imdea **energy** institute

research for a **sustainable energy development**

institute
imdea
energy

annual report

2013

foreword

foreword

David Serrano
Director of the IMDEA Energy Foundation

Móstoles, March 2014

annual report
2013

It is a great pleasure for me to introduce the Annual Report of the IMDEA Energy Institute, describing and recording the main activities and achievements corresponding to 2013. IMDEA Energy is a R&D institution aimed to the development of energy technologies that are expected to contribute to a low-carbon energy system. Created by the Regional Government of "Comunidad de Madrid" as a Foundation, IMDEA Energy operates with a very efficient and flexible management system, whereas scientific excellence, international impact and cooperation with industry are the key drivers of its activities.

The Scientific Programme of IMDEA Energy includes a number of topics with strong interest and relevance, according to both scientific and technological aspects: concentrating solar thermal power systems, production of sustainable fuels (advanced biofuels and hydrogen), energy storage materials and devices (electrochemical capacitors, flow and metal-air batteries, thermal and thermochemical energy storage), smart management of electricity demand, energy systems with enhanced efficiency and confinement and valorisation of CO2 emissions.

The researchers at IMDEA Energy are integrated in six different research units with a great variety of backgrounds and specialisations: mechanical, electrical and chemical engineering, physics, biology, chemistry, biochemistry, environmental science, etc. This provides the Institute with a multidisciplinary team of researchers, which as an essential feature to undertake the study of complex energy systems. By the end of 2013, the staff working in IMDEA Energy reached a total of 60 persons (47 researchers, 5 technicians and 8 management personnel). About two third of the researchers hold a Ph.D degree, with up to 16 different nationalities being represented in agreement with the international profile of the IMDEA Energy Institute. In addition about 50 B.Sc. and M.Sc. students, from different universities and countries, have been trained by participating in the different research topics of the Institute.

The research activities of IMDEA Energy are mainly organized within the framework of research projects approved in competitive calls and research contracts with private companies. A total of 19 research projects funded by public administrations, with a strong contribution of international projects, and 12 contracts with companies have been under development along 2013, whereas up to 23 personnel grants have been active. These figures show once more the success of IMDEA Energy in getting external funding, accounting for about 1.7 Meuros in 2013, which has allowed almost half of the total operational costs of the Institute to be covered with external incomes. Cooperation with industry has steadily grown in 2013, which is a fact of special relevance since one of the main goals of the IMDEA Energy Institute is to work together with the industrial sector to promote innovation and technology transfer activities.

The results obtained in the different research lines and topics have led to a significant and increasing number of scientific contributions: 46 scientific works published in indexed journals, 5 book chapters, 1 patent and 73 communications presented in scientific congresses. Likewise, IMDEA Energy researchers have participated in a wide variety of scientific dissemination actions, such as invited lectures in courses, masters and technical seminars.

The infrastructures and laboratories of IMDEA Energy are located in the Technological Park of Móstoles. The building has been constructed in two phases, the second one being finished at the end of 2012 and occupied along 2013. The whole building has received an Energy Efficiency Label of category A and the Gold LEED certificate, the latter having a high international recognition for buildings with a minimum environmental impact. The availability of additional space has made possible the setting up of a number of singular scientific equipment in the pilot plants, as it is the case of the solar simulator and the batteries test bench, and also the organization and hosting of a significant number of events to increase the external visibility of IMDEA Energy.

As a summary, I am glad to state that IMDEA Energy has already become a centre of reference in energy research at both national and international levels thanks to the excellent work and strong effort of its staff, as well as to the continuous support received from the Regional Government of "Comunidad de Madrid".

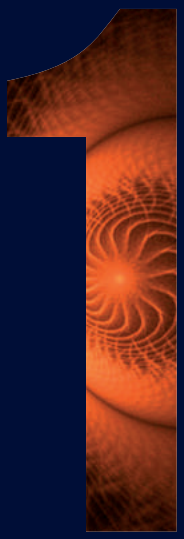
table of contents

table of contents

annual report

2013

general presentation



annual report

2013

The IMDEA Energy Institute is a Research Centre established by the Regional Government of Comunidad de Madrid and operates as a not-for-profit foundation. The Scientific Programme of the IMDEA Energy Institute aims at contributing to the future establishment of a sustainable energy system. Thereby, two main objectives are guiding the work-programme:

- R&D activities focused on fostering the development of renewable energies.
- R&D activities aimed at developing clean energy technologies that have none or minimal environmental impact.

The ultimate goal of the IMDEA Energy Institute is to achieve outstanding scientific and technological contributions for reaching a sustainable energy system. The IMDEA Energy Institute is charged with strengthening and having a significant impact on the R&D activities on energy themes by bringing together high quality researchers, providing them with excellent infrastructures and resources, and promoting their close collaboration with the industrial sector.

Research topics addressed at the IMDEA Energy Institute are concentrated within the following six areas:

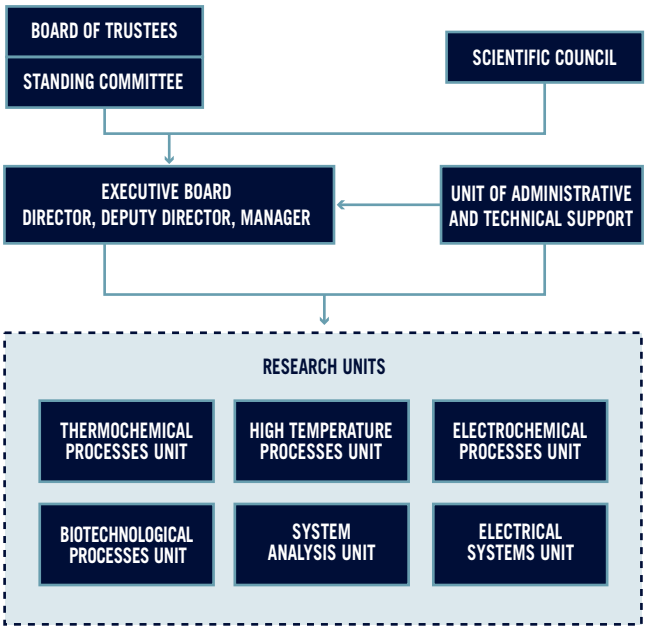
- Solar energy systems and technologies, with special emphasis in concentrating solar power.
- Production of sustainable fuels for the transport sector: hydrogen, biofuels and waste-derived fuels.
- Energy storage coupled to renewable energies.
- Smart management of electricity demand.
- Energy systems with enhanced efficiency.
- Confinement and valorization of CO_2 emissions.

The strategic framework guiding the R&D priorities of IMDEA Energy is based on goals and priorities established by energy plans and research programmes at regional, national and European levels; such as the European Strategic Energy Technology (SET) Plan with selected targets for 2020, 2050 and Horizon2020; the Plan for Renewable Energy of Spain; technology roadmaps of recognized international institutions and associations and implementation agreements of the International Energy Agency.

governing bodies and functional structure

annual report 2013

The organization and functional structure of the IMDEA Energy Institute is summarized in the following diagram with indication of its main bodies and units:



2.1. Board of Trustees

The Board of Trustees is the highest decision-making body of IMDEA Energy. It is responsible for its government, representation and administration, aiming to ensure the achievement of the objectives purposed by the institution. It is composed by scientists with international prestige, energy experts, and representatives of the regional administration, universities, public research centres, and industry sectors. The meetings of the Board of Trustees are held twice per year since its creation.

BOARD OF TRUSTEES

Prof. Dr. Martin Kaltschmitt
President of the Foundation
Director of Institute of Environmental Technology and Energy, Hamburg University of Technology, Germany

Excma. Sra. Lucía Figar de Lacalle
Vice-president of the Foundation
Regional Minister of Education, Youth and Sport
Comunidad de Madrid, Spain

REGIONAL ADMINISTRATION REPRESENTATIVES

Ilma. Sra. Rocío Albert López-Ibor
General Director of Universities and Research
Comunidad de Madrid, Spain

Mr. Juan Ángel Botas Echevarría
Deputy General Director for Research
Comunidad de Madrid, Spain

Mr. José de la Sota Ríus
General Manager of "Fundación para el conocimiento madri+d"
Comunidad de Madrid, Spain

LOCAL ADMINISTRATION REPRESENTATIVES

Mr. Carlos Blanco Bermejo
Director of Innovation of Madrid Network
Madrid Network and Móstoles Technology Park, Madrid, Spain

INSTITUTIONAL TRUSTEES

Prof. Dr. Rafael van Grieken Salvador
Full Professor of Chemical Engineering
Rey Juan Carlos University, Spain

Prof. Dr. Cayetano López Martínez
General Director of "Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas", CIEMAT, Spain.

Prof. Dr. Carlos Sánchez López
Full Professor of Physics, Department of Materials
Autónoma University of Madrid, Spain

Prof. Dr. Benjamín Calvo Pérez
Director of Gómez Pardo Foundation
Polytechnic University of Madrid, Spain

SCIENTIFIC TRUSTEES

Dr. Nazim Muradov
Principal Research Scientist
Florida Solar Energy Center, University of Central Florida, USA

Prof. Dr. Adriano García-Loygorri
President of the Social Council
Polytechnic University of Madrid, Spain

Prof. Dr. Antonio Monzón Bescos
Director of the Chemical Engineering and Environmental Technologies Department, University of Zaragoza, Spain

Dr. Michael Epstein
Head of Solar Research Facilities Unit
Weizmann Institute of Science, Israel

EXPERT TRUSTEES

Mr. José Jacinto Monge Gutiérrez
Rey Juan Carlos University
Móstoles, Spain

Mr. Íñigo Sabater
Vice President of Global Business Development, VESTAS
Madrid, Spain

COMPANIES TRUSTEES

Mr. José Javier Brey Sánchez
Abengoa S.A
Director of Abengoa Hidrógeno
Seville, Spain

Mr. Valentín Ruiz Santaquiteria
Repsol, S.A
Director of Technologies in New Energies
Móstoles, Spain

Mr. Agustín Delgado Martín
Iberdrola, S.A.
Director of Innovation
Madrid, Spain

SECRETARY

Mr. Alejandro Blázquez Lidoy
Consultalia

Standing Committee

The Standing Committee holds a large fraction of delegated Powers of the Trust, with the aim to support the day-to-day operation of the Foundation. The composition of the Standing Committee as of December 31st, 2013 is listed below:

- Ilma. Sra. Rocío Albert López-Ibor
- Mr. Juan Ángel Botas Echevarría
- Mr. José de la Sota Ríus
- Mr. Rafael van Grieken Salvador
- Mr. Julián García Pareja, Secretary

2.2. Scientific Council

The IMDEA Energy Scientific Council is composed by the scientific members of the Board of Trustees and an additional number of scientists. This Council is aimed to advise and to help the Director of the Institute in elaborating the scientific programme and in establishing the goals to be achieved by periods of four years as well as of assessing the annual performance of the Institute.

SCIENTIFIC COUNCIL

Prof. Dr. Martin Kaltschmitt
Director of Institute of Environmental Technology and Energy, Hamburg University of Technology, Germany

Dr. Nazim Muradov
Principal Research Scientist Florida Solar Energy Center, University of Central Florida, USA

Prof. Dr. Antonio Monzón Bescós
Director of the Chemical Engineering and Environmental Technologies Department, University of Zaragoza, Spain

Dr. Michael Epstein
Head of Solar Research Facilities Unit Weizmann Institute of Science, Israel

Dr. Carmen M. Rangel
Research Coordinator LNEG, Portugal

Prof. Dr. Javier Soria Ruiz
Research Professor Institute of Catalysis and Petrochemistry, CSIC, Spain

Prof. Dr. Aldo Steinfeld
Professor of Renewable Energy Carriers at the ETH Zurich and Head of the Solar Technology Laboratory at the Paul Scherrer Institute, Switzerland

Prof. Dr. Iacovos Vasalos
Emeritus Research Professor Chemical Process Engineering Research Institute (CPERI), Greece

Prof. Dr. Adriano García-Loygorri
President of the Social Council Polytechnic University of Madrid, Spain

Prof. Dr. Nikos Hatziargyriou
Full Professor Power Division of the Electrical Engineering Department, National Technical University of Athens, Greece

Dr. Francisco Gírio
Coordinator of the Bioenergy Unit, National Laboratory of Energy and Geology, Portugal

Prof. Dr. Francesc Castells
Emeritus Professor University of Barcelona, Spain

2.3. Executive Board

The Executive Board is composed of the General Director, the Deputy Director and the General Manager. The Executive Board is responsible for managing and dealing with the main business administration and scientific activities of the whole Institute, except those decisions taken by or shared with the Board of Trustees.

General Director: Prof. David Serrano Granados

The General Director is the chief executive of the IMDEA Energy Institute and chairman of the Executive Board. It is elected by the Board of Trustees, being responsible for the management, supervision and promotion of the organization activities, including business and research administration. Moreover, he is in charge of representing the interests of the Institute both internally and externally according to the directions approved by the Board of Trustees.

Deputy Director: Dr. Manuel Romero Álvarez

The Deputy Director supports the work and may take over some of the responsibilities of the General Director. Likewise, the Deputy Director may represent the IMDEA Energy Institute on behalf of the General Director.

General Manager: Ms. Marta Jiménez Menéndez

The General Manager is responsible for the management and coordination of the different administration issues, such as financial & accounting, legal aspects, human resources and general services. The latter includes all those services that support the day-to-day running activities of the different Research Units and administration staff of the Institute. The General Manager is also in charge of elaborating the general budget draft, which is submitted annually for approval by the Board of Trustees.

2.4. Research units

The researchers and scientists in the IMDEA Energy Institute are organized in Research Units defined according to their expertise and specialization. The following six R&D Units have been operational during 2013:

- Thermochemical Processes Unit
- Electrochemical Processes Unit
- Biotechnological Processes Unit
- High Temperature Processes Unit
- Electrical Systems Unit
- System Analysis Unit

2.5 Management, Administration & Technical Support Unit

By the end of 2013 the Management, Administration and Technical Support Unit of IMDEA Energy is formed by 10 persons, whose main function is to perform and manage a variety of management activities, such as accounting, expenses, contracts, inventory, project management, and technical support, which are essential for supporting the work of the different scientists and R&D units.

A novelty of the Management, Administration and Technical Support Unit in 2013 was the creation of the Development and Technology Transfer Area with the main objective of reinforcing the Institute´s external relationships. In 2013 the Institute has launched a strategy to promote a greater visibility of its R&D&i capabilities and to reinforce the projects and contracts with companies. Thereby, it has been organized an important number of visits and meetings with a wide variety of companies from the energy sector. Likewise, it has been reinforced the presence of the Institute in some industrial forums and platforms and different events have been organized with an important industrial participation.

The Management, Administration and Technical Support Unit includes the following areas of work:

Economic Management and Human Resources Area

- Ms. Nuria Merino Benito, Responsible
- Ms. Andrea García García
- Ms. Isabel Gámez Soria

Main responsibilities of this area are as follows:

- Accounting and financial management.
- Purchases management and monitoring.

- Supplier's management.
- Human resources management.
- Elaboration and update of the inventory.
- Travel and allowance.
- Labor risks prevention.
- General services management.
- Bibliographic resources management.
- Institute webpage update.

Project Management Area

- Dr. Carmen Pérez Rodríguez
- Ms. Eloísa Mateos Sevilla

Their main responsibilities are as follows:

- R&D project management and support.
- Identification and dissemination of R&D funding opportunities (regional, national and international calls).
- Preparation of proposals to be submitted to public R&D calls.
- Contracts with companies and agreements assessment.
- Intellectual property rights management.
- Technology watch reports.
- Elaboration of the Institute annual activities report.

Development and Technology Transfer Area

- Dr. Félix Marín Andrés, Responsible

Its final objective is to increase the national and international visibility of the R&D&i capabilities and scientific infrastructure of IMDEA Energy that make the Institute a valuable partner for companies, research centers and universities all over the world.

Infrastructure and Facilities Area

- Ms. Silvia Mateo Rincón, Responsible

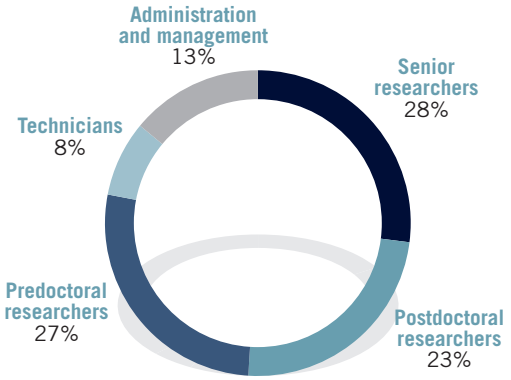
The main competences of this area are focused on building facilities management, building adaptation works to the requirements of the scientific activities, building maintenance management, scientific equipment support and building supplier' management.

Technical Support Area

- Ms. Mª Eugenia di Falco Salmerón, Laboratory Technician
- Ms. Laura García Firgaira, Laboratory Technician
- Dr. Fernando Picó Morón, Microscopy Technician
- Dr. Javier Celaya, Pilot Plant Technician
- Pablo Matatagui, Electrical Laboratory Technician

This Area is formed by the technical staff working in the IMDEA Energy laboratories, as responsible of managing and using the scientific equipment and infrastructures of general use of the Institute.

At the end of 2013, the personnel working in the IMDEA Energy Institute reached 60 persons, 47 researchers, 5 technicians and 8 management staff. In addition, about 40 undergraduate students have been doing different types of work and activities (internships and B.Sc and M.Sc final projects) in connection with the IMDEA Energy Institute. The year 2013 has been a very special year in terms of hiring and leaving of personnel. In 2013, 15 researchers finished their contracts with the Institute, 11 of them were predoctoral researchers. On the other hand, 12 new researchers, one pilot plant technician and the responsible for development and technology transfer were hired by IMDEA Energy in 2013.



research lines

annual report

2013

The research lines addressed at the IMDEA Energy Institute cover the research topics outlined in the Scientific Programme, being distributed within the following areas:

3.1. Concentrating solar power

The Concentrating Solar Thermal Power (CSP) systems are important candidates for providing the bulk solar electricity needed within the next few decades in highly irradiated regions and emerging solar markets. The approval in the past few years of specific financial incentives in Spain, USA, Italy, Algeria, India and China and some relevant projects funded by the World Bank in developing countries like Egypt, Mexico and Morocco, are serving as technology and market drivers. In most cases Spanish companies are leading the developments and subsequently revitalizing the demand of R&D.

This first generation of commercial projects is mainly based on technological developments and concepts matured after more than two decades of research. Nevertheless, the current generation of solar thermal power plants is still based on conservative schemes and technological devices which do not exploit the enormous potential of concentrated solar energy. Commercial projects use technologies of parabolic troughs with low concentration in two dimensions and linear focus, or systems of central tower and heliostat fields, operating with thermal fluids at relatively modest temperatures, below 400 ºC. The most immediate consequence of these conservative designs is the use of systems with efficiencies below 20% in the conversion of direct solar radiation to electricity, the tight limitation in the use of efficient energy storage systems, the high water consumption and land extension due to the inefficiency of the integration with the power block, the lack of rational schemes for their integration in distributed generation architectures and the limitation to reach the temperatures needed for the production of solar fuels, like hydrogen.

The main technological challenges to be faced by the concentrating solar energy technologies in the following years are:

- Significant improvement of global profitability of solar thermal power plants, through a cost reduction of the main system components like absorbers, receivers and solar concentrators, the reduction of associated O&M and elaboration of testing procedures and measurement techniques.
- Better integration of CSP systems into thermal power plants by developing advanced designs able to create more efficient and modular schemes of hybridization or solar stand-alone systems with heat storage, as well as other applications like the generation of solar fuels or chemical products.

3.2. Production of sustainable fuels

The transport sector plays a relevant role in the energy panorama of both Spain and "Comunidad de Madrid". Most of the liquid fuels so far employed have a fossil origin, and therefore the transport sector is responsible in a large extent for the greenhouse gases emissions. Accordingly, the development of alternative and environmentally friendly fuels is of high interest. Within this research line two different areas are considered:

Advanced Biofuels

Biofuels are renewable energy sources because they are products derived from biomass, principally from plants. The CO_2 emitted during their transformation into useful energy is balanced, at least in part, by the CO_2 absorbed during the growth of the plants. While some biofuels have already reached the production at a commercial scale, many limitations still exist that hinder the substitution of conventional liquid fuels at significant rates. Accordingly, the use of biofuels must be currently supported by the public administrations through tax reduction policies or by making mandatory the inclusion of a minimum amount of biofuels in the formulation of commercial fuels. Likewise, in many cases the raw materials employed for biofuels production are also applied in the food manufacture. This fact may have undesired effects by coupling the energy and food markets. This is the case of bioethanol production from sugar-rich plants and the biodiesel production from oil-rich crops (first generation of biofuels). Therefore, a very important challenge is the development of new processes for the production of biofuels using raw materials which are not applied in the food industry, such as lignocellulosic materials, microalgae and agriculture wastes (advanced biofuels). Areas for technology development in this field are:

- Development of innovative processes for the production of advanced biofuels from biomass resources different than those of common use by the food industry: production of bioethanol by hydrolysis and fermentation of lignocellulosic biomass, catalytic pyrolysis of agriculture and forestry residues for the production of bio-oils, and development of feasible processes for turning microalgae carbohydrates into biofuels.

- Optimization and improvement of biofuel production via flash pyrolysis or catalytic pyrolysis of lignocellulose biomass. This route also implies the subsequent catalytic hydrodeoxygenation processes for upgrading bio-oils. Research should concentrate on the development of very active and selective multifunctional catalysts and the possible integration of biomass transformation processes into oil refineries in order to develop and demonstrate the feasibility of the bio-refinery concept.

CO_2-free Hydrogen Production

Hydrogen is considered as a clean fuel since the only product formed during its combustion is water. However, hydrogen is not a primary energy source as it cannot be found free in our planet. Currently, almost all the hydrogen is produced by steam reforming of natural gas, but this process generates significant CO_2 emissions. Therefore, new CO_2-free routes must be developed for obtaining hydrogen in order to achieve a fully sustainable energy vector. In this way, methane decomposition, using both thermal and catalytic treatments, has been recently proposed as an interesting alternative for hydrogen generation because the carbon contained in methane is fixed as a carbonaceous solid and therefore no CO_2 is released. Other production routes that may need long term developments are those related to the hydrogen generation from water using renewable energies to perform H_2O dissociation. The following R&D lines summarize the priorities in the hydrogen production field:

- Hydrogen production by decarbonisation of hydrocarbons, with special emphasis in biogas (methane) decomposition. As this process involves the formation of large amounts of solid carbon, CO_2 emissions can be avoided, but at the same time it makes necessary the development of new commercial applications for this by-product. In this respect, controlling the selectivity to the different carbon allotropes is crucial to facilitate the applicability of this product in electronic or as an additive of building materials.

- Development of hydrogen production via thermochemical processes using solar power and hybrid cycles. This line requires the development of new thermochemical cycles having high overall efficiencies and stability during the cyclic operation, as well as moderate working temperatures.

- Hydrogen generation by photocatalytic and photoelectrochemical dissociation of water. Although these transformations present the advantage of taking place at room temperature, the main challenge is the development of systems having high efficiency and stability under visible and near-UV light irradiation as to achieve an efficient solar energy conversion.

3.3. Energy storage coupled to renewable energies

The main objective of the R&D in this field is to develop technologies and systems for the storage of energy enabling the increased penetration of renewable energies and the distributed generation of electricity. The energy storage systems that are considered of interest for being investigated at the IMDEA Energy Institute are the following:

Electrochemical energy storage

In this topic, research aims to the development of newer, safer and more environmentally friendly electrochemical storage systems, namely batteries and capacitors. Sustainable electric grids involve a considerable proportion of renewable generation and the manageability of such type of grids requires an increasing capacity of electrical energy storage for a variety of uses such as voltage sags and reactive power compensation, peak shaving, frequency regulation, load shifting, renewables firming, black start and many others. Likewise, sustainable transport is based on electrification and electric accumulators in which much higher energy densities are required if the range of electric vehicles has to be extended to values that make them more acceptable for a majority of drivers. At the same time accumulators for transport applications must provide sufficient power to facilitate good dynamic behavior, long cycle life to avoid early battery replacements, guaranteed safety in case of crash or abuse, and everything at contained cost. Such combination of requirements makes this an extremely demanding application for electrochemical storage systems. The research programme focuses on how newer materials and designs may improve the performance of these systems and on the application of electrochemical storage systems to renewable power generation, sustainable buildings and electrical vehicles. R&D priorities in this field are the following:

- High energy-density electrochemical capacitors for stationary and transport applications, with focus on using both electrochemical double layer capacitor and pseudocapacitor approaches. Emphasis is placed on non-conventional electrolytes such as hydrogels, ionic liquids, polymeric ionic liquids, and electrode materials alternative to activated carbons, such as carbon fibers, carbon nanotubes, metal oxide nanoparticles…

- Low-cost flow batteries for stationary applications in solar and wind power plants with research on (a) new highly reversible redox couples as advanced electrolytes with higher energy efficiency and lower cost, and (b) nanoporous separators as an alternative to traditional ion exchange membranes increasing proton selectivity via pore size exclusion.

