Materials and Interfaces, 456, 11,2 9, 25824, 25832,10.1021/acsami.9b05244, Article. IF:8.

Hadke S., Levcenko S., Sai Gautam G., Hages C.J., Márquez J.A., Izquierdo-Roca V., Carter E.A., Unold T., Wong L.H.**"Suppressed Deep Traps and Bandgap Fluctuations in Cu2CdSnS4 Solar Cells with ?8% Efficiency",** 2019**,** Advanced Energy Materials, 884, 9, 45, 1902509, 10.1002/aenm.201902509, Article. IF:24.

Giraldo S., Jehl Z., Placidi M., Izquierdo-Roca V., Pérez-Rodríguez A., Saucedo E.**"Progress and Perspectives of Thin Film Kesterite Photovoltaic Technology: A Critical Review",** 2019**,** Advanced Materials,809,31,16,1806692,19,10.1002/adma.201806692, Review, Open Access. IF:25.

Dimitrievska M., Oliva F., Guc M., Giraldo S., Saucedo E., Pérez-Rodríguez A., Izquierdo-Roca V.**"Defect characterisation in Cu2ZnSnSe4 kesterites: Via resonance Raman spectroscopy and the impact on optoelectronic solar cell properties", 2019,** Journal of Materials Chemistry A, 7,21,13293,13304,1,10.1039/c9ta03625c, Article. IF:10.733.

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Yaroslav E. Romanyuk, Stefan G. Haass, Sergio Giraldo, Marcel Placidi, Devendra Tiwari, David J Fermin, Xiaojing Hao, Hao Xin, Thomas Schnabel, Marit Kauk-Kuusik, Paul Pistor, Stener Lie, Lydia H Wong **"Doping and alloying of kesterites",** 2019**,** Journal of Physics Energy,1, 4, 44004,3,10.1088/2515-7655/ab23bc, Article, Open Access.

T. Ratz, G. Brammertz, R. Caballero, M. León, S. Canulescu, J. Schou, L. Gütay, D. Pareek, T. Taskesen, D.-H. Kim, J.-K. Kang, C. Malerba, A. Redinger, E. Saucedo, BShin11, HTampo12, KTimmo13, NDNguyen1 andBVerman **"Physical routes for the synthesis of kesterite",** 2019**,** Journal of Physics Energy,1, 4, 42003,2,10.1088/2515-7655/ab281c, Article, Open Access.

Samantha N. Hood, Aron Walsh, Clas Persson, Konstantina Iordanidou, Dan Huang, Mukesh Kumar, Zacharie Jehl, Maykel Courel, Johan Lauwaert, Sanghyun Lee **"Status of materials and device modelling for kesterite solar cells",** 2019**,** Journal of Physics Energy,1, 4, 42004, 10.1088/2515-7655/ab2dda, Article, Open Access.

Charlotte Platzer-Björkman1, Nicolas Barreau2, Marcus Bär3,4,5,6, Leo Choubrac7, Louis Grenet8,9, Jaeyeong Heo10, Tomas Kubart1, Alberto Mittiga11, Yudania Sanchez12, Jonathan Scragg1, Soumyadeep Sinha10and Matteo Valentin **"Back and front contacts in kesterite solar cells: state-of-the-art and open questions"** ", 2019, Journal of Physics Energy,1, 4, 44005,10.1088/2515-7655/ab3708, Article, Open Access.

Susan Schorr, Galina Gurieva, Maxim Guc, Mirjana Dimitrievska, Alejandro Pérez-Rodríguez, Victor Izquierdo-Roca, Claudia S. Schnohr, Juran Kim, William Jo, José Manuel Merino **"Point defects, compositional fluctuations, and secondary phases in non-stoichiometric kesterites",** 2019**,** Journal of Physics Energy,2,1,12002, 10.1088/2515-7655/ab4a25, Article, Open Access.

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Arnou P., Lomuscio A., Weiss T.P., Siopa D., Giraldo S., Saucedo E., Scarpulla M.A., Dale P.J.**"Continuous-wave laser annealing of metallic layers for CuInSe2 solar cell applications: Effect of preheating treatment on grain growth",** 2019**,** RSC Advances, 10,1,584,594,10.1039/c9ra06896a, Article, Open Access.IF:3.049.

Lee S., Price K.J., Saucedo E., Giraldo S.**"Engineering of effective back-contact barrier of CZTSe: Nanoscale Ge solar cells – MoSe2 defects implication",** 2019**,** Solar Energy, 194, 114,120, 10.1016/j.solener.2019.10.042, Article. IF:4.674.

Sanchez T.G., Regalado-Pérez E., Mathew X., Sanchez M.F., Sanchez Y., Saucedo E., Mathews N.R.**"Ge doped Cu2ZnSnS4: An investigation on absorber recrystallization and opto-electronic properties of solar cell",**2019**,** Solar Energy Materials and Solar Cells, 198,44,52,3, 10.1016/j.solmat.2019.04.011, Article. IF:6.019.

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Grau S., Giraldo S., Saucedo E., Morante J.R., Llobet A., Gimbert-Suriñach C**."Multi-layered photocathodes based on Cu2ZnSnSe4 absorber and MoS2 catalyst for the hydrogen evolution reaction"**, 2019, Journal of Materials Chemistry A, 7, 42, 24320,24327,10.1039/c9ta08818k, Article. IF:10.733.

DOCTORAL THESES

Presented theses:

PhD student: Ignacio Becerril-Romero
PhD supervisor: E.Saucedo, P. Pistor
Title: Alternative substrates for sustainable and Earth-abundant thin film photovoltaics
Presented date: 28/10/2019 – Universitat de Barcelona; IREC

Ongoing theses:

PhD student: Pedro Vidal
PhD supervisor: Dr. Edgardo Saucedo, Dr. Victor Izqueirdo-Roca
Title: Alternative substrates for sustainable and Earth-abundant thin-film solar cells in the context of Building integrated photovoltaics
Starting date: 09/2018

PhD student: Robert Fonoll-Rubio
PhD supervisor: Dr. Marcel Placidi, Dr. Victor Iquierdo-Roca
Title: Advanced characterization of interfaces in thin film absorber materials for photovoltaic applications
Starting date: 10/2018

PhD student: Mohammed Salem
PhD supervisor: Dr. Edgardo Saucedo, Dr. Marcel Placidi
Title: Wide band-gap Cu(In,Ga)(S,Se)2 for innovative thin film photovoltaic applications
Starting date: 02/2018

PhD student: Sergio Ramírez
PhD supervisor: Dr. Edgardo Saucedo, Dr. Fabián Pulgarín
Title: Desarrollo de celdas solares en configuración de estrato y superestrato de nuevas tecnologías de películas delgadas de Sb2Se3 mediante rutas físicas
Starting date: 01/2018

PhD student: Viviana Hernández Calderón
PhD supervisor: Prof. Osvaldo Vigil Galán, Dr. Yudania Sánchez
Title: Desarrollo de capas ventana mediante rutas químicas basadas en las técnicas CBD y SILAR para su aplicación en celdas solares
Starting date: 01/2018

PhD student: Jacob Andrade Arvizu
PhD supervisor: Dr. Edgardo Saucedo, Dr. Osvaldo Vigil-Galan
Title: Band gap grading strategies for high efficiency kesterite based thin film solar cells
Starting date: 02/2017

PhD student: Alejandro Hernández
PhD supervisor: Dr. Edgardo Saucedo, Dr. Paul Pistor
Title: Tecnologías fotovoltaicas sostenibles de bajo coste y alta eficiencia para nuevos módulos solares basados en elementos abundantes en la corteza terrestre
Starting date: 12/2015

PATENTS

Title: Characterization of the composition of a deposited layer of an alloy of type I-(III',III'')-(VI'-VI'')
Publication number: WO2011148084 (A1)
Publication date: 2011-12-01
Inventors: Bermúdez Benito, Verónica; Saucedo Silva, Edgardo; Salvador Jaime-Ferrer Jesús; Pérez Rodríguez, Alejandro; Morante Lleonart Ramírez; Fontané Sánchez, Javier; Izquierdo Roca, Víctor; Álvarez García, Jacobo
Applicants: Nexcis; Institut de Recerca en Energia de Catalunya (IREC); Universitat de Barcelona (UB) (UB); Bermúdez Benito, Verónica; Saucedo Silva, Edgardo; Salvador Jaime-Ferrer, Jesús; Pérez Rodríguez, Alejandro; Morante Lleonart, Joan Ramon; Fontané Sánchez, Javier; Izquierdo Roca, Víctor; Álvarez García, Jacobo
International classification: G01N21/65
Cooperative Patent Classification: G01N21/65, G01N21/6489
Application number: WO2011FR51157
Date of application: 2011/05/20
Priority numbers: FR20100002208 20100526

Title: Method of monitoring and control of processes of chemical or electrochemical deposition of thin layers and device to carry it out
Publication number: WO2011158223 (A1)
Publication date: 2011-12-22

Inventors: Bermúdez Benito, Verónica; Jaime Ferrer, Jesús Salvador; Saucedo Silva, Edgardo; Pérez Rodríguez, Alejandro; Morante Lleonart, Joan Ramon; Fontané Sánchez, Javier; Izquierdo Roca, Víctor; Álvarez García, Jacobo, Grand Pierre-Philippe; Fairbrother, Andrew; Sylla, Diouldé.
Applicants: Nexcis; Universitat de Barcelona (UB); Institut de Recerca en Energia de Catalunya (IREC)
International classification: G01N21/65
Cooperative Patent Classification: G01N21/65, G01N21/8422, G01N2021/8411, G01N2021/8416
Application number: WO2011IB52691; EP20140179973
Date of application: 2011/06/20
Priority numbers: ES20100030945 20100618; EP20140179973 20140806

Title: Device for generating electric power from small movements
Publication number: US8633605 (B2); US2012104765 (A1)
Publication date: 2012-05-03
Inventors: Esteve Tinto, Jaume; Acero Leal, Maria Cruz; Fondevilla Sala, Núria; Pérez Rodríguez, Alejandro; Serre Christophe
Applicants: Esteve Tinto, Jaume; Acero Leal, Maria Cruz; Fondevilla Sala, Nuria; Pérez Rodríguez, Alejandro; Serre Christophe; Universitat de Barcelona (UB); Consejo Superior Investigación
International classification: F03G7/08, H02K35/04
Cooperative Patent Classification: H02K35/02
Application number: US201013377061
Date of application: 2010/06/15
Priority numbers: ES20090030320 20090616, WO2010ES70400 20100615

OUTREACH

Several outreach activities were organized by the group during 2018, mainly in the frame of STARCELL and INFINITE-CELL project. In particular, STARCELL organized a dedicated workshop on earth abundant materials for photovoltaic applications at the E-MRS spring Meeting in Strassbourg, France. STARCELL and INFINITE-CELL were also very active in the co-organization of the 9th European Kesterite Workshop in Ghent, Belgium, and cotributing to organize the pre-workshop student day. The group also organized an Industrial Workshop for promoting emerging photovoltaic technologies in Europe in the frame of STARCELL project together with the company Midsummer, in Stockholm, Sweden, and participated in the organisation of the Symposium S9 (Advanced PV Technologies and Concepts with new functionalities) at the NanoGe Fall Meeting 2018 (Torremolinos, Spain, October 2018).

DOCTORAL THESES

Presented Theses:

PhD graduate: Francesco Chiabrera
PhD supervisor: A. Tarancón, I. Garbayo
Title: Interface Engineering in Mixed Ionic Electronic Conductor Thin Films for Solid State Devices
Presented date: 28/6/2019

Ongoing Theses:

PhD student: Valerie Siller
PhD supervisor: Dr. Albert Tarancon, Dr. Alex Morata
Title: Thin film all-solid-state lithium ion batteries

PhD student: Yunqing Tang
PhD supervisor: Francesco Maria Chiabrera, Alex Morata, Albert Tarancón
Title: Mixed ionic and electronic conduction in nanostructured materials for energy applications

PhD student: Simone Anelli
PhD supervisor: Albert Tarancón Rubio, Marc Torrell Faro, Federico Baiutti
Title: Advanced concepts for Solid Oxide Electroylzer Cells

PhD student: Arianna Pesce
PhD supervisor: Alex Morata, Albert Tarancón
Title: 3d printing of ceramic based energy conversion devices

PATENTS

Title: Solid oxide electrolyte membrane supported on doped silicon ribs for uses in micro solid-oxide fuel cells
Inventors: Garbayo Senosiain, Iñigo; Sabate Vizcarra, Maria De Les Neus; Salleras Freixes, Marc; Tarancón Rubio, Albert; Morata García, Alejandro
Applicants: Consejo Superior Investigación; Institut de Recerca en Energia de Catalunya (IREC)
Application number: ES20120030973
Date of application: 2012

Title: Sensor electroquímico de estado sólido y procedimiento para su fabricación
Inventors: Morata García, Alejandro; Garbayo Senosiain Iñigo; Tarancón Rubio, Albert; Sabaté Vizcarra, María De Les Neus; Fonseca Chacharo, Luis; Salleras Freixes, Marc; Morante Lleonart, Joan Ramon
Applicants: Institut de Recerca en Energia de Catalunya (IREC); Consejo Superior Investigación; Universitat de Barcelona (UB)
Application number: ES20130031791

Date of application: 2013

Title: NANOSTRUCTURES OF CONCENTRIC LAYERS
Inventors: Morata García, Alex; Tarancón Rubio, Albert; Gadea Díez, Gerard
Applicant: IREC
Application number: WO2016198712 (A1)
Also published as: EP3306685 (A1), ES2593656(A2), ES2593656 (B1), ES2593656 (R1)
Priority Date: 08/06/2015

OUTREACH

The outreach activities of the group have been addressed to different communities (society, industrial sector, and scientific community and policy makers) through the participation of the group members in conferences, debates, meeting with industrial partners and workshops focused on the general dissemination of new materials and technologies for energy applications. In this sense the group have received the FCH-JU award for the Cell3Ditor project, as the most innovative project, after an open online votation proces.
Related with this continuous dissemination activities, it is worth to highlight the participation of Albert Tarancón in the exhibition “After the end of the World"- Beta Station. In the frame of this programme Albert Tarancón gave two talks "The Future of Energy and the Energy of the Future" and "After the end of the World"- City station, where after visiting the installation of the exhibition “Aerocene”, by Tomás Saraceno, Albert Tarancón, and Pedro Gómez-Romero (professor of research and scientific communicator of the CSIC and director of the NEO-Energy Group of the Catalan Institute of Nanoscience and Nanotechnology, ICN2 (CSIC-CERCA-Centro Severo Ochoa) talk about the future of energy and new technologies that can change the current paradigm while anticipating possible scenarios for the future. Albert Tarancón have also participated in the organization of the workshop Energy Self-consumption" within "The Environmental Health Clinic" where three different activities were offered at the CCCB:

- Photocatalytic paint (see more info at: https://estaciociutat.org/en/photocatalytic-paint/#)

- Construction of a solar furnace (see more info at: https://estaciociutat.org/en/construction-of-a-solar-furnance/#)

- Photovoltaic panels (see more info at: https://estaciociutat.org/en/plaques-fotovoltaiques/#)

Besides these activities the group has published different articles that, besides the international peer reviewed scientific publications of the group, pretend to reach the social engagement with the scientific fields covered by the research group.

Some of this publications worth to be highlighted are: the articles published in the mobility section of Infotransit blog “El cotxe d’hidrogen: “Piles de combustible per a una autonomia de 600 km” M. Torrell (http://infotransit.blog.gencat.cat/), the paper published in the "Revista Española de Física" entitled "Generación de combustibles sintéticos a partir de H2O y CO2: Electrolizadores de óxido sólido" M. Torrell Vol 33 (2019)(http://revistadefisica.es/index.php/ref/issue/view/152) and the contribution in website of Barcelona city hall about the sustainability of the electric vehicle entitled “El vehicle elèctric no és tan net com sembla” (http://ajuntament.barcelona.cat/lafabricadelsol/ca/noticia/el-vehicle-elzuctric-no-zss-tan-net-com-sembla) published by “La Fabrica del Sol”, a culture centre dedicated to energy and sustainability. The group, also participates in the initiative of the same centre to promote the debates with Barcelona citizens with energy researchers called “Vermuth amb bona energia” with the

participation of Aitor Hornés who talked and discussed about the role of the H2 technologies in the new energy scenario.

The group also participate in the debate “Mercados del hidrógeno en España. Regiones que apuestan por la innovación" organised by the "Plataforma Tecnologica Española de Hidrogeno y Pilas de Combustible; PTE-HPC" where M. Torrell presented the roadmap and present activity of Catalunya in terms of Hydrogen and Power to Gas technologies.

6.2. ENERGY EFFICIENCY IN SYSTEMS, BUILDINGS AND COMMUNITIES AREA

The main objective of the technological research and technical development area focuses on the development of energy efficiency to buildings, systems and communities. Based on the Nearly Zero Energy concept applied to buildings, it expands the concept to communities such as districts, cities and rural areas as well as industrial systems.

This concept involves working on the design of the building or system as an active part of the de district, community or industrial system. The main energy efficient technologies considered are intelligent lighting, building design and modelling, integration of electricity and thermal energy (heating and cooling), renewable and decentralized energy resources, green IT, e-mobility, micro grids and smart grids and energy management and control systems. In addition, research economic analysis and regulation activities support the energy efficiency research lines.

6.2.1. ENERGY SYSTEMS ANALYTICS

6.2.2 POWER SYSTEMS

6.2.3 THERMAL ENERGY & BUILDING PERFORMANCE

6.2.1. ENERGY SYSTEMS ANALYTICS GROUP

The Team

(permanent and temporary positions, tenure tracks and fellowships)

Dr. Cristina Corchero, Energy Systems Analytics Group Leader Dr. Victor Jose Ferreira, Postdoctoral Researcher Dr. Lluc Canals, Postdoctoral Researcher Alba Colet, Staff Engineer Lucía Igualada, Staff Engineer Alaia Sola, Project Engineer David Cardoner, Project Engineer Jordi Farre, Staff Engineer Antoni Company, Project Engineer Mattia Barbero, Predoctoral Student Fernando Garcia, Visiting Predoctoral Student Daniel Ramon Lumbierres, Project Engineer

The Energy Systems Analytics group works to accelerate the energy transition through the economic and environmental optimal integration of complex energy systems. Energy systems integration aims to explore ways for energy systems to work more efficiently on their own and with each other. We recognize the evolving demands of the energy field as it moves away from individual energy devices and towards complex energy systems that require advanced management to guarantee optimal performance.

With expertise in the modelling, optimization and sustainability and economic assessment of energy systems, we can better understand how to increase reliability, reduce costs, and minimize environmental impacts of our energy systems.

The Energy Systems Analytics group uses advanced mathematical, statistical and engineering techniques to answer the new energy systems challenges. Our group aims to develop and refine advanced techniques to progress towards the economically and environmentally sustainable energy systems of tomorrow.

Specifically our research lines are:

- Smart Energy Management: optimal energy management systems, flexibility integration, hybrid systems management and integration
- New market agents functionalities definition and evaluation
- Sustainable mobility integration: infrastructure optimization, V2X technologies, urban e-mobility solutions
- Sustainability and economic assessment: life cycle assessment and life cycle cost, levelized cost of energy, business model evaluation
- Novel energy system optimization methods and data management techniques
- Data science for energy systems: data forecasting based on machine learning algorithms, patterns recognition and stochastic modelling for optimization and simulation.

We work closely with industry to apply advanced data science and optimization techniques to allow optimal management of novel energy systems that integrate new technologies, new market schemes or regulation frameworks.

ACTIVITIES

The Energy System Analytics (ESA) Group makes use of the shared facilities with Power System (PS) group. IREC Energy SmartLab at Barcelona Headquarters is a flexible and innovative experimental that provides unique emulation and testing facilities which operates a number of configurable units. The units can be configured to work as energy generators (e.g. Solar PV), energy storage nodes or energy consumption nodes. Also, real storage systems (flywheel, super-capacitors and batteries), wind turbine emulators (SCIG, DFIG and PMSG) and PEV charging point are integrated. Finally, there is a grid emulator allowing studying different grid perturbations and configurations. Moreover, a descriptive video can be found in the following link: https://vimeo.com/111393514.
This laboratory is prepared to test aggregation software, energy management software, advance SCADA systems and to perform Power-Hardware-In-The-Loop (PHIL) testing which means that data will be exchanged from a simulation software with certain models (e.g. power system network of a whole area) and the grid emulator.

HIGHLIGHTS GROUP

- **International Energy Agency Operating Agent on Vehicle to Grid Technologies**

Dra. Cristina Corchero represents Spain as electric vehicle expert within the Technological Cooperation Program on Hybrid an Electric Vehicle, leading the task on Vehicle Grid Technologies and participating as expert in the Electric Buses, Interoperability and Raw Materials for EV tasks. Task 28, led by Dra. Corchero, is the task with the higher number of participating countries within the TCP and its success is highly recognized.

- **Integration of second life battery in a public library – REFER project**

REFER project is part of the RIS3CAT Energy Community where, within other activities, IREC has integrated a second life electric vehicle battery in the self-consumption system of a library. Up to our knowledge, it is the first time that an EV battery without refurbishment has been integrated in a public building, to do so, several technological and regulatory issues have been solved. Press and scientific community has express their interest.

- **iREMS – IREC Energy Management System - installed in three Barcelona buildings, GrowSmarter project**

iREMS, an energy management system developed by Energy Systems Analytics group, has been successfully installed and validated in three different buildings, including Nissan headquarters. This software is executed both locally and from the cloud and is able to optimally manage the self-consumption installations enhancing the commercial performance.

PROJECTS

Title: Qualification of innovative floating substructures for 10MW wind turbines and water depths greater than 50m.
Acronym: Lifes 50 Plus
Description: The focus of the project will be on floating wind turbines installed at water depths from 50m to about 200m. The consortium partners have chosen to focus on large wind turbines (in the region of 10MW), which are seen as the most effective way of reducing the Levelized Cost of Energy (LCOE). The objective of the proposed project is two-fold: 1. Optimize and qualify, to a TRL5 level, two (2) substructure concepts for 10MW turbines. The chosen concepts will be taken from an existing list of four (4) TRL>4 candidates currently supporting turbines in the region of 5MW. The selection of the two concepts will be made based on technical, economical, and industrial criteria. An existing reference 10MW wind turbine design will be used throughout the project. 2. More generally, develop a streamlined and KPI-based methodology for the design and qualification process, focusing on technical, economical, and industrial aspects. This methodology will be supported by existing numerical tools, and targeted development and experimental work. It is expected that resulting guidelines/recommended practices will facilitate innovation and competition in the industry, reduce risks, and indirectly this time, contribute to a lower LCOE. End users for the project deliverables will be developers, designers and manufacturers, but also decision makers who need to evaluate a concept based on given constraints. The proposed project is expected to have a broad impact since it is not led by single group of existing business partners, focusing on one concept only. On the contrary, it will involve a strong consortium reflecting the value chain for offshore wind turbines: researchers, designers, classification societies, manufacturers, utilities. This will ensure that the project's outcomes suit the concrete requirements imposed by end-users.
Funding: H2020
Project ID: 640741
Type: Competitive EU
Partners: Sintef Ocean AS (MAR), Danmarks Tekniske Universitet (DTU), Offshore Renewable Energy Catapult (ORE CATAPULT), Politecnico di Milano (POLIMI), FUNDACION Tecnalia Research & Innovation (TECNA), Fundacio Institut de Recerca en Energia de Catalunya (IREC), Universitaet Stuttgart (USTUTT), Iberdrola Ingenieria Y Construccion SAU (IBER), Dr Techn Olav Olsen As (OOLSEN), Ramboll Management Consulting GMBH (RAMBOL), Germanischer Lloyd Industrial Services GMBH (DNVGL), IDEOL, Ramboll Ims Ingenieurgesellschaft MBH (RAMBOLLL), Nautilus Floating Solutions SL (NAUTILUS)
Date: 6/1/2015-4/30/2019
Group: Energy Systems Analitics
P.I: Cristina Corchero García
URL:
https://lifes50plus.eu/,https://drive.google.com/open?id=14UR0z26sKNmrEbam9AzzBtWARYArDUAz

Title: Gestión Energética e Integración de los Distritos Urbanos en las Redes Inteligentes
Acronym: Geidi

Description: The project SEMIOTIC aims to answer to the need to manage energy efficient Smart Communities from data generated by IoT (Internet ofThings) sensors, studying various problems related to (i) the process of data generated by IoT sensors, (ii) the impact of these data on theenergy management of Smart Communities. Specifically, the issues addressed are: the semantic representation of the data generated by IoT nodes, the performance of semantic queries, the control of the accuracy and security of such data and how to use the information obtained to optimize the energy management of urban districts within the Smart Grids.In addition, SEMIOTIC incorporates a prospective activity exploring ideas that may lead to future lines of work - for example, analysis oftextual information in social networks, analysis of activity patterns from data mobility, and optimization of energy infrastructure in urbanenvironments to a new paradigm of generalization of distributed power generation systems.In order that the results achieved are based on realistic scenarios and have maximum impact, the project combines research of theoreticalnature with the development of tools and platforms.SEMIOTIC addresses an issue of extreme importance (energy efficiency) by integrating ideas and solutions in various fields (IoT, semantic data, statistical models). Without this integration, the expected results could not be achieved. The nature of the problemaddressed by SEMIOTIC is therefore clearly multidisciplinary, and thus, it is defined as a coordinated project in which three researchgroups that have complementary profiles are involved.
Funding: Retos Investigació
Project ID: TIN2016-78473-C3-3-R
Type: Competitive Nationals
Partners: Universitat Politècnica de Cataluña (UPC), Barcelona Supercomputing Center (BSC), Fundacio Institut de Recerca en Energia de Catalunya (IREC)
Date: 12/30/2016-12/29/2019
Group: Energy Systems Analitics
P.I: Cristina Corchero García
Other group: Thermal Energy & Building Performance- Dr. Jaume Salom Tormo.

Title: Re-usable and re-configurable parts for sustainable LED-based lighting systems (Repro-light)
Acronym: Repro-light
Description: The Repro-light project aspires to successfully initiate a transformation of the European LED lighting industry by the year 2020 since European lighting companies have been facing fierce competition from Asia while at the same time prices for LED luminaires are rapidly falling. By developing an intelligent LED-based luminaire with a modular, stackable architecture the project seeks to change the industry's view of the LED luminaire as a generic, disposable object into a customized, sustainable product with high functional value. Breaking the rules of traditional luminaire design by using innovative technologies and materials to completely forgo wiring and make luminaires completely stackable as in the Repro-light project has never been attempted before. Through the modular design and the development of a smart production scheme costs and time of luminaire manufacturing can be reduced substantially as well as their environmental impact. Now is an extremely crucial moment for creating a sustainable solution for

LED luminaires since the LED market is in the middle of a massive transformation, changing the value proposition of LED-based lighting solutions from a focus on energy efficiency to functional values. The Repro-light luminaire will fulfil this value propositions by employing intelligence and having a positive impact on peoples' health. The Repro-light consortium is perfectly suited to be the spearhead of this lighting "revolution" as the entire value chain is represented and the consortium is structured around a sound industrial backbone. With representatives and driving forces of the European lighting industry as well as manufacturers of basic products, experts on lighting sustainability and the Social Sciences, the Repro-light consortium possesses the excellence and the influence to not only execute this project successfully but also invoke a sustainable change in the European lighting industry beyond the lifetime of the project.
Funding: H2020
Project ID: 768780
Type: Competitive EU
Partners: Bartenbach GMBH (BART), Fundacio Institut de Recerca en Energia de Catalunya (IREC), Itz Innovations- Und Technologiezentrum GMBH (ITZ), Trilux Gmbh & Co Kg (TXKG), Luger Siegfried (LUGER), Mondragon Goi Eskola Politeknikoa Jose Maria Arizmendiarrieta S COOP (MU-ENG), BJB GMBH & CO KG (BJB), Grado Zero Espace SRL (GZE), Daniel Rohner (ROHNER)
Date: 10/1/2017-9/30/2020
Group: Energy Systems Analitics
P.I: Cristina Corchero García
URL: https://www.repro-light.eu/,https://drive.google.com/open?id=1d6F2qG83oFtC8l8vC_ZXBlHMks493gv4

Title: Empowering women to take action against energy poverty in the Mediterranean
Acronym: EmpowerMed
Description: In the Mediterranean countries, the coastal areas are facing several specific challenges when it comes to energy poverty, mainly connected with thermal comfort of dwellings. Buildings are scarcely isolated, often there are no heating systems in buildings, or those are highly inefficient, and the cooling component is more important than in other areas, calling for a diversity of energy services beyond heating. Women and women-led households are disproportionately affected by energy poverty, while women's agency is highlighted in acting against energy poverty. Although there is some knowledge on the health impacts of energy poverty, involving health practitioners in the energy poverty action is rare. This is why the main objective of the project is to contribute to energy poverty abatement in the Mediterranean through a) implementing a set of practical energy efficiency and RES measures, tailored to empower households in energy poverty and specifically focused on women and health, b) assessing their efficiency and impacts to formulate policy recommendations and c) promoting policy solutions among key actors for stimulating action against energy poverty at local and EU level. The project will first build networks with local actors in pilot regions (WP1) and transfer knowledge and experience to build capacity of all involved actors for implementing practical measures (WP2). The core of the project is implementation of practical measures to tackle energy poverty, such as community approaches, household visits, doit-yourself

approaches, support for small investments and health workshops (WP3). The impacts and success of the implemented measures will be assessed and analysed (WP4) to support formulation of policy recommendations, which
will be advocated among key actors to stimulate and support policies against energy poverty (WP5). Project results and outcomes will be disseminated among the target groups to ensure a wide reach out at local, national and EU level.
Funding: H2020
Project ID: 847052
Type: Competitive EU
Partners: Focus Drustvo Za Sonaraven Razvoj (FOCUS), Drustvo Za Oblikovanje Odrzivog Razvoja (DOOR), SOGESCA s.r.l., Universitat Autonoma de Barcelona (UAB), Fundacio Institut de Recerca en Energia de Catalunya (IREC), Geres Groupes Energies Renouvables (GERES), Associacio Catalana d'Enginyeria Sense Fronteres (ESF), Women Engage For A Common Future Ev (WECF), Milieukontakt Shqiperi (MiA)
Date: 6/1/2019-5/31/2023
Group: Energy Systems Analitics
P.I: Lluc Canals Casals
Other group: Thermal Energy & Building Performance-Dr. Jaume Salom Tormo
URL:
https://cordis.europa.eu/project/id/847052,https://drive.google.com/open?id=1Zm5OGoEOwI52OpBRpzQuFodzkv5RyznE

Title: REDUCCIÓ ENERGÉTICA I FLEXIBILITAT EN EDIFICIS EN REHABILITACIÓ.
Acronym: REFER
Description: El projecte REFER pretén fomentar la reducció de la despesa i la millora en l'eficiència energètica dels edificis. Al no haver-hi una sola tipologia d'edificis s'ha dividit el marc d'actuació en dues branques, els edificis terciaris i els residencials. Les vies principals de millora són diferents en cada cas, essent els sistemes de gestió de l'energia quelcom molt interessant per a edificis terciaris i les millores en climatització pel que fa a edificis residencials. Per tal de millorar la gestió energètica s'implementaran sistemes de mesura, de generació i d'emmagatzematge i es crearan sistemes de
comunicació entre els diferents elements per tal de poder gestionar el conjunt. Així, les tecnologies implementades seran validades amb diferents demostradors: La biblioteca Tirant lo Blanc de Montgat pel que fa als edificis terciaris i a més de 300 usuaris per analitzar els resultats del sector residencial.
Tanmateix, moltes altres tecnologies que no s'implementen als demostradors i que poden participar en la flexibilització energètica dels edificis del futur seran millorats mitjançant la introducció de nous conceptes que seran validats en un paquet de treball destinat a tal efecte. En aquest sentit, s'implementaran nous conceptes per a millorar substancialment les tecnologies de panells solars fotovoltaics i piles de combustible i noves metodologies per la reutilització de bateries de vehicle elèctric en edificis. Finalment, es crearà un software per determinar fàcilment possibles millores energètiques en edificis en rehabilitació.
Funding: Ris3Cat
Project ID: COMRDI15-1-0036-07

Type: Competitive Nationals
Partners: COMSA Corporación De Infraestructuras SL (COMSA), Area Metropolitana De Barcelona (AMB), Aleaciones De Metales Sinterizados SA (AMES), Baxi Calefacción SLU (BAXI), Centre Internacional De Mètodes Numèrics En Enginyeria (CIMNE), Fundació Centre Tecnològic de Manresa (CTM), Dexma Sensors SL (DEXMA), Centre Tecnològic de Catalunya (EURECAT), Francisco Albero SAU (FAE), Fundacio Institut de Recerca en Energia de Catalunya (IREC), Acondicionamiento Tarrassense (LEITAT), Millor Energy Solutions, Universitat Politèctica de Catalunya (UPC), Worldsensing SL, Control Intel·Ligent de l'energia SCCL
Date: 6/1/2016-6/1/2019
Group: Energy Systems Analitics
P.I: Cristina Corchero García
Other groups: Nanoionic and Fuel Cells- Dr. Albert Tarancón Rubio, Thermal Energy & Building Performance- Dr. Jaume Salom Tormo, Solar Energy Materials and Systems- Dr. Alejandro Pérez-Rodríguez.

Title: Growsmarter
Acronym: Growsmarter
Description: GrowSmarter aims to:
• Improve the quality of life for European citizens by better mobility, housing and the quality of urban infrastructure while improving the citizens economy by lower energy costs and creating as much as 1500 new jobs (on the demonstration level).
• Reduce the environmental impact by lower energy needs by 60 % and increased use of renewable energy thus reducing GHG emissions even more.
• Create sustainable economic development by demonstrating and preparing a wider rollout of smart solutions.
GrowSmarter will demonstrate at 3 lighthouse cities 12 smart, integrated solutions as a way of preparing for a wider market rollout. These solutions are integrated in specially chosen sites making demonstration easy to reach and take part of for the 5 follower cities and other European and international study groups. All the smart solutions are fit into the Lighthouse-cities strategic development plans and the follower cities replication plans.
The solutions solve common urban challenges such as:
• Renewal of existing buildings. GrowSmarter demonstrates the cost efficient renewal of 100.000 square meters of Nearly Zero or low energy districts reducing energy demand by 70-90%,
• Integrated infrastructures for ICT, street lighting, smart grids district heating and smarter waste handling
• Sustainable urban mobility for both passenger and gods integrated in smart grids, biofuels from household waste thus reducing local air quality emissions by 60%.
The integration of Cities, strong group of industrial partners together and quality research organisations guarantee that the solutions will be both validated by independent research organisations and transformed into Smart Business Solutions by industry for the wider rollout to Europe.

Growsmarter builds on integrated, close to the market solutions, to form business models for their wider deployment by the industrial partners. The project will help Europe GrowSmarter.
Funding: H2020
Project ID: 646456
Type: Competitive EU
Partners: STOCKHOLMS STAD, STADT KOLN, Institut Municipal D'informatica De Barcelona, Iclei European Secretariat GMBH, Iclei Europasekretariat GMBH (ICLEI), Kungliga Tekniska Hoegskolan (KTH), Universidad De Navarra (IESE), STADT GRAZ, Municipiul Suceava (Suceava), Authority For Transport In Malta Transport, Camara Municipal Do Porto, Cork City Council, Regional Environmental Center for Central and Eastern Europe -Rec, Envac AB , Dalkia Sverige AB (L&T), Fortum Sverige AB (Info24), Carrier Transport AB, Sweden, Skanska Sverige AB (SKANSKA), Insero AS (IEM), Rheinenergie (RE), Ampido GMBH, Stattauto Koeln Gesellschaft fuer Car Sharing MBH (Cambio Köln), AGT Group (R&D) GMBH (AGT), Deutsche Wohnungsgesellschaft Mbh-Dewog (DEWOG), Endesa SA, Retevision SA, Anteverti Consulting SL, Barcelona Supercomputing Center - Centro Nacional De Supercomputacion (BSC), Centre Internacional de Metodes Numerics en Enginyeria (CENIT), Naturgy Energy Group SA, Fundacio Privada I2CAT, Internet I Innovacio Digital a Catalunya (I2CAT), Fundacio Institut de Recerca en Energia de Catalunya (IREC), Philips GmbH (Phillips), Schneider Electric Industries SAS, Urbisup Consulting SL (Urbis Up), Polis - Promotion of Operational Links With Integrated Services, Association Internationale (POLIS), IBM Svenska AB (IBM), Endesa Energia S.A., Endesa Distribucion Electrica S.L (Endesa Distribu), Schneider Electric Espana SA, Nissan Iberia, S.A.
Date: 1/1/2015-12/31/2019
Group: Energy Systems Analitics
P.I: Manel Sanmartí Cardona
Other group: Thermal Energy & Building Performance- Dr. Jaume Salom Tormo
URL: https://grow-smarter.eu/home/,https://drive.google.com/open?id=1Cg3PsJdiDHPHaxoLJUlXo6ENQfNHgfN8

Title: Electro-depuració d'aigües residuals industrials: viabilitat tècnica, ambiental i econòmica
Acronym: ELDE
Description: Amb el projecte ELDE es pretén millorar els resultats obtinguts amb els tractaments de depuració convencionals en les aigües residuals de tres sectors industria ls: paperer, químic i de curtits, els quals generalment es caracteritzen per presentar una elevada contaminació, principal ment en relació al color, elevat contingut de matèria orgànica i alta salinitat. Sota el nom de “electrodepuració” es vol reflectir l’objectiu general del projecte que consisteix en utilitzar tecnologies basades en l’electricitat per tal d’eliminar els diversos contaminants presents en les aigües residuals aprofitant les sals que contenen. El projecte ELDE està dons enfocat a transformar el greu problema de la salinitat en una avantatja, ja sigui mitjançant la separació de les sals i la matèria orgànica per la seva reutilització, o bé aprofitant les sals per generar oxidants capaços de destruir el s

contaminants orgànics. La generació d'oxidants in situ evitaria el transport, manipulació i sobredosificació de productes químics.
Funding: Ris3Cat
Project ID: COMRDI16-1-0066-05
Type: Competitive Nationals
Partners: Universitat Politècnica de Catalunya (UPC), Fundació CTM Centre Tecnològic (CTM), Fundacio Institut de Recerca en Energia de Catalunya (IREC), Técnica y proyectos S.A (TYPSA), Waterologies S.A., Lavola 1981 S.A, Pere Valls S.A.
Date: 7/1/2018-6/30/2021
Group: Energy Systems Analitics
P.I.: Cristina Corchero García
Other groups: Power Systems- Dr. José Luis Domínguez, Solar Energy Materials and Systems- Dr. Alejandro Pérez-Rodríguez
URL: http://www.comunitataigua.cat/projects/elde/

Title: Valorització de les dades de la IoT.
Acronym: FEM IoT P2
Description: Moltes ciutats i territoris han anat realitzant des de fa uns anys una important inversió de recursos per disposar de les seves plataformes IoT de ciutats intel·ligents, moltes d'aquestes plataformes han estat finançades per iniciatives públiques, que han servit per dinamitzar la implantació de les plataformes IoT. Tal i com s'exposa a l'estratègia SMARTCAT, per poder arribar a complir els seus objectius és essencial que s'integrin en aquestes plataformes un conjunt d'elements externs i interns i uns algoritmes d'intel·ligència que impactin en els serveis públics sense formar part d'aquests. Entenent com objectes interns, els edificis, carrers i altres infraestructures, com ports, aeroports, estacions de metro, edificis públics, etc., que disposen d'un conjunt de dades que han de traslladar-se a la ciutat perquè aquesta pugui planificar millor els seus serveis. A més, les ciutats estan en contacte permanent amb altres ciutats i àrees metropolitanes que estan influenciades pel mateix clima, i també estan connectades a xarxes de subministrament que superen l'àmbit de ciutat. Totes aquestes interrelacions i dependències influeixen sobre els problemes a solucionar i els serveis que es presten, és el que s'entén com a objectes externs. El gran valor del IOT vindrà també per la compartició i explotació de les dades en diferents aplicacions i models. Tanmateix, la interoperabilitat global de les infraestructures de hardware i software generalment es basa en estàndards, però com que el món de l'IoT està en permanent evolució sense una coordinació i control tècnic centralitzat específic, en els pròxims anys es desenvoluparan i proposaran moltes solucions i pseudo-estàndards. Això provocarà una major heterogeneïtat i, per tant, dificultat en connectar dades. De fet, actualment existeixen molts estàndards (de facto) diferents en l'àmbit de IoT dirigits a: comunicacions, hardware, software i dades. Per tant, és fonamental proporcionar enfocaments capaços d'integrar, interconnectar, fusionar, plataformes d'anàlisi de dades heterogènies per construir ecosistemes interoperables a gran escala, i d'aquesta manera poder construir nous serveis sobre aquestes plataformes. Es treballarà en dos casos d'ús: un de control dels fluxos energètics als carrers i un altres cas de sistema intel·ligent de control de mobilitat i intensitat de trànsit, que té relació amb

el P1. Els desenvolupaments seguiran la filosofia de xarxes definides en base al concepte de "Software Defined Networks" (SDN), és a dir, (i) gestió centralitzada; (ii) separació completa dels components; (iii) interfícies estàndard obertes per a la comunicació basades en Aplicacions d'Interfície de Programació (API), protocols de flux obert i cloud-computing per aconseguir flexibilitat. Els algorismes avançats d'anàlisi de dades es centraran en mètodes d'extracció d'indicadors per a sèries temporals multi variants i en la classificació i previsió d'esdeveniments complexos basats en tècniques d'intel·ligència artificial.
Funding: Emergents
Project ID: IU16-011655
Type: Competitive Nationals
Partners: Centre Internacional de Mètodes Numèrics en Enginyeria (CIMNE), Barcelona Supercomputing Center-Centro Nacional de Supercomputación (BSC-CNS), Fundació Internet i Innovació Digital a Catalunya (i2CAT), Universitat Politècnica de Catalunya (UPC), Institut de Recerca en Energia de Catalunya (IREC), Universitat Rovira i Virgili (URV) Centre de Visió per Computador (CVC), Centre Tecnològic de Catalunya (Eurecat), Universitat Pompeu Fabra (UPF)
Date: 5/2/2019-4/30/2021
Group: Energy Systems Analitics
P.I: Cristina Corchero García.

PUBLICATIONS

Articles and Journals from ISI Database

Jorda-Capdevila, D., Casals, L.C.**"Water management in the media and research: Dissemination in catalonia and its capture by private companies"**, 2019, International and Multidisciplinary Journal of Social Sciences,8,3,267,288,10.17583/rimcis.2019.4600, Article, Open Access

Canals Casals L., Barbero M., Corchero C.**"Reused second life batteries for aggregated demand response services"**, 2019, Journal of Cleaner Production, 212,99,108,8, 10.1016/j.jclepro.2018.12.005, Article. IF:6.395.

Casals, L.C., Amante García, B., Canal, C.**"Second life batteries lifespan: Rest of useful life and environmental analysis"**, 2019, Journal of Environmental Management, 232,354,363, 10.1016/j.jenvman.2018.11.046, Article, Open Access. IF:4.865.

Casals, L.C., Rodríguez, M., Corchero, C., Carrillo, R.E.**"Evaluation of the end-of-life of electric vehicle batteries according to the state-of-health"**, 2019, World Electric Vehicle Journal,0.1,10,4,63,10.3390/wevj10040063, Article, Open Access.
Wolff D., Casals L.C., Benveniste G., Corchero C., Trilla L.**"The effects of lithium sulfur battery ageing on second-life possibilities and environmental life cycle assessment studies"**, 2019, Energies, 12,12,2440,10.3390/en12122440, Article, Open Access. IF:2.707.