- High-performance flow batteries based on the use of organic redox couples, to avoid transition metals, making the electrolytes more environmentally friendly and

providing unusually high energy densities that would make flow batteries useful in transport applications.

- Electrically rechargeable metal-air batteries characterized for their very high energy densities and with abundant and low cost raw materials (in the case of sodium, magnesium and aluminum), which make them ideal candidates for transport applications, where Li-ion systems do not reach the cost and performance objectives.

Thermal and thermochemical energy storage

To the urgent need to provide a higher degree of dispatchability to renewable energy power plants and grid-stability, it should be added the interest on enhancing the performance of (high-energy consuming) thermal processes and optimising the heat management in net-zero building. All these issues converge in an active R&D program in the field of thermal energy storage. The IMDEA Energy Institute addresses within its strategic programme research activities on materials and storage systems making use of sensible, latent and/or thermochemical heat. They comprise water adsorption on porous materials for low temperature (80-120 ºC) seasonal storage, phase change materials (PCM) and gas/solid systems customized for medium (250-400 ºC) and high temperature redox systems for high temperatures (400-900 ºC). PCMs and thermochemical storage are mainly focused on solar thermal applications.

3.4. Smart management of electricity demand

Further deployment of renewable energy technologies and decarbonisation of energy supply mix in electricity networks are both pending on a consensual solution for a series of complex legal, economic and technical issues. This fact underlines the importance of introduction of new flexible power network architectures and development of new network management algorithms. Increased levels of energy system integration and modularity are expected with the clear objective of improving the security of supply of critical loads, improving the load factor of distribution feeders and providing for all network users more flexibility in grid connection and accessing the future real-time electricity market. Smart management algorithms rely largely on the capacity of information technologies to acquire and distribute real-time data between all the parties in future power networks and also on the deployment of various types of energy storage devices across the network. The core R&D lines and topics of the IMDEA Energy Institute in regard to the smart management techniques for future electricity networks are as follows:

- New management algorithms for introducing more flexibility in achieving energy balance in all principal subsystems forming electricity networks - generation, distribu-

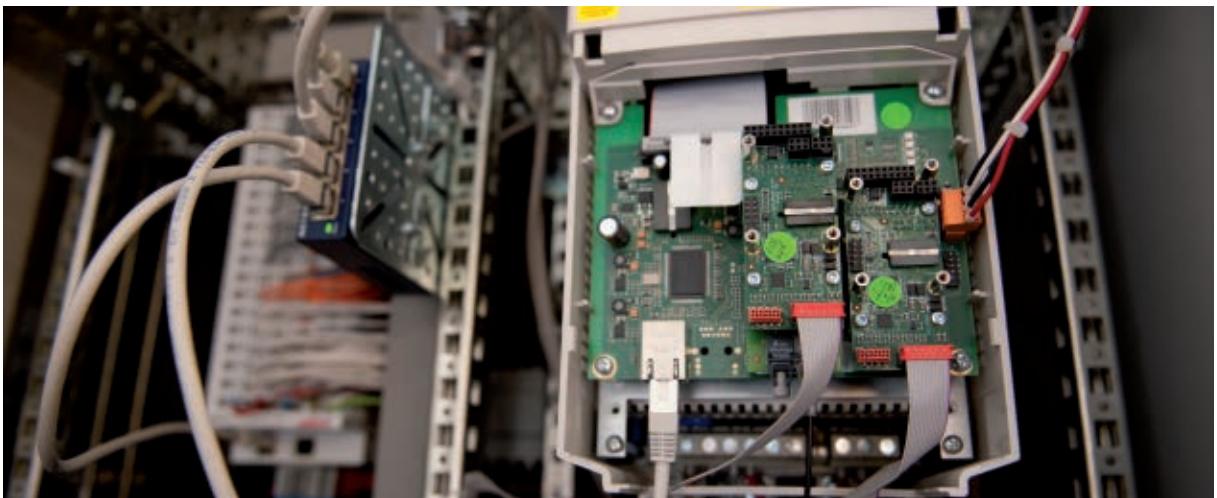
tion and consumption. Centralised and decentralised control architectures, real-time measurement and control, more intensive use of energy storage systems are only some of the proposed solutions. It is also relevant the creation of new energy-aware services and demand response schemes for final energy users, network operators and energy providers. Development of new power network models that include both dynamic and stochastic properties for the connected network devices is one of the principal tasks. The main concepts being developed within this area are next described:

- "Smart Neighbourhoods", "Smart Buildings" and "Smart Homes". Starting from the definition of local energy demand, energy supply available and relevant cost information, an optimal hybrid generation system can be proposed. This coordinated scheme is possible to apply on different power levels and can produce significant cost and energy savings as well as an additional level of flexibility in meeting the energy demand. Effects of integration of on-site renewable generation for improving autonomy, self-consumption and net balance are all under investigation.

- Energy efficiency in industrial applications. Development of the next generation of industrial control systems is necessary to achieve high efficiency of energy consumption and high flexibility of energy demand. This also assumes research and development of real-time algorithms for estimation and optimisation of energy consumption and control of available energy storage devices and power electronics interfaces.

- Integration of energy storage to electricity networks. Various scenarios on how distributed energy storage devices (including electric vehicle battery storage) can be used to contribute to network control, increase capture from intermittent energy sources and provide vehicle charging are investigated.

- Electrical energy conversion and power interfaces. Power electronics converters emulating operation and dynamics of real distribution feeders, generators and load profiles provide the testing environment for development and implementation of algorithms for future power networks. The system optimisation targets can be then flexibly changed to match any power network scenario and verify the control criteria set.



3.5. Energy systems with enhanced efficiency

In the IMDEA Energy Institute the use of energy systems with enhanced efficiency are contemplated from the point of view of better integration of solar thermal power plants in advanced thermodynamic cycles and/or cogeneration systems and the connection to the smart electricity management of demand. Research activities focus onto the hybridization of several renewable energy sources for applications in dwellings, hotels, commercial centres, power plants and communities. The optimization of this integration implies the design of efficient integration schemes, flowsheeting and performance analysis with appropriate tools. Controllability and management of demand are also key aspects in this research field.

Polygeneration and efficient end-use of energy are topics of enormous impact on energy saving and efficiency enhancement. The combination and integration of several products or energy vectors like electricity, heat, cooling or water desalination should lead to a more efficient energy cascade and facilitate the penetration of modular integrated utility systems. Since most polygeneration systems make use of rejected heat, for example from gas turbines, solar receivers, chemical reactors or heat-exchangers operating at moderate temperatures, they are strongly connected to new developments on thermal power generation systems.

An additional issue of interest is the development of water treatment technologies with a very efficient use of the energy supplied to remove dissolved ions from hard, brackish or sea water and the production of the smallest possible amount of effluents. This will be based on novel deionization technologies but also in the appropriate design of the electrochemical reactor and of the treatment process, as well as the selection of adequate operating conditions.

3.6. Confinement and valorization of CO_2 emissions

This topic tries to cope with the increasing CO_2 concentration in the atmosphere by fixing these emissions by different methodologies. So far most of the initiatives carried out in this line have been focused in the CO_2 concentration and capture, but enormous uncertainties still exist about the stability of the stored CO_2. Likewise, a number of alternatives have been recently proposed with the objective of considering the feasibility of the re-use and valorization of CO_2 produced by the combustion.

Based on this context, the following R&D themes are considered at the IMDEA Energy Institute within this topic:

- Evaluation of the viability of the different alternatives under consideration for CO_2 confinement: storage in exhausted mine sites, accumulation in the deep waters of the ocean and confinement in form of carbonates and solid carbon, by means of life cycle analysis.

- Development of CO_2 valorization routes by its transformation into high-demand valuable products. Since this kind of processes will be in most cases endothermic, solarisation of the CO_2 transformation will be necessary in order to get a positive overall energy balance. This can be accomplished by photocatalytic or thermocatalytic routes. In this respect the main challenge is to achieve larger production yields, since those obtained up to now are far from being competitive with other technologies. Likewise, the demand of the transformed products is a key reference in order to determine the feasibility of the different alternatives considered.

scientists and research units

annual report 2013

The different strategic research lines are covered through R&D Units characterized by their specialisation fields. This results on an efficient transversal organization, which is providing high versatility for dealing with the different research topics and high flexibility for being adapted to the changes in the R&D needs along the time.

The different Research Units included in the IMDEA Energy Institute are the following:

- **Unit of Thermochemical Processes (TCPU).** Involved in production of clean and sustainable fuels, using different raw material sources, like hydrogen (methane decomposition, thermochemical cycles) and biofuels (biomass pyrolysis and hydrotreating processes). It is also active in CO_2 valorization (photocatalytic process) and waste conversion into energy products.

- **Unit of High-temperature Processes (HTPU).** This unit is largely focused in the development of projects related to concentrating solar power, although its expertise is also of high interest in other topics such as thermal energy storage, solar-driven hydrogen production and CO_2 valorization.

- **Unit of Electrochemical Processes (ECPU).** This unit plays a leading role on the development of new electrochemical energy storage systems coupled to renewable energies, sustainable buildings and green vehicles (ultracapacitors and batteries) and energy efficient water treatment systems (capacitive deionization).

- **Unit of Biotechnological Processes (BTPU).** This unit is engaged in the development of novel processes for biofuels production with primary focus on technologies to convert biomass (lignocellulosic biomass, algae, and other biological material) into biofuels. The BTPU researchers are working to improve the efficiency and economics of the biochemical conversion process by focusing on the most challenging steps such as both enzyme and fermenting microorganisms development and biofuels production from microalgae.

- **Unit of Electrical Systems (ELSU).** This unit deals mainly with the R&D activities related to the smart management of electricity demand, and related topics like integration of renewables in distributed generation systems, design and control of microgrids, industrial energy saving and power network simulation.

- **Unit of System Analysis (SAU).** This unit provides global analysis of the different energy alternatives and problems, including technological-scientific aspects, like life cycle assessment, but also economic, social, legal and environmental issues.

4.1. Thermochemical Processes Unit

Research activities

One of the main aims of the Thermochemical Processes Unit (TCPU) is to provide technological alternatives to the current dependence of fossil fuels, particularly for the transportation sector. Obviously, this is a very ambitious task, pursued by many research groups worldwide, and it requires a multidisciplinary approach in order to identify the most reliable and sustainable resources, and the most efficient and cost effective processes considering the final application niches. Within this general framework, the activity of the TCPU is focused on the study of catalysts for their application in some of the chemical transformations which are likely to play a relevant role in the establishment of a more rational energy model.

Special attention is being paid to the development of feasible routes for the generation of CO_2-free hydrogen. In this context, some of the most promising approaches are water splitting either by means of thermochemical cycles coupled to solar concentrating power or by photocatalytic processes under softer conditions. With regard to this last process, it is worth mentioned that recently researchers of the TCPU have developed very efficient photocatalysts by modification of $NaTaO_3$ with rare earths cations. Methane decomposition is also an interesting alternative for hydrogen production, which simultaneously can yield different carbon materials with attractive electronic properties. Furthermore, if biogas is used as raw material, the sustainability of the decarbonisation process in terms of the reduction of CO_2 emissions is highly favourable. For this reaction TCPU has proved that catalysts based on metallic cobalt can be very efficient for reducing the process temperature and, under some specific conditions, they can favour the formation of graphene.

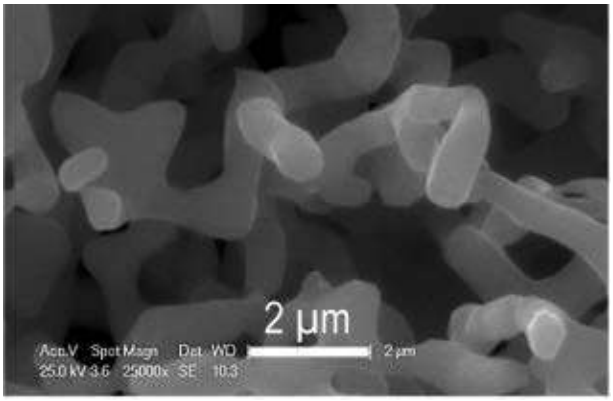
The possible utilization of residues as feedstock for fuel production, as well as the development of second-generation biofuels, are also strategic research lines of the TCPU. Currently, heterogeneous catalysts for pyrolysis are being optimized. On the other hand,

the hydrotreating of bio-oils, obtained either from flash pyrolysis of agro-forestry wastes or triglycerides extracted from specific energetic crops such as microalgae, is one of the approaches currently explored for upgrading biofuels in order to improve its compatibility with conventional ones. This research line relies on the design of multifunctional heterogeneous catalysts with enhanced selectivity and stability. In this way, very positive results have been obtained using affordable hydrogenating phases based on transition metals dispersed on micro-meso porous supports with moderate acidity.

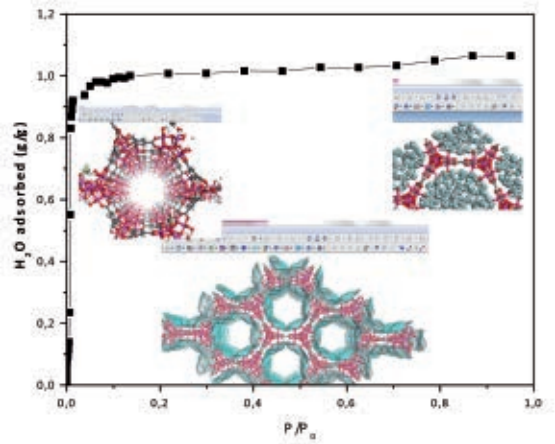
Mimicking plant photosynthesis to fix atmospheric CO_2 and transform it into useful chemicals is a long term challenge which is been approached by photocatalytic processes using semiconductors. Although the efficiency of this technology is still far from that required for commercial development, it holds a remarkable potential for storing solar energy as useful chemicals like light hydrocarbons (mainly methane) or methanol. Besides, this process could contribute to reduce significantly CO_2 emissions. Within this field the research activities of the TCPU have been mainly focussed on the fundamental understanding of the mechanisms of this photoactivated process by using specialized spectroscopic techniques such as TAS (Transient Absorption Spectroscopy).

Another area of activity of this unit is focused on the development of materials with enhanced heat storage capacity in connection with thermosolar power production. For domestic low temperature applications water adsorbents are being monitoring, whereas for high temperature applications redox reactions of transition metal oxides such as Mn_2O_3/Mn_3O_4 are being investigated. On this application, chemical composition and morphology have revealed as a crucial aspect determining the stability and the kinetics of the redox processes.

As most of the above mentioned processes imply the use of catalysts, it is worth emphasising the capacity of the TCPU to develop macroporous, mesostructured and microporous solids with different functionalities that can be adapted for a wide variety of energy-related processes.



Material for thermochemical energy storage after cycling at high temperature



Molecular simulation of water adsorption isotherms for a MOF used in seasonal heat storage

scientists

Prof. David P. Serrano

Research Professor,
Head of the Unit

He is Full Professor of Chemical Engineering at Rey Juan Carlos University and Director of IMDEA Energy. He is also the Head of the Thermochemical Processes Unit. He received his Ph.D. from Complutense University of Madrid (1990) awarded with the Extraordinary Mention and he has been Visiting Scholar in the California Institute of Technology (CALTECH, 1991) and in the California University of Santa Barbara (2006). He was appointed as Professor at Complutense University of Madrid (1990-1999), and subsequently at Rey Juan Carlos University. In the latter, he has been in charge of different management and academic positions: Coordinator of the Environmental Sciences Area (1999-2001), Vice-rector for Research and Technological Innovation (2001-2002) and Head of the Chemical and Environmental Technology Department (2002-2007). His main research interests are development of novel zeolitic and mesostructured materials, plastic wastes valorisation, production of advanced biofuels from different biomass sources and hydrogen production free of CO2 emissions. He has been involved in more than 50 research projects funded by both public and industrial partners. He is author of about 150 publications in scientific journals, 5 patents and of 4 books. Besides he has presented more than 200 communications in scientific conferences. At present, his h index is 34. He has supervised 19 Ph.D. theses. He is member of the editorial board of several journals and of the scientific council of CIESOL and the German Biomass Research Centre.

Dr. Juan M. Coronado

Senior Researcher

He received his Ph.D. in Chemistry from the Complutense University of Madrid in 1995. In 1997 he was awarded a grant of the "Marie Curie" EU program and spent two years as a postdoctoral fellow at the University of Dundee (UK). He was a "Ramón y Cajal" researcher at the ICP-CSIC. Since 2005 he was a tenured scientist at CIEMAT. In 2009 he was appointed as senior researcher at IMDEA Energy. His scientific activity is mainly focused on the development of processes for the production of sustainable biofuels using advanced hydrodeoxygenation catalysts, the photocatalytic valorization of CO_2 and the development of new materials for thermochemical storage. He has published more than 80 research papers, he has presented more than 80 communications to international and national conferences and he has participated in 12 research projects funded by different public institutions and companies.

Dr. Victor A. de la Peña

Senior Assistant Researcher

He obtained his Ph.D. in 2003 at Catalysis and Petrochemistry Institute of CSIC. In 2004, he was awarded with a "Juan de la Cierva" fellowship at the UB and since 2008 he is a "Ramón y Cajal" researcher of the TCPU. Among other topics, his research interests are focused on heterogeneous catalysis, theoretical chemistry and in-situ characterization fields and their application on selective reactions of energetic interest. He is author of 58 publications in peer-reviewed journals and 1 world patent. He has participated in 40 scientific conferences, and he has been involved in 10 research projects.

Dr. Patricia Pizarro
Associated Researcher

She received her Ph.D. in Chemical Engineer in 2006 with extraordinary Award from Rey Juan Carlos University, where she is now Associated Professor. She is an expert in the preparation of mesostructured and zeolitic materials. She has published 25 scientific articles, presented over 40 communications to conferences and she has participated in 22 research projects. In addition, she has supervised 21 Student Research Projects at Rey Juan Carlos University.

Dr. Prabhas Jana
Postdoctoral Researcher

He moved to IMDEA Energy after finishing his Ph.D. in the National Chemical Laboratory (NCL), Pune (India). He has a considerable expertise on the preparation of catalysts including those based on supported gold nanoparticles. He is author of 30 articles in several international journals and he holds 4 U.S. patents.

Dr. Yongxing Yang
Postdoctoral Researcher

He received his Ph.D. at Dalian Institute (China) and he has been a postdoctoral fellow at Laval University (Canada). His research activity has been focussed on the development of hydrotreating catalysts. He is author of 15 articles in international journals and 1 patent.

Dr. Javier Fermoso
Postdoctoral Researcher

He carried out his doctoral thesis at the National Institute of Coal, CSIC in Oviedo (Spain) focused on the high-pressure co-gasification of coal and biomass. From 2010 to 2012 he was working at the Catalysis Group at the Norwegian University of Science and Technology, NTNU in Trondheim (Norway). He is co-author of 20 research articles and he has presented more than 25 communications to conferences.

Dr. Inés García
Associate Postdoctoral Researcher

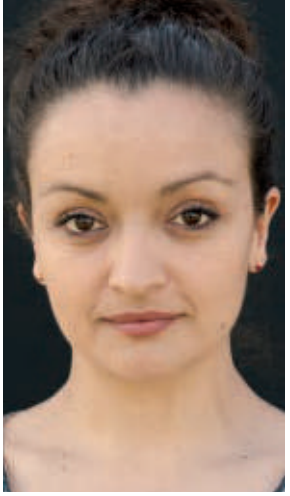
She received her Ph. D. at Rey Juan Carlos Universityy in 2009. Currently, she works as assistant lecturer in the Department of Chemical and Energy Technology at Rey Juan Carlos University. Her current research is focused on the synthesis and catalytic application of zeolitic materials with hierarchical porosity for the production of 2nd Generation biofuels.

Dr. Sankaranarayanan T. Murugan
Postdoctoral Researcher

He received his Ph.D. degree from Anna University, Chennai, India on March 2013 with the research performed at the National Centre for Catalysis Research under the supervision of Prof. S. Sivasanker. He has 6 publications in international journals. He has participated in 10 research projects.

Cristina Ochoa
Predoctoral Researcher

Graduated in Technical Industrial Engineering and in Chemical Engineering by Rey Juan Carlos University. Master in Engineering of Chemical and Environmental Processes. Predoctoral researcher working on biofuel upgrading.



Alicia Bayón
Predoctoral Researcher

Graduated in Technical Industrial Engineering by Rey Juan Carlos University. Master in Energy Technology and Resources. Master in Engineering of Chemical and Environmental Processes. Predoctoral researcher working on hydrogen production by thermochemical cycles.

Laura Collado
Predoctoral Researcher

Graduated in Environmental Sciences by Alcalá de Henares University. Master in Energy Technology and Resources by Rey Juan Carlos University. Predoctoral researcher working on CO2 valorization

Alfonso J. Carrillo
Predoctoral Researcher

Graduated in Chemical Engineering by the University of Salamanca in 2009. Master in Renewable Energies by the University of Leon. Predoctoral researcher working on materials for thermochemical storage.

Antonio M. Berenguer
Predoctoral Researcher

Graduated in Chemical Engineering by the University of Granada (2011). He holds a Master in Renewable Energies from the University of Jaén, (2012). He is currenly working on the development of catalyst for hydrotreating.

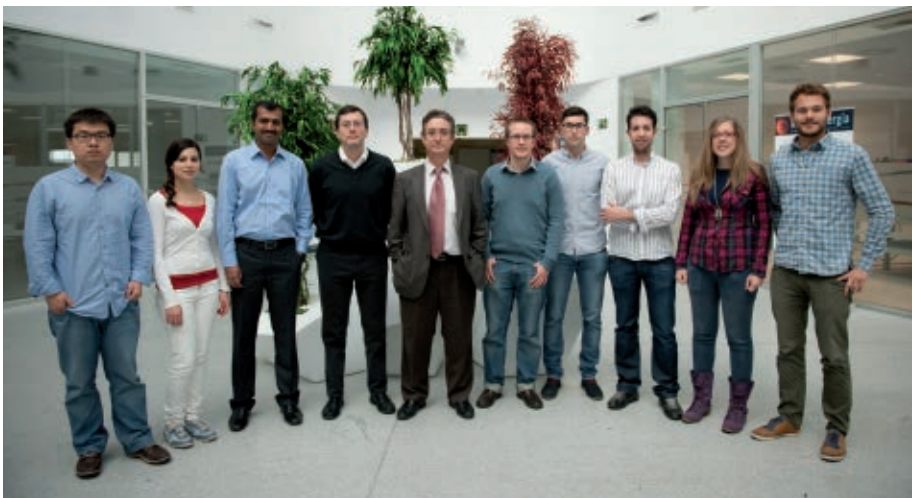
4.2. High Temperature Processes Unit

Research activities

The High Temperature Processes Unit (HTPU) has as main objective the development of efficient and cost-effective high temperature technologies and applications with special emphasis on Concentrating Solar Power Systems (CSP) and production of Solar Fuels and Chemicals (SFC). The commercial deployment of CSP systems in Spain and elsewhere, still based on first generation technologies, is accelerating the development of new solar concentrators, absorbers, high-temperature materials, heat storage and demanding the technical support from new laboratories and research institutions like the IMDEA Energy Institute.

The development of modular solar central receiver schemes for high and ultra-high temperature applications is one of the key topics of research of the HTPU. Sizing and optical analyses of those systems imply the improvement of ray tracing techniques. In 2013 the work on advanced ultra-modular systems has been focused on the "Vertical Heliostat Field" (VHF) concept that proposes a solution to integrate solar heliostat fields into urban communities with acceptable optical efficiencies for Concentrating Solar Power systems. It is based on a heliostat field arranged on a vertical surface, conceived to be integrated in a building façade. The work has involved the optical optimization of this concept; the development of a methodology to determine its capabilities for shading of façades and the analysis of glint and glare in urban environments. A patent application on this concept has been filed. A second outcome in 2013 has been the optical design, construction, commisioning and characterization of a 42 kWe high flux solar simulators. Ray tracing techniques were used to optimize array of reflectors and associated optical engineering.

High temperature solar receivers making use of volumetric porous absorbers or directly illuminated particle receivers are two of the key topics of research of HTPU. In 2013 a new volumetric absorber was developed. It consists of a stack of thin multi-channel monoliths with square cross section channels and where the relative position between consecutive layers is shifted in the transversal direction. The study included the influence



of surface optical properties (absorptivity and reflectivity), the geometrical characteristics of the structure (length, wall thickness and spacing between elements) and the incident radiation profile (related to different heliostats field configurations). For experimental characterization of absorber materials a fully equipped test bench has been developed, including mass flow control, temperature measurement and imaging in the visible and infrared spectrum using CCD, CMOS and IR cameras. Particle receivers based upon the use of rotary kilns or circulating fluidized beds are also subject of research and development for thermal and chemical applications. The work in 2013 focused on the development of a packed bed and a rotary kiln. In addition HTPU is participating in a European Project aiming to develop a new heat transfer fluid with air high charged in particles.