Lerch M., De-Prada-Gil M., Molins C.**"The influence of different wind and wave conditions on the energy yield and downtime of a Spar-buoy floating wind turbine"**, 2019, Renewable Energy, 136,1,14,2, 10.1016/j.renene.2018.12.096, Article. IF:5.439.

DOCTORAL THESES

Ongoing Theses:

PhD student: Alaia Sola
PhD supervisor: Dra. Cristina Corchero, Dr. Pau Fonseca (UPC)
Title: Urban-scale energy modelling

PhD student: Mattia Barbero
PhD supervisor: Dra. Cristina Corchero, Dr. F. Javier Heredia (UPC)
Title: Demand Aggregator Optimal Strategies: from the Bidding to the Execution

PhD student: Anzhelika Ivanova
PhD supervisor: Cristina Corchero, Pau Fonseca
Title: Optimal Sensor Placement for Accurate State Estimation in Active Distribution Networks

PhD student: Markus Lerch
PhD supervisor: Dr. Mikel de Prada, Dr. Climent Molins (UPC)
Title: Techno-economic assessment, modelling and optimization for floating offshore wind farms

PhD student: Fernando Garcia
PhD supervisor: Dra. Cristina Corchero, Dr. Francisco Diaz (UPC)
Title: Optimal location of storage systems in the distribution network

PhD student: Gabriela Benveniste
PhD supervisor: Dra. Cristina Corchero, Dra. Beatriz Amante (UPC)
Title: LCA y análisis económico de sistemas innovadores de almacenaje eléctrico en Litio-azufre (Li-S)

Patents:

Title: Algoritmo de optimización de la gestión energética terciaria y secundaria de microredes (EMS)
Inventors: Cristina Corchero, Lucía Igualada, Miguel Cruz
Ref: B-1044-13 (Intellectual property registration)
Date: 05/03/2013

Title: CASE - A Commercial Aggregator Simulation Environment

Inventors: Cristina Corchero, Gerard del Rosario Calaf
Ref: B-2845-18 (Intellectual property registration)
Date: 03/12/2018

OUTREACH

- Participation at the IEA EBC Annex 67 Open Workshop, Barcelona, Spain, February 2018.
- Organization of IEA Expert Workshop "Wireless charging and V2G market and grid integration", Newcastle, UK, March 2018.
- Invited talk at "Jornada sobre agregadors elèctrics", organized by Enginyers Industrials Catalunya (EIC), Barcelona, Spain, May 2018.
- Participation in a round table about "New energy market" at "IV Assemblea General de la Comunitat RIS3CAT Energia", Barcelona, Spain, June 2018.
- Organization of IEA Workshop on Vehicle Grid Integration: from smart charge to vehicle-to-grid technology, Barcelona, Spain, 6th June 2018.
- Organization of IEA Expert Workshop "Vehicle-to-Everything Technology", Barcelona, Spain, 7th - 8th June 2018.
- Invited talk and round table at "EV Workshop" organized by "Cambra Comerç", Barcelona, Spain, October 2018.
- Participation at the Smart City Expo with pitch talks and IREC booth, Barcelona, Spain, November 2018.
- Session chair and organization on Vehicle Grid Integration at the IEEE Smart Grid for Smart Cities Forum, Gent, Belgium, November 2018.
- Session chair and organization on Smart Management at the Smart Grid Conference, Madrid, Spain, December 2018.

6.2.2. POWER SYSTEMS

The Team

(permanent and temporary positions, tenure tracks and fellowships)

Dr. Jose Luis Dominguez García, Power System Group Leader
Dr. Lluis Trilla Romero, Senior Research Staff
Dr. Hugues Renaudineau, Postdoctoral Researcher
Dr. Adedotun J. Agbemuko, Postdoctoral Researcher
Alba Colet, Head of Laboratory
Pol Paradell, Project Engineer
Toni Cantero, Project Engineer
Daniel Sanchez Muñoz, Project Engineer
Paschalia Stefadinou-Voziki, Project Engineer
Jose Ignacio Rapha Juan, Project Engineer
Anzhelika Ivanova, Project Engineer
Didac Bofill Izquierdo, Research Technician

The Power Systems group encompasses a wide-spectra of engineering disciplines (such as electrical, electronic, energy, communications, control, among others) required to comply with an evolving electrical system and sector. Our aim is to become an international point of reference in the R&D sector; with special emphasis in the field of power systems, grid integration and renewable energies.

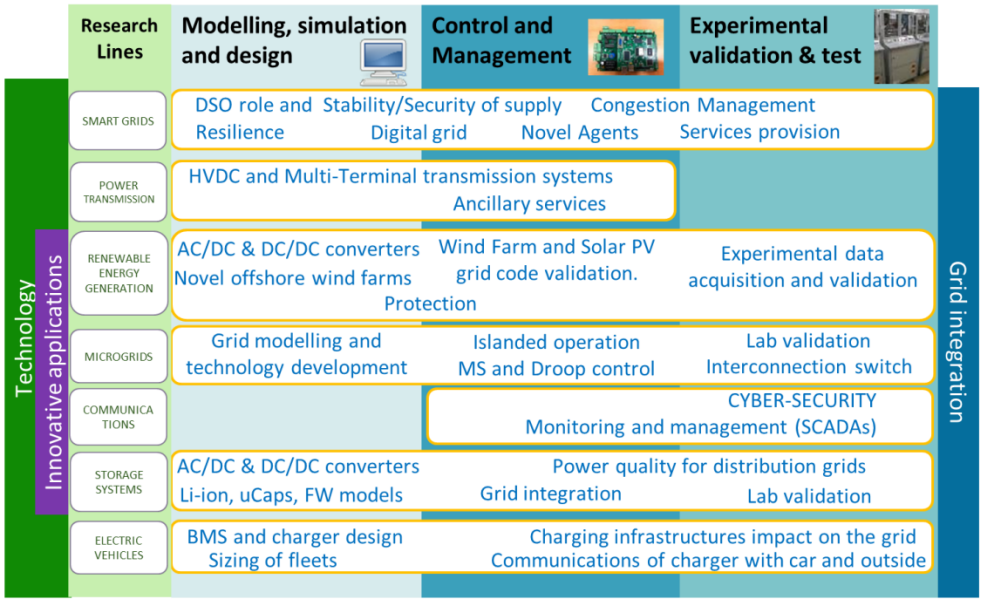
Our research lines are focused on the resolution of challenges of the future power systems, allowing larger integration of renewable energy sources, energy storage, as well as power converters and electric vehicles.

Our activities cover a wide range of topics within the whole power flow and value chain (from generation to consumption) including:

- Grid integration analysis of renewable sources
- Security and stability issues of both transmission and distribution networks
- Communication analysis
- Grid observability and controllability and power electronic design
- Installation and interaction on the electrical grid.

Furthermore, we work in the development and validation of tools and technologies, covering such diverse areas as:

- Modern power systems with distributed generation
- Smart grids and microgrids
- Electric vehicles and charging infrastructure
- Renewable power systems
- Offshore and onshore wind turbines and wind power plants
- Grid integration of RES
- PV power plants
- Energy storage
- Power electronics
- DC and AC technologies
- Smart grid automation and communications
- Cybersecurity



PROJECTS

Title: Innovative controls for renewable sources Integration into smart energy systems
Acronym: Incite
Description: The continuous increase of the share of renewable energy sources is redefining the electrical networks. In futureinfrastructures, an important number of agents (sources, storage devices and consumers) will have intelligentinterfaces allowing the regulation of the injection and extraction of power into the grid. This context will createmultiple alternatives to increase the efficiency in electricity generation and consumption, to reduce energy costs and toprovide a more reliable operation of electrical grids. These future networks will be only possible with suitable controlalgorithms. INCITE is a multi-sectoral consortium gathering experts on control and power systems, from academiaand industry with the purpose of providing innovative control solutions for the future electrical networks.
Funding: H2020
Project ID: 675318
Type: Competitive EU, Coordinator
Partners: Fundacio Institut de Recerca de l'Energia de Catalunya (IREC), Universitat Politecnica de Catalunya (UPC), Technische Universiteit Delf (TTU), Vlaamse Instelling Voortechnologisch Onderzoek N.V. (VITO), Alma Mater Studiorum -Universita di Bologna (UNIBO), Universite Joseph Fouriergrenoble (UJF), General Electric Deutschland Holding GmbH (General Electric), Efacec Energia - Maquinas Eequipamentos Electricos SA (Efacec Energia)
Date: 12/1/2015-11/30/2019
Group: Power Systems
P.I: José Luis Domínguez García
URL: http://www.incite-itn.eu/,https://drive.google.com/open?id=11VeLVVpe2loZEgzsxIq1Wq_vpQA31Un1

Title: Resilience to cope with climate change in urban areas - a multisectorial approach focusing on water
Acronym: Resccue
Description: RESCCUE aims to deliver a framework enabling city resilience assessment, planning and management by integrating into software tools new knowledge related to the detailed water-centred modelling of trategic urban services performance into a comprehensive resilience platform. These tools will assess urban resilience from a multisectorial approach, for current and future climate change scenarios and including multiple hazards. The project will review and integrate in the general framework existing options to assess climate change impacts and urban systems vulnerabilities allowing to assess multisectorial dependencies under multiple climate change scenarios. An adaptation strategies portfolio, including climate services, ecosystem-based approaches and resource efficiency measures will be incorporated as key components of the deployment strategy. The possible approaches will be ranked by their costefficiency in terms of CAPEX and OPEX

to evaluate their benefits potential. This will enable city managers and urban system operators deciding the optimal investments to cope with future situations. The validation platform is formed by 3 EU cities (Barcelona, Lisboa and Bristol) that will allow testing the innovative tools developed in the project and disseminating their results among other cities belonging to major international networks. In terms of market potential, RESCCUE will generate large potential benefits, in terms of avoided costs during and after emergencies, that will contribute to their large-scale deployment. The structure of the consortium will guarantee the market uptake of the results, as the complete value chain needed is already represented. The project is coordinated by Aquatec, a large consultancy firm part of a multinational company focused on securing and recovering resources, and includes partners from the research domain, operation of critical urban systems, city managers and international organisations devoted to urban resilience.
Funding: H2020
Project ID: 700174
Type: Competitive EU
Partners: Aquatec Proyectos para el Sector del Agua SA (AQUA), Centro Tecnologico del Agua, Fundacion Privada (CETAQUA), Fundacion para la Investigacion del Clima (FIC), Opticits Ingenieria Urbana SL (Opticits), The University Of Exeter (UNEXE), Laboratorio Nacional de Engenharia Civil (LNEC), Ajuntament de Barcelona (BARCELONA CC), Fundacio Institut de Recerca en Energia de Catalunya (IREC), United Nations Human Settlements Programme (UN Habitat), Edistribucion Redes Digitales SL (ENDESA), Camara Municipal de Lisboa (CML), EDP Distribuicao Energia SA (EDP DISTR), Hidra - Hidraulica e Ambiente LDA (HIDRA), Bristol City Council, Suez Advanced Solutions UK Limited (SASUK), Urban Dna Solutions LLP (UrbanDNA), ADP - Aguas de Portugal,SGPS SA (AdP SGPS), Ecole des Ingenieurs de la Ville Deparis (EIVP), Aguas do Tejo Atlantico SA (AdTA), Wessex Water Services Limited (WESSEX)
Date: 5/1/2016-4/30/2020
Group: Power Systems
P.I: José Luis Domínguez García
URL:
http://www.resccue.eu/,https://drive.google.com/open?id=178DFMqsKNo4mO5tYL39R23_MVIjoVXUc

Title: CoSt redUction and enhanced PERformance of PV systems
Acronym: SUPER PV
Description: SUPER PV is pursuing an ambitious bus realistic goal for innovative PV system cost reduction and consequentlysignificant LCOE reduction (26%-37%) by adopting hybrid approach combining technological innovations and DataManagement methods along the PV value chain. To achieve that, key actions will be implemented at three main levelswithin the PV value chain: PV module innovation level, power electronics innovation level and system integrationlevel. To ensure fast uptake of the project results by industry, state of the art modules (c-Si and flexible CIGS) andpower electronics products were utilised for adopting innovations developed by research centres. For cost reduction insystem integration and operation, Digitalization and Data Management solutions based on

Industry 4.0 approach willbe adopted following successful utilization of Building Information Modelling approach in the construction sector.Selected for uptake innovations will be compatible with existing manufacturing technological processes thus reducingimpact on Cost of Ownership and ensuring attractiveness of proposed technologies for PV manufacturers.Prototype SUPER PV systems will be produced in industrial environments and tested in different (including harsh)climate conditions to evaluate cost efficiency and demonstrate competitiveness of the proposed solutions. On the basisof test results, business cases for technologies under consideration will be performed, plans for production and marketreplication will be prepared. Project activities will be complemented by wide training and dissemination campaignensuring highest visibility and social impact of the project activities. By delivering to the market SUPERior PV products, the project will have twofold impact on EU PV sector:1. Will create conditions for accelerated large scale deployment of PV in Europe for both utility (non-urban) andresidential (urban) scenarios and2. Will help EU PV businesses to regain leadership on world market.
Funding: H2020
Project ID: 792245
Type: Competitive EU
Partners: Uab Soli Tek R&D (SOLITEK), Perspektyviniu Technologiju Taikomuju Tyrimu Institutas (PROTECH), Institut fur Solarenergieforschung GMBH (ISFH), Apollon Solar (APOLLON), Loser Chemie GMBH (LCH), Flisom AG (FLISOM), Tecnologia Navarra De Nanoproductos SL (TECNAN), Moroccan Foundation For Advanced Science Innovation And Research Fondation Mascir (MAScIR), Nederland Se Organisatie Voor Toegepast Natuurwetenschappelijkonderzoek TNO (TNO), SINTEF AS, Fundacion Para El Desarrollo Tecnologico Y Social (LUREDERRA), Eolane Combree , Cosylab Laboratorij Za Kontrolne Sisteme Dd (COSYLAB), Fundacio Institut de Recerca en Energia de Catalunya (IREC), Commissariat a l'Energie Atomique et aux Energies Alternatives (CEA), Cadcamation Kmr SA (CADCAMation), Ayesa Advanced Technologies SA (AYESA), Scuola Universitaria Professionale della Svizzera ITALIANA (SUPSI), Moroccan Agency for Solar Energy SA (MASEN), BNW-ENERGY, Icares Consulting (BI), Wirtschaft Und Infrastruktur GMBH & CO Planungs KG (WIP), Agence Nationale pour la Maitrise de l'Energie (ANME), Universitat Konstanz (UKON), Universite Mohammed V de Rabat (UMV), Univerza V Ljubljani (UL)
Date: 5/1/2018-4/30/2022
Group: Power Systems
P.I: José Luis Domínguez García
Other group: Solar Energy Materials and Systems- dr. Víctor Izquierdo, Energy Systems Analitics- Dr. Cristina Corchero
URL: https://www.superpv.eu/,https://drive.google.com/open?id=16gtJP1WNcezLTH2crT-AUduVBI4iphFh

Title: SDN - microgrid reSilient Electrical eNergy SystEm
Acronym: SDN-microSENSE
Description: The smart energy ecosystem constitutes the next technological leap of the conventional electrical grid, providingmultiple benefits such as increased reliability, better

service quality and efficient utilization of the existinginfrastructures. However, despite the fact that it brings beneficial environmental, economic and social changes, italso generates significant security and privacy challenges, as it includes a combination of heterogeneous, co-existingsmart and legacy technologies. Based on this reality, the SDN-microSENSE project intends to provide a set of secure, privacy-enabled and resilient to cyberattacks tools, thus ensuring the normal operation of EPES as well as the integrityand the confidentiality of communications. In particular, adopting an SDN-based technology, SDN-microSENSEwill develop a three-layer security architecture, by deploying and implementing risk assessment processes, self-healing capabilities, large-scale distributed detection and prevention mechanisms, as well as an overlay privacyprotection framework. Firstly, the risk assessment framework will identify the risk level of each component of EPES, identifying the possible threats and vulnerabilities. Accordingly, in the context of self-healing, islanding schemes andenergy management processes will be deployed, isolating the critical parts of the network in the case of emergency. Furthermore, collaborative intrusion detection tools will be capable of detecting and preventing possible threatsand anomalies timely. Finally, the overlay privacy protection framework will focus on the privacy issues, includinghomomorphic encryption and anonymity processes.
Funding: H2020
Project ID: 833955
Type: Competitive EU
Partners: Ayesa Advanced Technologies Sa (AYE), Panepistimio Dytikis Makedonias (UOWM), Ethniko Kentro Erevnas Kaitechnologikis Anaptyxis (CERTH), Preduzece Zatelekomunikacijske Uslugerealaiz doo Beograd (SAVSKIVENAC) (REAL), Atos Spain SA (ATOS), Schneider Electric France SAS (SEF), Public Power Corporation S.A. (PPC), Fundacion Tecnalia Research & Innovation (TECN), Dimos Avdiron (MOA), Innovative Energy and Information Technologies LTD (IEIT), Elektroenergien Sistemenoperator EAD (ESO), Cez Distribution Bulgaria AD (CEZ), Ubitech Ltd (UBITECH), Cyberlens Ltd (CLS), Sidroco Holdings Ltd (SID), Infinity Limited (0INF), Eight Bells Ltd (8BELLS), Incites Consulting SARL (INC), Energynautics GMBH (ENERGYNAUTICS), Norges Teknisk-Naturvitenskapelige Universitetntnu (NTNU), Siaxampanis E.E. (ALKYONIS), Gottfried Wilhelm Leibnizuniversitaet Hannover (LUH), Ravna Hydro Ltd (VETS), Fundacio Institut de Recerca en Energia de Catalunya (IREC), Estabanell Y Pahisa Energia SA, (EPESA)
Date: 5/1/2019-4/30/2022
Group: Power Systems
P.I: José Luis Domínguez García
URL:
https://www.sdnmicrosense.eu/,https://drive.google.com/open?id=1i8x6yNBU9l0LRNZwtMaOUluakkw_C8ls

Title: COst REduction and increase performance of floating WIND technology
Acronym: COREWIND
Description: Floating offshore wind is still a nascent technology and its LCOE is substantially higher than onshore and bottomfixed offshore wind, and thus requires to be drastically reduced. The COREWIND project aims to achieve significant cost reductions and enhance performance of floating wind technology through the research and optimization of

mooring and anchoring systems and dynamic cables. These enhancements arisen within the project will be validated by means of simulations and experimental testing both in the wave basin tanks and the wind tunnel by taking as reference two concrete-based floater concepts (semi-submersible and spar) supporting large wind turbines (15 MW), installed at water depths greater than 40 m and 90 m for the semisubmersible and spar concept, respectively. Special focus is given to develop and validate innovative solutions to improve installation techniques and operation and maintenance (O&M) activities. They will prove the benefits of concrete structures to substantially reduce the LCOE by at least15% compared to the baseline case of bottom-fixed offshore wind, both in terms of CAPEX and OPEX. Additionally, the project will provide guidelines and best design practices, as well as open data models to accelerate the further development of concrete-based semi-submersible and spar FOWTs, based on findings from innovative cost-effective and reliable solutions for the aforementioned key aspects. It is aimed that the resulting recommendations will facilitate the cost-competitiveness of floating offshore wind energy, reducing risks and uncertainties and contributing to lower LCOE estimates.
COREWIND aims to strength the European Leadership on wind power technology (and specially floating). To do so, the project consortium has been designed to ensure proper collaboration between all stakeholders (users, developers, suppliers, academia, etc.) which is essential to accelerate commercialization of the innovations carried out in the project.
Funding: H2020
Project ID: 815083
Type: Competitive EU ,Coordinator
Partners: Fundacio Institut de Recerca en Energia de Catalunya
(IREC), Danmarks Tekniske Universitet (DTU), INNOSEA , JDR Cable Systems Ltd (JDR), Ramboll Ims Ingenieurgesellschaft MBH (RAMBOLL), Fundacion Instituto de Hidraulica Ambiental de Cantabria (FIHAC), UL International GMBH (UL INT), WindEurope (WindEurope), Politecnico di Milano (POLIMI), Universitat Politecnica de Catalunya (UPC), Equinor ASA, Cobra Instalaciones Y Servicios S.A (COBRA), Universitaet Stuttgart (USTUTT).
Date: 9/1/2019,2/28/2023
Group: Power Systems
P.I: José Luis Domínguez García
Other group: Energy Systems Analitics- Dr. Cristina Corchero García
URL:
http://corewind.eu/,https://drive.google.com/open?id=1Weg60kP_RdmNjCtEAJ7DQLNQ4sHHQulg

Title: Desenvolupament experimental de noves tecnologias d'automatització de la xarxa de mt a catalunya
Acronym: NaENCAT
Description: El proyecto NAenCAT, pretende ser un referente de las nuevas Smart Grid, dotando de innovadores sistemas de sensorización, telemando y automatización distribuidaa la red eléctrica de Cataluña. Pare ello, empresas punteras del sector como son Ormazabal, ZIV, iGRid, IREC, Comercial Vallesanay Electra Caldensehan unido esfuerzos para poder desarrollar y probar estas tecnologías en NAenCAT.