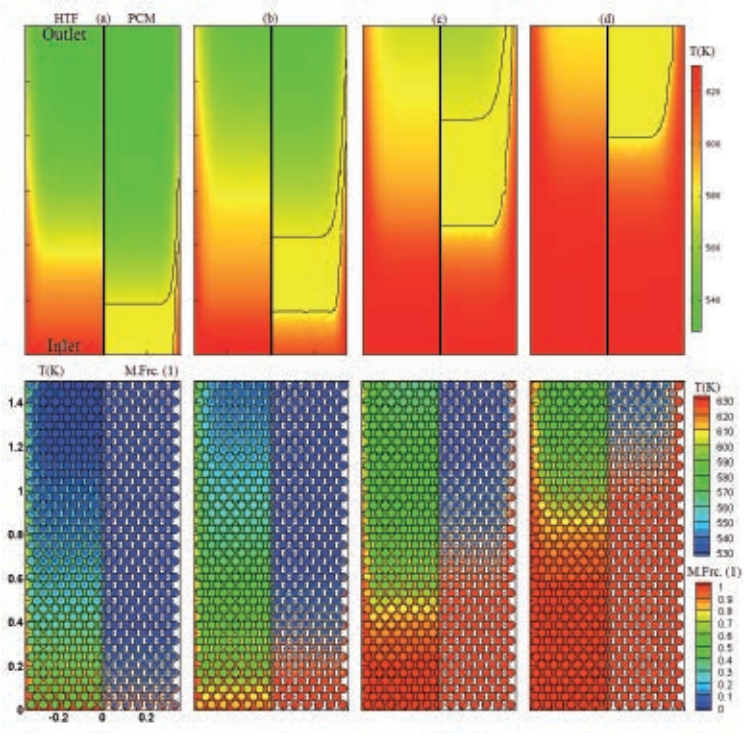
Thermal energy storage (TES) systems based on phase change materials (PCM) can be smaller, more efficient and a lower cost alternative to sensible thermal storage systems for application to CSP. However, most PCMs have low thermal conductivity which leads to slow charging and discharging rates. Several methods employed by researchers to enhance the heat transfer in PCMs include, using extended surfaces, thermal conductivity enhancement using metallic structures, PCM impregnated foams, dispersion of highly conductive particles and encapsulation of PCM. IMDEA Energy carried out textural and thermal characterization of PCMs and developed modelling tools both for individual pellets and storage systems. Storage by means of chemical reactions has also been considered by many researchers for a wide range of temperatures using reversible endothermic/exothermic reactions. TES based on thermochemical cycles is an interesting option as reversible chemical reactions can provide high energy storage density at low cost. Drawbacks may include complexity, cyclability, uncertainties in the thermodynamic properties of the reaction components and of the reaction kinetics under a wide range of operating conditions, high cost, toxicity, and flammability. IMDEA Energy in 2013 conducted research on manganese oxide based systems as potential TES candidates for solar thermal power plants and built a 100 Wh test bed able to test gas-solid reactions at different fluidization regimes up to 1000ºC.

Characterization techniques, measurement of temperatures inside receiver cavities and high-flux measurement are relevant topics of research, still needing substantial improvement. HTPU is developing a world-class characterization laboratory with thermal imaging systems, CCD cameras, pyrometers, calorimeters, pyranometers, radiometers and spectroradiometers. A 7 kW solar simulator, with motorized test bed, for testing components and receivers/reactors at high temperature/high flux solar systems and a new 42 kW solar simulator were implemented.

Solar fuels and chemicals are a medium to long-term application of CSP systems with an enormous potential. The developments being carried out by HTPU on high temperature receivers and systems can be adapted for application on solar-driven production of hydrogen via thermochemical cycles and are performed in cooperation with the Thermochemical Processes Unit (TCPU). The motivation behind the R&D on solar-driven thermochemical

cycles stems from the capability of solar towers to reach temperatures up to 2000ºC and energy fluxes up to 5000 kW/m^2. The MO_{ox}/MO_{red} systems currently studied are based on CeO_2/Ce_2O_3, Mn_2O_3/MnO and $M_xFe_{3-x}O_4$ ferrites, being M a generic metal. One of the key aspects to solve is the optimization of the integration of the chemical process into the solar system. Optical losses at the heliostat field and thermal losses at the solar reactor may lead to an unacceptable decrease of global efficiency. In particular, in 2013 HTPU has dealt with the testing of a solar reactor at laboratory scale for the endothermal reduction step of the Mn_2O_3/MnO cycle for the production of hydrogen. Tests were conducted for different configurations of pellets. In addition the sizing of a solar reactor of 200 kWth for the reduction/oxidation of mixed ferrites, to be implemented in 2014 at the Plataforma Solar de Almería, was carried out. HTPU contributed to the optical optimization of the reactor cavity.

Activities of HTPU in 2013 also involved a number of system integration analysis of new technologies and components in CSP plants. The main focus was the analysis of integration in hotels in combination with PV and geothermal. Another activity carried out involved the flowsheeting and process integration of high temperature steam electrolyzers in direct steam generation solar thermal power plants with central receivers and linear Fresnel reflectors.



Temperature evolution in a packed bed of spherical capsules filled with phase change materials. (Top) Two-phase homogeneous model (Bottom) considering capsules distribution inside the container.

scientists

Dr. Manuel Romero

Research Professor,
Head of the Unit

He received his Ph.D. in Chemical Engineering in 1990 by the University of Valladolid. At present he is Deputy Director and Principal Researcher of the HTPU at IMDEA Energy. M. Romero has received the "Farrington Daniels Award-2009", by the International Solar Energy Society, conferred for his R&D contributions to the development of high temperature solar concentrating systems. At present he is Vice-President of Science & Technology affairs of ISES and member of its Board. In June 1985 he joined CIEMAT, (Spain's National Laboratory for Energy Research), working as Project Manager till 2002 with responsibilities on R&D for solar thermal power plants and solar hydrogen. In 2002 he became Director of the Plataforma Solar de Almería and Director of the Renewable Energy Division of CIEMAT since June 2004 till August 2008. During his career he has participated in 55 collaborative R&D projects in energy research, 20 of them financed by the European Commission. He was Associate Editor of the ASME Journal of Solar Energy Engineering since January 2007-2013 and Associate Editor of the International Journal of Solar Energy since January 2002 till January 2007. He is AE of the International Journal of Energy Research (IJER) published by Wiley & Sons since December 2009. Editor of 6 books related to solar concentrating technologies. He is author of 3 chapters in handbooks of solar energy, 40 papers in scientific journals with SCI and 100 publications in books of proceedings with ISBN. He is co-author of four international patents.

Dr. José González

Senior Researcher

He received his Ph.D. in Physics from the University of Cantabria (Spain) in 1999 and his Habilitation à Diriger des Recherches from the University Paul Sabatier, Toulouse (France) in 2007. Between 2000 and May 2009 he worked as R&D engineer – Project manager at the Center for Energy and Processes – MINES ParisTech. In September 2006 he became Associate Professor at MINES ParisTech (or Ecole Nationale Supérieure des Mines de Paris). Currently, his research interests concern concentrating solar energy systems and technologies. José González has participated in 24 national and international research projects and published 40 papers in peer review journals. He has two international patents one French and two Spanish patents and he is author or coauthor of more than 90 communications in national and international conferences.

Dr. Carlos Pérez

Visiting Researcher

Ph.D. in Engineering by National Autonoma University of Mexico (Universidad Nacional Autónoma de México, UNAM). He graduated with distinction in 2007. The same year, he joined the group of Solar Concentration, at the Centre for Energy Research, UNAM, Mexico. There, he developed solar concentration optical systems, studied transportation phenomena in solar systems and implementation of control systems. He has collaborated in five Mexican research projects, published 6 papers, two Mexican patents and he is author of more than 20 communications in national and international conferences.

Dr. Selvan Bellan

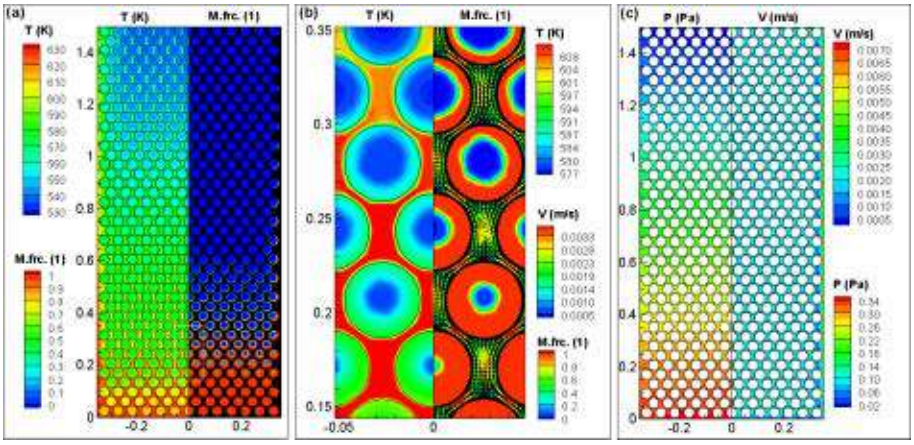
Postdoctoral Researcher

He received the Ph.D. in Physics from VIT University (India) in 2010. He was awarded the Junior Research Fellowship for his doctoral research from BRNS and spent a research stay at Laser and Plasma Technology division, Bhabha Atomic Research Center (BARC), India (2007-2009). After finishing his Ph.D work, he joined as Scientific Officer in Center for Research in Thermal Management, Karunya University, India (2009-2010), and later he worked as Research Scientist in Development Department, Plasma Giken Co., Ltd, Tokyo, Japan (2010-2011). In this period, he focused on 3D numerical modeling on Cold Spray Processes and spent a research stay in the Joining and Welding Research Institute, Osaka University, Japan. Currently, his research area is numerical modeling on concentrating solar energy systems. He has published 8 papers in peer reviewed international journals and 12 papers in international and national conferences.

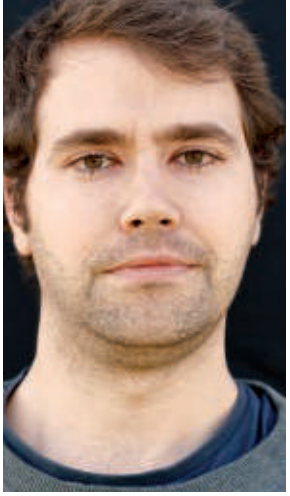
Dr. Jian Li

Postdoctoral Researcher

He received his Ph.D. in Electrical Engineering from the Institute of Electrical Engineering, Chinese Academy of Sciences (China). He has published 6 research papers in SCI journals, including Solar Energy Materials & Solar Cells, Solar Energy, Renewable Energy, etc., and 5 papers in international conferences. Currently, his research is mainly focused on optical and energy characterization of solar concentrating systems under high flux/high temperature conditions.



Computational Fluid Dynamic analysis on thermal storage in a packed bed composed of spherical capsules filled with phase change material.

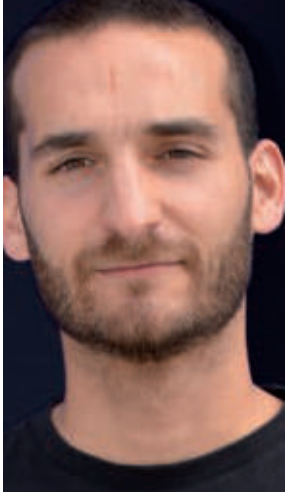


Aurelio J. González
Predoctoral Researcher

Graduated in Mechanical Engineering by the Polytechnic University of Valencia. Master on Renewable Energy, Hydrogen and Fuel Cells by CSIC-UIMP. Predoctoral researcher working on concentrating optics design and ray tracing techniques.

Elisa Alonso
Predoctoral Researcher

Graduated in Chemical Engineering by the University of Salamanca. Master in Energy Technology and Resources by Rey Juan Carlos University. Predoctoral researcher working on solar receivers and reactors



Javier Sanz
Predoctoral Researcher

Graduated in Mechanical Engineering by the University Carlos III of Madrid. Master in Engineering of Chemical and Environmental Processes. Predoctoral researcher working on integration of advanced solar thermal power systems.

Fabrisio L. Gómez
Predoctoral Researcher

Graduated in Mechanical and Electrical Engineering by Universidad Iberoamericana (UIA). Master in Energy Engineering by UNAM, Mexico. Predoctoral researcher working on measurement and characterization of high flux/high temperature solar systems.

Sandra Alvarez
Predoctoral Researcher

Graduated in Chemical Engineering by the University Rey Juan Carlos. Predoctoral researcher working on thermochemical energy storage systems for solar thermal power plants.

Alessandro Gallo
Predoctoral Researcher

Graduated from University of Bologna in Energy Engineering. MSc Degree in Energy Engineering from University La Sapienza of Rome. Predoctoral researcher working on integration of solar energy technologies in energy systems and buildings.

4.3. Electrochemical Processes Unit

Research activities

One of the main targets of the Electrochemical Processes Unit (ECPU) is to provide new concepts and technological alternatives for electrochemical energy storage. The energy storage systems developed by the ECPU are aimed to be applied both to renewable energies and to the electrification of transport. The other main target of the ECPU is to provide new concepts and technological alternatives for efficient water treatment by means of electrochemical capacitors. The energy efficiency is the main objective, but the proposed technology also involves high water recovery, low effluent production, and low operating cost because neither high pressures nor membranes are required.

Energy storage is becoming a critical issue in electric grids in which a large contribution of renewable sources is creating a mismatch between generation and demand. In this way, bulk storage technologies enable utilities and system operators to harvest the full potential of intermittent renewable power by storing wind and solar energy produced during off-peak periods. Large-scale storage technologies connected at the transmission level offer ancillary services such as following load, providing ramping duty, or stabilizing voltage and frequency. Finally, smaller-scale distributed energy storage technologies can enhance service to end-users by providing ride-through protection against outages; such systems can also improve power quality by protecting against harmonic distortions, voltage sags, and surges. Depending on the specific application, different technologies can be applied. Specifically, the ECPU works on large storage capacity systems by using flow batteries, and in high power and rapid response systems based on electrochemical capacitors.

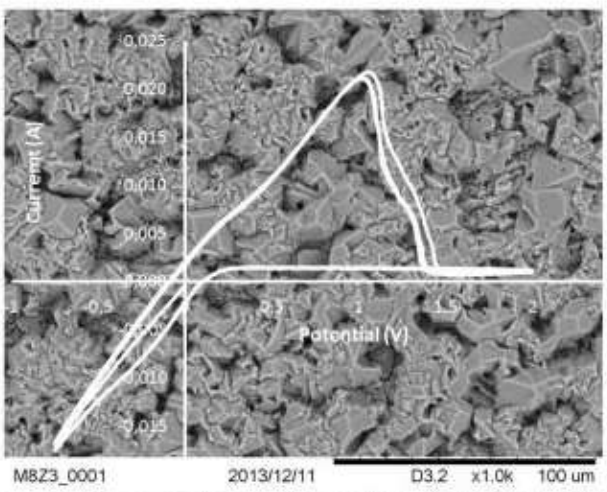
In the ECPU we believe that electrification of both the mobility and transport system is one possible answer to the challenge created by a combination of factors as for instance, the limitation of fossil energy resources, the impact on the climate change of CO_2 emissions from internal combustion engines, a growing demand for mobility and energy in

emerging regions, and the continuous increase of population concentrated in urban areas that lead to higher requirements of transportation of goods and persons. Consequently, new concepts and new technologies need to be developed to realize efficient electric vehicles suited for mobility in urban areas.

Regarding cruising range, affordability and space provided in the vehicle, today's electric vehicles fulfil customer requirements only to a limited extent. From a customer point of view, the main difference between an internal combustion engine and an electric vehicle (EV) is the significantly lower autonomy of EV and the longer recharging time. Nowadays, the major technological limitation to bridge these gaps relays in the battery. Advanced batteries with higher energy densities are necessary for extending the range of EV as well as to shorten the recharge time. Technologies such as Li-ion batteries are currently under development, but in the ECPU we want to go further working on newer technologies of much higher energy densities such as metal-air batteries.

Other requirement of full electric and hybrid electric vehicles is an efficient regenerative braking system in which the energy must be rapidly recovered and stored. Furthermore, power peaks for acceleration and for steep slopes require additional power supply to the motor drive that can be reached by over dimensioning of the battery or by implementing technologies complementary to batteries such as capacitors. This last is the approach selected at the ECPU, which is now working on hybrid capacitors with higher energy densities.

The ECPU research activities also involve simulation and modeling of energy storage devices, as well as testing of batteries and supercapacitors to monitor their electrical performance and lifetime evolution of capacity, resistance and power.



Aluminum electrodeposited at room temperature from 1-Butyl-3-methylimidazolium chloroaluminate ionic liquid. A cyclic voltammetry is also included to show the oxidation and reduction of Al with an overpotential of about 1V

scientists

Prof. Marc A. Anderson

Research Professor,
Head of the Unit

He is Head of the Electrochemical Processes Unit (ECPU). At the same time he is Chair of the Environmental Chemistry & Technology Program at the University of Wisconsin-Madison, where he is also Full Professor at the Department of Civil & Environmental Engineering. He received his Ph.D. in Environmental Engineering from Johns Hopkins University in 1976. He has been Visiting Researcher in the Catholic University of Louvain (Belgium, 1981), the Institute of Ceramics and Glass of CSIC (Spain, 1989), and CIEMAT (Spain, 2002). His main research interests are chemistry and materials science aspects of micro and nanoporous thin-films applied to a variety of uses, but mostly in areas related to their photoelectrochemical and electrochemical properties. He has been involved in many research projects supported with public and private funds coming from US organizations and private companies. He is author of about 200 publications in scientific journals, more than 25 patents and of 1 book. His historical Hirsch Scientific Index is 48. Besides, he has presented numerous communications in scientific conferences, many of them as keynote speaker.

Dr. Jesús Palma

Senior Researcher

He is Senior Researcher of the ECPU and Lecturer at Rey Juan Carlos University. Formerly he was Director of the R&D Centre of Tecnicas Reunidas. He received his Ph.D. in Chemistry from Autonoma University of Madrid in 1994. He has been Visiting Researcher at the Imperial College (UK), the Energy Research Centre of the Netherlands (ECN) and the University of Wisconsin-Madison (USA); and in research centers of companies such as Iberdrola (Spain), Ansaldo Ricerche (Italy) and Philips Components (Netherlands). His work has been mainly related to electrochemistry and electrochemical engineering applied to energy storage, energy conversion, metal recovery, and decontamination of residues and effluents. He has participated in more than 40 research projects funded by public institutions, national and international companies; being the principal researcher of about 20. He has been involved in 6 European research projects. He is co-author of about 20 scientific papers in international journals and 1 patent.

Dr. Raúl Díaz

Senior Assistant Researcher

He is a "Ramon y Cajal" researcher of the ECPU. He received his Ph.D. in Chemistry from the University of Barcelona in 2002. He has experience in the fields of electrochemistry and materials science, including postdoctoral stays in the Department of Chemistry of the University of California Berkeley and in the Materials Science Division of the Lawrence Berkeley National Laboratory. He is author of around 30 publications in journals and holds 1 international patent. He has participated in more than 30 scientific conferences, and 15 research projects. In 2010 he received one of the "R&D 100 Awards" for technological innovation.

Dr. Rebeca Marcilla
Senior Assistant Researcher

She is a "Ramon y Cajal" researcher of the ECPU. She received her Ph.D. in Chemistry by the University of the Basque Country in 2006. After her PhD, she joined the Technological Center CIDETEC (Centre for Electrochemical Technologies) and performed two research stays at the Eindhoven University of Technology (Chemical Engineering and Chemistry-Polymer Chemistry) and at the University College London (London Center for Nanotechnology). Her main research interest is the development of electrochemical energy storage devices by using new Ionic Liquid-based electrolytes. She is co-author of more than 40 scientific papers in international journals and 2 patents. Her Hirsch Scientific Index is 21.

Dr. Chandrasekaran Ramasamy
Senior Assistant Researcher

Ph.D. degree at Physics center from Anna University. Postdoctoral researcher at Alagappa University (Karaikudi, India), Aichi Institute of Technology (Nagoya, Japan), Tsukuba, (AIST west, Japan), Kansai University (Osaka, Japan) and Central electrochemical research institute, CSIR-CECRI (Karaikudi, India). His main research activities are electrochemical and physical characterizations of electrode and electrolyte materials. He has about 20 research articles in his credits. He has received 7 patents and contributed to 6 scientific meetings at national and international level.

Dr. Enrique Garcia-Quismondo
Postdoctoral Researcher

Ph.D. degree in Chemistry by Autonoma University of Madrid in 2010. He has worked at the R&D Centres of Exide-Technologies and Tecnicas Reunidas, building up an experience of 10 years in the fields of advanced lead-acid batteries, flow batteries and metal-air batteries, participating in research projects funded by the European Union, the Spanish Government and by private companies. He is specialized in development of electrochemical prototypes, through modelling, design and assembling of cells and packs, and scaling them up. Currently he is working in the development of electrochemical energy storage prototypes by using new concepts generated in the laboratory. In 2013 he received a grant from Iberdrola Foundation under the Call "Research in Energy and Environment 2013-2014" .

Susana Vaquero
Predoctoral Researcher

Graduated in Chemistry by Complutense University of Madrid. Master in Energies and Fuels for the Future by Autonoma University of Madrid. Predoctoral researcher working on the designing and testing of electrochemical capacitors based on carbons.

Suheda Isikli
Predoctoral Researcher

Graduated in Chemistry by the Middle East Technical University of Ankara (Turkey). Master in Energies and Fuels for the Future by Autonoma University of Madrid. Predoctoral researcher working on the electrochemistry and energy applications of organic compounds.

Laura Sanz
Predoctoral Researcher

Graduated in Chemical Engineering by Rey Juan Carlos University. Master in Electrochemistry: Science and Technology by Autonoma University of Madrid. Predoctoral researcher working on redox flow batteries.

Girum Tiruye
Predoctoral Researcher

Graduated in Applied Chemistry by Arba Minch University, Ethiopia in 2009. Master in Environmental Sciences by Wageningen University and Research Center (WUR), The Netherlands. Predoctoral researcher working on “Application of Innovative Polyelectrolytes and Graphitic Materials in Supercapacitors”.

Cleis Santos
Predoctoral Researcher

Graduated in Chemical Engineering by Rey Juan Carlos University. Master in Energies and Fuels for the Future by Autonoma University of Madrid. Predoctoral researcher working on materials and designs for capactive deionization for water treatment.

Ignacio Almonacid
Researcher in Training

Garduated in Industrial Technical Engineering by Polytechnic University of Madrid. He is working on fast batteries charge experiments to automotive.

4.4. Biotechnological Processes Unit (Joint Unit CIEMAT / IMDEA Energy)

Research activities

This unit is engaged in the development of novel processes for biofuels productions. The objective of BTPU is to develop knowledge, processes and technologies to produce biofuels by biological processes from lignocellulosic biomass and microalgae. The BTPU researchers are working on the most challenging steps of the production process such as both enzyme and fermenting microorganisms development and the production of bioethanol and biogas from microalgae.The joint research group is an integrated team of scientists from IMDEA Energy and CIEMAT (Public research Agency for excellence in energy and environment attached to Spanish Ministry of Economy and Competitiveness) who are specialist in different areas of producing energy by means of biotechnological processes.

Regarding the research line focused on microalgae, the activity developed was aimed at the determination of structural and storage carbohydrates of microalgae and cyanobacteria. Structural carbohydrates are nowadays regarded as the major drawback for biofuel production since they protect the microalgae cells towards any bioconversion. The research conducted in the unit using microalgae biomass for biofuel purposes is targeted at the production of biogas. In this sense, the cell wall disruption of the microalgae biomass is a must for and efficient biogas conversion. The research activity has been devoted to evaluate and adapt to microalgae biomass different pretreatment methods currently applied to other lignocelullosic biomasses.