Por un lado, en el proyecto se desarrollarán nuevos sensores adaptados a las características técnicas de la red eléctrica de Cataluña, lo que permitirá aumentar el conocimiento de lo que está pasando en la red. El desarrollo del sistema de sensorización se basará en criterios de bajo coste y adaptación al sistema de automatización distribuida de la red que también se propone en este proyecto. En este sentido, se desarrollarán algoritmos para localizar de forma eficiente los sensores en la red.
Por otro lado, se ampliarán las capacidades de los sistemas de telemando actuales, que serán más robustos y de menor coste, lo que permitirá flexibilizar la operación de red y un despliegue más rápido. Fruto del mayor conocimiento que se tendrá de la red gracias al sistema de sensorización, el telemando dispondrá de información más fiable, precisa y actualizada para gestionar de forma centralizada la red y anticipar posibles congestiones en la misma o solventar incidencias existentes de forma eficaz. En este sentido, también se estudiarán los potenciales beneficios para la operación de la red de los sistemas de almacenamiento de energía y su integración en el telemando.
A otro nivel de operación de la red, se incorporará una solución innovadora para la automatización inteligente distribuida que complemente la solución de telemando centralizado actual, lo que permitirá que la red se auto-cicatrice sola en caso de avería. La automatización distribuida de las redes de distribución requerirá de las tecnologías de vanguardia en el sistema de sensorización que se desarrollarán en este proyecto.
Los tres sistemas mencionados sobre los que se basará NAenCAT dispondrán de equipos de comunicación que permitirán el envío de información entre cada sensor y los centros de control (telemando) por un lado, y entre un sensor y otro (automatización distribuida) por otro.
Finalmente, se desarrollarán algoritmos avanzados para la correcta coordinación de los sistemas y tecnologías anteriormente descritos, así como para convertir en información útil los datos generados por los sistemas. En este sentido, se combinarán modelos de red con datos sensorizados para obtener de forma económicamente eficiente estimaciones del estado de la red.
Todas estas tecnologías se instalarán y validarán en la red, para poder estudiar su impacto y beneficio respecto a los sistemas actuales y así poder planificar su instalación masiva a medio plazo, convirtiendo la red eléctrica de Cataluña en una red todavía más inteligente.
Funding: Ris3Cat
Project ID: COMRDI15-1-0039-01
Type: Competitive Nationals
Partners: Electra Caldense, S.A, Institut de Recerca en Energia de Catalunya (IREC), iGrid, S.L., Ormazabal Media Tensión S.L., ZIV Aplicaciones y Tecnologóa S.L.U., Comercial Vallesana de Suministros SA
Date: 3/1/2017-4/15/2020
Group: Power Systems
P.I: José Luis Domínguez García.

ACTIVITIES

The group activities cover a wide range of topics within the whole power flow and value chain (from generation to consumption) including grid integration analysis of renewable sources, security and stability issues of both transmission and distribution networks, as well as communication analysis, grid observability and controllability and power electronic design, installation and interaction on the electrical grid. These work lines include the development and validation of tools and technologies. The main areas of activity are Modern power systems with distributed generation, Smart grids and microgrids, Electric vehicles and charging infrastructure, Renewable power systems, Offshore and onshore wind turbines and wind power plants, Grid Integration of RES, PV power plants, Energy storage, Power electronics, DC and AC technologies, Smart Grid automation and communications, and Cybersecurity.

Facilities of PS Group:

The Power System (PS) Group makes use of the shared facilities with Energy System Analytics (ESA) group as part of the Electrical Engineering Research Area.

The Electrical Engineering Research Area has a flexible and innovative experimental lab known as IREC Energy SmartLab at Barcelona Headquarters. This laboratory provides unique emulation and testing facilities which operates a number of configurable units. The units can be configured to work as energy generators (e.g. Solar PV), energy storage nodes or energy consumption nodes. Also, real storage systems (flywheel, super-capacitors and batteries), wind turbine emulators (SCIG, DFIG and PMSG) and PEV charging point are integrated. Finally, there is a grid emulator allowing studying different grid perturbations and configurations. Moreover, a descriptive video can be found in the following link: https://vimeo.com/111393514

This laboratory is prepared to perform Power-Hardware-In-The-Loop (PHIL) testing which means that data will be exchanged from a simulation software with certain models (e.g. power system network of a whole area) and the grid emulator. Then, the grid emulator translates the signals received into voltage and current signals making them inputs on to the rest of the laboratory equipment connected to the test. Additionally, this facilities allows real equipment validation from monitoring systems to power converters of certain size.

HIGHLIGHTS GROUP

- **SUPERPV Kick-Off and Work Package Leadership**

  SUPERPV is a collaborative European-funded project initiated in 2018 by 26 partners. SUPERPV project targets a significant LCOE reduction (26%-37%) for European-made PV by tackling in an integral way three cornerstone steps: module, power electronics and System Integration & O&M. Power system group is the leader of WP4 responsible of Power Electronics, Monitoring and Communications. (more info in: www.superpv.eu).

- **Best Paper award at IFAC CPES 2018**

  Adedotun J. Agbemuko has won the Best Paper Award at the IFAC 10th Symposium on Control of Power and Energy Systems (CPES 2018) Conference in Tokyo (4-6-September-2018) for his work "An integrated approach to understanding the impact of network resonances and control on dynamic responses in VSC-HVDC networks". Details on the work can be found: https://doi.org/10.1016/j.ifacol.2018.11.726

- **Award of the Distinguished Visitor Fellowship 2018 by the Royal Academy of Engineering of United Kingdom**

Dr. Jose Luis Domínguez-García has been awarded by the RAENG of UK with the Distinguished Fellowship. This is a prestigious programme enables a UK university to host visits from world leading internationally-based researchers from an overseas centre of excellence. This award demonstrates the International relevance of the group which attracts UK institutions to start collaborations in Power Systems, Grid Integration and RES.

- **Field Test Pilot in GRACIOSA project**

  The Power System group has a key partner of the collaborative project GRACIOSA. This project led by ENDESA had as objective to demonstrate in the Graciosa Island (Canary Islands) the concept of Smart microgrids, by installing Energy storage, monitoring, photovoltaics and self-consumption Systems. IREC has been responsable of developing the microgrid manager and SCADA ensuring the proper interaction among all technologies. Video can be found in the following:
  https://twitter.com/Endesa/status/973499799474335744 and
  https://www.youtube.com/watch?v=aGJoSQS6Ym8&t=211s

- **Dissemination activities**

The Power Systems group have published several papers in relevant (high impact factor, Q1) scientific journals of the field, including IEEE Transactions, Elsevier, among others; and participated in a large number of events (including Mobile Talks, from Mobile World Congress) disseminating the results and Research lines being carried out by the team


Insights on the Provision of Frequency Support by Wind Power and the Impact on Energy Systems

Sustainable Energy Technologies and Assessments

Sensitivity analysis on the levelized cost of energy for floating offshore wind farms


Demonstration of a microgrid manager in a distribution grid with high PV penetration and Storage: La Graciosa case study

PUBLICATIONS

Articles and Journals from ISI Database

Sowa I., Domínguez-García J.L., Gomis-Bellmunt O.**"Impedance-based analysis of harmonic resonances in HVDC connected offshore wind power plants"**, 2019, Electric Power Systems Research, 166,61,72,1, 10.1016/j.epsr.2018.10.003, Article. IF:3.022.

Bianchi F.D., Dominguez-Garcia J.L., Vrana T.K.**"Distributed Frequency Control with Partial Information Using MT-HVDC Grids and WPPs"**, 2019, IEEE Systems Journal, 13,2,8470249,1694,1701,10.1109/JSYST.2018.2869547, Article. IF:4.463.

Agbemuko A.J., Domínguez-García J.L., Prieto-Araujo E., Gomis-Bellmunt O.**"Dynamic modelling and interaction analysis of multi-terminal VSC-HVDC grids through an impedance-based approach"**, 2019, International Journal of Electrical Power and Energy Systems, 113,874,887,1, 10.1016/j.ijepes.2019.06.029, Article. IF:4.418.

Boersma S., Doekemeijer B.M., Siniscalchi-Minna S., van Wingerden J.W.**"A constrained wind farm controller providing secondary frequency regulation: An LES study"**, 2019, Renewable Energy, 134,639,652,3, 10.1016/j.renene.2018.11.031, Article, Open Access. IF:5.439.

Siniscalchi-Minna S., Bianchi F.D., De-Prada-Gil M., Ocampo-Martinez C.**"A wind farm control strategy for power reserve maximization"**, 2019, Renewable Energy, 131,37,44,11, 10.1016/j.renene.2018.06.112, Article, Open Access. IF:5.439.

Wolff D., Casals L.C., Benveniste G., Corchero C., Trilla L.**"The effects of lithium sulfur battery ageing on second-life possibilities and environmental life cycle assessment studies"**, 2019, Energies, 12,12,2440,10.3390/en12122440, Article, Open Access. IF:2.707.

Lerch M., De-Prada-Gil M., Molins C.**"The influence of different wind and wave conditions on the energy yield and downtime of a Spar-buoy floating wind turbine"**, 2019, Renewable Energy, 136,1,14,2, 10.1016/j.renene.2018.12.096, Article. IF:5.439.

DOCTORAL THESES

Presented theses:

Date: November 2019
PhD student: Adedotun J. Agbemuko
PhD supervisor: Dr. Jose Luis Domínguez-García
Title: Control strategies for hybrid AC-DC grids

Ongoing theses:

PhD student: Paschalia Stefanidou-Voziki
PhD supervisor: Dr. Jose Luis Domínguez-García
Title: Fault detection and identification tools for distribution networks

PhD student: Sara Siniscalchi
PhD supervisor: Dr. Mikel De Prada
Title: Distributed control strategies for wind farms for grid support

PhD student: Anzhelika Ivanova
PhD supervisor: Dr. Jose Luis Domínguez-García
Title: Optimal Sensor placement for accurate state estimation in active distribution networks

PhD student: Markus Lerch
PhD supervisor: Dr. Mikel De Prada
Title: Techno-economic assessment, modelling and optimization for floating offshore wind farms

Date: November 2019
PhD student: Adedotun J. Agbemuko
PhD supervisor: Dr. Jose Luis Domínguez-García
Title: Control strategies for hybrid AC-DC grids

Patents:

Title: Multiphase generator-conversion systems
Publication number: WO2015086801 (A1)
Publication date: 2015-06-18
Inventors: Gomis Bellmunt, Oriol; Domínguez García, José Luis; Aragüés Peñalba, Mónica
Applicants: Alstom Renewable Technologies

International classification: H02J3/38, H02M5/458, H02M7/04
Cooperative Patent Classification: H02M7/04, H02J3/386, H02M5/22, H02M5/458
Application number: WO2014EP77518
Date of application: 2014/12/12
Priority numbers: EP20130382511 20131213

Title: Harmonics mitigation in multiphase generator-conversion systems
Publication number: WO2015086800 (A1)
Publication date: 2015-06-18
Inventors: Gomis Bellmunt, Oriol; De Prada Gil, Mikel; Díaz González, Francisco; Prieto Araujo, Eduardo
Applicants: Alstom Renewable Technologies
International classification: H02P9/10, H02P9/30, H02P21/00
Cooperative Patent Classification: H02P9/105, H02P9/30, H02P21/24, H02P2101/15
Application number: WO2014EP77516
Date of application: 2014/12/12
Priority numbers: EP20130382510 20131213

OUTREACH

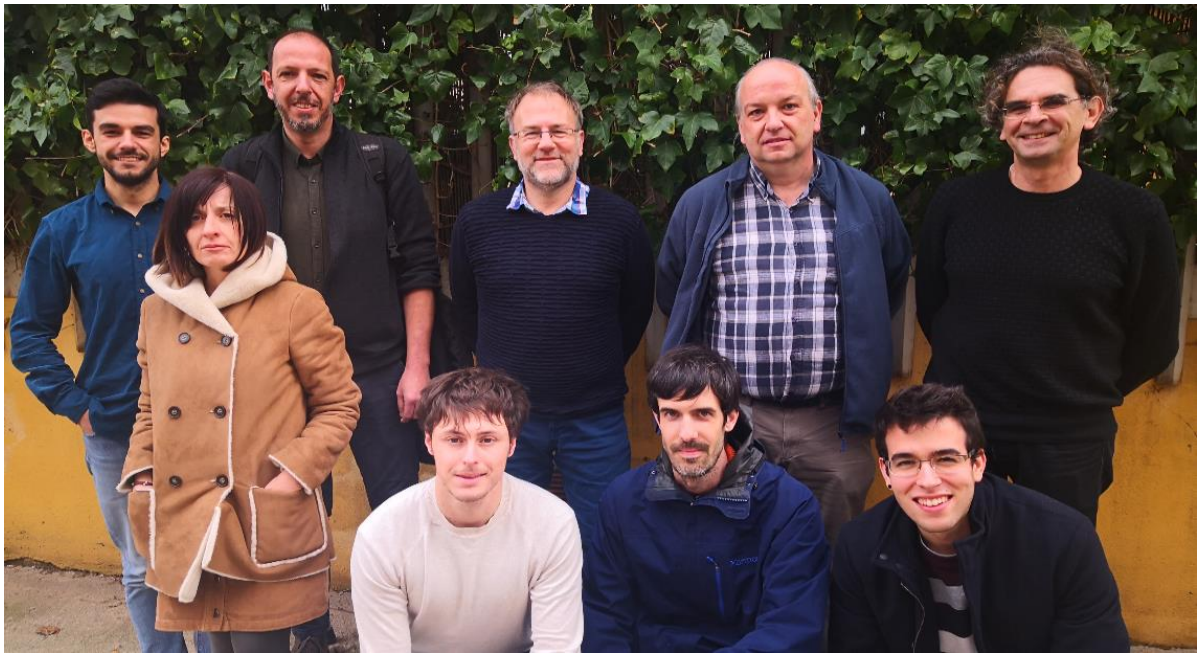
- Participation in a round table as speaker at the Mobile Talks on “Energy Digitalization”, Barcelona, Spain.
- Invited seminar on “frequency support provision from wind power plants” at University of Strathclyde, Glasgow, UK.
- Invited seminar on “Electric vehicles integration” at the Universitat Politecnica de Catalunya (UPC), Barcelona, Spain.
- Presentation and Lab visit for engineering students from EEBE (UPC)
- Presentation and Lab visit for International Master Students from InnoEnergy programmes.
- Participation at the SmartCity Expo World Congress, Barcelona, Spain
- Organization and host of a workshop on “new HVDC technologies and Integration”, with more than 30 international participants.
- Organization of the seminar “BlockChain and Energia” at IREC, Barcelona, Spain.

6.2.3. THERMAL ENERGY & BUILDING PERFORMANCE

The Team

(permanent and temporary positions, tenure tracks and fellowships)

Dr. Jaume Salom, Group Leader Dra. Elena Fuentes, Staff Scientist Dra. Joana Ortiz, Staff Scientist Dr. Joaquim Romaní, Postdoctoral Researcher Dr. Paolo Civero, Postdoctoral Researcher Dr. Jordi Pascual, Postdoctoral Researcher Juan Francisco Belio, Laboratory Support Paolo Taddeo, Project Engineer Thibault Pean, Predoctoral Student Ivan Bellanco, Predoctoral Student



Thermal Energy & Building Performance group aims to investigate and develop an integrated and systemic approach towards zero energy communities. Globally speaking, the building sector is responsible for 40% of primary energy consumption. Our vision is to investigate in solutions and strategies that accelerate the reduction of greenhouse gas emissions through human-centred design, energy efficiency measures, integration and management of energy systems, particularly distributed renewable sources in the built environment as part of urban communities.

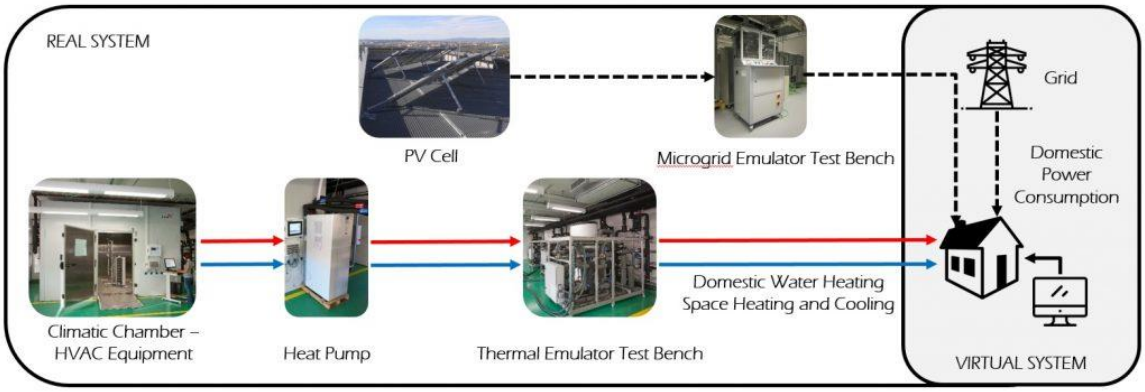
In order to develop solutions for reducing energy consumption, we take an approach that is not only technological, but also holistic in that it considers aspects that are crucial for

buildings, offices and cities, such as air quality, indoor environment and socio-economic impacts, including benefits on occupants' health. Buildings should be considered as nodes of the overall energy system that fight against climate change challenges, being so important to consider the integration with the energy infrastructures: the electrical grid or district heating and cooling networks.

The key research lines that define our activity are:

- Zero energy and flexible energy buildings and communities
- Energy infrastructures for low energy cities
- Green IT

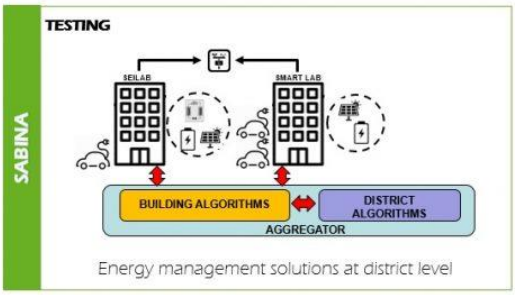
SEILAB provides advanced expertise to assess the development and integration of renewable energy solutions and innovative thermal and electrical equipment that are designed to improve energy efficiency in buildings and energy systems.

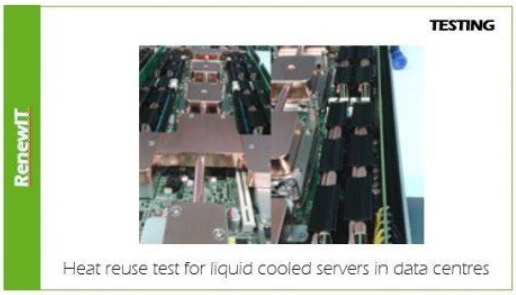


CAPABILITIES

- Semi-virtual testing approach: operation of real equipment as a function of dynamic virtual models
- Testing the performance of components or complex energy systems under defined building and environmental conditions
- Development and integration of innovative, sustainable and renewable building energy supply systems: thermal solar systems, photovoltaics, micro-cogeneration, energy storage, heat pumps and other HVAC equipment
- Analysis of equipment behaviour at particular transient phases
- SEILAB and Energy SmartLab are connected allowing to test aggregator policies and management strategies for districts

HIGHLIGHTS





PROJECTS

Title: SmArt BI-directional multi eNergy gAteway (SABINA)
Acronym: Sabina
Description: Flexibility needs to be added to Europe's power system to accommodate an increasing share of variable power generation from renewable sources. Indeed, service quality issues start to arise on the grid when this share in electricity consumption reaches 10%. To meet the EU's targets for reduction of greenhouse gas emissions this share should rise to 30% by 2030 and up to 50% by 2050. The cost of this transition and the necessary measures to guarantee stable and continuous supply are a major political concern. The SABINA project responds to it by targeting the cheapest possible source of flexibility: the existing thermal inertia in buildings and the coupling between heat and electricity networks it enables. This coupling requires accurately estimating the thermal inertia of many buildings. SABINA's partner the University of Navarra has created a breakthrough, automatic method for this estimation, which shall be scaled up, validated and integrated in a complete management system through this project. This system will operate on two complementary time horizons:
• One day: aggregation and management at the district level of the electric and thermal flexibilities, and conversion and storage of the excess electrical energy to thermal energy in the freely available building inertia.
• Seconds to minutes: local control of inverters feeding renewable electricity to the grid, with optimal parametersautomatically determined at the district level.
Research partners will develop novel control and optimization algorithms, and integrate and evaluate the system in lab and operational settings. The SABINA solution is compatible with both new and existing buildings; it is planned to be deployed within five years of the

end of the project. Lead users are present in the consortium: Telvent and SMS plc, the coordinator, for the architecture, and Insero for the business model it enables; compliance and contribution to relevant standards will be ensured by the European Digital SME Alliance.
Funding: H2020Project ID: 731211
Type: Competitive EU
Partners: SMS Energy Services Ltd (SMS), CSEM Centre Suisse D'electronique et de Microtechnique SA - Recherche et Developpement (CSEM), Universidad de Navarra (UNAV), Insero AS (INS), Fundacio Institut de Recerca en Energia de Catalunya (IREC), Schneider Electric Espana SA (SCHE), National Technical University of Athens - NTUA (NTUA), European Digital Sme Alliance (DSME), Amires Sro (AMI).
Date: 11/1/2016-10/31/2020
Group: Thermal Energy & Building Performance
P.I: Jaume Salom Tormo
Other group: Energy Systems Analitics- Dr. Cristina Corchero García
URL: https://sabina-project.eu/,https://drive.google.com/open?id=1avCG-Xxt2v5DaeQJmFe_ZY9tjigejNBR

Title: Trigeneration systems based on heat pumps with natural refrigerants and multiple renewable sources
Acronym: TRI-HP
Description: The overall goal of the TRI-HP project is the development and demonstration of flexible energy-efficient andaffordable trigeneration systems. The systems will be based on electrically driven natural refrigerant heat pumpscoupled with renewable electricity generators (PV), using cold (ice slurry), heat and electricity storages to provideheating, cooling and electricity to multi-family residential buildings with a self-consumed renewable share of 80%.TRI-HP systems will include advanced controls, managing electricity, heat and cold in a way that optimizes theperformance of the system and increases its reliability via failure self-detection. The flexibility will be achieved byallowing for three heat sources: solar (with ice/water as storage medium), ground and ambient air. The innovationsproposed will reduce the system cost by at least 10-15% compared to current heat pump technologies with equivalentenergetic performances. Two natural refrigerants with very low global warming potential, propane and carbon dioxide, will be used as working fluids for adapted system architectures that specifically target the different heating andcooling demands across Europe. The newly-developed systems will find application in both new and refurbishedmulti-family buildings, allowing to cover the major part of Europe's building stock. The new systems reduce GHGemissions by 75% compared to gas boilers and air chillers. The TRI-HP project will provide the most appropriateknowledge and technical solutions in order to cope with stakeholder's needs, building demand characteristics, localregulations and social barriers. Two system concepts will be developed for two different combinations of heat sources, i) dual ground/air source and ii) solar with ice-slurry as intermediate storage. These two concepts combined with thetwo heat pump types developed (CO2 and propane) will lead to three complete systems (CO2-ice, propane-ice andpropane-dual) that will be tested in the laboratory.

Funding: H2020
Project ID: 814888
Type: Competitive EU
Partners: HSR Hochschule Fur Technik Rapperswil (HSR), Fundacion Tecnalia Research & Innovation (TECNALIA), Cadena Systems AG (Cadena), Fundacio Institut de Recerca en Energia de Catalunya (IREC), Alfa Laval Lund AB (ALFA LAVAL), Industrielack AG (ILAG), ISOE GMBH , Norges Teknisk-Naturvitenskapelige Universitet NTNU (NTNU), Teknologisk Institut (DTI), Hochschule Karlsruhe-Technik und Wirtschaft (UASKA), Federatie Van Verenigingen Voor Verwarming Enluchtbehandeling In Europa Vereniging (REHVA), Grvefc SL (EFC).
Date: 3/1/2019-2/28/2023
Group: Thermal Energy & Building Performance
P.I: Jaume Salom Tormo
Other group: Energy Systems Analitics- Dr. Cristina Corchero García
URL: https://www.rehva.eu/eu-projects/project/tri-hp,https://drive.google.com/open?id=1lvLa7wUTs_gOJwSnSBLjgnS14vliNU84

Title: MED programme Networks for an Innovative Cooperation in Energy efficiency
Acronym: Mednice
Description: The Horizontal Project MEDNICE, lead by the Euromed Cities Network, will anchor a MED community around energy issues that public organisations face, as a hub for Energy Efficiency (EE) innovative and shared solutions, in order to promote modular projects' results and increase their impact on public policies. This strategic project of coordination, communication, and capitalization relies on the support and the participation of all the actors working on this topic. The Euromed Cities Network, comprising around 150 cities in 25 countries of Europe and the Mediterranean shores, has been selected after responding the call of proposals opened by the Interreg Med Programme, covering 13 countries, from Portugal to Cyprus. The Energy Efficiency issue is at the core of the European action. Working together with a relevant European scale consortium (*), the Euromed Cities Network will coordinate 10 modular projects.
Funding: Med Programme
Project ID: 2MED15_2.1_HP_007
Type: Competitive EU
Partners; City of Nice, Energy Cities, Fundacio Institut de Recerca en Energia de Catalunya (IREC), Euro-Mediterranean Center on Climate Change Foundation, Regio of Noth Aegean.
Date: 7/1/2016-10/31/2019
Group: Thermal Energy & Building Performance
P.I: Joana Aina Ortiz
URL: https://efficient-buildings.interreg-med.eu/,https://drive.google.com/open?id=1wIEUvbDMjkujB_QLUABqgyEIcyKP_IE4

Title: Bases de disseny d'una microsolució tic eficienjt i competitiva
Acronym: MICROTIC

Description: El projecte d'innovació de microsolucions TIC eficients i competitives per a PIMER pretén crear les bases d'un producte/solució que cobreixi les necessitats de les PIMES. Les PIMES actualment no poden disposar de solucions TIC ""all in one"" (dades, connectivitat, seguretat, escalables, eficients energèticament i portables) que les acompanyin en l'evolució del seu negoci. A mès a mès es pretén innovar en el possible model de negoci entenent l'actual com un potencial fre, intertant ajudar a la PIME a maximitzar l'ús del seu capital al sey core business, i minimitzant l'impacte de la potencial inversió en solucions TIC.
Funding: Ris3Cat
Project ID: COMRD15-1-0040-01
Type: Competitive Nationals
Partners: Armengol & Ros Consultors i Associats SLP (ARCBcn), Schneider Electric España SA, Fundacio Institut de Recerca en Energia de Catalunya (IREC)
Date: 11/2/2016-11/30/2019
Group: Thermal Energy & Building Performance
P.I: Jaume Salom Tormo

Title: PEDRERA. Positive Energy Districts renovation model
Acronym: PEDRERA
Description: PEDRERA project aims to provide an innovative energy renovation model able to accelerate the urban transition towards Positive Energy Districts (PEDs) in the new era of emerging smart technologies and to validate economic feasibility of the business models, guaranteeing interoperability and replicability at EU scale. The use of the SDL language will afford maximum flexibility to the model, integrating GIS, new processes and procedures to the system in a co-simulation scenario of energy efficiency measures at district scale. The impact of the competencies provided by the host institutions and achieved during the fellowship will shape an expert profile in Energy Efficiency for working in internationally recognized academic centers, research agencies or R&D companies.
Funding: Accio
Project ID: TECSPR18-1-0044
Type: Competitive Nationals
Partners: Fundacio Institut de Recerca en Energia de Catalunya (IREC)
Date: 8/26/2019-8/25/2021
Group: Thermal Energy & Building Performance
P.I: Paolo Civiero

Title: Smart and local reneWable Energy DISTRICT heating and cooling solutions for sustainable living
Acronym: WEDISTRICT
Description: The overall objective of WEDISTRICT is to demonstrate DHC as an integrated solution that exploits the combination of RES, thermal storage and waste heat recycling technologies to satisfy 100% of the heating and cooling energy demand in new DHC and up

to 60-100% in retrofitted DHC. For this purpose, the focus of WEDISTRICT is largescale replication of best practice: better valorisation of local resources, like renewable and waste heat by making District Heating and Cooling networks more efficient in relation to the use of new resources. In parallel, systems will evolve to provide even more flexible solutions by the integration of innovative molten-salts based thermal storage, the interaction with other energy networks (electricity and gas) and the involvement of end-users (operators and consumers) through ICT-based control and decision making. Finally, to enable significant expansion, costeffectiveness will be enhanced by transitioning from handicraft to more industrialised solutions that integrate LEAN methodologies to optimise processes and lower costs.
Funding: H2020
Project ID: 57801
Type: Competitive EU
Partners: Ingenieria Especializada Obra Civil e Industrial SA (ACCING), District Heating Eco Energias SL (DHECO), Atos Spain SA, Ramboll Danmark A/S (RAM), Compania Espanola De Petroleos SA (CEPSA), Universitatea Politehnica din Bucuresti (UPB), Rise Research Institutes of Sweden AB (RISE), Fundacio Institut de Recerca en Energia de Catalunya (IREC), European Science Communication Institute GGMBH (ESCI), R2M Solution (R2M SOLUTION), Laterizi Gambettola SRL (SOLTIGUA), Fresnex GMBH (FRESNEX), Seenso Renoval SL (SEE), Cirkularni Energetski Resursi doo za Projektiranje i Izgradnju
Energetskih Postrojenja (CER), Fertiberia SA (FERTIBERIA), Universidad de Cordoba (UCO), ISPE Proiectare si Consultanta SA (ISPE), Aalborg CSP AS (ACSP), Universidad Politecnica de Madrid (UPM), PGNIG Termika Energetyka Rozproszona SP. Z O.O (PTER),
Krajowa Agencja Poszanowania Energii Spolka Akcyjna (KAPE), AAF SA.
Date: 10/1/2019-4/1/2023
Group: Thermal Energy & Building Performance
P.I: Jaume Salom Tormo
URL: https://cordis.europa.eu/project/rcn/224589/factsheet/en,NO

Title: ECOS SGR 2017-2019
Acronym: ECOS SGR 2017-2019
Description: L'activitat científica del grup ECOS es focalitza en l'eficiència energètica i les energies renovables, especialment focalitzat en les energies renovables distribuïdes i les Smart Cities, amb una marcada orientació al desenvolupament tecnològic i de mercat en les següents línies:
- Edificis i Districtes d'Energia Neta nul·la
- Micro-xarxes i xarxes intel·ligents
- Integració de Renovables i emmagatzematge
- Green IT – Eficiència Energètica i renovables aplicada a les tecnologies de la informació
- Mobilitat Elèctrica
- Energia Eòlica Offshore
- Economia de l'Energia i Regulació

El grup ECOS disposa d'infraestructures i laboratoris concebuts com a plataformes flexibles i polivalents tant per al desenvolupament tecnològic amb industria com per a projectes competitius de recerca; entre d'altres: micro-xarxa, wind-lab, wind-pilot, SEILAB.

Funding: SGR
Project ID: 2017 SGR 1219
Type: Competitive Nationals
Partners: FUNDACIO INSTITUT DE RECERCA DE L'ENERGIA DE CATALUNYA
Date: 1/1/2018-12/31/2020
Group: Thermal Energy & Building Performance
P.I: Jaume Salom Tormo
Other group: Energy Systems Analitics- Dr. Cristina Corchero, Power Systems- Dr. José Luis Domínguez García

Title: Efficient Buildings
Acronym: Efficient Buildings
Description: As a MED hub for Energy Efficiency (EE) innovative and shared solutions, the MEDNICE project will anchor a MED community around energy issues that public organisations face in order to promote modular projects' results and increase their impact on public policies. Indeed, in the MED area, the majority of public buildings is not adequately designed to reduce their energy consumption and improve their EE performance. This is partly due to a lack of awareness of owners and managers and knowledge gaps regarding common answers to this transnational challenge. Thus the overall objective of MEDNICE is to empower MED projects' partners through the establishment of a MED community and a joint transnational framework around energy efficiency in public buildings. By setting up training and peer learning mechanisms, MEDNICE will contribute to increase the capacity of owners and managers of public buildings to design and implement better energy efficiency practices. It will set up a knowledge platform that will allow for capitalizing and communicating results and outputs of the modular projects. It will serve as a cornerstone of a transnational peer network laying the ground for a MED identity. MEDNICE will also analyze and summarize EE practices through thematic and policy papers to be promoted and benefit the MED community. Relying on Ambassadors this will help disseminate and transfer messages in order to advocate for specific MED EE policies and mainstream them in relevant strategies.
Funding: Med Programme
Project ID: 7MED19_2.1_HP_008
Type: Competitive Nationals
Partners: City of Nice, Energy Cities, Fundacio Institut de Recerca en Energia de Catalunya (IREC), Euro-Mediterranean Centre on Climate Change Foundation, University of Patras-Department of Civil Engineering, Centre for Renewable Energy Sources and Saving (CRES), Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), Portuguese Energy Agency.
Date: 11/1/2019-10/31/2023
Group: Thermal Energy & Building Performance
P.I: Jordi Pascual

PUBLICATIONS

Articles and Journals from ISI Database

Ortiz J., Casquero-Modrego N., Salom J.**"Health and related economic effects of residential energy retrofitting in Spain"**, 2019, Energy Policy, 130,375,388,1, 10.1016/j.enpol.2019.04.013, Article. IF:4.88.

Péan T., Costa-Castelló R., Fuentes E., Salom J.**"Experimental Testing of Variable Speed Heat Pump Control Strategies for Enhancing Energy Flexibility in Buildings"**, 2019, IEEE Access, 7,37071,37087,2,10.1109/ACCESS.2019.2903084, Article, Open Access. IF:4.098.

Péan T.Q., Salom J., Costa-Castelló R.**"Review of control strategies for improving the energy flexibility provided by heat pump systems in buildings"**, 2019, Journal of Process Control, 74,35,49,12, 10.1016/j.jprocont.2018.03.006, Article. IF:3.316.

Péan T., Costa-Castelló R., Salom J.**"Price and carbon-based energy flexibility of residential heating and cooling loads using model predictive control"**, 2019, Sustainable Cities and Society, 50,101579, 10.1016/j.scs.2019.101579, Article. IF:4.624.

Oró E., Taddeo P., Salom J.**"Waste heat recovery from urban air cooled data centres to increase energy efficiency of district heating networks"**, 2019, Sustainable Cities and Society, 45,522,542,6, 10.1016/j.scs.2018.12.012, Article. IF:4.624.

DOCTORAL THESES

Ongoing Theses:

PhD student: Thibault Q. Péan
PhD supervisor: Dr. Jaume Salom, Dr. Ramon Costa-Castelló
Title: Heat pump controls to exploit the energy flexibility of building thermal loads

PhD student: Ivan Bellanco Bellanco
PhD supervisor: Dr. Jaume Salom, Dr. Joan Manel Vallès Rasquera
Title: Automatic fault detection in domestic heat pump

OUTREACH

- Organization of the 6th Working Experts Meeting of the IEA EBC Annex67 Energy Flexible Buildings in Barcelona, Campus Diagonal Besòs, 26-28 March 2018 with more than 60 international experts attending

- Organization of Public Workshop "Energy Flexibility in Buildings: a Key asset in the future energy system", March 26, 2018, Sala Cotxeres Palau Robert, Barcelona, with two presentations from the group
    - Potential of low-energy residential buildings as thermal energy storage in district heating systems, Kyriaki Foteinaki, Technical University of Denmark (DTU), Invited Ph.D candidate at IREC
    - Potential of control strategies to enhance energy flexibility in residential buildings in Catalonia, Thibault Pean, IREC / INCITE EU project

- Organizes the workshop "Introduction to Nearly Zero Energy Buildings (nZEB)" at the School of Engineering of Barcelona East - EEBE (UPC), October 10th, 2018. The objective of the session is to introduce to the engineering students what is a nZEB building and which are its characteristics. The design and operation challenges to achieve an efficient buildings stock will be presented, as well as some best practices.

- Joint Organization with ICAEN, IREC, Leitat, Eurecat i CIMNE, of the 4th Eidtion of ”Curs sobre edificis de consum d’energia gairebé zero (nZEB)” with 6 sessions. October – November 2019. Specific contributions from IREC:
    - Rehabilitació energètica a escala de districte: experiències i oportunitats. Jaume Salom
    - Mesura d’inflitracions, Paolo Taddeo

- Organization of the seminar " Efficient systems integrating renewables in buildings and grid interaction " October 26th, 2018 with three presentations
    - “A co-simulation framework for assessing the interaction between heat pumps and the low voltage grid on a district scale” by Jalomi Maayan Tardif
    - “Energy Flexibility Strategies for Residential Buildings in Mediterranean Climates” by Ricardo Toffanin.
    - “Experimental investigation on the performance of a thermally-driven solar cooling System” by Ivan Bellanco.

- Participation in the 7th Working Experts Meeting of the IEA EBC Annex67 Energy Flexible Buildings in Montreal (Canada), École Polytechnique de Montréal, 10-12 October 2018 with more than 40 international experts attending
    - Free Case Presentation: “Co-Simulation Platform for the Assessment of the Interaction Between Heat Pumps and the Low Voltage Grid at the Feeder Level”

- Participation in the Follow up meetings as Invited Experts of the CESBA MED Project (Sustainable Med Cities), Ramon Pascual. Several meetings in the year.

- Workshop "Energy efficiency in sports facilities. Future challenges", organized jointly with the CCE, Institut Català d'Energia (ICAEN) and IREC, in the framweork of the Sustainable Energy Week. Presentation of the study:
    - "Energy diagnostic and potential energy savings of the sport facilities in Catalonia”, Joana Ortiz

- Sesion “Rehabilitación energética de la envolvente MASTER RERU”, Instituto Valenciano de la Edificación, Valencia, 26 Abril 2018

- Publication of the Report ”Residential Retrofits at District Level” together with InnoEnergy, IREC and AIGUASOL,. The study proposes different business models for large-scale retrofitting of residential building stock in urban areas, including cost-optimal energy efficiency measures, as a means to unblock poor residential retrofitting rates in EU Southern countries. Available on-line at: http://www.irec.cat/en/download-document/1920-residential_retrofits_web.html

- Participation as speaker in the seminar “Present i futur de les certificacions energètiques, edificis NZEB” organized by ACTECIR, Barcelona, 25 April 2018. Agenda: http://www.actecir.cat/images/icagenda/files/certificacions-enegetiques.pdf

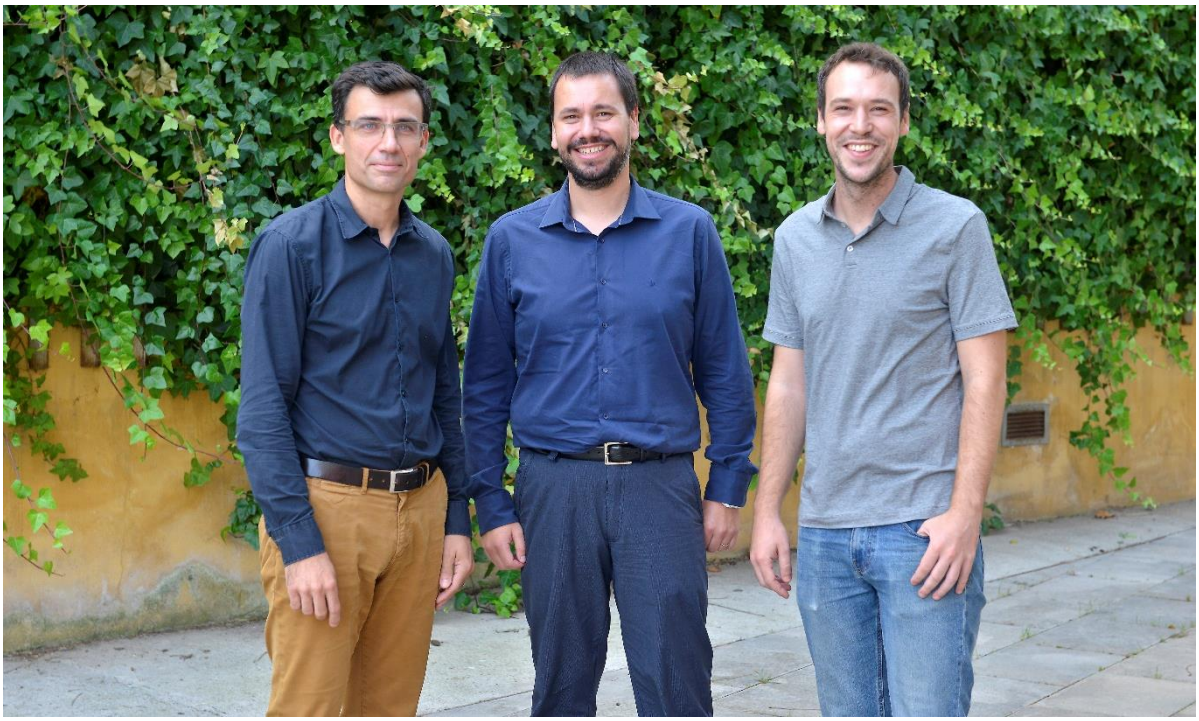
- Participation as speaker in the seminar “Soluciones técnico-económicas para la rehabilitación energètica de edificos” organized by Region de Murcia and the REHABILTE project, Murcia, 19 November 2018. Agenda: http://rehabilite.eu/uploads/downloads/programa-jornada-murcia-jueves-22-de-noviembre-de-2018/es/programa-jornada-murcia-jueves-22-de-noviembre-de-2018.pdf

7. PROGRAMMES

7.1. Program for Fusion Technology Development (bFUS)

The Team
(permanent and temporary positions, tenure tracks and fellowships)

Manel Sanmartí, Head of bFUS Program Oriol Nomen, Staff Engineer Daniel Sanchez, project engineer



Since 2010 IREC has been leading the “Barcelona Fusion Centre” (bFUS) programme with the aim of promoting and boosting research activities in the field of nuclear fusion technologies in Catalonia. This programme was developed within the framework of the international project ITER and the European Fusion Program by EUROfusion. IREC has been working on mechanical design of fusion components, energy storage systems, grid integration studies, cryogenics and cryodistribution, fuel cycle and superconductivity.

Since 2018, IREC has become the System Responsible of the High Energy Beam Transport Line (HEBT) and Beam Dump Subsystem of the Accelerator of the IFMIF DONES Facility. DONES is expected to be built in Granada, Spain and it will be the 1st facility to provide experimental data on the behavior of fusion reactor candidate materials under neutron irradiation levels of a fusion machine.

The bFUS Programme has also allowed IREC to establish technology transfer collaborations with Catalan industry. These collaborations have increased their technology capabilities allowing them to obtain industrial contracts in nuclear fusion and particle accelerators programs.

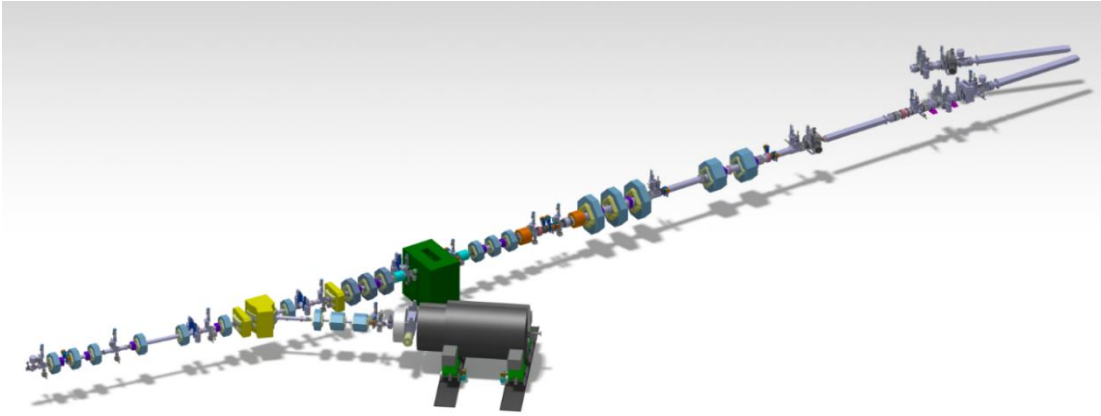
HIGHLIGHTS GROUP

- **IREC contributes to the IFMIF LIPAc fusion materials test facility in Japan**

  Members of the bFUS group have been contributing to the installation and commissioning of the HEBT and the Beam Dump of the Linear IFMIF Particle Accelerator (LIPAc) at Rokkasho, Japan, in the framework of the IFMIF/EVEDA project. The LIPAc is the 1st prototype accelerator aiming to demonstrate the feasibility of the accelerator for the International Fusion Materials Irradiation Facility (IFMIF).