Within the lignocellulosic research line, the activity has been centered in the selection and optimization of enzymes and microorganisms for the production of alternative biofuels. In this context, the research group has studied the enzymatic systems involved in the conversion of straw biomass into bioethanol (lignin degradation, biomass hydrolysis and inhibitors tolerance). Likewise, the research group also was following a genetic engineering approach in which fungal laccases (responsible for the detoxification of pretreated materials) can be expressed by yeast.

scientists

Dr. Mercedes Ballesteros

Research Professor,
Head of the Unit

Ph.D. in Biology by Autonoma University of Madrid and Master in Biotechnology by Complutense University of Madrid. Head of the joint Unit on Biotechnological Processes for Energy Production at IMDEA Energy from April 2011 and Head of Biofuels Unit at CIEMAT from January 2010. She was Head of Biomass Unit at CIEMAT (2004-2010) and Leader of the Liquid Biofuels Project (2000-2004). Project manager at CIEMAT since 1990 till 2000 with responsibilities on R&D for biomass characterization and energy production from biotechnological processes. She is member of the Spanish Society for Biotechnology (SEBIOT), of the European Biofuels Technology Platform (EBTP) and Vice-president of the Spanish Biomass Association (ADABE). Spanish representative in the European Bioenergy Industrial Initiative of the Strategy Energy Technology Plan, member of the Steering Group in the European Energy Research Alliance in Bioenergy and member of the Coordinator Core in the Spanish Technology Platform (Bioplat). She has been guest speaker at numerous meetings and conferences on energy, especially in the area of bioenergy. Teacher in many courses organized by various universities and organizations. She has participated in more than 50 R&D projects on biomass research, 10 of them financed by the European Commission. She has authored about 56 papers in SCI journals and 5 chapters in technical handbooks. She is co-author of 3 patents and external consultant for ECLAC of United Nations and the Spanish Agency for International Cooperation (AECID).

Dr. Cristina González

Senior Assistant Researcher

Her research career started in the University of Cincinnati (USA). There she has worked in developing analytical methods to quantify endocrine disruptor compounds in wastewater After that, she got her Ph.D. in Chemical Engineering and Environmental Technology at the University of Valladolid (2008). After her Ph.D., she joined the technological Center ITACyL where she worked on lab and real-scale plants dealing with livestock effluent treatments. After that, she got a postdoc position at the French National Institute for Agricultural Research (LBE-INRA, France) to work on the optimization of biogas production using microalgae. She is co-author of 23 scientific publications. Additionally, she has been involved in European and national funded research projects, as well as in projects with private companies.

Dr. Marie Demuez

Postdoctoral Researcher

Ph.D. in Biochemistry at the INSA of Toulouse (2007). She had a position in UC Davis / UC Berkeley and then a postdoctoral contract at IMDEA Energy to work on biological production of hydrogen by nitrogenase. She is co-author of 5 scientific publications, and has been involved in European and national funded research projects. She has participated in 8 national and international research projects.

Dr. Mª. José Negro
Associated Senior Researcher

Her research career has been developed in the Biofuels Unit at Renewable Energies Division of the Department of Energy of CIEMAT. She has more than 20 years of experience in the development of biomass as renewable energy source. The main research areas include production and characterization of starchy and lignocellulosic biomass, including biological processes for energy production from biomass, ethanol production by enzymatic hydrolysis, microorganisms research for biofuel production, fermentative processes and biomass pre-treatment. She is co-author of more than 37 peer-reviewed papers and book chapters and co-inventor of 2 patents. She has supervised 1 Ph.D. Thesis and 2 Master theses. She has participated as external evaluator of research projects (FONDECYT-Chile, NWO-Netherlands).

Dr. Ignacio Ballesteros
Associated Senior Researcher

He is a Senior Researcher at CIEMAT. He obtained his Ph.D. degree in Biology at the University of Alcalá de Henares (2000). His entire research career has been developed within the Department of Renewable Energy at CIEMAT. His research has focused on the production of biofuels and their use in the transport sector, mainly in bioethanol production processes from lignocellulosic biomass: characterization of raw materials; lignocellulosic biomass pre-treatment; hydrolysis of polysaccharides (acid and enzymatic) and fermentation. He is the co-author of more than 40 peer-reviewed papers and book chapters, and co-inventor of 3 patents. He has participated in more than 30 national and international research projects, focusing on the production of bioethanol from biomass. He has supervised 2 PhD Thesis.

Dr. Felicia Sáez
Associated Senior Researcher

She has developed her research career in Renewable Energy Division, Department of Energy of CIEMAT. Her research has focused on the development of analytical techniques necessary for the determination of chemical compounds generated at various stages during the chemical and biological processes for the bioethanol production from biomass and those techniques for emissions testing produced in the process of transformation of biomass into heat and electricity, including the environmental aspects of this renewable energy. She has 28 years of experience in the area of obtaining liquid biofuels and study of conventional emissions and polycyclic aromatic compounds produced in the biomass combustion process. She has participated in more than 30 national and international projects. She is co-author of around 40 papers presented in research journals and congress proceedings and of over 25 technical reports in the area of biomass in relation to development projects.

Antonio D. Moreno
Predoctoral Researcher

Graduated in Biochemistry by the University of Extremadura. Diploma of Advanced Studies in Biochemistry and Molecular Biology. Predoctoral researcher working on the development of biological systems for detecting interactions of oxygen sensitive proteins. He is the co-author of 6 peer-reviewed papers.

Alfredo Oliva
Predoctoral Researcher

Graduated in Biology by the University of Alcala (Spain). Master in Genetic and Cellular Biology. Predoctoral researcher working in the improvement of lignocellulosic ethanol production by displaying laccases on fermentative yeast.

Ahmed Mahdy
Predoctoral Researcher

Graduated in Genetic Engineering by the University of Zagazig (Egypt). Master in Microbiology. Predoctoral researcher working on biological pretreatments for cell wall disruption of microalgae accumulation of carbohydrates and subsequent conversion to bioogas.

Lara Méndez
Predoctoral Researcher

Graduated in Biology by Complutense University (Spain). Master in Clinical Analysis. Predoctoral researcher working on thermochemical pretreatments for cell wall disruption of microalgae and cyanobacteria and subsequent conversion to biogas.

4.5. Electrical Systems Unit

Research activities

The main objective of the Electrical Systems Unit is to actively participate in the undergoing process of conceptual and practical changes in the way how electrical energy is generated, distributed, stored and consumed. There is now a widely adopted consensus that the conventional methods of energy management used for electricity generation, transmission and distribution cannot provide the required level of system reliability and robustness. The principal challenges are, therefore, the creation of new, highly coordinated and decentralised management algorithms that would truly harness the advantages of the new information flows provided by real-time monitoring and control resources.

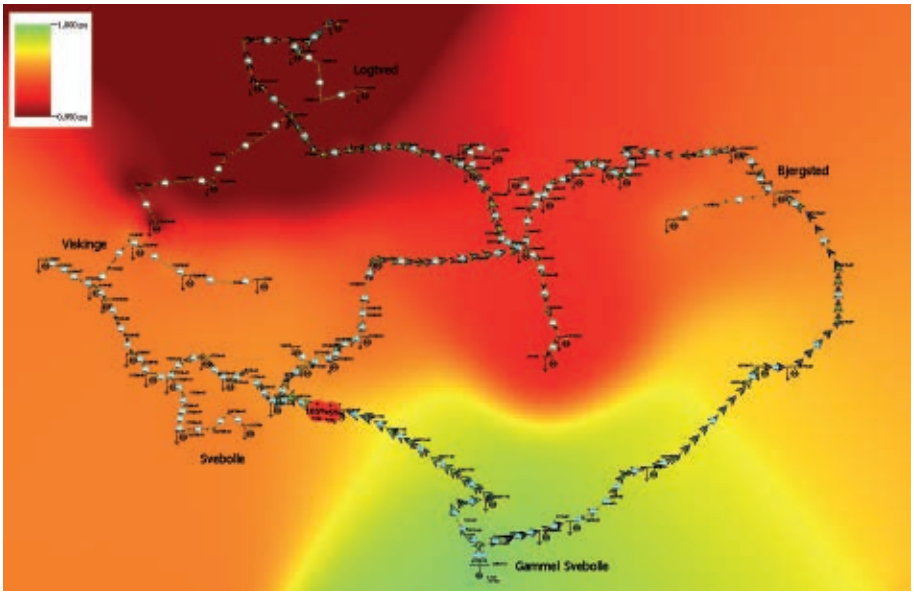
Active management of power networks is the principal research line. The focus is on development of new services and related tools for distribution system operators (DSOs) and incorporation of end users to the management schemes. Intelligent services for distribution networks like state estimation, voltage control, congestion management etc. have all been under investigation. Demand management, in general, and new schemes for coordinated demand response, in particular, are one of the main research challenges. Also, reliability analysis for power networks with high penetration of renewable technology have been studied.

“Smart buildings” and “Smart homes”, their energy management, coordination and integration to power networks, represent important activities of this research unit. Starting from a holistic approach when looking into energy demand of a building, the optimal demand management techniques are proposed and developed. Meanwhile, the options for renewable integration and storage device utilisation are explored in order to improve the building autonomy and increase its self-consumption.

Another related topic is energy management in microgrids where both islanded and grid-connected networks are considered. Control aspects for power converters, renewable and storage management, proactive and optimal dispatch algorithms and stability analysis for small power networks are all investigated. By using our facilities in the "Smart Energy Integration Lab" we are now in position to recreate any energy scenario or particular event of interest for renewable and storage integration.

Improving energy efficiency in industrial applications has been an already well established line of research. By using detail modelling of the consumption profiles and by identifying the principal patterns along the nominal modes of operation, the possibilities for energy saving are sought. Principal technologies behind the energy efficiency improvement are information systems, power electronics converters and energy storage systems.

Energy storage systems, their charge/discharge process, their integration to power networks and their application to electric vehicles have been of particular interest. The research activities include both development of future battery test equipment based on advanced power electronics interfaces and also development of management and control algorithms for storage applications.



Results of state estimation for a distribution power network

scientists

Dr. Milan Prodanovic

Senior Researcher,
Head of the Unit

He received his B.Sc. degree in Electrical Engineering from the University of Belgrade, Serbia in 1996 and obtained his Ph.D. degree from Imperial College, London, UK in 2004. From 1997 to 1999 he was engaged with GVS engineering company, Serbia, developing power electronic circuits and control algorithms for inverter and UPS systems. Milan has been Work Package leader in a number of national and international projects and was closely collaborating with his partners in UK, Belgium, Switzerland, Kenya and Japan. Milan authored several journal and conference papers and is holder of 3 international patent applications in the area of energy efficiency and converter control. His research interests lie in design and control of power electronic systems, real-time simulation of power networks, decentralized control of distribution power networks and microgrids and energy efficient industrial applications.

Dr. Jörn Klaas Gruber

Postdoctoral Researcher

He obtained his first degree at University of Stuttgart in 2002, his MSc degree from Polytechnic University of Valencia in 2004 and his Ph.D. from University of Seville in Automation and Control Engineering in 2010. Thereafter, he joined Gamesa, working in the area of wind turbine control before joining IMDEA Energy. His research interests are in the fields of smart grid optimization, model predictive control, nonlinear and robust control, distributed generation and decentralized control. He is author of a number of international journal and conference papers and holds 2 international patents.

Dr. Francisco Huerta

Postdoctoral Researcher

Francisco graduated in Telecommunications Engineering (2004) and in Electronics Engineering (2006) from the University of Alcalá (Spain). He obtained his doctoral degree in 2011 from the same university as a holder of a prestigious funding scheme PIA introduced by the Regional Government of Madrid. Francisco has authored various journal and conference articles and he has participated in several research projects related to control and applications of power electronics converters in renewable energy systems and control of grid connected power electronics converters. His research interests include converter control, power quality, distributed generation systems and microgrids.

Dr. Barry Hayes
Postdoctoral Researcher

Barry received the B. Eng. degree in Electrical and Electronic Engineering from University College Cork and a Master degree from the National University of Ireland Maynooth. He then moved to the University of Edinburgh, Scotland, where he completed his Ph. D. in 2013. As part of his Ph.D. research, he had a placement at National Grid at the UK Energy Network Centre in Berkshire, England in 2011. In addition, Barry has worked as a Research Fellow at the University of Edinburgh in projects related to power system reliability and wind resource assessment and has published a number of journal and conference papers.

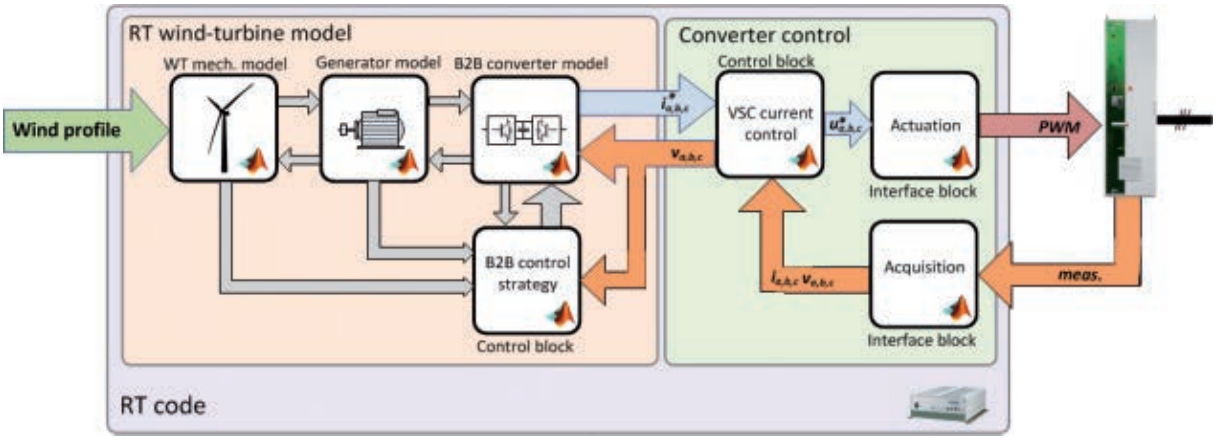
Tokhir Gafurov
Predoctoral Researcher

MSc Degree in Electric Power Systems from Tashkent State Technical University in Uzbekistan and MSc Degree in Mechanical Engineering from Royal Institute of Technology (KTH) in Sweden. He worked for three years as an electrical engineer in Design Surveying & Scientific-Research JSC "Sredazenergosetprojekt" in Uzbekistan and two years as a junior gas turbine aerodynamicist at Siemens Industrial Turbomachinery AB in Sweden. He is currently predoctoral researcher in energy efficiency in industrial applications, renewable integration and future energy markets.

Belén Téllez
Predoctoral Researcher

Engineering Degree in Electronics and Telematics from University of Málaga, Spain. Predoctoral researcher working in the development of intelligent algorithms for management of future power networks.

Model-based emulation of permanent magnet synchronous generator for wind energy



4.6. System Analysis Unit

Research activities

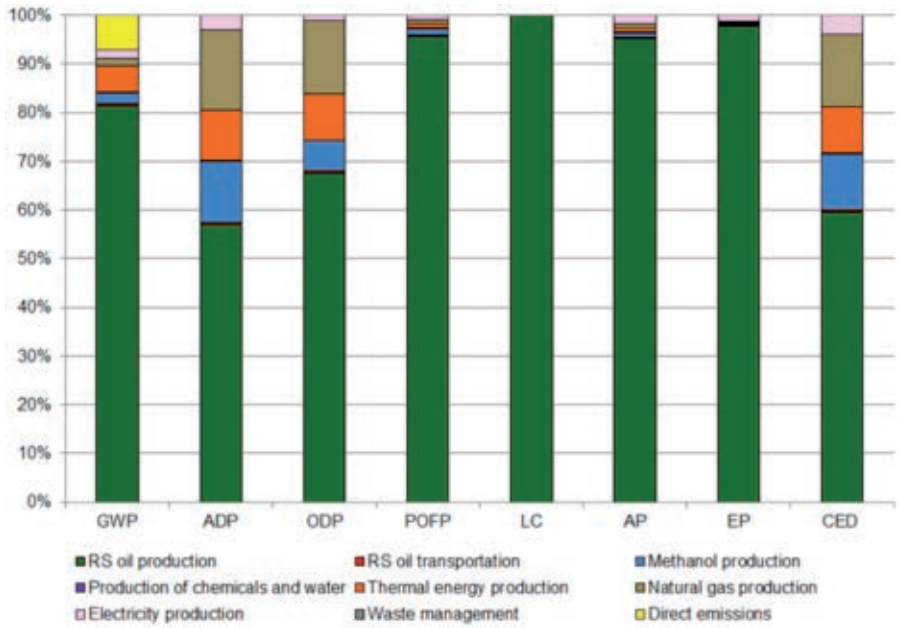
During 2013,one of the key activities of SAU has been the development of new tools to assess the performance of energy systems. Emergy and Data Envelopment Analysis (DEA) coupled to Life Cycle Assessment (LCA) were applied to wind farms to determine their environmental performance and efficiency, respectively. They are now being applied to new energy systems like biofuels or solar.

The research on clean fuels was continued focusing on LCA and exergy studies. On one hand, studies on biodiesel production from cardoon (Cynara cardunculus) and Fischer-Tropsch products from biosyngas were carried out. On the other hand, the exergetic balance of fast pyrolysis process for bio-oil production was analyzed based on the simulation model developed along 2012. Also on clean fuels, a process for the obtaining of ethanol from microalgae (*Chlorella vulgaris)* was designed to optimize energy balance and environmental profile. The results showed a better performance in comparison to the obtaining of biodiesel.

On the field of hydrogen production, the simulation of gasification processes was completed and the model developed was used to determine its LCA, taking into account different raw materials (waste and energy crops), different layouts and the coproduction of electricity. They were compared to stem reforming of different raw materials. Also, the research on hybridization of photovoltaics with biomass to generate hydrogen was completed, optimizing the flow-sheet and determining the main economical parameters. The cost of the hydrogen produced ranks over 6,5 $/kg which can be considered competitive, especially when it can benefit from scale economy. From the simulation results of this research, a new study that is on the edge between hydrogen production and CO_2

valorisation was initiated. It consists on the coelectrolysis of steam and CO_2 to produce syngas in high temperature electrolyzers. As well in CO_2 capture and valorisation, the feasibility of its capture, transport and storage with and without enhanced resource recovery was studied from environmental and thermodynamic points of view.

Finally, a new research line was started out on social aspects of energy systems. Along 2013, new indicators taking into account geographic and economic scope were developed.



Environmental characterization of hydrogen production via bioglycerol steam reforming

scientists

Dr. Javier Dufour

Senior Researcher,
Head of the Unit

B.Sc. (1990) and Ph.D. (1995) in Chemical Sciences, with emphasis on Industrial Chemistry, by Complutense University of Madrid, where he developed his teaching career from 1991 until 2003. Previously, he got a grant for researching at the National Centre for Metallurgical Research (CSIC). He enjoyed a postdoctoral stay at the TNO Institute for Industrial Technology (Holland) during 1996 and 1997. In this time, his main research lines were focused on the design of processes for the recovery of metallurgical and steelmaking wastes and the conservation of cultural heritage goods supported on paper. He joined Rey Juan Carlos University in 2003, where he is currently Associate Professor. He is Coordinator of the Ph.D. Programme on Chemical and Environmental Engineering at the Rey Juan Carlos University and Chairman of the Resources Commission of ESCET. His main research lines are energy systems analysis, life cycle assessment and management of processes and products, simulation and optimization of processes, and economical estimations. He is author of 60 papers published in international journals, more than 100 contributions to conferences and 3 patents. He has collaborated in 43 research projects, being the responsible researcher in 18 of them. Currently, he is the Coordinator of the Spanish Network of LCA.

Dr. Diego Iribarren

Postdoctoral Researcher

Ph.D. in Chemical and Environmental Engineering (2010) at the University of Santiago de Compostela. His research includes environmental management (Life Cycle Assessment, Carbon Footprinting, LCA+ Data Envelopment Analysis), as well as simulation and optimization of production systems. He has been involved in 9 research projects and published more than 20 research articles.

Dr. Fontina Petrakopoulou

Postdoctoral Researcher

Ph.D. in Energy Engineering from the Technical University of Berlin (Germany) in 2010. Her work focuses on the simulation, evaluation and improvement of energy conversion systems using cost- and environmentally-related exergy-based methods. She is author of 2 book chapters and 15 papers. She has participated in 27 international conferences and workshops.

Dr. Abel Sanz
Postdoctoral Researcher

Ph.D. in Chemical Engineering (2012) by Complutense University of Madrid. His investigation is focused in the simulation, design and optimization of processes in the energy field.

Dr. Tadhg O´Mahony
Postdoctoral Researcher

Following completion of his BSc and Dip in Environmental Management, he worked in industry for two years. He was awarded an Irish government scholarship and successfully completed his Ph.D. (2010) in Dublin Institute of Technology on scenario analysis of the Irish energy system.

Jens Peters
Predoctoral Researcher

Dipl. Ing. in Electronic Engineering (Information Technologies) from TU Munich, Germany (2003) and MSc in Renewable Energies, Fuel Cells and Hydrogen from Universidad Internacional Menéndez Pelayo and CSIC (2010). Predoctoral researcher working on assessment of biomass pyrolysis.

Ana Susmozas
Predoctoral Researcher

Chemical Engineer by Rey Juan Carlos University of Madrid in 2010. Predoctoral researcher working on biomass gasification.

Pedro Luis Cruz
Predoctoral Researcher

Chemical Engineer by Rey Juan Carlos University of Madrid in 2013. He is predoctoral researcher working on biomass integration in crude refineries.

Mario Martín
Predoctoral Researcher

BSC on Enviromental Science by Rey Juan Carlos University of Madrid in 2013. He is predoctoral researcher. His research is devoted to the development of tools to assess the environmental performance of energy systems.

facilities and scientific infrastructures

annual report 2013

5.1. Building and general infrastructures

The building and laboratories of IMDEA Energy Institute are located at the Technological Park of Móstoles on a land with 10,000 m^2. The ownership of the land was ceded in 2008 by the Municipality of Móstoles. Design and construction of the building was conceived in two consecutive phases.

The first phase of the construction was commissioned by July 2011, with 3,139 m^2 of surface built above ground level and 583 m^2 underground. Phase 1 includes spaces for up to a maximum of 60 persons and 6 research groups as well as an auditorium, a parking lot, and provisional areas for the administration and management. During January 2012 the transfer of personnel and equipment of IMDEA Energy Institute to the Phase 1 of the building took place. The end of construction works and commissioning of Phase 2 was completed at the beginning of 2012, with 3,180 m^2 of surface built above ground level and 1,000 m^2 underground.

The design incorporates high efficiency systems in terms of energy saving and comfort, as well as geothermal pumps, cogeneration with natural gas and solar thermal and photovoltaic systems, determining an Energy Efficiency Label of Category A for the building and the Gold LEED certificate, indicative of a minimum environmental impact of both the building and the construction process, having a high international recognition.

Along the year 2013 several research units, the Executive Board and the management and administrative staff moved to the second phase of the building. Likewise a number of singular scientific equipment was installed in the pilot plants, like for example the solar simulator and the batteries test bench. Also, in 2013 it took place the inauguration ceremony of the new building under the presidency of Mr. Ignacio González, President of Comunidad de Madrid.

Inauguration of the IMDEA Energy Institute building.

Lateral view of the IMDEA Energy Institute building.

The IMDEA Energy headquarters have been built thanks to the funding coming from different sources: the Regional Government of "Comunidad de Madrid", the Spanish Ministry of Economy and Competitiveness and European Union Structural Funds.

5.2. Scientific equipment and laboratories

Considering the multidisciplinary character of energy research, the need of scientific instrumentation, devoted to support and complement the experimental research performed by the different research units, was considered crucial for establishing the IMDEA Energy Institute as a world-class research centre. These laboratories have been provided with some of the state-of-the-art instruments for the characterization of solids and surfaces. In addition, this facility is also provided with advanced equipment for chemical and thermal analyses. In order to facilitate their utilization and management the apparatus were grouped in the following laboratories:

Laboratory of Thermal and Chemical Analysis

- ICP-OES (Chemical Measurements) Perkin Elmer OPTIMA 7300DV with autosampler.
- Microwave for sample Digestion Anton Parr Multiwave 3000.
- Thermal Diffusivity Measurements Equipments Netzsch LFA 457 Microflash.
- Thermo Gravimetric Analyser (TGA/DSC) TA Instrument.

Laboratory of Spectroscopy

- UV/Vis/NIR Spectrometer (Optical Properties Measurements) Perkin Elmer Lambda 1050.
- Fluorescence Spectrometer (Optical Properties Measurements) Perkin Elmer Ls 55.
- Two FTIR Spectrometer NICOLET 6700 with MCT detector and provided with the following accessories: TG-FTIR, DRIFT Chamber, ATR Cell, Veemax, and Fiber Optic.
- Laser Raman Spectrometer Jasco NRS-5100 with two laser sources (λ= 532 nm and 785 nm) with a LINKAM atmospheric chamber.

Laboratory of Structural and Textural Properties

- Multypicnometer (Materials Density Measurements) Quantachrome Instruments MVP.6DC.
- Quadrasorb (Analysis of Textural Properties) Quantachrome Instruments SI MP-9.
- Autosorb (Analysis of Textural Properties) Quantachrome Instruments Asiq Mv022.
- Chemisorption Analyzer (reduction/desorption/oxidation), provided with Thermal Conductivity Detector (TCD) or Mass Spectrometry, Micromeritics Autochem II.
- XRD diffractometer X'Pert Por MPD.
- XRD diffractomer Bruker D8 Advanced provided with a high temperature cell and a Ag source for performing Pair Distribution Function (PDF).