- **System Responsible for the HEBT and Beam Dump of IFMIF DONES.**

During 2018, IREC has become the System Responsible of the HEBT and Beam Dump Subsystem of the Accelerator of the IFMIF DONES Facility. DONES is expected to be built in Granada, Spain and it will be the 1st facility to provide experimental data on the behaviour of fusion reactor candidate materials under neutron irradiation levels of a fusion machine.



PROJECTS

Title: DONES
Acronym: DONES
Funding: H2020
Type: Competitive EU, Linked third party
Date: 1/1/2018-12/31/2020
Group: B_Fus
P.I: Oriol Nomen Escoda

Title: Fusion in Catalonia
Acronym: FusionCAT
Description: The objective of FusionCAT is to establish an active fusion community in Catalonia. FusionCAT is formed by 7 partners that are leading institutions in Catalonia in their respective fields. Most of them have on-going involvement in fusion R&D through participation in the EU fusion research programme, contracts with ITER and Fusion for Energy (F4E), national fusion projects as well as collaborations with CIEMAT. FusionCAT consists of 11 original R&D projects, organized in 3 focused work packages building on the complementary fields of well-recognized expertise of the partners and the synergies between them, as well as a strong dissemination and technology transfer programme. It aims to establish technology transfer from the partners to industry in order to develop industrial competences in Catalonia for the realization of fusion energy. Transfer of relevant know-how is sought in particular. This is essential and timely because the development of fusion energy requires that the role of the industry changes from being a provider of high-technology components to being the driver of fusion development. The projects focus on numerical modelling, analysis and design of fusion reactor components and processes, fusion reactor software development (including high performance computing) and validation as well as diagnostic methods and instrumentation. The key fusion technologies addressed are tritium breeding blankets, high temperature superconducting magnets and fusion reactor materials. Seven companies have already expressed their interest to participate in the Industrial Advisory Board of the project. It facilitates the exchange of ideas and contacts with industrial stakeholders. In addition, an Advisory Board is formed by invited world-leading experts in the field. The main key indicators will be the number of highly-skilled jobs created and the number of contracts and collaboration agreements with industry.
Funding: Emergents
Project ID: IU16-011702
Type: Competitive Nationals
Partners: Barcelona Supercomputing Center-Centro Nacional de Supercomputación (BSC-CNS), Fundació b_TEC Campus Diagonal-Besòs (BTEC), EURECAT Centre Tecnològic de Catalunya (EURECAT, Institut de Ciència de Materials de Barcelona (ICMAB-CSIC), Institut Químic de Sarrià (IQS), Institut de Recerca en Energia de Catalunya (IREC), Universitat Politècnica de Catalunya (UPC)
Date: 7/1/2019-6/30/2022
Group: b_Fus
P.I: Oriol Nomen Escoda

DOCTORAL THESES

Ongoing theses:

PhD candidate: Oriol Nomen
Title: Beam transport and beam dump sections of facilities for qualification of fusion reactors materials
Director: Dr. Youri Koubychine (UPC), Dr. Fernando Arranz (Ciemat)

Date: 2019

OUTREACH

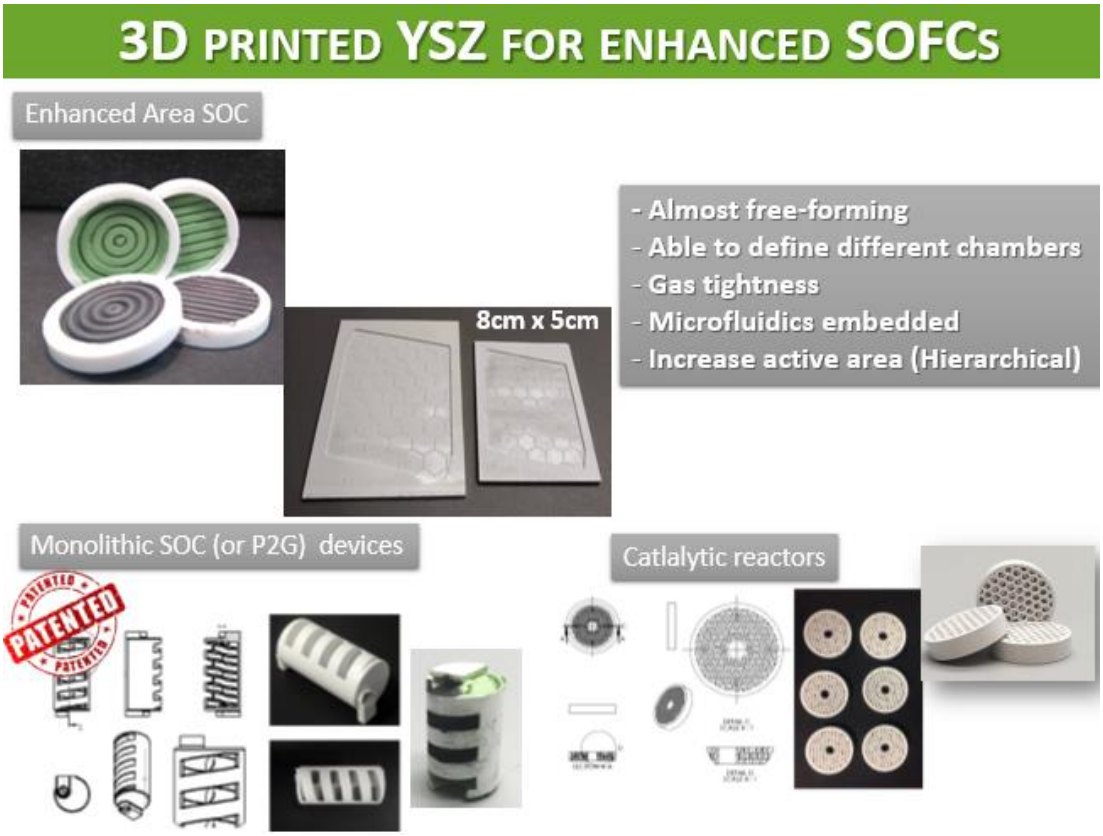
- Participation in the 5th WPENS Technical Meeting at Saclay, France. 10th – 12th April 2018.

- Participation in the 6th WPENS Technical Meeting at Kraków, Poland. 17th – 19th October 2018.

8. SCIENTIFICAL AND INSTITUTIONAL HIGHLIGHTS

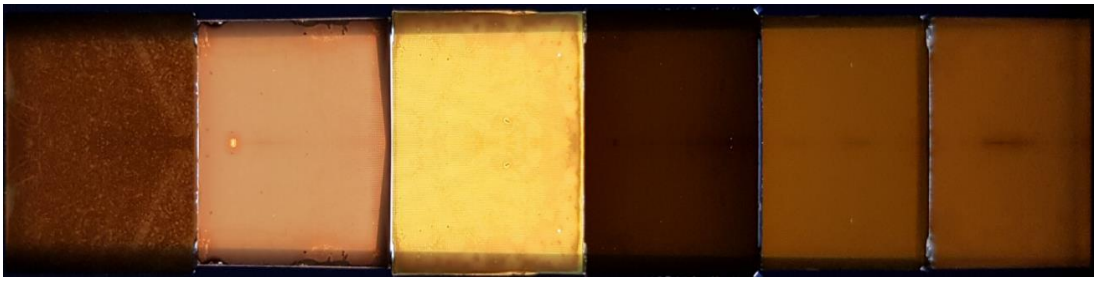
- <u>3D advanced ceramics printing technologies</u>

IREC undertakes the energy challenges reinforcing our expertise in smart functional materials developing greener and costeffective upscalable technologies,
Therfore, new 3D advanced ceramic printing technologies have been implemented highlighting additive manufacturing technologies for large area materials at high performance/low cost.



- <u>High efficient photovoltaic thin film for Building Integrated PV</u>

  Thin film photovoltaic is a promising alternative especially addressed for building integrated photovoltaic. It can cover more than 20% of the overall PV market in the next future.
  IREC has success in the implementation of different PV thin films technologies, especially kesterites, in ceramic tiles as support.
  Likewise, this high efficient IREC PV technology has industrially been assessed to implement smart window.



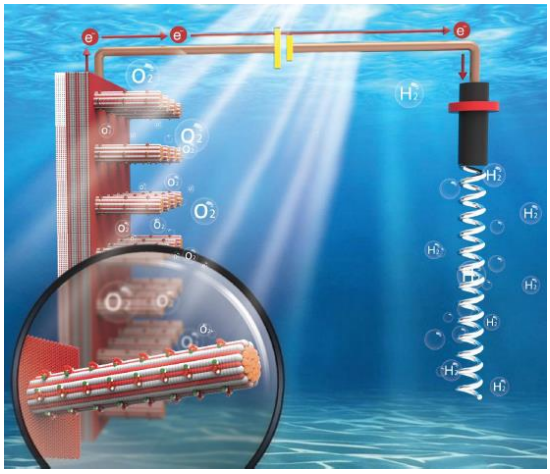
PV thin films integrated into ceramic tiles.

IREC semi-transparent absorbers for solar windows

EC has approved an important coordinated project, "Solar Win", in the Fast Track program to promote Innovation. It is focused on the demonstration and test at the industrial scale and in conditions real of the next-generation photovoltaic windows transparent and non-intrusive, which are a strong increase in the area available in buildings for the generation of photovoltaic electricity.
Likewise, IREC is coordinating the "Tech4Win" EC project- It is focused on photovoltaic cells applied to transparent glass for buildings

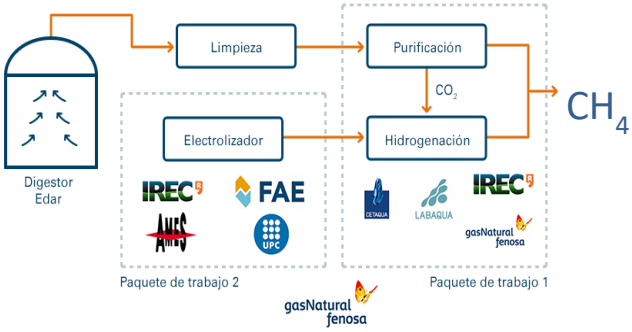
- <u>Solar Hydrogen Pilot Plant</u>

A two-year service provision contract with Repsol and Enagás, for the development of solar fuel generation technologies addressed to implement a pilot plant for the solar hydrogen production has been signed.



- <u>Methanation Pilot Plant</u>.

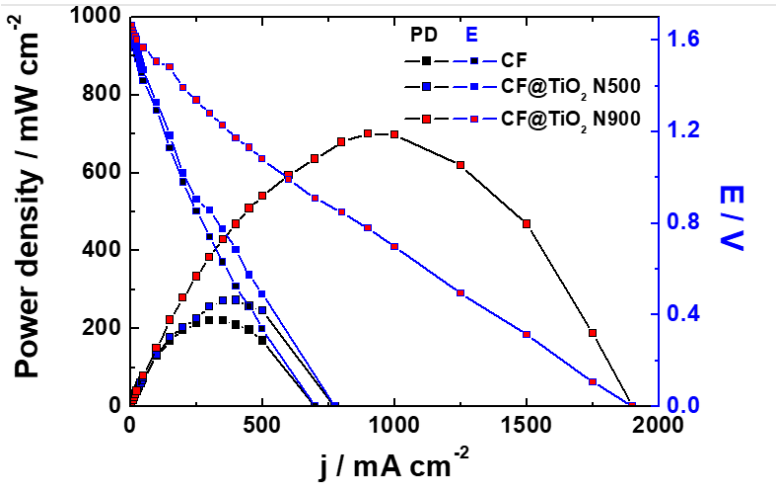
IREC has moved their advanced laboratory results to a field pilot plant in a waste water depuration plant located in Sabadell as example of new strategies for CO2 reduction on the base of power to gas technologies in new energy models for a sostenible society.



ENERGY WEEK
An initiative of the European Commission
ENERGIA
CO_2SIN

- New applications of redox flow batteries.

IREC is collaborating with the company HidraRedox for developing new prototypes of flow redox batteries.



- Recharging station for electrical vehicle

IREC has launched several new applications for enhancing electrical mobility. Based on the results of the Cofast project by IREC, a new recharging station has been implemented in Mataró.

- Advanced harvesting systems based on nanoionica.

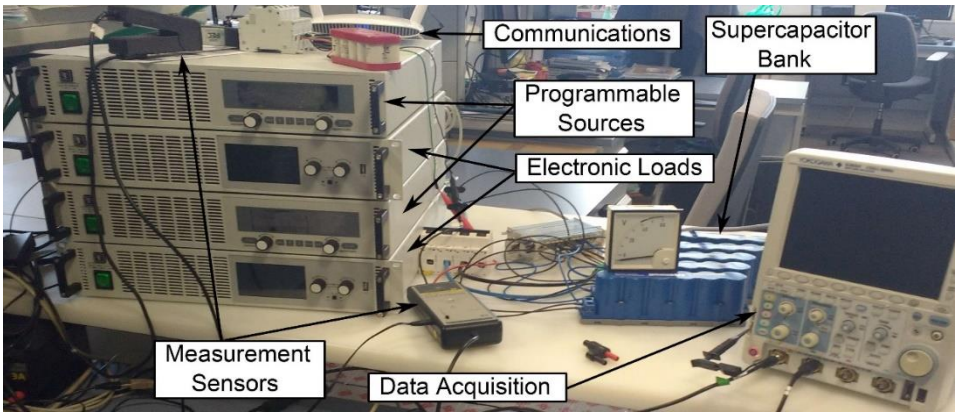
Recent approval of the European “Harvestore” project. It is a large coordinated project of the call “FET Proactive” of the nanoionics research line, focused on portable energy sources. The "µ-harvestorers" developed in this project will collect and store energy from heat and light at the same time, to serve for a new generation portable devices. They will be powerful, small and friendly to the environment

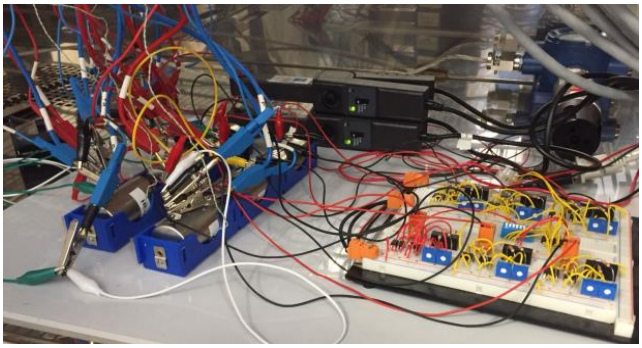
- IREC is collaborating with the Port Authority of Barcelona

Recent agreement with the Port Authority of Barcelona to enhance the collaboration of both institutions, and submit joint project proposals with the participation of APB, TMB, Air Liquide, Naturgy or Enagás, and promote the application of hydrogen technologies in the Port of Barcelona. First service provision agreement for the definition of the APB strategic plan.

- New battery management system for LiS battery has been implemented.

In the frame of the EU Helis project where high performant LiS cells have been developed by IREC, now a new management systems have been implemented to facilitate the application of these type of advanced and highly performant batteries for electrical mobility





- Wind offshore project

  "Corewind" is a new project coordinated by IREC, focused on reducing the costs of offshore floating wind energy. Our technical tasks focus on the optimization of the wiring of the offshore wind farm.

- Stratgegy Cyber security program for new management of the energy

  "SDN MicroSense" is a project focused on the analysis of cybersecurity in electrical networks, increasing your resilience. Our technical tasks include the development of new controls and network management algorithms.

- Smart grids applied at the Graciosa Island.

  IREC smart management developments have been applied in the Graciosa Island project implemented for assessing the reability of the new energy models in a sostenible society based in the management of the smart grids.

- New strategy in the integration of renewable eneergies in buildings.

  The European project "We District" has been aproved. Its objective is to demonstrate the integration of energies renewable, thermal accumulation systems and waste heat recovery systems in district heat networks and cold (District Heating and Cooling) to meet up to 100% of the demand for heating and cooling in networks.
  Calculation and monitoring of the demonstrator associated with heat recovery of CPDs with DHC fuel cells.
  In addition to other transversal projects, the objective of the project is to develop a masterplan for positive energy neighborhoods, considering technical, financial, legal and social aspects, in different European contexts, climates and markets, including its demonstration in pilot buildings / neighborhoods. IREC is leading the work package for the development of energy flexibility management technology in buildings and neighborhoods and the development of simulation tools at the urban level. Design and evaluation of the demonstration of "La Estrella" in the city of Badalona (2 buildings with 64 homes)

- IREC in the Nature Index database

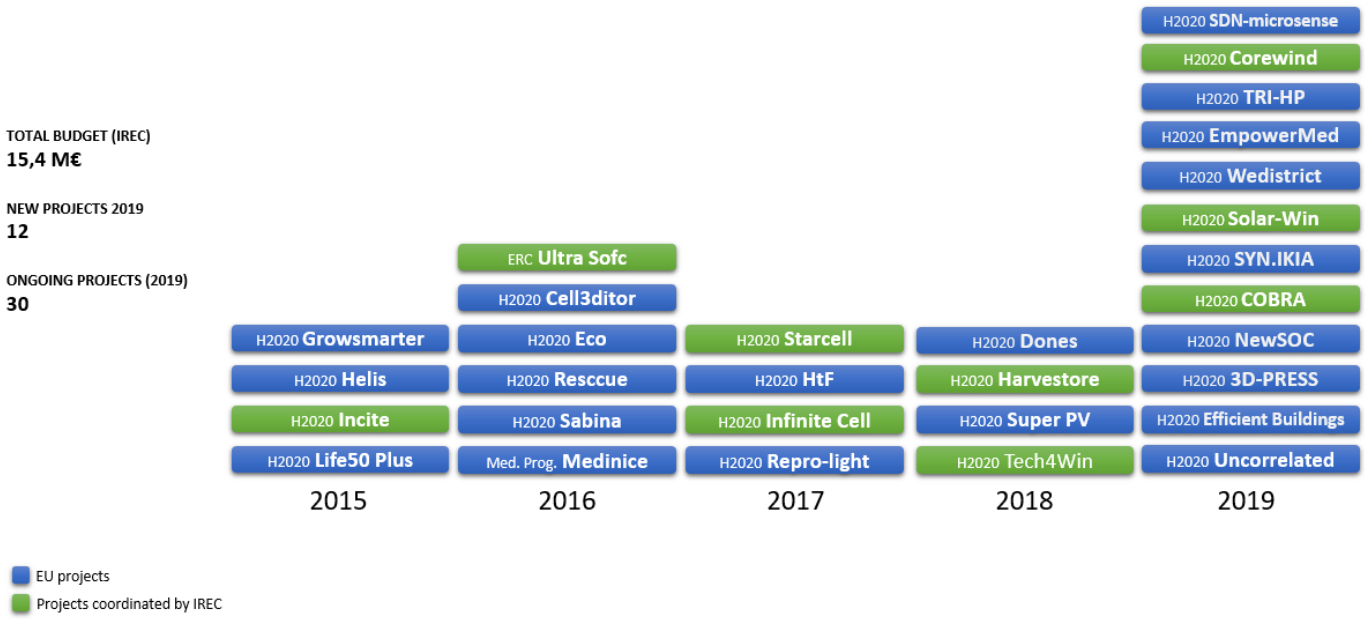
IREC, in spite of its small size in comparison to other institutions, has confirmed its excellence in science in the Nature Index 2018. According to it, IREC has been ranked in the top positions as Catalonian research centers or as Spanish center in comparison with other institutions working in the field of energy. The Nature Index database, which tracks the author affiliations collected from high quality scientific articles published in 68 high quality science journals independently selected by a panel of active scientists, is an indicator of an institution impact compared to other ones in the world.

9. SCIENTIFIC AND TECHNOLOGIC INPUTS SUMMARY

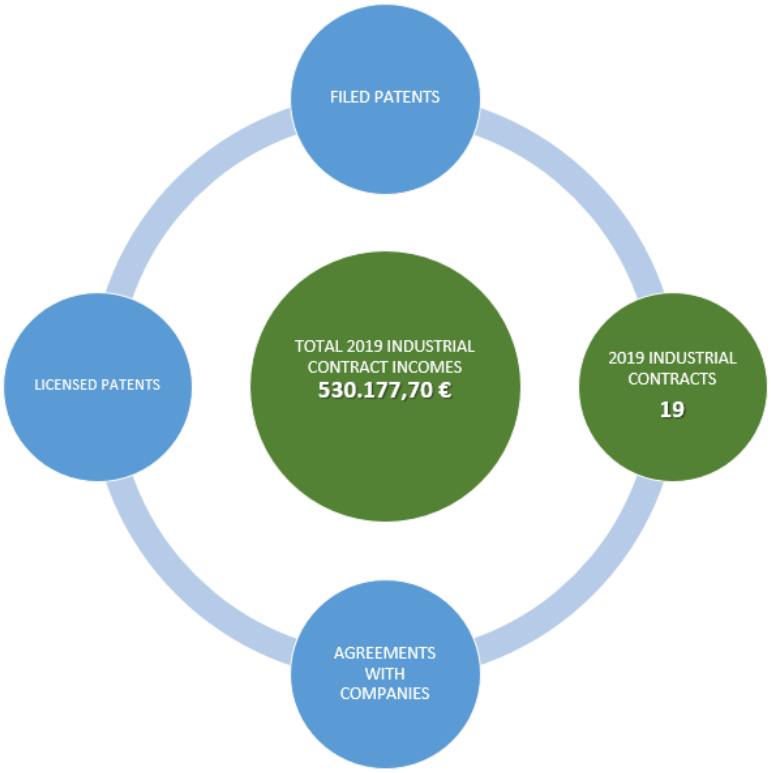
IREC's PROJECTS SUMMARY

The weighted average Technology Readyness Level of IREC ongoing projects is 4.5.

The following the picture shows a detail of the 30 European ongoing projects during 2019, identifying the year from the start of each project and also the role of IREC, as well as coordinating or participating in the projects. During 2019, 12 new European projects were funded by the European Comission. These 30 European projects in execution during 2019, involve a total amount of 15,4 million euros of European funding.



Following, the picture shows a detail of actions connecting industry with our knowledge and developments, as industrial projects and patents (filed and licensed):

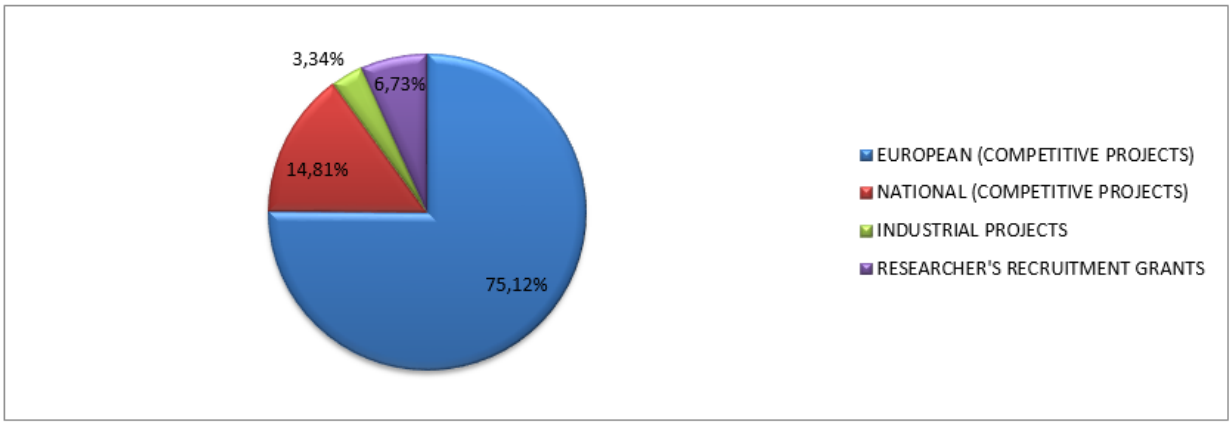


ONGOING PROJECTS

Regarding current situation at the end of December 2019, we show the amount and share of the ongoing projects portfolio.

Figures below show the expected income for the next years from the ongoing projects at the end of 2019:

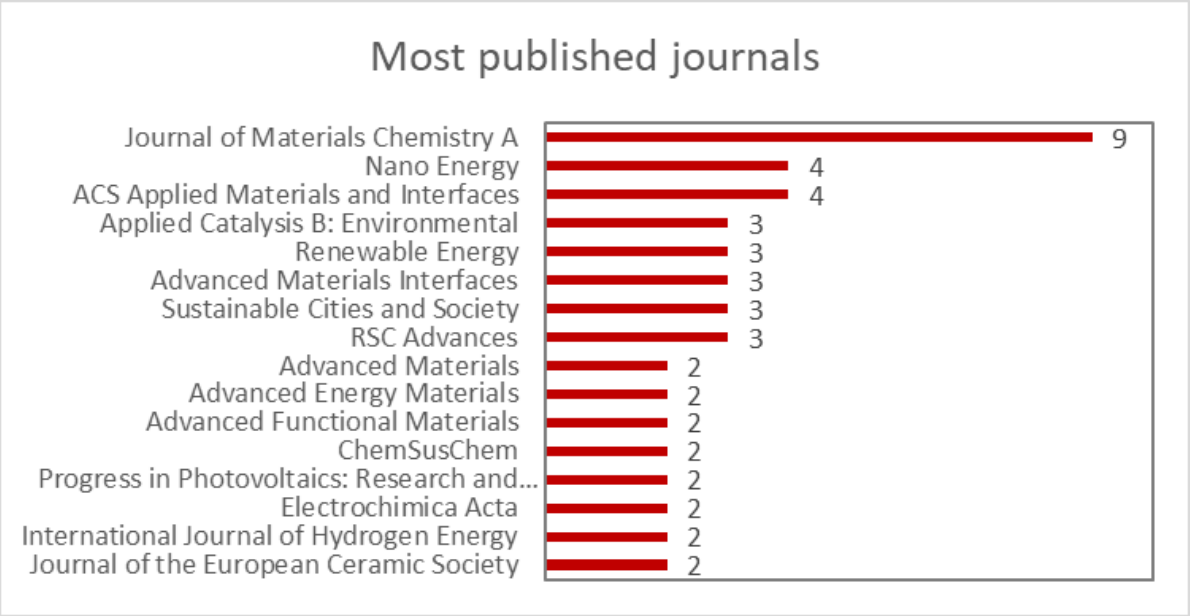
Origin	Income (€)	%	Nº Projects	€ / project
EUROPEAN (COMPETITIVE PROJECTS)	9.827.525	75,12%	25,00	393.101
NATIONAL (COMPETITIVE PROJECTS)	1.938.150	14,81%	34,00	57.004
INDUSTRIAL PROJECTS	436.340	3,34%	22,00	19.834
RESEARCHER'S RECRUITMENT GRANTS	881.140	6,73%	17,00	51.832
Total general	**13.083.155**	**100%**	**98,00**	**133.502**



10. SCIENTIFIC AND TECHNOLOGIC OUTPUTS SUMMARY

The outputs of the performed activities reveal that the institute is characterized by excellent research outcomes. IREC at the end of 2019, after 6 years of having finished its laboratories in 2013, counted 1093 publications and more than 27000 citations with an average ratio of about 25 citations per paper and a total h index of 77.

In 2019 IREC researchers published 83 articles in international scientific journals with impact factor, with an average impact factor of 8.25. 98.80% of the papers were in first quartile (Q1) journals, and 32% were published in journals with impact factor above 10 and 37% above IF=8.



THE 10 HIGHTLY CITED PAPERS

#	Authors	Title	Publication	Impact Factor	Q	Cited by
1	Giraldo S., Jehl Z., Placidi M., Izquierdo-Roca V., Pérez-Rodríguez A., Saucedo E.	Progress and Perspectives of Thin Film Kesterite Photovoltaic Technology: A Critical Review	Advanced Materials	25.809	Q1	47
2	Liu J., Luo Z., Li J., Yu X., Llorca J., Nasiou D., Arbiol J., Meyns M., Cabot A.	Graphene-supported palladium phosphide PdP 2 nanocrystals for ethanol electrooxidation	Applied Catalysis B: Environmental	14.229	Q1	21
3	Zhang X., Luo J., Wan K., Plessers D., Sels B., Song J., Chen L., Zhang T., Tang P., Morante J.R., Arbiol J., Fransaer J.	From rational design of a new bimetallic MOF family with tunable linkers to OER catalysts	Journal of Materials Chemistry A	10.733	Q1	21
4	Ibupoto Z.H., Tahira A., Tang P., Liu X., Morante J.R., Fahlman M., Arbiol J., Vagin M., Vomiero A.	MoS x @NiO Composite Nanostructures: An Advanced Nonprecious Catalyst for Hydrogen Evolution Reaction in Alkaline Media	Advanced Functional Materials	15.621	Q1	18
5	Zuo Y., Liu Y., Li J., Du R., Yu X., Xing C., Zhang T., Yao L., Arbiol J., Llorca J., Sivula K., Guijarro N., Cabot A.	Solution-Processed Ultrathin SnS 2 -Pt Nanoplates for Photoelectrochemical Water Oxidation	ACS Applied Materials and Interfaces	8.456	Q1	14
6	Péan T.Q., Salom J., Costa-Castelló R.	Review of control strategies for improving the energy flexibility provided by heat pump systems in buildings	Journal of Process Control	3.316	Q1	14
7	Canals Casals L., Barbero M., Corchero C.	Reused second life batteries for aggregated demand response services	Journal of Cleaner Production	6.395	Q1	13
8	Casals, L.C., Amante García, B., Canal, C.	Second life batteries lifespan: Rest of useful life and environmental analysis	Journal of Environmental Management	4.865	Q1	13
9	Masciandaro S., Torrell M., Leone P., Tarancón A.	Three-dimensional printed yttria-stabilized zirconia self-supported electrolytes for solid oxide fuel cell applications	Journal of the European Ceramic Society	4.029	Q1	13
10	Zhang C., Biendicho J.J., Zhang T., Du R., Li J., Yang X., Arbiol J., Zhou Y., Morante J.R., Cabot A.	Combined High Catalytic Activity and Efficient Polar Tubular Nanostructure in Urchin-Like Metallic NiCo2Se4 for High-Performance Lithium–Sulfur Batteries	Advanced Functional Materials	15.621	Q1	12
11	Guilera J., Del Valle J., Alarcón A., Díaz J.A., Andreu T.	Metal-oxide promoted Ni/Al 2 O 3 as CO 2 methanation micro-size catalysts	Journal of CO2 Utilization	5.189	Q1	12
12	Yi M., Zhang C., Cao C., Xu C., Sa B., Cai D., Zhan H.	MOF-Derived Hybrid Hollow Submicrospheres of Nitrogen-Doped Carbon-Encapsulated Bimetallic Ni-Co-S Nanoparticles for Supercapacitors and Lithium Ion Batteries	Inorganic Chemistry	4.85	Q1	12

IMPACT FACTOR & RANKING RESULTS OF THE TOP 10 PUBLICATIONS OF 2018

#	Authors	Title	Publication	Impact Factor	Q
1	Giraldo S., Jehl Z., Placidi M., Izquierdo-Roca V., Pérez-Rodríguez A., Saucedo E.	Progress and Perspectives of Thin Film Kesterite Photovoltaic Technology: A Critical Review	Advanced Materials	25.809	Q1
2	Chiabrera F., Garbayo I., López-Conesa L., Martín G., Ruiz-Caridad A., Walls M., Ruiz-González L., Kordatos A., Núñez M., Morata A., Estradé S., Chroneos A., Peiró F., Tarancón A.	Engineering Transport in Manganites by Tuning Local Nonstoichiometry in Grain Boundaries	Advanced Materials	25.809	Q1
3	Hadke S., Levcenko S., Sai Gautam G., Hages C.J., Márquez J.A., Izquierdo-Roca V., Carter E.A., Unold T., Wong L.H.	Suppressed Deep Traps and Bandgap Fluctuations in Cu2CdSnS4 Solar Cells with ≈8% Efficiency	Advanced Energy Materials	24.884	Q1
4	Tang P.-Y., Han L.-J., Hegner F.S., Paciok P., Biset-Peiró M., Du H.-C., Wei X.-K., Jin L., Xie H.-B., Shi Q., Andreu T., Lira-Cantú M., Heggen M., Dunin-Borkowski R.E., López N., Galán-Mascarós J.R., Morante J.R., Arbiol J.	Boosting Photoelectrochemical Water Oxidation of Hematite in Acidic Electrolytes by Surface State Modification	Advanced Energy Materials	24.884	Q1
5	Hermans Y., Murcia-López S., Klein A., Jaegermann W.	BiVO4 Surface Reduction upon Water Exposure	ACS Energy Letters	16.331	Q1
6	Zhang C., Biendicho J.J., Zhang T., Du R., Li J., Yang X., Arbiol J., Zhou Y., Morante J.R., Cabot A.	Combined High Catalytic Activity and Efficient Polar Tubular Nanostructure in Urchin-Like Metallic NiCo2Se4 for High-Performance Lithium–Sulfur Batteries	Advanced Functional Materials	15.621	Q1
7	Ibupoto Z.H., Tahira A., Tang P., Liu X., Morante J.R., Fahlman M., Arbiol J., Vagin M., Vomiero A.	MoS x @NiO Composite Nanostructures: An Advanced Nonprecious Catalyst for Hydrogen Evolution Reaction in Alkaline Media	Advanced Functional Materials	15.621	Q1
8	Shi Y., Fluri A., Garbayo I., Schwiedrzik J.J., Michler J., Pergolesi D., Lippert T., Rupp J.L.M.	Zigzag or spiral-shaped nanostructures improve mechanical stability in yttria-stabilized zirconia membranes for micro-energy conversion devices	Nano Energy	15.548	Q1
9	Domnez Noyan I., Gadea G., Salleras M., Pacios M., Calaza C., Stranz A., Dolcet M., Morata A., Tarancon A., Fonseca L.	SiGe nanowire arrays based thermoelectric microgenerator	Nano Energy	15.548	Q1
10	Yu X., Zhang C., Luo Z., Zhang T., Liu J., Li J., Zuo Y., Biendicho J.J., Llorca J., Arbiol J., Morante J.R., Cabot A.	A low temperature solid state reaction to produce hollow MnxFe3-xO4 nanoparticles as anode for lithium-ion batteries	Nano Energy	15.548	Q1
11	Avireddy H., Byles B.W., Pinto D., Delgado Galindo J.M., Biendicho J.J., Wang X., Flox C., Crosnier O., Brousse T., Pomerantseva E., Morante J.R., Gogotsi Y.	Stable high-voltage aqueous pseudocapacitive energy storage device with slow self-discharge	Nano Energy	15.548	Q1

11. SPIN-OFFS

The institute's ongoing commitment is to making real contributions to industry and society. The resulting culture of innovation and entrepreneurship have the added benefit of preparing its researchers for the more diverse, more imaginative manifestations of public-private research collaborations of the future.

As a result of this commitment has provided two spin-offs:

» Ledmotive Technologies S.L

» Eolos Floating Lidar Solutions

11.1. LEDMOTIVE TECHNOLOGIES S.L

LEDMOTIVE is the first spin-off from IREC. It has gathered more than 3.5M€ in total funding and its selling its products in all the continents.
Leader: Dr. Josep Carreras. IREC
Promoting Institution: Fundació Institut de Recerca en Energia de Catalunaya (IREC)
Shareholders: Dr. Josep Carreras, Meritxell Carreras, IREC, IESE Investors, Private Investors and Victoria Capital Group.

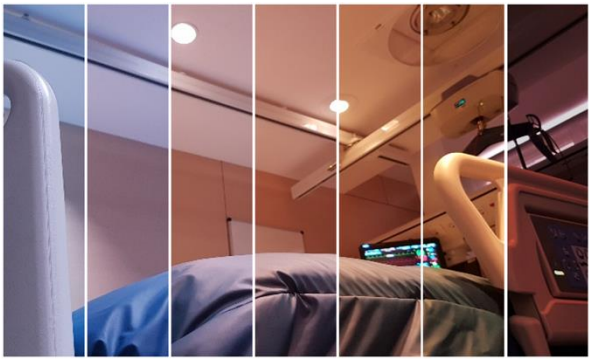
LEDMOTIVE lighting technology allows users to recreate any light spectrum. Lighting can be adjusted at different times of day and in different situations to respond to natural circadian rhythms, with demonstrated positive effects on productivity and health. Founded in 2012, the company now has 15 employees and is selling its products across the globe.

They are pioneers of light with our spectral control technology. The aim is to establish a reference point in the market where light represents a major value-added. We are committed to light as a means to improve people's quality of life. The fundamental pillars are innovation, development, protection of intellectual property related to spectral control, and integration through different technological platforms. Ledmotive believe in ideas argued under the strictest scientific principles and in the effort behind these ideas to make them a reality.

The natural evolution of leds: improving human well-being: Its multispectral lighting system allows the dynamism of natural light to be transferred to closed environments. In particular, this technology has promising potential in the health sector, given that this system improves the mood and increases the well-being and quality of life of patients, providing an adequate atmosphere in harmony with circadian rhythms.

In 2019, the VEGA07 Module from Ledmotive Technologies was named the "most important Enabling Technology of the year" at the LUX Awards 2019, the most important award ceremony in the world for the Lighting industry.

LEDMOTIVE: light, a quality-of-life factor



According to the WHO, most people spend about 90% of their time indoors. However, exposure to natural light has many health benefits: it facilitates nocturnal rest, improves school performance, and even significantly reduces the likelihood of mental illness at certain ages (1). For this, it is essential that the circadian rhythm (the biological clock that regulates the hours of sleep and wakefulness) be altered as little as possible. Experts in the field insist that the lack of a certain type of light stimulates the body's production of melatonin. This hormone ensures that the biological clock is reset to zero every 24 hours and protects the body from inflammatory diseases and aging.

It is clear that the artificial lighting of interior spaces affects production of melatonin and ends up modifying the sleep patterns of people who spend a lot of time in closed spaces.

LEDMOTIVE: lighting technology for people's well-being

In 2012, aware that LED technology would represent the future of lighting and that there was still work to be done to develop light systems that could considerably improve well-being, Josep Carreras, founder and CTO of LEDMOTIVE and holder of a PhD in Physics, decided to develop a technology capable of adapting perfectly to people's circadian rhythm. This led to the launch of LEDMOTIVE spectral control technology (patented in 21 countries) that allows the reproduction of natural light, including its changes throughout the day, with the highest visual quality and without resorting to high luminous intensities.

This system combines the light of 7 differentiated colour channels to produce any spectrum of light within the visible range. This makes it possible to eliminate or modify the light that produces the most harmful effects (e.g. violet light) or to emphasize the light that provides the greatest benefits, depending on each correct moment and application. The daily solar pattern is not a simple change in light tonality (Correlated Colour Temperature - CCT) but rather a complete and continuous evolution of the spectrum.

With LEDMOTIVE technology it is possible to programme a lighting sequence for circadian cycles, which oscillates between the light spectrum of a sunrise and a sunset, reproducing

the hourly variations of sunlight. In this way, the biological clock can be synchronized by artificial light, when there are reasons that prevent access to natural exposure.

LEDMOTIVE: technology ready to make the leap in Europe

According to Meritxell Carreras, CEO of the company, “LEDMOTIVE wants to expand and above all seeks to reach international markets such as England, France, Belgium, Germany and Sweden”. Meritxell Carreras points out that the high degree of technology acceptance in Spain, especially in the hospital sector, leads them to believe that they can achieve a major market share in this area. LEDMOTIVE has installed its technology in the new smart Intensive Care Unit of the Vall d’Hebron Hospital in Barcelona, one of the biggest in Europe and the largest in Spain, to encourage better orientation and to help patients to recover. For this purpose, 21 March has been established as the light-model day, so thanks to LEDMOTIVE technology it is always spring in the ICU.

The applications of this lighting system are innumerable. For example, in schools, to improve student performance and in offices to improve employee well-being and productivity; or in Nordic countries, to reduce seasonal depression due to the absence of sunlight.

11.2. EOLOS FLOATING LIDAR SOLUTIONS

Spin-off of IREC's Offshore Wind department, created in March 2014.
Leader**:** Rajai Aghabi Rivas
Promoting Institution: Fundació Institut de Recerca ene Energia de Catalunaya (IREC)
Shareholders: Rajai Aghabi, KIC InnoEnergy

Description:

As a result of the 3-year innovation project "Neptune", the Offshore Wind Group of IREC, jointly with 5 other partners (Naturgy, UPC, CIEMAT, University of Stuttgart, and SIMO), developed back in 2014 a technology with high market potential that consists of an energy autonomous system capable of taking accurate and reliable wind measurements at height of up to 200 meters at any offshore locations, independent of water depth.

The spin-off company EOLOS FLOATING LIDAR SOLUTIONS, S.L. was set up in March 2014, with the objective of commercializing the resulting product of the "Neptune" project, through a license agreement signed with all the "Neptune" partners. .

Five years later, in 2019, EOLOS is a 17-people company with operations in three continents (Europe, Asia and the USA) and a 600m2 workshop plus offices in Montcada i Reixac (Barcelona), from where it assembles its technology and coordinates its world operations.

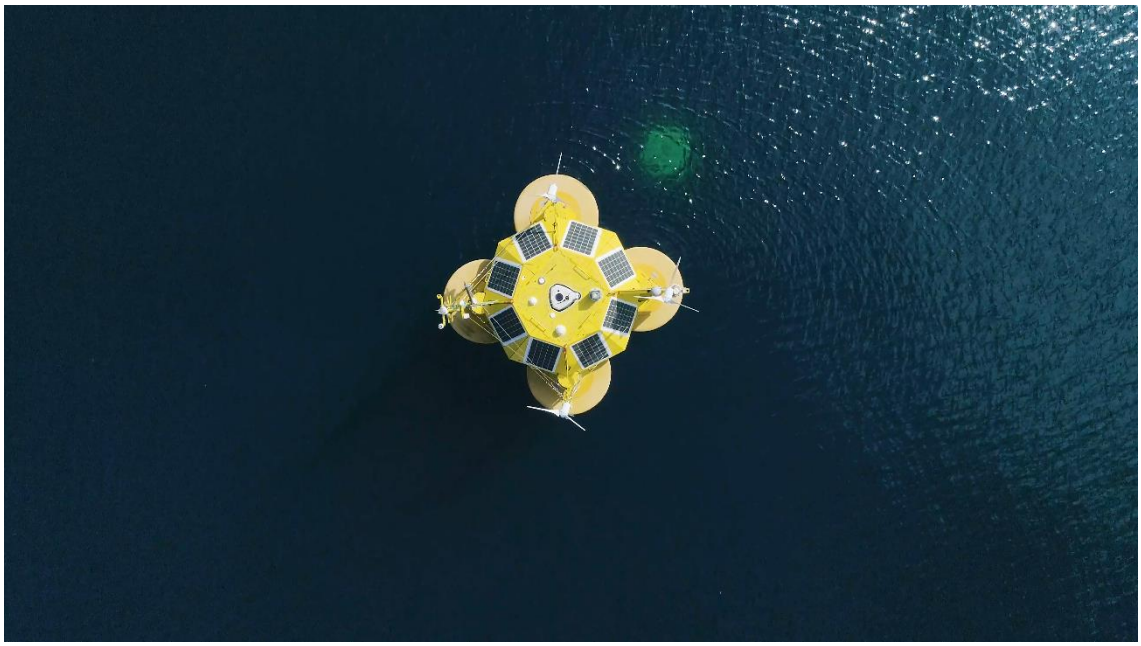
The EOLOS technology helps to:

Significantly reduce capital costs (up to 10x less than bottom fixed met masts) during the development phase, when the final investment decision (FID) has not yet been reached.

Pre-FID cost of money for developers is high as it involves a significant risk since only a portfolio approach hedges against failure.