Laboratory of Microscopy

- Bench-top Scanning Electron Microscope Model Hitachi TM-1000. It includes an Energy Dispersive X-Ray analyzer from Oxford Instruments.
- Atomic Force Microscope Model Park XE-100 with 12 µm Z, 100 µm X-Y scan ranges. Close loop. Available modes: contact, non-contact, lateral force, magnetic force, scanning tunnelling, electrochemistry, scanning kelvin probe, photoconductivity.
- Stereo microscope with transmitted and reflected light with continuous zoom 0.67-4.5x
- Biological optical microscope with 5 plan achromatic objectives (4 x, 10 x, 20 x, 40 x and 100 x immersion). Both optical microscopes are equipped with 3-Megapixel CCD digital camera.

In addition, the following equipments have been acquired for specific use within the different research units:

- High Temperature Processes Unit: scientific installation for generating high radiation fluxes/temperatures and characterizing them. It has a closed box equipped with a laboratory-scale 7 kW_e solar simulator capable of delivering 2000 kW/m^2, including gas feeding and gas extraction and water cooling systems for materials and receivers testing under well-controlled conditions, thermal imaging and CCD cameras, Gardon-type calorimeters and bicromatic pyrometers, gas analysis test bed (H_2, O_2, CO, CO_2, CH_4) for continuous gas monitoring and micro-gas chromatograph, and data acquisition instruments. Heliostat of 150 m^2 for outdoor testing.

- Thermochemical Processes Unit: one high pressure continuous flow microactivity reactor for catalytic assays, three batch high pressure reactors, one lab scale pyrolysis reactor, one photocatalytic reactor provided with a UV-transparent window and with gas and liquid manifold, four GC (two of the them with double channel), a GC-MS with multisampler, a mass spectrometer for gas analysis (up to 200 amu), two tubular furnaces, centrifuge, balls mill, high power ultrasonic probe, microwave oven, an spectrometer for lamp calibration, three ovens (one with vacuum), and a rotary evaporator.

- Electrochemical Processes Unit: one precision potentiostat, one routine potentiostat, two multipotentiostats totalizing 15 standard channels, 4 impedance channels, and three power booster channels, a Z potential meter, cryostat, a glove box, four ovens (one with vacuum), climatic chamber, an automatic film applicator, a dip coater, a hydraulic press, and several multipurpose filter-press electrochemical reactors.

- Biotechnological Processes Unit: french press, microwave, homogenizator, FPLC, HPLC with refraction index and UV-Vis detector, GC with flame ionization detector, centrifuge, ultracentrifuge, incubation and laminar flow cabinet, autoclave, classic polymerase chain reaction, Quantitative Real-Time polymerase chain reaction, Gel Doc system, electroporator, shakers, photobioreactors.

- Electrical Processes Unit: two bench power supplies, four-channel oscilloscope, digital multimetre, three differential, high bandwidth voltage probes, three 100A, high bandwidth current probes.

Likewise, the following software for scientific and technical applications is available:

- Software HSC Chemistry 6.1
- VAPS 5.2
- CFD code COMSOL
- Simapro 7.2 Professional
- MATLAB-ALL and Simulink
- Trace Pro
- TRNSYS 16 and 17
- Aspen Plus
- Solidworks premium
- LABVIEW
- Ebsilon Professional
- IPSA
- PowerWorld

5.3. Pilot plants

A great effort has been devoted along 2013 to set up and put in operation a number of research facilities and equipment at pilot plant scale, as described below.

The laboratories have been mostly equipped with funds received from R&D projects and from the National Programme of Technical-Scientific Infrastructures, National Subprogramme of Actions for Scientific and Technological Parks, Ministry of Science and Innovation and from European Union Structural Funds.

Smart Energy Integration Lab

Electrical Systems Unit has created a test environment specifically designed for research, development and testing of control algorithms in energy systems. This environment is named “Smart Energy Integration Lab” for accelerating the process of control design development necessary for connecting energy resources to electricity networks. The approximate lab capacity for power processing is 210 kVA and it is formed by a set of power electronics converters, resistive loadbanks, 47 kWh battery system, distribution panels and monitoring and control systems. This platform allows analysis, development and testing of realistic scenarios for energy integration in both AC and DC networks and also operation of distribution power networks, islanded networks and microgrids. The

results obtained from this test environment are more reliable and accurate than any model based computer simulation.

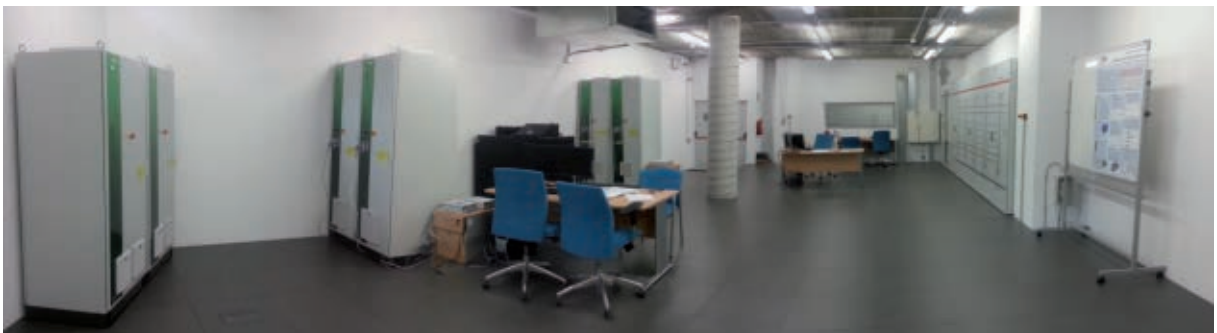
What distinguishes this laboratory is its flexibility in implementation of control algorithms and simple access to all test and management data from any part of the network. The lab microgrid is capable of recreating a large number of different events that occur in real power networks and, therefore, represents a useful tool when it comes to research, development and implementation of energy management algorithms. For example, the lab network is capable of emulating at the same time a generation and load mix consisting of various wind, photovoltaic and conventional generators and passive and active loads all together connected to a wide area network whose dynamic is emulated in real-time. The role for the power converters acting as energy resources in such network is simply defined by assigning a different control block to each one of them. In addition to this, the battery system installation offers all the flexibility needed for the development of management algorithms for future power network.

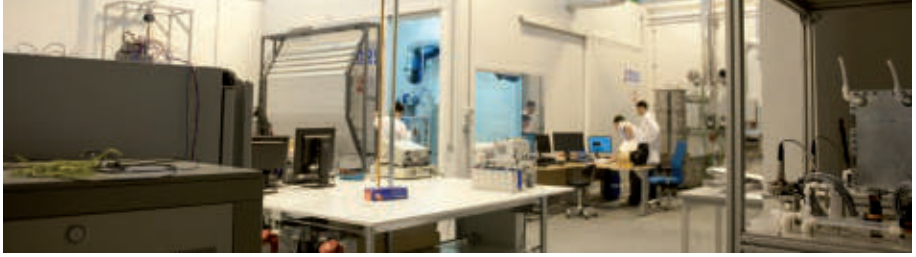
The Smart Energy Integration Lab consists of:

- 4 x 15 kVA three-phase power inverters
- 2 x 75 kVA three-phase power inverters
- 4 industrial PCs with RT operating systems
- 2 x 30 kW balanced and unbalanced, programmable resistive loadbanks
- 47.5 kWh Li-Ion battery system with BMS
- 90 kW Bidirectional, wide bandwidth, programmable battery charger
- Distribution panels with 5 independent busbars and contactor control
- Independent monitoring and control system

Control algorithms for power inverters are programmed via Matlab Simulink and code generation tools and are then executed in real-time on industrial PCs. Real-time data exchange provides access to all control variables and parameters during the test. In this way the desired flexibility in reproducing real dynamic characteristics of any energy source, generator or load it is achieved.

The monitoring and control system allows an independent, remote, real-time access to laboratory resources including the network reconfiguration, control of contactors and connection to the external power grid. Moreover, by harnessing the potential of the communication network installations any centralised or decentralised management control algorithm can be achieved.





High Flux Solar Simulator

The 42 kWe high-flux solar simulator (HFSS) (called KIRAN42) is a facility that recreates in the laboratory the high flux densities met in solar concentrating systems in well-defined conditions without the external perturbations due to the intermittency of the solar resource. This HFSS allows achieving up to 14 kW of radiant energy with a peak flux of 3,500 kW/m^2. The associated pilot plant consists in a 7 m x 5 m x 4 m enclosure divided in two compartments separated by 2.20 m x 2.00 m window. One room contains the high-flux solar simulator (including reflectors, lamps and power supplies...) and the shutter (which is required to attenuate the radiation generated by the lamps). The second room is devoted to house the experimental test beds. It has been supplied with electricity, gases, water cooling circuit, gas extraction and a positioning table with a maximum load capacity of 300 kg. KIRAN42 is composed of seven independent units distributed at the vertices and center of a regular hexagon. Each unit consists of an elliptical aluminum reflector and a 6 kWe short-arc Xenon lamp mounted on a common support, which provides two degrees of freedom in azimuth and elevation. The facility design allows different aiming point strategies (and therefore various flux density distributions) on the working plane. Finally, the overall pilot plants is monitored and controlled by means of network composed by cRIO and cDAQ instruments under LabView.

Electrochemical Devices Test Plant

This pilot plant is designed to test cells, modules and small packs of batteries and electrochemical capacitors under controlled temperature and humidity conditions. Electrical tests can be made with two dedicated programmable cyclers, one with three low power channels (300 W) and the other with three high power channels (8 kW). Parallel combinations of channels allow maximum operating voltages and currents of 120 V and 600 A, respectively. Tests of charge and discharge duty cycles can be programmed in controlled voltage, current, power and resistance. Additionally, frequency response analyses are also possible. The pilot plant incorporates a bench test unit specifically designed for flow batteries and capacitive deionization reactors. It has two independent circuits of electrolytes with one storage tanks, temperature control, valves, piping and instruments for measuring temperature, flow rates, pressure, pH, conductivity and redox potential. Flexible test programming, process control and data acquisition is made in LabView environment.

Photobioreactors Pilot Plant

The pilot plant consists of two types of photobioreactors, namely open (raceways) and closed to the atmosphere (bubbled-columns). The working volume of the raceways is 0.3 m^3 each. In the case of the closed photobioreactor, it consists of three modules of 4 columns each module. Each column has a working volume of 0.76 m^3, thus each module present the same volume as the raceway reactors. The pilot plant is highly versatile since the reactors may be operated independently or in sequential mode. The photobioreactors are fully equipped to monitor the microalgae cultivation online. This singular infrastructure has been designed in order to compare and optimise two of the most common algae cultivation systems. Performance, productivity and associated costs of different algae cultivation systems will be compared at pilot scale.

Pilot Plant for the Production of Advanced Biofuels

The pilot plant for the production of advanced biofuels via thermochemical transformation is designed to carry out the following processes:

- Catalytic Pyrolysis of Biomass. The system consists of a fluidized bed reactor which is fed by an Archimedes screw with the lignocellulosic biomass. The unit may operate with (catalytic pyrolysis) or without catalyst (thermal pyrolysis) under a high flow of N_2 to achieve very short residence times. The reactor operates at atmospheric pressure and temperatures between 400 and 600 °C. After a series of successive filters the bio-oils can be condensed and collected in a reservoir.

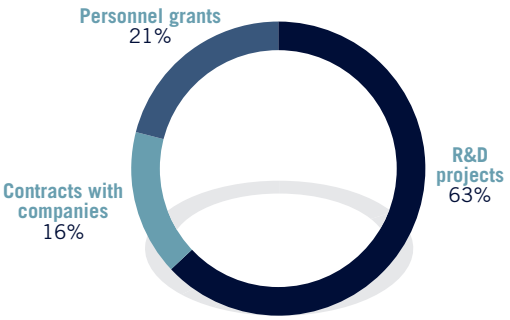
- Hydrodeoxygenation. Fast pyrolysis oil can be introduced via a high pressure high accuracy liquid pump in a continuous fixed bed reactor where it is subjected to a treatment of catalytic hydrodeoxygenation at temperatures between 200 and 350 ° C and using hydrogen pressures up to 50 bar. The outlet stream of the reactor goes throughout a gas-liquid separator to split the two fractions and collect the upgraded biofuel.

These two separate reactors can operate independently or coupled in series depending on the characteristics of the assay.

R&D projects, contracts and grants

annual report 2013

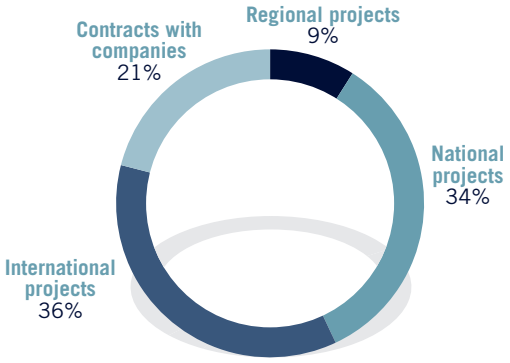
The total external funding obtained and spent by IMDEA Energy coming from R&D projects, contracts with companies and personnel grants during 2013 reached the amount of 1.7 M€. The main source of funding came from R&D projects (63%), following by personnel grants (21%) and contracts with companies (16%).



Total external funding obtained by IMDEA Energy from R&D projects, contracts with companies and personnel grants in 2013.

6.1. R&D projects and contracts

The external funding obtained and spent by IMDEA Energy Institute from R&D projects and contracts with companies during 2013 has reached the amount of 1.356.557 €. The main source of the external funding in 2013 came from the international research projects (36%), following by R&D projects corresponding to national calls (34%), contracts with companies (21%), and finally from regional calls (9%).



Total external funding obtained by IMDEA Energy from R&D projects and contracts with companies in 2013.

The following list shows the R&D projects and contracts active in 2013:

Regional projects

Title/Acronym: Modular, efficient and dispatchable high flux solar thermal power systems/ SOLGEMAC
Partners: IMDEA Energy Institute (Coordinator); INTA; Rey Juan Carlos University; Autonoma University of Madrid; CIEMAT; Abengoa Hidrógeno; Torresol Energy Investments
Period: 2010-2013
Funding Institution/Program: Comunidad de Madrid/ Program of R&D activities between research groups in Technology
IMDEA Energy Institute external funding: 267.205 €

Title/Acronym: Use of agro-forest and oily residues to produce clean transportation fuels/ RESTOENE
Partners: CSIC (Coordinator); Rey Juan Carlos University; Autonoma University of Madrid; CIEMAT; Petrolab; IMDEA Energy Institute; Abengoa Bioenergy; Repsol; Green Fuels
Period: 2010-2013
Funding Institution/Program: Comunidad de Madrid/ Program of R&D activities among research groups in Technology
IMDEA Energy Institute external funding: 134.790 €

National projects

Title/Acronym: Multipurpose electrochemical reactor for energy and environmental applications/REM
Partners: PROINGESA (Coordinator); IMDEA Energy Institute
Period: 2010-2013
Funding Institution/Program: Ministry of Economy and Competitiveness/Sub-program INNPACTO 2010
IMDEA Energy Institute external funding: 131.359 €

Title/Acronym: Production of hydrogen via solar driven high temperature process/SolH2
Partners: Abengoa Hidrógeno (Coordinator); IMDEA Energy Institute; University of Seville; CIEMAT
Period: 2011-2014
Funding Institution/Program: Ministry of Economy and Competitiveness/Sub-program INNPACTO 2011

IMDEA Energy Institute external funding: 107.100 €

Title/Acronym: Application of capacitive deionization to wastewater treatment/ADECAR
Partners: Isolux Ingeniería (Coordinator); IMDEA Energy Institute; Nanoquimia; Proingesa; University of Cordoba
Period: 2011-2014
Funding Institution/Program: Ministry of Economy and Competitiveness/Sub-program INNPACTO 2011
IMDEA Energy Institute external funding: 222.649 €

Title/Acronym: Tailored semiconductor nanocrystals for supercapacitors/CAPSETA2
Partners: IMDEA Energy Institute (Coordinator); SAFT Batteries; EINSA
Period: 2012-2014
Funding Institution/Program: Ministry of Economy and Competitiveness/Subprogram of Fundamental not-oriented research
IMDEA Energy Institute external funding: 145.200 €

Title/Acronym: Oxygen generation and transport based-on manganese oxides solar thermochemical processes/SOLARO2
Partners: IMDEA Energy Institute (Coordinator); Iberdrola; Fundación Ciudad de la Energía
Period: 2012-2014
Funding Institution/Program: Ministry of Economy and Competitiveness/Subprogram of Fundamental not-oriented research
IMDEA Energy Institute external funding: 205.700 €

Title/Acronym: Development of novel catalytic systems for the production of 2nd-Generation Biofuels by deoxygenation of lignocellulosic biomass processes/LIGCATUP
Partners: IMDEA Energy Institute (Coordinator); URJC; Repsol; Abengoa Bioenergy; Algaenergy
Period: 2012-2014
Funding Institution/Program: Ministry of Economy and Competitiveness/Subprogram of Fundamental not-oriented research
IMDEA Energy Institute external funding: 169.400 €

Title/Acronym: Assessment of the manufacturing routes of high energy density biofuels from lignocellulosic via platform molecules/ASBIOPLAT
Partners: URJC (Coordinator); IMDEA Energy Institute; Novotec Consultores
Period: 2012-2014
Funding Institution/Program: Ministry of Economy and Competitiveness/Subprogram of Fundamental not-oriented research
IMDEA Energy Institute external funding: 71.390 €

Title/Acronym: Development of a process at pilot plant scale for the production of advanced biofuels by hydrodeoxygenation of second generation vegetable oils and pyrolysis bio-oils
Partners: Abengoa Research (Coordinator); IMDEA Energy Institute; Camelina Company España
Period: 2012-2015
Funding Institution/Program: Ministry of Economy and Competitiveness/Sub-program INNPACTO 2012
IMDEA Energy Institute external funding: 309.942 €

Title/Acronym: Development of high performance supercapacitors by using novel ionic liquid-based electrolytes/SUPERLION
Partners: IMDEA Energy Institute (Coordinator); Repsol; Solvionic
Period: 2013-2015
Funding Institution/Program: Ministry of Economy and Competitiveness/Subprogram of Fundamental not-oriented research
IMDEA Energy Institute external funding: 174.330 €

Title/Acronym: Design of multifunctional redox systems based on mesoporous transition metal oxides for thermochemical energy storage/MULTISTOR
Partners: IMDEA Energy Institute (Coordinator); Repsol; Abengoa Hidrógeno
Period: 2013-2015
Funding Institution/Program: Ministry of Economy and Competitiveness/Subprogram of Fundamental not-oriented research
IMDEA Energy Institute external funding: 140.400 €

International projects

Title/Acronym: ADvanced Electrolyser for hydrogen production with renewable energy sources/ADEL
Partners: HTceramix (Coordinator); Accelopment; Commissariat à l'Energie Atomique; Deutsches Zentrum für Luft und Raumfahrt; European Institute for Energy Research; Eidgenössische Materialprüfungs-und Forschungsanstalt; Hynergreen Technologies; HyGear; IMDEA Energy Institute; Joint Research Center; SOFCpower; Topsoe Fuel Cell; Empresarios Agrupados Internacional
Period: 2011-2013
Funding Institution/Program: European Union/FP7-Cooperation Program-FCH JU. Call identifier: FCH-JU-2009-1
IMDEA Energy Institute external funding: 114.500 €

Title/Acronym: New materials for sorption-based thermal energy storage/STOREHEAT
Partners: National Institute of Chemistry (Coordinator); IMDEA Energy Institute; Silkem
Period: 2011-2014
Funding Institution/Program: European Union and "Fundación Madri+d para el Conocimiento"/MATERA-ERANET-Call 2010

Title/Acronym: Thermochemical energy storage for concentrated solar power plants/TCSPower
Partners: Deutsches Zentrum für Luft- und Raumfahrt (Coordinator); Siemens CSP; Bühler; Eramet et Comilog Chemicals; IMDEA Energy Institute; Paul Scherrer Institute; Universität Siegen
Period: 2011-2015
Funding Institution/Program: European Union/FP7-Cooperation. Call identifier: FP7-ENERGY-2011-1
IMDEA Energy Institute external funding: 436.418 €

Title/Acronym: Concentrated Solar Power in Particles/CSP2
Partners: Centre National de la Recherche Scientifique (Coordinator); The University of Warwick; Eidgenössische Technische Hochschule Zürich; IMDEA Energy Institute; COMESSA; Torresol Energy Investments; European Powder & Process Technology
Period: 2011-2015
Funding Institution/Program: European Union/FP7-Cooperation. Call identifier: FP7-ENERGY-2011-1
IMDEA Energy Institute external funding: 203.478 €

Title/Acronym: Energy demand aware open services for smart grid intelligent automation/SmartHG
Partners: Sapienza University of Rome (Coordinator); Aarhus University; IMDEA Energy Institute; Joint Institute for Power and Nuclear Research; ATANVO; GridManager; Panoramic Power; Solintel; SEAS – NVE; Kalundborg Municipality; Minskenergo
Period: 2012-2015
Funding Institution/Program: European Union/FP7-Cooperation. Call identifier: FP7-ICT-2011-8
IMDEA Energy Institute external funding: 440.832 €

Title/Acronym: Training network in innovative polyelectrolytes for energy and environment/RENAISSANCE
Partners: University of the Basque Country (Coordinator); CNRS-University of Bordeaux I; Max Planck Institute of Colloids and Interfaces; Linköping University; University of Liege; IMDEA Energy Institute; Kitozyme; Procter & Gamble Italia; Procter & Gamble Services Company; Repsol
Period: 2012-2016
Funding Institution/Program: European Union/FP7-People Program. Call identifier: FP7-PEOPLE-2011-ITN
IMDEA Energy Institute external funding: 223.481 €

Title/Acronym: CAScade deoxygenation process using tailored nanoCATalysts for the production of BiofuELs from lignocellullosic/CASCATBEL
Partners: IMDEA Energy Institute (Coordinador); ENCE; Universita' Degli Studi di Milano Bicocca; Charles University in Prague; Institute of Physical Chemistry; Universiteit Utrecht; Aston University; Abengoa Research; ETH; Max Planck Institut fuer Kohlenforschung; MAST Carbon International; Silkem; Nanologica; Center for Research and Technology Hellas/Chemical Process and Energy Research Institute; ENI; Hamburg University of Technology; OUTOTEC
Period: 2013-2017
Funding Institution/Program: European Union/FP7-Cooperation. Call identifier: FP7-NMP-2013-LARGE-7 IMDEA Energy Institute external funding: 850.217 €

The following international project has been approved during 2013 and will start in 2014:

Title/Acronym: Scientific and Technological Alliance for Guaranteeing the European Excellence in Concentrating Solar/ STAGE-STE
Partners: CIEMAT (Coordinator); more than 40 partners, companies, universities, research centres, associations, from all over the world.
Period: 2014-2018
Funding Institution/Program: FP7-Cooperation. Call identifier: FP7-ENERGY-2013-IRP
IMDEA Energy Institute external funding: 472.222 €

Contracts with companies

Title/Acronym: Energy efficiency in systems for vibration testing
Company: IMV Corporation (Japan)
Period: 2010-2014
IMDEA Energy Institute external funding: 77.303 €

Title/Acronym: Innovative latent thermal energy storage system for concentrating solar power plants
Company: E.ON (Germany)
Period: 2011-2013
Program: EON International Research Initiative 2009-Announcement: "Heat storage for concentrating solar power"
IMDEA Energy Institute external funding: 120.066 €

Title/Acronym: Development of a modular central receiver concentrated solar power plant for decentralized power generation/CRISPTower
Company: Sunborne Energy Technologies (India)
Period: 2011-2014
IMDEA Energy Institute external funding: 81.320 €

Title/Acronym: Visualising the smart home: creative engagement with customer data
Company: E.ON (Germany)
Program: E.ON International Research Initiative 2012-Announcement: "Smart home a new customer relationship with energy"
Period: 2012-2013
IMDEA Energy Institute external funding: 75.771 €

Title/Acronym: FOTOCON-CO2
Company: REPSOL (Spain)
Period: 2012-2013
IMDEA Energy Institute external funding: 110.613 €

Title/Acronym: FLEXIBIORREFINERÍA
Company: REPSOL (Spain)
Period: 2012-2013
IMDEA Energy Institute external funding: 110.000 €

Title/Acronym: Waste to Biofuel/WASBIO
Company: Abengoa Bioenergía Nuevas Tecnologías (Spain)
Period: 2012-2013
IMDEA Energy Institute external funding: 33.082 €

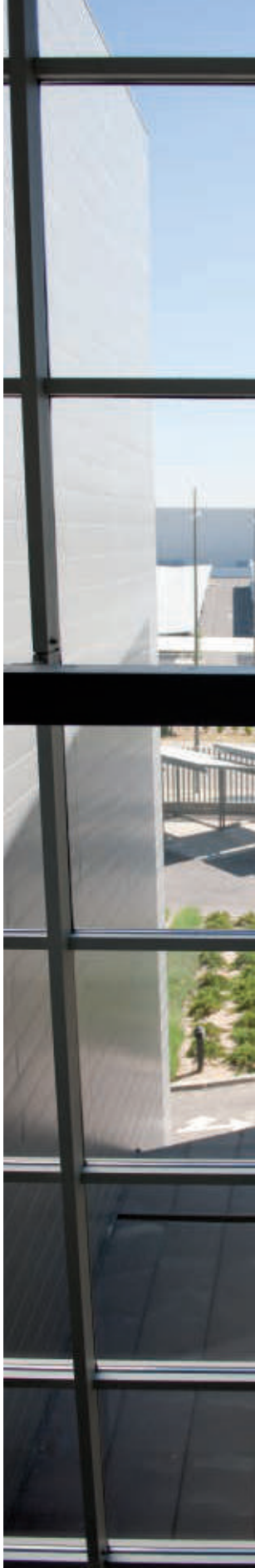
Title/Acronym: Design of sensors based on semiconductor materials for use in fire detection in tunnels/FIRETUNNEL
Company: Euroconsult Andalucía (Spain)
Period: 2013
IMDEA Energy Institute external funding: 9.600 €

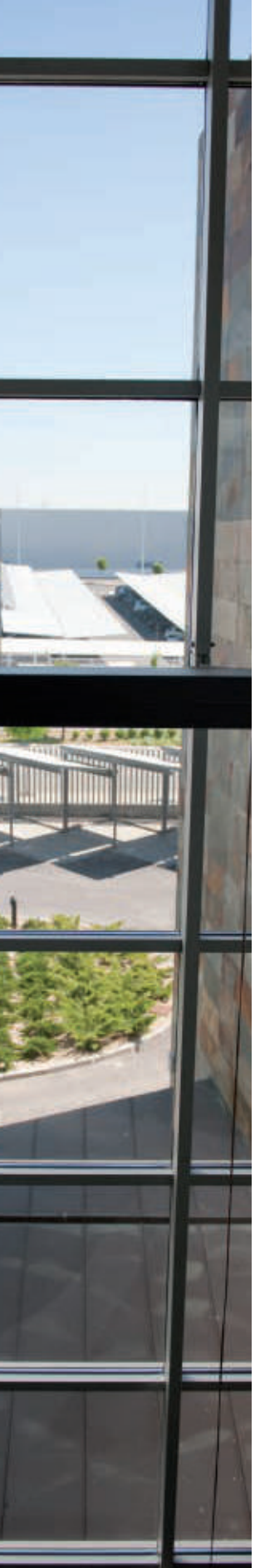
Title/Acronym: Development of a management system for loading and unloading of batteries in a temperature controlled environment
Company: Álava Ingenieros (Spain)
Period: 2013
IMDEA Energy Institute external funding: 8.688 €

Title/Acronym: Ecodesign of products
Company: REPSOL (Spain)
Period: 2013-2014
IMDEA Energy Institute external funding: 34.235 €

Title/Acronym: Study about the effect of ripple of recharge current in lithium ion batteries
Company: REPSOL (Spain)
Period: 2013-2014
IMDEA Energy Institute external funding: 22.198 €

Title/Acronym: Development of a rechargeable metal-air battery
Company: Albufera Energy Storage (Spain)
Period: 2013-2016
IMDEA Energy Institute external funding: 90.385 €

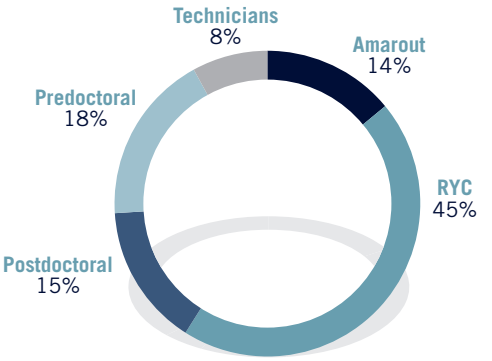




6.2. Researcher grants and mobility actions

6.2.1. Researcher grants

The extermal funding obtained by IMDEA Energy from fellowships and grants during 2013 according to the funding source, has been the amount 355.132 €. The main source of external funding has been obtained again from the Ramón y Cajal (RYC) program (45%).



The following grants have been awarded to researchers of IMDEA Energy, being active in 2013:

Program: "Marie Curie" AMAROUT Europe. FP7-People Program. Call identifier: FP7-PEOPLE- 2007-2-3-COFUND
Period: 2010-2013
Funding Institution: European Union
IMDEA Energy Institute external funding: 72.095 €
Dr. Milan Prodanovic

Program: "Marie Curie" AMAROUT Europe. FP7-People Program. Call identifier: FP7-PEOPLE- 2007-2-3-COFUND
Period: 2011-2013
Funding Institution: European Union
IMDEA Energy Institute external funding: 33.828 €
Dr. Chandrasekaran Ramasamy

Program: "Marie Curie" AMAROUT Europe. FP7-People Program. Call identifier: FP7-PEOPLE- 2007-2-3-COFUND
Period: 2011-2013
Funding Institution: European Union
IMDEA Energy Institute external funding: 30.688 €
Dr. Carlos Pérez

Program: "Marie Curie" AMAROUT Europe. FP7-People Program. Call identifier: FP7-PEOPLE- 2007-2-3-COFUND
Period: 2011-2013
Funding Institution: European Union
IMDEA Energy Institute external funding: 35.157 €
Dr. Fontina Petrakopoulou

Program: "Marie Curie" AMAROUT Europe. FP7-People Program. Call identifier: FP7-PEOPLE- 2007-2-3-COFUND
Period: 2012-2013
Funding Institution: European Union
IMDEA Energy Institute external funding: 16.918 €
Dr. Selvan Bellan

Program: Contract for the support of research staff 2008
Project: Map interactions of proteins involved in the biosynthesis of iron-molybdenum cofactor of nitrogenase
Period: 2009-2013
Funding Institution: Comunidad de Madrid
IMDEA Energy Institute external funding: 68.250 €
Mr. A. David Moreno

Program: Ramón y Cajal 2008
Project: Materials and components for electrochemical energy storage
Period: 2009-2013
Funding Institution: Ministry of Economy and Competitiveness
IMDEA Energy Institute external funding: 177.480 €
Dr. Raúl Díaz

Program: Ramón y Cajal 2008
Project: Development of active catalytic materials for the reduction of CO_2 with water under mild conditions. Removal and valorization of CO_2
Period: 2009-2013
Funding Institution: Ministry of Economy and Competitiveness
IMDEA Energy Institute external funding: 177.480 €
Dr. Víctor A. de la Peña

Program: Ramón y Cajal 2009
Project: Development and validation of kinetic mechanisms and multi-fluids numerical model adapted to the synthesis of nanomaterials in the gas phase and plasma-assisted combustion
Period: 2010-2014
Funding Institution: Ministry of Economy and Competitiveness
IMDEA Energy Institute external funding: 177.480 €
Dr. José González

Program: Technical Support Staff 2010
Period: 2010-2013
Funding Institution: Ministry of Economy and Competitiveness
IMDEA Energy Institute external funding: 37.800 €
Ms. M. Eugenia Di Falco

Program: Predoctoral Research Grant (FPI)
Project/Acronym: CO_2 valorization by photocatalytic processes/FOTOVALCO2
Period: 2010-2014
Funding Institution: Ministry of Economy and Competitiveness
IMDEA Energy Institute external funding: 97.000 €
Ms. Laura Collado

Program: Juan de la Cierva 2010
Project: Valorization of CO_2 with photocatalysis under mild conditions
Period: 2011-2013
Funding Institution: Ministry of Economy and Competitiveness
IMDEA Energy Institute external funding: 100.980 €
Dr. Prabhas Jana

Program: Technical Support Staff 2011
Period: 2011-2014
Funding Institution: Ministry of Economy and Competitiveness
IMDEA Energy Institute external funding: 57.600 €
Dr. Fernando Picó

Program: Call for research funding in energy and environment 2012-2013
Project: Environmental sustainability of energy systems for co-production of bioelectricity and biofuel using the Fischer-Tropsch process
Period: 2012-2013
Funding Institution: Foundation IBERDROLA
IMDEA Energy Institute external funding: 20.000 €
Dr. Diego Iribarren

Program: Ramón y Cajal 2011
Project: Intelligent power interfaces for real-time management of future power networks
Period: 2012-2016
Funding Institution: Ministry of Economy and Competitiveness
IMDEA Energy Institute external funding: 168.600 €
Dr. Milan Prodanovic

Program: Ramón y Cajal 2011
Project: Application of ionic liquid-based materials in high performance supercapacitor
Period: 2012-2016
Funding Institution: Ministry of Economy and Competitiveness
IMDEA Energy Institute external funding: 168.600 €
Dr. Rebeca Marcilla

Program: Fellowship of Ministry of Higher Education
Project: Characterization and development of indigenous microalgae for biofuels production
Period: 2012-2016
Funding Institution: Ministry of Higher Education
IMDEA Energy Institute external funding: 108.000 €
Mr. Ahmed Abdel-Mohsen Mahdy

Program: Call for research funding in energy and environment 2013-2014
Project: Redox flow batteries for consumption management of electric power
Period: 2013-2014
Funding Institution: IBERDROLA Foundation
IMDEA Energy Institute external funding: 20.000 €
Dr. Enrique García-Quismondo

Program: "Marie Curie" AMAROUT Europe II. FP7-People Program. Call identifier: FP7-PEOPLE-2011-COFUND
Period: 2013-2016
Funding Institution: European Union
IMDEA Energy Institute external funding: 56.658 €
Dr. Tadhg O'Mahony

Program: "Marie Curie" AMAROUT Europe II. FP7-People Program. Call identifier: FP7-PEOPLE-2011-COFUND
Period: 2013-2016
Funding Institution: European Union
IMDEA Energy Institute external funding: 56.652 €
Dr. Jian Li

Program: "Marie Curie" AMAROUT Europe II. FP7-People Program. Call identifier: FP7-PEOPLE-2011-COFUND
Period: 2013-2016
Funding Institution: European Union
IMDEA Energy Institute external funding: 55.876 €
Dr. Barry Hayes

Program: "Marie Curie" AMAROUT Europe II. FP7-People Program. Call identifier: FP7-PEOPLE-2011-COFUND
Period: 2013-2016
Funding Institution: European Union
IMDEA Energy Institute external funding: 55.514 €
Dr. Sankaranayanan Thangaraju

Program: Predoctoral Research Grant (FPI)
Project/Acronym: Development of novel catalytic systems for the production of 2nd generation biofuels by deoxygenation of lignocellulosic biomass processes/LIGCATUP
Period: 2013-2017
Funding Institution: Ministry of Economy and Competitiveness
IMDEA Energy Institute external funding: 97.000 €
Mr. Antonio M. Berenguer

6.2.2. Mobility actions

Stay at Paul Scherrer Institut, Villigen, Switzerland
Program: Access to Facilities-European Program SFERA
Project/Acronym: Thermal characterization of innovative ceramic absorbers for volumetric receivers/TH-CRABS
Period: 1 week, 2013
Funding Institution: European Union
Dr. José González and Mr. Fabrisio Gómez

Stay at CRP Henri Tudor, Luxembourg
Period: 4 months, 2013
Funding Institution: IMDEA Energy Institute
Dr. Diego Iribarren

Stay at University of Wisconsin-Madison, USA
Period: 3 months, 2013
Funding Institution: IMDEA Energy Institute
Dr. Enrique Gacía-Quismondo

Stay at Forschungszentrum Jülich, Germany
Period: 3 months, 2013
Funding Institution: IMDEA Energy Institute
Ms. Ana Susmozas

Visiting researchers

Ms. Catherine Lee, PhD Student
Origin institution: Massachusetts Institute of Technology, USA
Unit: Electrochemical Processes Unit
Period: 2 months, 2013
Activity: Modelling of electrochemical devices for energy storage and environmental applications

Mr. Rohan Kulkarni, PhD Student
Origin institution: Massachusetts Institute of Technology, USA
Unit: Electrochemical Processes Unit
Period: 2 months, 2013
Activity: Exploration of sulfides as electrode materials in supercapacitors

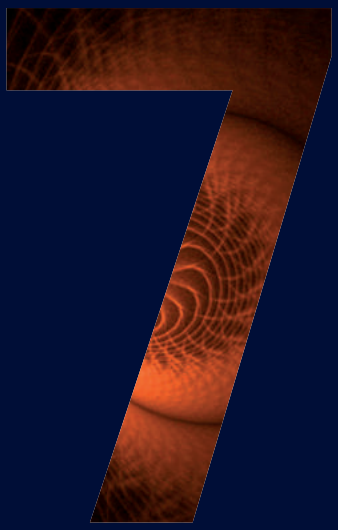
Mr. David Lloyd, PhD Student
Origin institution: University of Aalto, Helsinki, Finland
Unit: Electrochemical Processes Unit
Period: 1 week, 2013
Activity: Collaboration for the development of a test bench for flow batteries

Mr. Matteo Bortolato, PhD Student
Origin institution: University of Padova, Italy
Unit: High Temperature Processes Unit
Date: 1,5 months, 2013
Activity: Modelling and performance analysis of modular solar central receiver systems with hybrid solar converters for distributed poly-generation

Ms. Mª Carmen Zafra, PhD Student
Origin institution: University of Córdoba, Spain
Unit: Electrochemical Processes Unit
Date: 1 week, 2013
Activity: Preparation of electrodes for capacitive deionization for ADECAR project

Ms. Fátima Nadia Ajjan Godoy, PhD Student
Origin institution: Linköping University Sweden
Unit: Electrochemical Processes Unit
Date: 1 week, 2013
Activity: Training in electrochemistry and electrochemical storage systems promoting the Researcher's Exchange activities planned within the European Project RENAISSANCE (ITN)

cooperation framework



annual report 2013

7.1. Cooperation with research institutions and universities

The following table lists cooperation activities established with different Research Institutions and Universities that have been active during 2013.

Institution	Cooperation
Rey Juan Carlos University (Spain)	Cooperation in projects and activities related to solar concentrating systems and the production of sustainable fuels (Projects: SOLGEMAC, RESTOENE LIGCATUP and ASBIOPLAT). Period: 2008-2014
Centre of Energy, Environmental and Technological Research (Spain)	Cooperation in projects and activities related to solar concentrating systems, the production of sustainable fuels and hydrogen (Projects: SOLGEMAC, RESTOENE and SolH2). Joint Unit CIEMAT/IMDEA Energy Period: 2008-2014
Autonoma University of Madrid (Spain)	Cooperation for research on the use of quinones applied to electrochemical storage devices (Project SOLGEMAC) and on the production of second generation biofuels (Project RESTOENE). Period: 2010-2013
CSIC Catalysis and Petrochemistry Institute (Spain)	Cooperation for the production of second generation biofuels (Project RESTOENE). Period: 2010-2013
National Institute of Aerospace Technique (Spain)	Cooperation on integration of micro-turbines and Stirling engines on solar concentrating systems (Project SOLGEMAC). Period: 2010-2013
European Institute for Energy Research (Germany)	Cooperation within the framework of ADEL project for the production of hydrogen. Period: 2011-2013
Commissariat à l'Energie Atomique (France)	Cooperation within the framework of ADEL project for the production of hydrogen. Period: 2011-2013
Eidgenössische Materialprüfungs- und Forschungsanstalt (Switzerland)	Cooperation within the framework of ADEL project for the production of hydrogen. Period: 2011-2013
Indian Institute of Technology Delhi/Center for Energy Studies (India)	Participation in the project funded by the company Sunborne Energy Technologies Period: 2011-2014

Institution	Cooperation
University of South Florida (USA)	Coordinator of the project funded by the company E.ON titled "Innovative Latent Thermal Energy Storage System for Concentrated Solar Power Plants", as well as participation in the project funded by the company Sunborne Energy Technologies. Period: 2011-2014
University of Seville (Spain)	Cooperation within the framework of SolH2 project for hydrogen production. Period: 2011-2014
University of Córdoba (Spain)	Cooperation within the framework of ADECAR project for the application of capacitive deionization to wastewater treatment. Period: 2011-2014
National Institute of Chemistry (Slovenia)	Cooperation in the project STOREHEAT for development of materials for thermal energy storage. Period: 2011-2014
Istituto per la Microeletronica e Microsistemi-CNR (Italy)	Cooperation within the framework of CAPSETA2 project for the design of supercapacitors. Period: 2011-2014
University of Warwick (United Kingdom)	Cooperation within the framework of CSP2 project for solar concentrating systems. Period: 2011-2015
Centre National de la Recherche Scientifique (France)	Cooperation in projects related to solar concentrating systems (Project CSP2). Period: 2011-2015
Deutsches Zentrum für Luft und Raumfahrt e. V. (Germany)	Cooperation within the framework of ADEL project for the production of hydrogen. Cooperation within the framework of TCSPower project related to solar concentrating systems. Period: 2011-2015
Paul Scherrer Institute (Switzerland)	Cooperation within the framework of TCSPower project related to solar concentrating systems. Period: 2011-2015
Institute of Energy Technology (Switzerland)	Cooperation in the project funded by the company Sunborne Energy Technologies, CSP2 project for solar concentrating systems and CASCATBEL project for the production of second-generation biofuels. Period: 2011-2017
National Autonoma University of Mexico (Mexico)	Cooperation framework agreement for the development of joint R&D projects, exchange of personnel, internships, among other activities. Period: 2011-present
City University London (United Kingdom):	Cooperation in the project funded by the company E.ON for developing user-oriented Smart Home services. Period: 2012-2013

Institution	Cooperation
Sapienza University of Rome (Italy)	Coordinator of the project SmartHG for smart grid intelligent automation. Period: 2012-2015
University of the Basque Country (Spain)	Coordinator of the project RENAISSANCE for training network in innovative polyelectrolytes for energy and environment. Period: 2012-2016
Max Planck Institut fuer Kohlenforschung (Germany)	Cooperation within the framework of CASCATBEL project for the production of second-generation biofuels. Period: 2013-2017
CERTH/CPERI (Greece)	Cooperation within the framework of CASCATBEL project for the production of second-generation biofuels Period: 2013-2017
Hamburg University of Technology (Germany)	Cooperation within the framework of CASCATBEL project for the production of second-generation biofuels. Period: 2013-2017
Heyrovsky Institute (Czech Republic)	Cooperation within the framework of CASCATBEL Project for the production of second-generation biofuels. Period: 2013-2017

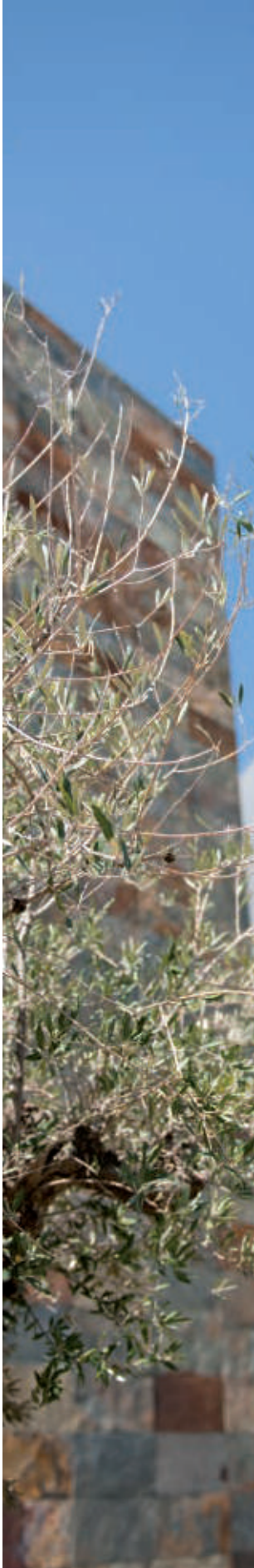
7.2. Cooperation with other IMDEA Institutes

The following table lists cooperation agreements established with other IMDEA Institutes, which have been active during 2013.

Name	Cooperation activities
IMDEA Software IMDEA Materials IMDEA Networks IMDEA Water IMDEA Food IMDEA Nanoscience	Cooperation within the framework of AMAROUT I/II Program. Period: 2009-2013 (Amarout I) Period: 2013-2016 (Amarout II)

7.3. Cooperation with industry

The cooperation with industry has steadily grown in 2013, most of it related to projects and contracts for specific research activities. This fact is of special relevance for the IMDEA Energy Institute as one of its main goals is to work together with the industry sector to promote innovation and technology transfer. The following table lists the companies that have projects and contracts in collaboration with the IMDEA Energy Institute.



Name	Cooperation activities
Green Fuels (Spain)	Cooperation within the framework of RESTOENE project on second generation biofuels. Period: 2010-2013
IMV Corporation (Japan)	Cooperation on energy efficient processes. Period: 2010-2014
Abengoa Bioenergía Nuevas Tecnologías (Spain)	Cooperation in projects related to second generation biofuels (Projects: RESTOENE, LIGCATUP and WASBIO). Period: 2010-2014
PROINGESA (Spain)	Cooperation on energy efficient processes for water treatment with capacitive deionization (Projects: REM and ADECAR). Period: 2010-2014
Torresol Energy Investments (Spain)	Cooperation on solar concentrating systems (Projects: SOLGEMAC and CSP2). Period: 2010-2015
Abengoa Hidrógeno (Spain)	Cooperation in projects and activities related to hydrogen production and thermochemical energy storage (Projects: SOLGEMAC, SolH2 and MULTISTOR). Period: 2010-2016
Empresarios Agrupados Internacional (Spain)	Cooperation within the framework of ADEL project for the production of hydrogen. Period: 2011-2013
E.ON (Germany)	Cooperation in projects on energy storage and smart homes. Period: 2011-2013
Accelopment (Switzerland)	Cooperation within the framework of ADEL project for the production of hydrogen. Period: 2011-2013
HTceramix (Switzerland)	Cooperation within the framework of ADEL project for the production of hydrogen. Period: 2011-2013
HyGear (Netherlands)	Cooperation within the framework of ADEL project for the production of hydrogen. Period: 2011-2013
SOFCpower (Italy)	Cooperation within the framework of ADEL project for the production of hydrogen. Period: 2011-2013
Topsoe Fuel Cell (Denmark)	Cooperation within the framework of ADEL project for the production of hydrogen. Period: 2011-2013

Name	Cooperation activities
Sunborne Energy Technologies (India)	Coordinator of the project titled "Development of a Modular Central Receiver Concentrated Solar Power Plant for Decentralized Power Generation". Period: 2011-2014
Silkem (Slovenia)	Cooperation in the project STOREHEAT for development of materials for thermal energy storage. Period: 2011-2014
Isolux Ingeniería (Spain)	Cooperation within the framework of ADECAR project for the application of capacitive deionization to wastewater treatment. Period: 2011-2014
Nanoquimia (Spain)	Cooperation within the framework of ADECAR project for the application of capacitive deionization to wastewater treatment. Period: 2011-2014
Bühler (Switzerland)	Cooperation within the framework of TCSPower project related to solar concentrating systems. Period: 2011-2015
COMESSA (France)	Cooperation in CSP2 project related to solar concentrating systems. Period: 2011-2015
Eramet et Comilog Chemicals (Belgium)	Cooperation within the framework of TCSPower project related to solar concentrating systems. Period: 2011-2015
European Powder & Process Technology (Belgium)	Cooperation in CSP2 project related to solar concentrating systems. Period: 2011-2015
Siemens Concentrated Solar Power (Israel)	Cooperation within the framework of TCSPower project related to solar concentrating systems. Period: 2011-2015
Algaenergy (Spain)	Cooperation within the framework of LIGCATUP project for the production of second generation biofuels. Period: 2012-2014
REPSOL (Spain)	Cooperation for the production of second generation biofuels. (Projects: RESTOENE, LIGCATUP, SUPERLION, MULTISTOR, FOTOCON-CO2, FLEXIBIORREFINERÍA). Period: 2012-2016
SAFT Batteries (Spain)	Cooperation within the framework of CAPSETA2 project for the design of supercapacitors. Period: 2012-2014
Equipos Industriales de Manutención (Spain)	Cooperation within the framework of CAPSETA2 project for the design of supercapacitors. Period: 2012-2014

Name	Cooperation activities
Iberdrola (Spain)	Cooperation within the framework of SOLARO2 project for solar thermochemical processes based on manganese oxides. Period: 2012-2014
Novotec Consultores (Spain)	Cooperation within the framework of ASBIOPLAT project for the production of biofuels. Period: 2012-2014
Abengoa Research (Spain)	Cooperation for the production of second generation biofuels. (Projects: INNPACTO'12 and CASCATBEL). Period: 2012-2017
Camelina Company España (Spain)	Cooperation for the production of second generation biofuels. Period: 2012-2015
Euroconsult Andalucía (Spain)	Cooperation for the design of sensors based on semiconductor materials Period: 2013
Álava Ingenieros (Spain)	Cooperation for the development of a management system for loading and unloading of batteries. Period: 2013
Albufera Energy Storage (Spain)	Cooperation for the development of a rechargeable metal-air battery. Period: 2013-2016
Solvionic (France)	Cooperation within the framework of SUPERLION project for development of supercapacitors. Period: 2013-2015
MAST Carbon International (United Kingdom)	Cooperation within the framework of CASCATBEL project for the production of biofuels. Period: 2013-2017
Silkem (Slovenia)	Cooperation within the framework of CASCATBEL project for the production of biofuels and of STOREHEAT project for thermochemical energy storage. Period: 2012-2017
Nanologica (Sweden)	Cooperation within the framework of CASCATBEL project for the production of biofuels. Period: 2013-2017
Outotec (Germany)	Cooperation within the framework of CASCATBEL project for the production of biofuels. Period: 2013-2017

7.4. Cooperation with networks and associations

IMDEA Energy, since its creation, has considered as a relevant activity its participation in associations, technology platforms, expert groups and alliances of the energy sector. This is also a means of increasing the external visibility of IMDEA Energy, establishing new links with companies and research institutions and to gain updated information on the different initiatives related to the different energy topics. The following list gives the main associations in which IMDEA Energy has participated as a member in 2013:

- Joint Programme on Energy Storage in the EERA (European Energy Research Alliance) with the objective to formulate proposals to the Strategic Energy Technology (SET) Plan of the European Union.
- Joint Programme on Bioenergy in the EERA (European Energy Research Alliance) with the objective to formulate proposals to the Strategic Energy Technology (SET) Plan of the European Union.
- Joint Programme on Concentrating Solar Power in the EERA (European Energy Research Alliance) with the objective to formulate proposals to the Strategic Energy Technology (SET) Plan of the European Union.
- Joint Programme on Economic, Environmental and Social Impacts of Energy Policies and Technologies in the EERA (European Energy Research Alliance) with the objective to formulate proposals to the Strategic Energy Technology (SET) Plan of the European Union.
- Research Grouping of the Joint Undertaking on Fuel Cells and Hydrogen of the VII Framework Programme of the EC (N.ERGHY).
- European Industrial Initiative in Bioenergy (BBI).
- Alliance of Energy Research and Innovation (ALINNE) as members and at the Committee of Strategies.
- Cluster on Sustainability and Renewable Energies of Madrid Network.
- Spanish Technological Platform on Hydrogen and Fuel Cells.
- Spanish Technological Platform on CSP technologies Solar Concentration.
- Spanish Technological Platform for Biomass (BIOPLAT).
- Spanish Technological Platform for Energy Efficiency (PTE-EE).
- Spanish Electrical Grid Platform (FutuRed).
- Spanish Network of Life Cycle Assessment.
- Thematic Network LIGNOCEL on Biotechnology of Lignocellulosic Materials.
- International Solar Energy Society (ISES).
- HIA30 of the International Energy Agency.

scientific results

annual report 2013

The works published by researchers of the IMDEA Energy Institute during 2013 is listed below, as well as the communications to congresses.