EOLOS can be installed earlier in the development phase, potentially reducing the wind speed measurement uncertainty and therefore the financial risks.

In addition, it offers positional flexibility and can be reused in other areas within a wind farm site (or on other sites), potentially reducing the wind speed measurement uncertainty.



12. CORPORATE DEVELOPMENT AND TECHNOLOGY TRANSFER (CD&KTT)

The Team

(permanent and temporary positions, tenure tracks and fellowships)

Manel Sanmartí, Head of the Unit Federico Noris, Competitive programs and industrial contracts officer Marta Fonrodona, Technology Transfer officer Anna Magrasó, RIS3CAT Energy Community Manager Joana Tarrés, "Energy for Society" (XRE4S) Research network manager Alexandra Lozano, IP Officer

The main objective of the Corporate Development and technology Transfer (CD&KTT) unit is to provide support to the research groups in competitive programs and relationship with industry. It manages IREC's Intellectual Property assets and strategies in close collaboration with the research groups and proposes valorization strategies in order to maximize the impact of the Institute. In addition, it represents IREC in many national and European committees, associations and industrial organizations like Innoenergy, EMIRI, EERA, CEEC, PTE-ee and others fostering international recognition and positioning for the Institute. The CD&KTT unit also manages IREC's transverse projects like the RIS3CAT Energy Community, the "Energy for Society" (XRE4S) research network, the IREC's contribution to the PROENCAT and the strategic alliance with Eurecat.

The main activities have focused on the above mentioned programs and projects. In addition, preparation activities in the field of IP portfolio management, competitive projects and industrial commercial plan have been started and will be consolidated during 2019.

The Energy for Society (XRE4S) Research Network

The Energy for Society (XRE4S) research network proposal was created in 2018 as an expansion and continuation of the Advanced Materials for Energy Network (XaRMAE) which has been operating since 2004. The objective of the network is to boost the success of technology transfer activities and increase the industrial and social impact of energy research activities in Catalonia. The XRE4S is currently composed of 35 research groups from universities (UB, UPC, UdL, UdG, URL-La Salle, UVic), research institutions (BSC, CIMNE, CSIC, ICN2, ICIQ, IREC) and technological centers (Eurecat). In total, the network is made up of more than 400 researchers and 20 FTE working in low carbon technologies, energy efficiency and smart grids. Strategic alliances have been set up with the Catalonia Energy Cluster (industry relationship), InnoEnergy (innovation and entrepreneurship), DEMETER Capital (investors) and Barcelona ACTIVA (training).

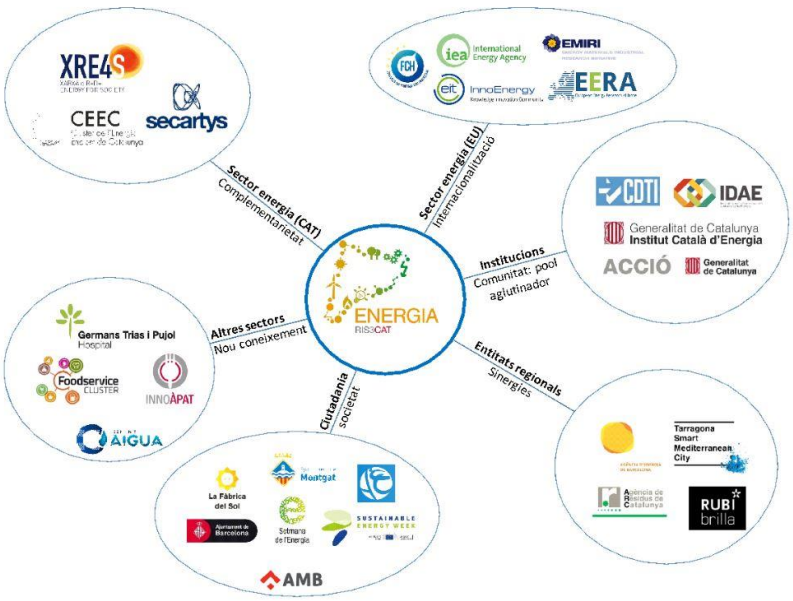
The five years' work programme of the XRE4S focuses on technology transfer actions, valorization programmes, networking, capacity building and training activities for researchers.

The RIS3CAT Energy Community

IREC has led the RIS3CAT Energy Community since 2016 as part of the Catalan regional smart specialization strategy (RIS3CAT) developed in the framework the European Research Innovation Strategy for Smart Specialization (RIS3). The RIS3CAT Energy Community aims at improving competitiveness and specialization of the Catalan energy sector with the participation of the most relevant Catalan energy stakeholders (the so called quadruple helix: industry, research and academia, public sector, end users and consumers). The RIS3CAT Energy Community is a €9M action plan (2015-2019) focused on developing 3 large R&D and 4 innovation projects with more than 35 partners and 80 associates around 3 priority lines: low carbon technologies (LCT), Energy Efficiency (EE) and Smart Grids (SG).

The RIS3CAT Energy Community projects are:

- Refer (COMSA EMTE, R&D): Flexibility and energy reduction in buildings rehabilitation to get near zero energy emission buildings.
- NaenCat (Electra Caldense, R6D): New Technologies to increase observability, security and flexibility of the electric grid in Catalonia.
- Cosin (Naturgy, R6D): Development of new fuels, through fuel synthesis and electrolysis.
- Flexedinet (iEnergy, Innovation): Information system for energy saving, flexibility and optimization of the use and demand of energy in buildings.
- MicroIT (ARC BCN, Innovation): Creation of new products and business models to offer energy efficiency solutions to SMEs.
- Estorelot (iGRID, Innovation): Integration of distributed energy resources (DER) and energy storage to improve the management of renewable energy power plants.
- LCA Enerboost: Development of a new tool to boost the energy sector sustainability.



KIC Innoenergy

KIC Innoenergy is a European-wide company created to help promoting a sustainable future through innovation in the energy field. It was in its origin one of the first Knowledge and Innovation Communities (KICs) fostered by the European Institute of Innovation and Technology (EIT). Although the headquarters are in the Netherlands, activities take place thanks to a network of offices located in Belgium, France, Germany, the Netherlands, Spain, Portugal, Poland and Sweden. The project has nowadays 27 shareholders, including top ranking industries, research centers and universities. All of them are key players in the energy field. But beyond this, there are 160 associate and project partners forming a strong network for sustainable energy innovation throughout Europe; working simultaneously in education, innovation projects and business creation.

EIT InnoEnergy

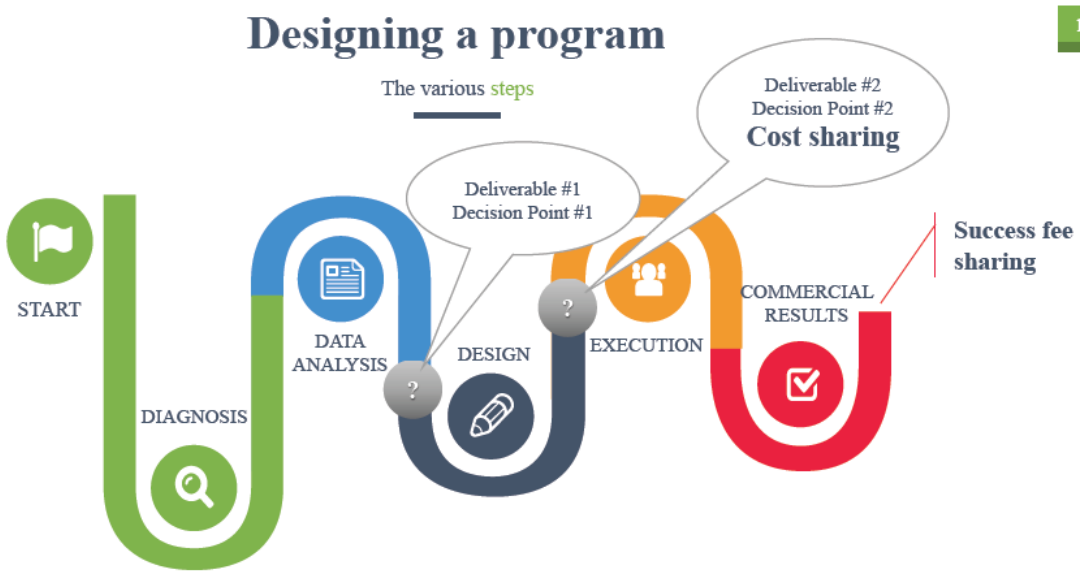
IREC is founder and shareholder of the KIC InnoEnergy, a Europe-wide company created to help promote a sustainable future through innovation in the energy field. Created in 2011, it is one of the first Knowledge and Innovation Communities (KICs) fostered by the European Institute of Innovation and Technology. In recent years, IREC has been actively participating in several InnoEnergy activities and programmes:

- more than 15 IREC's PhD candidates have participated in the InnoEnergy PhD school, each receiving specific entrepreneurship training and completing a 6 month internship in an industrial companies.
- and enhancing innovation in sustainable energy in Europe. One of these projects has concluded with the creation of the EOLOS spin-off which is currently in the market. Another project (COFAST) has concluded in a licencing agreement with an industrial partner who is commercializing the product developed in the project.

The "Lab to Market (L2M)" program

IREC has developed during the last years several innovative projects, as a partner or as a leader, thus contributing to achieve the objectives of promoting and enhancing innovation in sustainable energy in Europe. IREC and InnoEnergy have developed a joint program in order to increase the technology transfer of IREC's research results to market, the so called "Lab to Market" (L2M) programme.

This programme has the objective to analyse several IREC technologies including their technological maturity, the level and strategy of IP protection, and market potential in order to assess their potential for future commercialization. The following figure shows the program phases.



The L2M programme has analysed 20 technologies developed (or being developed) by IREC research groups (Diagnosis phase), selecting the top 5 most promising technologies.

In the Data Analysis phase, these 5 technologies were deeply analysed in collaboration with external experts (canvas analysis, market assessment, deep IP assessments). Finally, 2 technologies were selected for the Design Phase including a commercialization strategy proposition (spin-off creation). These technologies are:

- 3D printed SOFC: IREC and the research team decided to continue the technology development, extend IP protection and internally redefine the exploitation strategy.
- Energy aggregator (CASE): the negotiations for a technology licensing agreement with an energy management SaaS company did not conclude in early 2019. IREC and the researchers are currently taking part in The Collider programme, and also in negotiations with InnoEnergy in order to create a spin-off based on this technology.

As a result of the programme, IREC has:

- Evaluated 20 technologies for potential market exploitation including recommendations for future development.
- Performed deep analysis on 5 of those technologies related to market potential, IP protection and technology maturity including specific recommendations for future commercialization.
- Provided final recommendations and commercialization strategies for the 2 selected technologies, one of which is currently in the process of creating a spin-off.
- Extended knowledge of valorisation, IP protection and exploitation analysis and strategies for the KTT team.
- Provided training and practice of technology and market assessment for researchers.

IREC-Eurecat Energy Joint Unit

In 2017, IREC and EURECAT (the Technology Centre of Catalonia) signed a strategic agreement with the support of the Generalitat of Catalonia in order to implement a joint unit for technological and business development in the energy field.

The joint unit aims at promoting joint actions by sharing technical and human resources to maximize competitive and industrial funding opportunities and synergies between the institutions and their research groups.

PROJECTS

Title: Coordinación de la Comunidad RIs3CAT Energía
Acronym: Ris3Cat
Description: El Proyecto de Coordinación de la Comunidad Energía tiene por objetivo garantizar el correcto desarrollo del Plan de Actuaciones 2016-2018, la consecución de los objetivos e impacto de los proyectos, así como de la Comunidad, consolidar el Plan de Actuaciones con actividades complementarias y definir una estrategia de consolidación más allá de 2019. La Comunidad RIS3CAT Energía ha desarrollado 3 proyectos de R+D+I y 4 proyectos de Innovación dentro del sector energético en Cataluña. Estos proyectos cubren los tres ejes estratégicos definidos en el plan de actuaciones: eficiencia energética (EE), redes inteligentes (SG) y tecnologías bajas en carbono (LCT).
Funding: Ris3Cat
Project ID: COM15-1-0008
Type: Competitive Nationals, Coordinator
Partners: Fundacio Institut de Recerca de l'Energia de Catalunya (IREC)
Date: 3/1/2016-4/15/2020
Group: Corporate Development and Technology Transfer
P.I: Manel Sanmartí Cardona
URL: https://ris3catenergia.wordpress.com/

13. OUTREACH & SOCIETY

The future of our planet and a more sustainable and equitable society depend on our use of energy, one of the important pillars of society's progress. Nowadays, the role of the energy system is one of the priorities of the scientific, political, economic and social agenda, given the wide repercussions it has on the planet.

The foreseeable depletion of fossil resources and climate change as a result of greenhouse emissions have generated a series of challenges that transcend individual actors and national spheres, and thus require global research efforts towards common solutions.

We have to rethink how we manage energy, and find new and better sources. In this sense, IREC's experience in collaborating with society allows us to Shape Energy for a Sustainable Future. This interaction allows us to channel expectations and social demands, as well as make progress in aspects such as citizen awareness, responsible energy consumption and contribute to the promotion of open dialogue between different actors (society, industry and public sector).

At IREC, we aim to have an impact and boost the energy transition our planet needs, in collaboration with society that allows a mutually beneficial relationship.

We work with leading researchers around the world, as well as with industry and public administration. Therefore, we understand that it's crucial to engage in fruitful discussions with communities that represent the needs and opportunities of our society: learners of all ages, and people that as individuals or in their roles as entrepreneurs or managers, are confronting decisions about energy in their daily lives.

This is why we foster open dialogue and mutual learning between our team and society. Together, we have a better chance of overcoming the challenges before us.

In this regard, IREC encourages public participation and collaboration to raise new questions and co-create a new scientific culture. Some of the outreach activities that IREC takes part are:

- IREC Open Days and Mapping
- European Researchers' Nights
- International Day of Energy Efficiency
- Workshops in the frame of the International Day of Women and the Girls in Science
- Gonano Innovation and co-creation workshop (add link to EU initiative)

In the local and national area, we participate in initiatives such as:

- Fotciencia
- 100tífiques
- Promotion of scientific vocations (Espai Jove – Ajuntament de Barcelona)
- 10alamenos9 Festival
- Collaborations with some artists in the framework of the Nanocaedre activity.

Our researchers are also frequently sharing their expertise via round table discussions and public talks at third-party events, as well as through publications and interviews in the media.

In addition to these institutionally led activities, our groups actively participate in the dissemination of the publicly funded projects that they are involved in, including the organization of events for the general public, dissemination in national and international conferences, and training sessions, among others.

Committed to public engagement

IREC is firmly committed to the promotion of an informed public that can then engage in decision-making for the future of energy. In this sense, we've increased the number and scope of activities in recent years and, as a result, citizen participation is now an integral component of our program.

This outreach strategy falls in line with policies set out by the relevant governing bodies of Spain and the EU. It is through these open, trans-disciplinary conversations that we are fostering more democratic science policies and building a more evidence-informed society.

14. THE TEAM

INDEX OF THE IREC STAFF AND RESEARCHERS AT 31.12.2019

NAME		POSITION
Morante Lleonart, Joan Ramon	(8)	Director

AREAS

Management and Administration

Chulilla Corral, Elisabeth	Corporate Communications Manager and Director Assistant
Collado Borrull, Miguel Angel	Maintenance
Colomina Martinez, Montserrat	Administrative Staff
Fontana Vinelli, Raquel	Administrative Staff
González Villanueva, Emilio	Administrative Staff
Lara Bejar, Yolanda	Head of Accounting
Marfà Sánchez, Jaume	Director of Finance and Management Area
Mediano Valiente, Begoña	Health and Safety Technician
Ramírez Galaso, Eduardo	Administrative Staff
Torregrosa Mora, Francesc	Head of Human Resources
Valls Mariscal, Francesc	Head of Maintenance

Research Management Services

Francisco García, Inés	Researcher Manager
Hernández Rodríguez, Elba Maria	Researcher Manager
Herrera Rodríguez, Josep M.	Researcher Manager
Baboim Vall, Vanessa	Head of Researcher Management

Viaplana Rueda, Rita		Researcher Manager

Corporate Development and Technology Transfer

Fonrodona Turón, Marta		Project Developer
Magrasó Sola, Anna		Project Developer
Noris, Federico		Project Developer
Sanmarti Cardona, Manel		Head of Technology Transfer
Tarres Font, Joana		Project Developer

Advanced Materials and Systems For Energy Area

Morante Lleonart, Joan Ramon	(8)	Head of Area
Sylla, Dioulde		Laboratories Technician

Functional Nanomaterials Research Group

Cabot, Andreu	(9)	Group Leader
Guardia Giros, Pablo	(3)	Researcher
Liashenko, Ievgenii	(4)	Phd Fellowship
Ramon Ferrer, Alberto	(5)	Phd Fellowship

Solar Energy Materials and Systems Research Group

Andrade Arvizu, Jacob Antonio	Phd Fellowship
Becerril Romero, Ignacio	Phd Fellowship
Fonoll Rubio, Robert	Phd Fellowship
Giraldo Muñoz, Sergio	Phd Fellowship
Guc, Maxim	Researcher

Hernández Martinez, Alejandro	(5)	Phd Fellowship
Izquierdo Roca, Victor		Researcher
Jehl, Zacharie Victor Samuel N	(9)	Researcher
Lopez Garcia, Alejandro Jose		Phd Fellowship
Perez Rodriguez, Alejandro	(8)	Group Leader
Placidi, Marcel Jose		Researcher
Sanchez Gonzalez, Yudania		Laboratory Technician
Saucedo Silva, Edgar Ademar		Researcher
Vidal Fuentes, Pedro		Phd Fellowship

Nanoionic and Fuel Cells Research Group

Alayo Bueno, Nerea		Researcher
Anelli, Simone		Phd Fellowship
Baiutti, Federico		Researcher
Bernadet, Lucile		Researcher
Bianchini, Marco		Researcher
Chiabrera, Francesco		Phd Fellowship
Garbayo Senosiain, Iñigo		Researcher
Hornes Martinez, Aitor		Researcher
Morales Comas, Miguel		Researcher
Morata Garcia, Alejandro		Researcher
Nuñez Eroles, Marc		Laboratory Technician
Pacios Pujado, Merce	(3)	Researcher
Pesce, Arianna		Phd Fellowship
Siller, Valerie		Phd Fellowship
Sojo Gordillo, Jose Manuel		Phd Fellowship
Tang, Yunqing		Phd Fellowship

Tarancón Rubio, Albert	(9)	Group Leader
Torrell Faro, Marc		Researcher

Energy Storage, Harvesting and Catalysis Research Group

Andreu Arbella, Teresa		Researcher
Argudo Moya, Marco Antonio		Laboratory Technician
Avireddy, Hemesh		Phd Fellowship
Berenguer Ruiz, Antonio Miguel		Researcher
Biset Peiro, Marti		Researcher
Carretero Gonzalez, Nina Magal		Laboratory Technician
Chakraborty, Monalisa	(3)	Phd Fellowship
Guilera Sala, Jordi		Researcher
Holovanova, Viktoriia	(3)	Phd Fellowship
Jacas Biendicho, Jordi		Researcher
Morante Lleonart, Joan Ramon	(8)	Group Leader
Murcia Lopez, Sebastian	(3)	Researcher
Pajares Rojas, Arturo Javier	(5)	Laboratory Technician
Urbain, Felix		Researcher
Vazquez Galvan, Francisco Javier		Phd Fellowship

Thermal Energy & Building Performance Research Group

Belio Gil, Juan Francisco	Laboratory Technician
Bellanco Bellanco, Ivan	Project Engineer
Fuentes Lopez, Maria Elena	Researcher
Ortiz Ferra, Joana Aina	Researcher
Pascual Pascuas, Ramon	Researcher

Pean, Thibault Quentin	(3)	Phd Fellowship
Romaní Picas, Joaquim		Researcher
Salom Tormo, Jaume		Group Leader
Taddeo, Paolo		Project Engineer

Energy Systems Analytics Research Group

Barbero, Mattia	Project Engineer
Benveniste, Gabriela	Researcher
Canals, Lluc	Researcher
Cardoner, David	Project Engineer
Chapman, Nicholas	Project Engineer
Colet, Alba	Laboratory Technician
Corchero, Cristina	Group Leader
Farre, Jordi	Project Engineer
Homs, Josep	Project Engineer
Igualada, Lucía	Project Engineer
Lerch, Markus	Phd Fellowship
Nuñez, Cristina	Researcher
Rodríguez, Marta	Project Engineer
Sola, Alaia	Project Engineer
Wolff, Deidre	Project Engineer

Power Systems Research Group

Agbemuk, Adedotun	(3)	Phd Fellowship
Cantero Toni		Project Engineer
Domínguez García, Jose Luis		Group Leader

Ivanova, Anzhelika		Phd Fellowship
Paradell Pol		Researcher
Sanchez Muñoz, Daniel		Project Engineer
Siniscalchi Sara	(3)	Phd Fellowship
Stefadinou-Voziki Paschalia		Project Engineer
Trilla Romero, Lluis		Researcher

bFUS Program

Nomen Escoda, Oriol	Researcher
Sanchez Herranz, Daniel	Project Engineer
Sanmarti Cardona, Manel	Manager Program

(1) Grant from the Ministry of Economy and Competitiveness, "Ramón y Cajal" Call
(2) Grant from the Ministry of Economy and Competitiveness "Juan de la cierva" Call
(3) Grant from the Ministry of Economy and Competitiveness "ITN; TechnioSpring; Beatriu de Pinós; DOC-FAM " Call
(4) Government of Catalonia, "Formació Investigació" Call
(5) Government of Spain, "Formación Personal Investigación" Call
(6) Government of Spain, "Formación de Profesorado Universitario" Call
(7) Government of Catalonia, "ICREA" Institution
(8) *Ascribed Professors from IREC Foundation Trustee Universities*
(9) *Grants for youth employment promotion Plan R+D+I*

12. ACKNOWLEDGMENTS

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