8.1. Scientific publications

The works published by researchers of IMDEA Energy during 2013 by source Scopus is listed below.

Scientific Journals

1. Aguado, J.; Serrano, D.P.; Escola, J.M.; Briones, L.
"Deactivation and regeneration of a Ni supported hierarchical Beta zeolite catalyst used in the hydroreforming of the oil produced by LDPE thermal cracking".
Fuel, **2013**, *109*, 679-686.

2. Alonso, E.; Hutter, C.; Romero, M.; Steinfeld, A.; González-Aguilar, J.
"Kinetics of Mn_2O_3-to Mn_3O_4 and Mn_3O_4-to-MnO redox reactions performed under concentrated thermal radiative flux".
Energy & Fuels, **2013**, *27 (8)*, 4884-4890.

3. Alvira, P.; Moreno, A.D.; Ibarra, D. Sáez, F.; Ballesteros, M.
"Improving the fermentation performance of *Saccharomyces cerevisiae* by laccase during ethanol production from steam-exploded wheat straw at high substrate loadings".
Biotechnology Progress, **2013**, *29 (1)*, 74-82.

4. Bayón, A.; De La Peña O'Shea, V.A.; Serrano, D.P.; Coronado, J.M.
"Influence of structural and morphological characteristics on the hydrogen production and sodium recovery in the NaOH-MnO thermochemical cycle".
International Journal of Hydrogen Energy, **2013**, *30 (8)*, 13143-13152.

5. Bellan, S.; Alonso, E.; Gómez-García, F.; Pérez-Rábago, C.; González-Aguilar, J.; Romero, M.
"Thermal performance of lab-scale solar reactor designed for kinetics analysis at high radiation fluxes".
Chemical Engineering Science, **2013**, *101*, 81-89.

6. Bottrell, N.; Prodanović, M.; Green, T.C.
"Dynamic stability of a microgrid with an active load". IEEE Transactions on Power Electronics, **2013**, *28 (11)*, 5107-5119.

7. Collado, L.; Jana, P.; Sierra, B.; Coronado, J.M.; Pizarro, P.; Serrano, D.P.; de la Peña O'Shea, V.A.
"Enhancement of hydrocarbon production via artificial photosynthesis due to synergetic effect of Ag supported on TiO_2 and ZnO semiconductors".
Chemical Engineering Journal, **2013**, *224*, 128-135.

8. Dufour, J.; Arsuaga, J.; Moreno, J.; Torrealba, H.; Camacho, J.
"Comparative life cycle assessment of biodiesel production from cardoon (Cynara cardunculus) and rapeseed oil obtained under Spanish conditions".
Energy & Fuels, **2013**, *27 (9)*, 5280-5286.

9. Dufour, J.; Martos, C.; Ruiz, A.; Ayuela, F.J.
"Effect of the precursor on the activity of high temperature water gas shift catalysts".
International Journal of Hydrogen Energy, **2013**, *38 (18)*, 7647-7653.

10. D'Vries, R.F.; de la Peña-O'Shea, V.A.; Snejko, N.; Iglesias, M.; Gutiérrez-Puebla, E.; Monge, M.A.
"H_3O_2 bridging ligand in a Metal–Organic Framework. Insight into the aqua-hydroxo-hydroxyl equilibrium: a combined experimental and theoretical study".
Journal of the American Chemical Society, **2013**, *135*, 5782-5792.

11. Epifani, M.; Díaz, R.; Force, C.; Comini, E.; Andreu, T.; Zamani, R.; Arbiol, J.; Siciliano, P.; Faglia, G.; Morante, J.R.
"Colloidal counterpart of the TiO_2-supported V_2O_5 system: A case study of oxide-on-oxide deposition by wet chemical techniques. Synthesis, Vanadium speciation, and gas-sensing enhancement".
The Journal of Physical Chemistry C, **2013**, *117 (40)*, 20697-20705.

12. Ferramosca, A.; Gruber, J.K.; Limon, D.; Camacho, E.F.
"MPC for tracking of constrained nonlinear systems. Application to a pilot plant".
Revista Iberoamericana de Automática e Informática Industrial (RIAI), **2013**, *10 (1)*, 18-29.

13. García-Quismondo, E.; Gómez, R.; Vaquero, F.; Cudero, A.L.; Palma, J.; Anderson, M.
"New testing procedures of a capacitive deionization reactor".
Physical Chemistry Chemical Physics, **2013**, *15 (20)*, 7648-7656.

14. García-Quismondo, E.; Santos, C.; Lado, J.; Palma, J.; Anderson, M.A.
"Optimizing the energy efficiency of capacitive deionization reactors working under real-world conditions". Environmental Science & Technology, **2013**, *47*, 11866-11872.

15. González-Fernández, C.; Ballesteros, M.
"Microalgae autoflocculation: an alternative to high-energy consuming harvesting methods".
Journal of Applied Phycology, **2013**, *25 (4)*, 991-999.

16. González-Pardo, A.; Cesar, S.; Gonzalez-Aguilar, J.; Romero, M.
"Optical performance of vertical heliostat fields integrated in building façades for concentrating solar energy uses".
Solar Energy, **2013**, *97*, 447-459.

17. Gruber, J.K.; Ramírez, D.R.; Limon, D.; Alamo, T.
"Computationally efficient nonlinear min–max model predictive control based on volterra series models-Application to a pilot plant".
Journal of Process Control, **2013**, *23 (4),* 543-560.

18. Hernández-Alonso, M.D.; García-Rodríguez, S.; Suárez, S.; Portela, R.; Sánchez, B.; Coronado, J.M.
"Operando DRIFTS study of the role of hydroxyls groups in trichloroethylene photo-oxidation over titanate and TiO_2 nanostructures".
Catalysis Today, **2013**, *206*, 32-39.

19. Iribarren, D.; Martín-Gamboa, M.; Dufour, J.
"Environmental benchmarking of wind farms according to their operational performance".
Energy, **2013**, *61*, 589-597.

20. Iribarren, D.; Petrakopoulou, F.; Dufour, J.
"Environmental and thermodynamic evaluation of CO_2 capture, transport and storage with and without enhanced resource recovery".
Energy, **2013**, *50 (1)*, 477-485.

21. Iribarren D.; Susmozas A.; Dufour J.
"Life-cycle assessment of Fischer-Tropsch products from biosyngas".
Renewable Energy, **2013**, *59*, 229-236.

22. Iribarren, D.; Vázquez-Rowe, I.
"Is labor a suitable input in LCA + DEA studies? Insights on the combined use of economic, environmental and social parameters".
Social Sciences, **2013**, *2 (3)*, 114-130.

23. Jana, P.; de la Peña O'Shea, V.A.; Coronado, J.M.; Serrano, D.P.
"H_2 production by CH_4 decomposition over metallic cobalt nanoparticles: Effect of the catalyst activation".
Applied Catalysis A: General, **2013**, *467*, 371–379.

24. Méndez, A.; Isikli, S.; Diaz, R.
"Influence of impregnation of activated carbon electrodes with p-benzoquinone on supercapacitor performance".
Electrochemistry, **2013**, *81*, 853-856.

25. Méndez, L.; Mahdy, A.; Timmers, R.A.; Ballesteros, M.; González-Fernández, C.
"Enhancing methane production of Chlorella vulgaris via thermochemical pretreatments".
Bioresource Technology, **2013**, *149*, 136-141.

26. Moreno, A.D.; Ibarra, D.; Ballesteros, I.; Fernández, J.L.; Ballesteros, M.
"Ethanol from laccase-detoxified lignocellulose by the thermotolerant yeast *Kluyvermoyces marxianus*–Effects of steam pretreatment conditions, process configurations and substrate loadings".
Biochemical Engineering Journal, **2013**, *79*, 94-103.

27. Moreno A.D.; Ibarra D.; Ballesteros I; González, A.; Ballesteros M.
"Comparing cell viability and ethanol fermentation of the thermotolerant yeast *Kluyveromyces marxianus* and *Saccharomyces cerevisiae* on steam-exploded biomass treated with laccase".
Bioresource Technology, **2013**, *135*, 239-245.

28. Moreno A.D.; Tomás-Pejó, E.; Ibarra, D.; Ballesteros, M.; Olsson, L.
"*In situ* laccase treatment enhances the fermentability of steam-exploded wheat straw in SSCF processes at high dry matter consistencies".
Bioresource Technology, **2013**, *143*, 337-343.

29. Moreno, A.D.; Tomás-Pejó, E.; Ibarra, D.; Ballesteros, M.; Olsson, L.
"Fed-batch SSCF using steam-exploded wheat straw at high dry matter consistencies and a xylose-fermenting *Saccharomyces cerevisiae* strain: effect of laccase supplementation".
Biotechnology for Biofuels, **2013**, *6*, 160.

30. Moreno, I.; Dummer, N.F.; Edwards, J.K.; Alhumaimess, M.; Sankar, M.; Sanz, R.; Pizarro, P.; Serrano, D.P.; Hutchings, G.J.
"Selective oxidation of benzyl alcohol using in situ generated H_2O_2 over hierarchical Au-Pd titanium silicalite catalysts".
Catalysis Science & Technology, **2013**, *3 (9)*, 2425-2434.

31. Moreno, J.; Dufour, J.
"Life cycle assessment of hydrogen production from biomass gasification. Evaluation of different Spanish feedstocks".
International Journal of Hydrogen Energy, **2013**, *38 (18),* 7616-7622.

32. Núñez, J.; de la Peña O'Shea, V.A.; Jana, P.; Coronado, J.M.; Serrano, D.P.
"Effect of copper on the performance of ZnO and ZnO_{1-x} N_x oxides as CO_2 photoreduction catalysts".
Catalysis Today, **2013**, *209*, 21-27.

33. Ochoa-Hernández, C.; Yang, Y.; Pizarro, P.; de la Peña O'Shea, V.A.; Coronado, J.M.; Serrano, D.P. "Hydrocarbons production through hydrotreating of methyl esters over Ni and Co supported on SBA-15 and Al-SBA-15".
Catalysis Today, **2013**, *210*, 81-88.

34. O'Mahony, T.
"Decomposition of Ireland's carbon emissions from 1990 to 2010: An extended Kaya identity".
Energy Policy, **2013**, *59*, 573-581.

35. O'Mahony, T.; Zhou, P.; Sweeney, J. "Integrated scenarios of energy-related CO_2 emissions in Ireland: A multi-sectoral analysis to 2020".
Ecological Economics, **2013**, *93*, 385-397.

36. Pablos, C.; van Grieken, R.; Marugán, J.; Adán, C.; Osuna, M.; Palma, J.
"Photoelectrocatalytic study and scaling up of titanium dioxide electrodes for wastewater treatment".
Water Science & Technology, **2013**, *68 (5)*, 999-1003.

37. Roeb, M.; Monnerie, N.; Houaijia, A.; Sattler, C.; Sanz-Bermejo, J.; Romero, M.; Canadas, I.; Castro, A.D.; Lucero, C.; Palomino, R.; Petipas, F.; Brisse, A.
"Coupling heat and electricity sources to intermediate temperature steam electrolysis".
Journal of Energy & Power Engineering, **2013**, *7 (11)*, 2068-2077.

38. Sanz, L.; Palma J.; García-Quismondo, E.; Anderson, M.
"The effect of chloride ion complexation on reversibility and redox potential of the Cu(II)/Cu(I) couple for use in redox flow batteries".
Journal of Power Sources, **2013**, *224*, 278-284.

39. Serrano, D.P.; Botas, J.A.; Pizarro, P.; Gómez, G.
"Kinetic and autocatalytic effects during the hydrogen production by methane decomposition over carbonaceous catalysts".
International Journal of Hydrogen Energy, **2013**, *38 (14)*, 5671-5683.

40. Serrano, D.P.; Coronado, J.M.; de la Peña O'Shea, V.A.; Pizarro, P.; Botas, J.A.
"Advances in the design of ordered mesoporous materials for low-carbon catalytic hydrogen production".
Journal of Materials Chemistry A, **2013**, *1 (39)*, 12016-12027.

41. Serrano, D.P.; Escola, J.M.; Pizarro, P.
"Synthesis strategies in the search for hierarchical zeolites".
Chemical Society Reviews, **2013**, *42 (9)*, 4004-4035.

42. Serrano, D.P.; Sanz, R.; Pizarro, P.; Peral, A.; Moreno, I.
"Improvement of the hierarchical TS-1 properties by silanization of protozeolitic units in presence of alcohols".
Microporous & Mesoporous Materials, **2013**, *166*, 59-66.

43. Susmozas, A.; Iribarren, D.; Dufour, J.
"Life-cycle performance of indirect biomass gasification as a green alternative to steam methane reforming for hydrogen production".
International Journal of Hydrogen Energy, **2013**, *38 (24)*, 9961-9972.

44. Vaquero, S.; Palma, J.; Anderson, M.A.; Marcilla, R.
"Mass-Balancing of electrodes as a strategy to widen the operating voltage window of carbon/carbon supercapacitors in neutral aqueous electrolytes".
International Journal of Electrochemical Science, **2013**, *8*, 10293-10307.

45. Vaquero, S.; Palma, J.; Anderson, M.; Marcilla, R.
"Improving performance of electric double layer capacitors with a mixture of ionic liquid and acetonitrile as the electrolyte by using mass-balancing carbon electrodes".
Journal of the Electrochemical Society, **2013**, *160* (*11*), A2064-A2069.

46. Wouters, J.J.; Lado, J.J.; Tejedor-Tejedor, M.I.; Perez-Roa, R.; Anderson, M.A.
"Carbon fiber sheets coated with thin-films of SiO_2 and λ-Al_2O_3 as electrodes in capacitive deionization: Relationship between properties of the oxide films and electrode performance".
Electrochimica Acta, **2013**, *112*, 763-773.

Patents

1. Application number: P201330186, title: "Batería de flujo acuosa con pares rédox orgánicos". Date of application: 13/02/2013 (O.E.P.M.). Holders: IMDEA Energy Institute; Autonoma University of Madrid. Inventors: Díaz, R.; Isikli, S.; Palma, J.; Carreño, M.C.; Ribagorda, M.; Guillamón, M.A.; Barradas, S.; Lecea, M.

Books/Chapters of books

1. Bellan, S.; Kandasamy, R. **2013**. Book: "Numerical simulation of plasma arc and plasma-substrate interaction". Ed. LAMBERT Academic Publishing (Germany). ISBN: 978-3-8484-8881-0.

2. Coronado, J.M.; Fresno, F.; Hernández-Alonso, M.D.; Portela, R.; García-Rodríguez, S.; Suarez, S.; de la Peña-O'Shea, V.A. **2013**. Book: "Design of advanced photocatalytic materials for energy and environmental applications". Ed: Springer. Eds: Coronado, J.M.; Fresno, F.; Hernández-Alonso, M.D.; Portela, R. ISBN: 978-1-4471-5061-9.

3. Iribarren, D.; Susmozas, A.; Sanz, A. **2013**. Chapter: "Contrasting the life-cycle performance of conventional and alternative diesel fuels". In: Diesel fuels: characteristics, performances and environmental impacts. Ed. Nova Science Publishers, New York (USA). Eds: Cristobal Silva and Agustin Rivera. ISBN: 978-1-62618-866-2 [hardcover]; ISBN: 978-1-62618-867-9 [ebook].

4. Iribarren, D.; Susmozas, A.; Sanz, A. **2013**. Chapter: "Life-cycle eutrophication impact of future energy systems". In: Eutrophication: Causes, Economic Implications and Future Challenges. Ed. Nova Science Publishers, New York (USA). ISBN: 978-1-62808-498-6 [hardcover]; ISBN: 978-1-62808-499-3 [ebook].

5. O´Mahony, T. **2013**. Book: "The future of Ireland to 2020. Putting the story in emission scenarios". Ed: LAMBERT Academic Publishing (Germany). ISBN: 978-3-659-30000-4.

Articles in general journals

1. García-Quismondo, E.; García Albiach, V.; De Miguel Navares, A.; Lavela Cabello, P.; Macías Gállego, C.
"Desionización capacitiva aplicada a la reutilización de aguas residuales"
RETEMA, Revista Técnica de Medio Ambiente, **2013**, *nº 167* (may-june), 30-35

2. Prodanovic, M.; Marín, F.
"Gestión de la energía en redes eléctricas inteligentes"
Article of opinion in website madrimasd. Date: 17/10/2013

3. Prodanovic, M.; Huerta, F.; Marín, F.
"La gestión energética en las redes eléctricas inteligentes"
Journal Electronoticias, **2013**, *nº 174-175* (november), 1174-1175

4. García-Quismondo, E.; Marcilla, R.; Palma, J.; Rodríguez, P.; Chacón, J.
"Baterías aluminio-aire recargables para el combatiente futuro"
Journal: Boletín de Observación Tecnológica en Defensa, *nº 40*, 3rd quarter **2013**

patents
chapters of books
articles

PhD thesis

Ph.D. Thesis

1. Title: Campos verticales de helióstatos para sistemas termosolares de receptor central: Comportamiento óptico-energético y aspectos de su integración en edificios y entornos urbanos
PhD student: Aurelio José González Pardo
Supervisor: Dr. Manuel Romero and Dr. José González-Aguilar
Tutor: Dr. Raúl Sanz Martín
Venue: Rey Juan Carlos University, Móstoles, Madrid
Date of defense: 19 June 2013

2. Title: Estudio de enzimas oxidorreductasas en la transformación de biomasa lignocelulósica en biocombustibles: deslignificación y destoxificación
PhD student: Antonio David Moreno García
Supervisor: Dr. Mercedes Ballesteros and Dr. David Ibarra
Venue: Complutense University of Madrid, Madrid
Date of defense: 16 September 2013

3. Title: Quinone-based organic redox compounds for electrochemical energy storage devices
PhD student: Süheda Isikli
Supervisor: Dr. Raúl Díaz Delgado
Tutor: Dr. M. Carmen Carreño García
Venue: Autonoma University of Madrid, Madrid
Date of defense: 31 October 2013

8.2. Congress communications

Invited lectures

1. Title: *Surface modification of metal oxides: a new strategy for improved supercapacitors*
Speaker: Díaz, R.
Congress: 2013 International Conference on Advanced Capacitors (ICAC 2013)
Venue: Osaka, Japan
Date: 27-30 May 2013
Organizer: The Committee of Capacitor Technology of the Electrochemical Society of Japan

2. Title: *The role of photocatalytic nanostructures on environmental and energy applications*
Speaker: Coronado, J.M.
Congress: 4th International Conference from Nanoparticles and Nanomaterials to Nanodevices and Nanosystems (IC4N)
Venue: Corfu, Greece
Date: 16-20 June 2013
Organizer: University of Texas at Arlington, USA

3. Title: *Solar thermal power plants, developing technologies for dispatchable solar electricity*
Speaker: Romero, M.
Congress: Eurotherm Seminar No. 98
Venue: Vienna, Austria
Date: 4-5 July 2013
Organizer: Vienna University of Technology

4. Title: *Ionic liquids and polymers for applications in energy production and storage*
Speaker: Marcilla, R.
Congress: Europolymer Conference 2013 "Polymers & Ionic Liquids" (EUPOC 2013)
Venue: Gargnano, Italy
Date: 1-5 September 2013
Organizer: Groupe Français des Polymères; Belgian Polymer Group; Associazione Italiana di Scienza e Tecnologia delle Macromolecole; University of Pisa

invited lectures

5. Title: *Producción de biocombustibles avanzados a partir de biomasa lignocelulósica mediante procesos termocatalíticos*
Speaker: Serrano, D.P.
Congress: XXXIV Reunión Bienal de la Real Sociedad Española de Química
Venue: Santander, Spain
Date: 15-18 September 2013
Organizer: RSEQ

6. Title: *Thermocatalytic processing of plastic wastes and biomass into advanced fuels and chemicals*
Speaker: Serrano, D.P. (Plenary conference)
Congress: 7th International Symposium on Feedstock Recycling of Polymeric Materials 2013 (ISFR)
Venue: Nueva Delhi, India
Date: 23-26 October 2013
Organizer: CSIR; FSRJ

7. Title: *New procedures and operational aspects for applying ultracapacitors in water treatment processes: Capacitive Deionization*
Speaker: Anderson, M.A.
Congress: 224th ECS The Electrochemical Society
Venue: San Francisco, USA
Date: 27 October-1 November 2013
Organizer: The Electrochemical Society

Oral Communications

1. Title: *Improvement of TiO_2 sensing performance by surface deposition of metal oxide species. Ethanol sensing with TiO_2-VO_x nanocrystals*
Authors: Epifani, M.; Comini, E.; Andreu, T.; Arbiol, J.; Díaz, R.; Siciliano, P.; Faglia, G.; Morante, J.R.
Congress: 2013 MRS Spring Meeting
Venue: San Francisco, USA
Date: 01-05 April 2013
Organizer: Materials Research Society

2. Title: *Concluding remarks of the* 2nd Iberoamerican Congress on Biorefineries
Author: Ballesteros, M.
Congress: 2nd Iberoamerican Congress on Biorefineries
Venue: Jaén, Spain
Date: 10-12 April 2013
Organizer: Cyted; Siadeb; Ifeja; University of Jaén; Diputación de Jaén

3. Title: *Enhancing the fermentability of steam-exploded wheat straw by laccase treatment previous SSCF processes at high dry matter consistencies*
Authors: Moreno, A.D.; Tomás-Pejó, E.; Ibarra, D.; Ballesteros, M.; Olsson, L.
Congress: 2nd Iberoamerican Congress on Biorefineries
Venue: Jaén, Spain
Date: 10-12 April 2013
Organizer: Cyted; Siadeb; Ifeja; University of Jaén; Diputación de Jaén

4. Title: *Optimal integration of ADEL IT-SOEC within a DSG-CRS*
Authors: Sanz, J.; Romero, M.; González-Aguilar, J.; Muñoz, J.
Congress: 2nd ADEL International Workshop
Venue: Córcega, France
Date: 8-9 May 2013
Organizer: ADEL Consortium

5. Title: *Proactive management for smart buildings: Resource management strategy*
Authors: Téllez, M.B.; Prodanovic, M.; Gallo, A.; González Aguilar, J.
Congress: 2nd International Conference on Smart Grids and Green IT Systems (SMARTGREENS 2013)
Venue: Aachen, Germany
Date: 9-10 May 2013
Organizer: INSTICC

6. Title: *Microporous aluminophosphates for thermochemical heat storage at low temperature via water sorption: FTIR study of the charge-discharge cycles*
Authors: López-Domínguez, M.; Ristic, A.; Zabukovec Logar, N.; Pizarro, P.; Serrano, D.P.; de la Peña O'Shea, V.A.; Coronado, J.M.

Congress: 2nd International Conference on Materials for Energy (EnMat II)
Venue: Karlsruhe, Germany
Date: 12-16 May 2013
Organizer: DECHEMA; Deutsche Gesellschaft fur Materialkunde eV; Karlsruhe Institute of Technology

7. Title: *Análisis de ciclo de vida de la producción de biodiesel a partir de residuos oleaginosos*
Author: Susmozas, A.
Congress: 2nd Workshop RESTONE
Venue: Móstoles, Madrid, Spain
Date: 23-24 May 2013
Organizer: IMDEA Energy Institute; Rey Juan Carlos University

8. Title: *Hidrotratamiento de ésteres metílicos usados como moléculas modelo de aceites vegetales para la producción de diésel renovable*
Author: Ochoa-Hernández, C.
Congress: 2nd Workshop RESTONE
Venue: Móstoles, Madrid, Spain
Date: 23-24 May 2013
Organizer: IMDEA Energy Institute; Rey Juan Carlos University

9. Title: Strategies for the addition of quinones on carbons for high energy density supercapacitors
Authors: Isikli, S.; Díaz, R.
Congress: 2013 International Conference on Advanced Capacitors (ICAC2013)
Venue: Osaka, Japan
Date: 27-30 May 2013
Organizer: The Committee of Capacitor Technology of the Electrochemical Society of Japan

10. Title: *An analysis of 2.5V carbon supercapacitor in an organic gel electrolyte based on polyethylene oxide-sodium imide salt*
Authors: Ramasamy, C.; Palma, J.; Anderson, M.A.
Congress: 2013 International Conference on Advanced Capacitors (ICAC2013)
Venue: Osaka, Japan
Date: 27-30 May 2013
Organizer: The Committee of Capacitor Technology of the Electrochemical Society of Japan

11. Title: *Performance of symmetric and asymmetric EDLCs based on a mixture of ionic liquid and acetonitrile as electrolyte*
Authors: Vaquero, S.; Palma, P.; Anderson, M.A.; Marcilla, R.
Congress: 3rd International Symposium on Enhanced Electrochemical Capacitors (ISEECap2013)
Venue: Taormina, Italy
Date: 3-7 June 2013
Organizer: CNR-ITAE-Istituto di Tecnologie Avanzate per l'Energia "Nicola Giordano"

12. Title: *Ultracapacitors acting as a capacitive deionization system: operational aspects*
Authors: García-Quismondo, E.; Palma, J.; Anderson, M.A.
Congress: 3rd International Symposium on Enhanced Electrochemical Capacitors (ISEECap2013)
Venue: Taormina, Italy
Date: 3-7 June 2013
Organizer: CNR-ITAE-Istituto di Tecnologie Avanzate per l'Energia "Nicola Giordano"

13. Title: *Life cycle assessment of bioethanol from microalgae*
Authors: Dufour, J.; Köhl, M.; Iribarren, D.; Petrakopoulou, F.
Congress: 21st European Biomass Conference and Exhibition (BC&E 2013)
Venue: Copenhagen, Denmark
Date: 3-7 June 2013
Organizer: ETA-Florence Renewable Energies; WIP

14. Title: *Life cycle performance of hydrogen production via bioglycerol steam reforming*
Authors: Susmozas, A.; Iribarren, D.; Sanz, A.; Dufour, J.
Congress: 10th Hypothesis Hydrogen and Fuel Cell Conference 2013
Venue: Edinburgh, United Kingdom
Date: 11-12 June 2013

Organizer: BDM; KTP

15. Title: *The role of manganese spinel properties on the hydrogen production efficiency via Mn_3O_4-NaOH thermochemical cycle*
Authors: Bayón, A.; de la Peña-O'Shea, V.A.; Serrano, D.P.; Coronado, J.M.
Congress: 10th Hypothesis Hydrogen and Fuel Cell Conference 2013
Venue: Edinburgh, United Kingdom
Date: 11-12 June 2013
Organizer: BDM; KTP

16. Title: *Pt deposition into mesostructured TiO_2 for photocatalytic hydrogen production*
Authors: Serrano, D.P.; Calleja, G.; Pizarro, P.; Gálvez, P.
Congress: 10th Hypothesis Hydrogen and Fuel Cell Conference 2013
Venue: Edinburgh, United Kingdom
Date: 11-12 June 2013
Organizer: BDM; KTP

17. Title: *Profitability assessment for self-sufficiency improvement in grid-connected non-residential buildings with on-site PV installations*
Authors: Téllez, M.B.; Prodanovic, M.
Congress: 4th International Conference on Clean Electrical Power (ICCEP 2013)
Venue: Alghero, Italy
Date: 11-13 June 2013
Organizer: ANAE-Associazione Nazionale Azionamenti Elettrici

18. Title: *Supply mix optimization for decentralized energy systems*
Authors: Gruber, J.K.; Mínguez-Fernández, J.L.; Prodanovic, M.
Congress: 2013 International Conference on Smart Grid (ICSG 2013)
Venue: Beijing, China
Date: 14-16 June 2013
Organizer: Engineering Information Institute (Engii)

19. Title: *CO_2 photoreduction performance of Au/TiO_2 catalysts: What role does gold play in the photocatalytic activity?*
Authors: Collado, L.; Moyano, E.; Sierra, B.; Jana, P.; Pizarro, P.; Coronado, J.M.; Serrano, D.P.; de la Peña-O'Shea, V.A.
Congress: 12th International Conference on Carbon Dioxide Utilization
Venue: Washington, USA
Date: 23-27 June 2013
Organizer: PSIEE-Penn State Institutes of Energy and the Environment

20. Title: *Diseño de heteroestructuras activas en la reducción fotocatalítica de CO_2: Bi_2WO_6 y Bi_2WO_6/TiO_2*
Authors: Collado, L.; Coronado, J.M.; Serrano, D.P.; de la Peña-O'Shea, V.A.
Congress: SECAT 2013
Venue: Seville, Spain
Date: 26-28 June 2013
Organizer: SECAT; University of Seville; Instituto de Ciencias de Materiales-CSIC

21. Title: *Enhancement of the water splitting activity by the Pt/M-$NaTaO_3$ (M = Y, La, Yb) photocatalysts*
Authors: Mata Montero, C.; Jana, P.; Pizarro, P.; Coronado, J.M.; Serrano, D.P.; de la Peña-O'Shea, V.A.
Congress: IV Iberian Symposium on Hydrogen, Fuel Cells and Advanced Batteries (HYCELTEC 2013)
Venue: Estoril, Portugal
Date: 26-28 June 2013
Organizer: SPM-Sociedade Portuguesa de Materiais

22. Title: *Narrowing the mesopore size distribution in hierarchical TS-1 zeolite by surfactant-assisted reorganization*
Authors: Sanz, R.; Serrano, D.P.; Pizarro, P; Moreno, I.; Shami, S.
Congress: 17th International Zeolite Conference (17th IZC)
Venue: Moscow, Russia
Date: 7-12 July 2013
Organizer: RNZA; IZA

23. Title: *Organic redox couples impregnated on carbons for high energy density supercapacitors*
Authors: Isikli, S.; Díaz, R.
Congress: Carbon 2013
Venue: Rio de Janeiro, Brasil
Date: 14-19 July 2013
Organizer: ABCarb; PETROBRAS

24. Title: *Effect of electrode mass-balancing in the electrochemical performance of carbon based supercapacitors in neutral aqueous electrolyte*
Authors: Vaquero, S.; Palma, J.; Marcilla, R.
Congress: XXXIV Reunión del Grupo de Electroquimica de la RSEQ y XV Encontro Ibérico de Electroquímica
Venue: Valencia, Spain
Date: 15-17 July 2013
Organizer: RSEQ; University of Valencia

25. Title: *Maximizing green diesel production by hydrotreating of methyl oleate by control catalyst acidity and operation temperature*
Authors: Ochoa-Hernández, C.; Yang, Y.; Pizarro, P.; de la Peña-O'Shea, V.A.; Coronado, J.M.; Serrano, D.P.
Congress: 11th European Congress on Catalysis (EuropaCat-XI)
Venue: Lyon, France
Date: 1-6 September 2013
Organizer: SCF; CPE; CNRS; ENS; IFP Energies Nouvelles; University of Lyon

26. Title: *Generation of uniform mesoporosity in hierarchical zeolites by combined seed silanization/surfactant rearrangement treatment*
Authors: Serrano, D.P.; Escola, J.M.; García, R.; Peral, A.; Linares, M.; Caldeira, V.P.; Souza, L.
Congress: 5th International Symposium. Advanced Micro- and Mesoporous Materials
Venue: Golden Sands, Bulgaria
Date: 6-9 September 2013
Organizer: ENSICAEN; University of Sofia; IGIC

27. Title: *Investigation and optimization of Copper-Chloride based electrolytes for redox flow battery applications*
Authors: Sanz, L.; García-Quismondo, E.; Palma, J.; Anderson, M.A.
Congress: 64th Annual Meeting of the International Society of Electrochemistry
Venue: Santiago de Querétaro, Mexico
Date: 8-13 September 2013
Organizer: ISE

28. Title: *Manganese oxide based thermochemical heat storage for CSP: Influence of synthesis parameters on the materials cyclability*
Authors: Carrillo, A.; Álvarez, S.; Romero, M.; Gonzalez-Aguilar, J.; Serrano, D.P.; Pizarro, P.; Coronado, J.M.
Congress: EuroMat 2013
Venue: Seville, Spain
Date: 9-13 September 2013
Organizer: FEMS

29. Title: *Desionización Capacitiva: Una tecnología para el tratamiento de aguas y el almacenamiento de energía*
Authors: García-Quismondo, E.; Santos, C.; Palma, J.; Anderson, M.A.
Congress: XXXIV Reunión Bienal de la Real Sociedad Española de Química
Venue: Santander, Spain
Date: 15-18 September 2013
Organizer: RSEQ

30. Title: *Numerical model for the chemical reduction of a metal oxide pellet driven by concentrated solar radiation*
Authors: Alonso, E; Selvan, S.; González-Aguilar, J.; Romero, M.
Congress: SolarPACES 2013
Venue: Las Vegas, USA
Date: 17-20 September 2013
Organizer: SolarPACES

31. Title: *Effect of rare earth metal doping (Y, La, Ce, Yb) on the photocatalytic activity of $NaTaO_3$ for hydrogen production*
Authors: Jana, P.; Mata, C.; Pizarro, P.; Coronado, J.M.; Serrano, D.P.; de la Peña-O'Shea, V.A.
Congress: 3rd EURopean Symposium on Photocatalysis (JEP 2013)
Venue: Portoroz, Slovenia
Date: 25-27 September 2013
Organizer: European Photocatalysis Federation; University of Nova Gorica

32. Title: *Steam-Iron process as an alternative to water gas shift reaction in biomass gasification*
Authors: Sanz, A.; Nieva D.; Dufour, J.
Congress: 5th World Hydrogen Technologies Convention (WHTC2013)
Venue: Shanghai, China
Date: 25-28 September 2013
Organizer: China Association for Hydrogen Energy (CAHE); International Association for Hydrogen Energy (IAHE)

33. Title: *Electrochemical energy storage technologies and applications*
Author: Díaz, R.
Congress: NEF 2013
Venue: Xi'an, China
Date: 26-28 September 2013
Organizer: BIT Congress Inc.

34. Title: *PV system model reduction for reliability assessment studies*
Authors: Gafurov, T.; Usaola, J.; Prodanovic, M.
Congress: 2013 IEEE European Innovative Smart Grid Technologies
Venue: Copenhagen, Denmark
Date: 6-9 October 2013
Organizer: Technical University of Denmark

35. Title: *Análisis del ciclo de vida para la selección de sistemas energéticos para la coproducción de biocombustibles sintéticos y electricidad*
Authors: Iribarren, D.; Susmozas, A; Dufour, J.
Congress: I Simposio de la Red Española de ACV
Venue: CIEMAT, Madrid, Spain
Date: 15 October 2013
Organizer: IMDEA Energy Institute; CIEMAT

36. Title: *Nuevas estrategias para la adición covalente y no covalente de quinonas sobre carbones*
Authors: Isikli, S.; Méndez, A.; Díaz, R.
Congress: XII Reunión del grupo español del carbón
Venue: Madrid, Spain
Date: 20-23 October 2013
Organizer: Grupo Español del Carbón

37. Title: *PV modeling for generation adequacy studies*
Authors: Usaola, J.; Ramírez-Jusdado, V.; Gafurov, T.; Prodanovic, M.
Congress: 3rd Solar Integration Workshop
Venue: Londres, United Kingdom
Date: 21-22 October 2013
Organizer: Energynautics

38. Title: *New procedures and operational aspects for applying ultracapacitors in water treatment processes: capacitive deionization*
Authors: García-Quismondo, E.; Santos, C.; Palma, J.; Anderson, M.A.
Congress: 224th The Electrochemical Society (ECS)
Venue: San Francisco, USA
Date: 21 October-1 November 2013
Organizer: The Electrochemical Society (ECS)

39. Title: *Optimización del suministro energético en sistemas descentralizados*
Authors: Gruber, J.K.; Mínguez, J.L.; Prodanovc´, M.
Congress: I Congreso Edificios Inteligentes
Venue: Madrid, Spain
Date: 23-24 October 2013
Organizer: Grupo Tecma Red

40. Title: *A novel lab-scale solar reactor for kinetic analysis of non-volatile metal oxides thermal reductions*
Authors: Alonso, E.; Pérez-Rábago, C.; González-Aguilar, J.; Romero, M.
Congress: Solar World Conference 2013 (ISES)
Venue: Cancún, Mexico
Date: 04-07 November 2013
Organizer: ISES; ANES

41. Title: *CRISPTower–A solar power tower R&D initiative in India*
Authors: Goel, N.; González-Aguilar, J.; Romero, M.; Steinfeld, A.; Stefanakos, E.; Goswami, D.Y.
Congress: Solar World Conference 2013 (ISES)
Venue: Cancún, Mexico
Date: 04-07 November 2013
Organizer: ISES; ANES

42. Title: *Coupling of a solid-oxide cell unit and a linear Fresnel reflector field for grid management*
Authors: Sanz-Bermejo, J.; González-Aguilar, J.; Gallardo-Natividad, V.; Romero, M.
Congress: Solar World Conference 2013 (ISES)
Venue: Cancún, Mexico
Date: 04-07 November 2013
Organizer: ISES; ANES

43. Title: *Determination of glint and glare of heliostat fields integrated on building façades*
Authors: González-Pardo, A.; González-Aguilar, J.; Romero, M.
Congress: Solar World Conference 2013 (ISES)
Venue: Cancún, Mexico
Date: 04-07 November 2013
Organizer: ISES; ANES

44. Title: *Numerical analysis on radiation heat transfer in volumetric solar receivers composed of stacked of thin monoliths*
Authors: Gómez-García, F.; Gonzalez-Aguilar, J.; Tamayo-Pacheco, S.; Olalde, G.; Romero, M.
Congress: Solar World Conference 2013 (ISES)
Venue: Cancún, Mexico
Date: 04-07 November 2013
Organizer: ISES; ANES

45. Title: *Optical analysis of a hexagonal 42kWe high-flux solar simulator*
Authors: Li, J.; González-Aguilar, J.; Pérez-Rábago, C.; Zeaiter, H.; Romero, M.
Congress: Solar World Conference 2013 (ISES)
Venue: Cancún, Mexico
Date: 04-07 November 2013
Organizer: ISES; ANES

46. Title: *Transient numerical analysis of storage tanks based on encapsulated PCMs for heat storage in concentrating solar power plants*
Authors: Bellan, S.; González-Aguilar, J.; Ramos Archibold, A.; Romero, M.; Rahman, M.M.; Stefanakos, D.Y.; Stefanakos, E.K.
Congress: Solar World Conference 2013 (ISES)
Venue: Cancún, Mexico
Date: 04-07 November 2013
Organizer: ISES; ANES

47. Title: *Forum on CSP developments worlwide*
Author: Romero, M.
Congress: Solar World Conference 2013 (ISES)
Venue: Cancún, Mexico
Date: 04-07 November 2013
Organizer: ISES; ANES

48. Title: *Static reference frame LQR optimal state-feedback control for static-series compensators*
Authors: Pérez, J.; Cóbreces, S.; Huerta, F.; Griñó, R.; Rodríguez, F.J.; Bueno, E.; Sanz, I.
Congress: 39th Annual Conference on IEEE Industrial Electronics Society (IECON 2013)
Venue: Vienna, Austria
Date: 10-13 November 2013
Organizer: IEEE

Poster communications

1. Title: *Microalgae carbohydrates profile: the effect of nutrients limitation*
Authors: Mahdy, A.; Méndez, L.; Demuez, M.; Ballesteros, M.; González- Fernández, C.
Congress: 2nd Iberoamerican Congress on Biorefineries
Venue: Jaén, Spain
Date: 10-12 April 2013
Organizer: Cyted; Siadeb; Ifeja; University of Jaén; Diputación de Jaén

2. Title: *Improving detoxification process by displaying laccases on fermentative yeast Kluyveromyces marxianus*
Authors: Oliva, A.; Demuez, M.; Moreno, A.D.; González-Fernández, C.; Ballesteros, M.
Congress: 2nd Iberoamerican Congress on Biorefineries
Venue: Jaén, Spain
Date: 10-12 April 2013
Organizer: Cyted; Siadeb; Ifeja; University of Jaén; Diputación de Jaén

3. Title: *Advantages of operating an IT-SOEC/DSG-CRS hybrid plant at high pressure*
Authors: Sanz, J.; Romero, M.; González-Aguilar, J.; Muñoz, J.
Congress: 2nd ADEL International Workshop
Venue: Córcega, France
Date: 8-9 May 2013
Organizer: ADEL Consortium

4. Title: *Study of the storage mechanism of Fe_3O_4 supercapacitors*
Authors: León-Reyes, A.; Chávez-Capilla, T.; Palma, J.; Díaz, R.; Epifani, M.
Congress: 2nd International Conference on Materials for Energy (EnMat II)
Venue: Karlsruhe, Germany
Date: 12-16 May 2013
Organizer: DECHEMA; Deutsche Gesellschaft fur Materialkunde eV; Karlsruhe Institute of Technology

5. Title: *Electrochemical capacitor studies on carbide derived carbon electrode with natural graphite addition in a Mg based organic media*
Authors: Ramasamy, C.; Palma, J.; Anderson, M.A.
Congress: 2nd International Conference on Materials for Energy (EnMat II)
Venue: Karlsruhe, Germany
Date: 12-16 May 2013
Organizer: DECHEMA; Deutsche Gesellschaft fur Materialkunde eV; Karlsruhe Institute of Technology

6. Title: *Thermochemical energy storage at high temperature via redox cycles of Mn-Co mixed oxides*
Authors: Carrillo, A.; Moya, J.; Bayón, A.; Jana, P.; de la Peña-O'Shea, V.A.; Romero, M.; González-Aguilar, J.; Pizarro, P.; Serrano, D.P.; Coronado, J.M.
Congress: 2nd International Conference on Materials for Energy (EnMat II)
Venue: Karlsruhe, Germany
Date: 12-16 May 2013
Organizer: DECHEMA; Deutsche Gesellschaft fur Materialkunde eV; Karlsruhe Institute of Technology

7. Title: *Predictive pyrolysis process modelling in Aspen Plus*
Authors: Peters, J.; Iribarren, D.; Dufour, J.
Congress: 2nd Workshop RESTOENE
Venue: Móstoles, Madrid, Spain
Date: 23-24 May 2013
Organizer: IMDEA Energy Institute; Rey Juan Carlos University

8. Title: *Diluted acid saccharification of Scenedesmus sp biomass for bioethanol production*
Authors: Méndez, L.; Mahdy, A.; Demuez, M.; Ballesteros, M.; González-Fernández, C.
Congress: 2nd Workshop RESTOENE
Venue: Móstoles, Madrid, Spain
Date: 23-24 May 2013
Organizer: IMDEA Energy Institute; Rey Juan Carlos University

9. Title: *Surface modified metal oxides for improved supercapacitors*
Authors: Epifani, M.; Chávez-Capilla, T.; Andreu, T.; Arbiol, J.; Palma, J.; Morante, J.R.; Díaz, R.
Congress: E-MRS 2013 Spring Meeting
Venue: Strasbourg, France
Date: 27-31 May 2013
Organizer: European Materials Research Society

10. Title: *Predictive pyrolysis process modelling in Aspen Plus*
Authors: Peters, J.; Iribarren, D.; Dufour, J.
Congress: 21st European Biomass Conference and Exhibition (BC&E 2013)
Venue: Copenhagen, Denmark
Date: 3-7 June 2013
Organizer: ETA-Florence Renewable Energies; WIP

11. Title: *An alternative approach for market integration of distributed energy resources*
Authors: Gafurov, T.; Téllez, M.B.; Prodanovic´, M.
Congress: 22nd International Conference and Exhibition on Electricity Distribution (CIRED 2013)
Venue: Stockholm, Sweden
Date: 10-13 June 2013
Organizer: CIRED

12. Title: *A study of mesoporous iron-substituted MCM-41 materials applied for the photocatalytic reduction of CO_2*
Authors: Collado, L.; Jana, P.; de la Peña-O'Shea; V.A.; Coronado, J.M.; Serrano, D.P.
Congress: 5th Czech-Italian-Spanish Conference on Molecular Sieves and Catalysis (CIS-5)
Venue: Segovia, Spain
Date: 16-19 June 2013
Organizer: SECAT; GEZ

13. Title: *Improved selectivity towards green diesel from the hydrotreating of methyl esters by controlling the acidity of zeolite based catalysts*
Authors: Ochoa-Hernández, C.; Yang, Y.; Pizarro, P.; Coronado, J.M.; Serrano, D.P.
Congress: 5th Czech-Italian-Spanish Conference on Molecular Sieves and Catalysis (CIS-5)
Venue: Segovia, Spain
Date: 16-19 June 2013
Organizer: SECAT; GEZ

14. Title: *Anaerobic digestibility of the algae Chlorella vulgaris bioethanol residue*
Authors: González-Fernández, C.; Velasco, M.; Ballesteros-Perdices, I.; Oliva, J.M.; Ballesteros-Perdices, M.
Congress: 13th World Congress on Anaerobic Digestion
Venue: Santiago de Compostela, Spain
Date: 25-28 June 2013
Organizer: University of Santiago de Compostela

poster communications

15. Title: *Hidrotratamiento catalítico de ésteres metílicos para la producción de diésel renovable empleando M/Zr-SBA-15 (M=Ni, Co)*
Authors: Ochoa-Hernández, C.; Yang, Y.; Pizarro, P.; de la Peña O'Shea, V.A.; Coronado, J.M.; Serrano, D.P.
Congress: SECAT 2013
Lugar: Seville, Spain
Date: 26-28 June 2013
Organizer: SECAT; University of Seville; Instituto de Ciencias de Materiales-CSIC

16. Title: *H_2 production by methane decomposition using pure silica materials as catalytic promoters*
Authors: Serrano, D.P.; Botas, J.A.; Pizarro, P.; Gómez, G.
Congress: 17th International Zeolite Conference (17th IZC)
Venue: Moscow, Russia
Date: 7-12 July 2013
Organizer: RNZA; IZA

17. Title: *Enhanced CO_2 capture over CMK carbons functionalized with amino groups*
Authors: Sanz, R.; Serrano, D.P.; Pizarro, P.; Arencibia, A.; López, A.L.; Esteban, E.; Domínguez, J.L.; Moriña, I.
Congress: 17th International Zeolite Conference (17th IZC)
Venue: Moscow, Russia
Date: 7-12 July 2013
Organizer: RNZA; IZA

18. Title: *Estudio de los mecanismos de almacenamiento en supercondensadores de Fe_3O_4*
Authors: León-Reyes, A.; Chávez-Capilla, T.; Epifani, M.; Palma, J.; Díaz, R.
Congress: XXXIV Reunión del grupo de Electroquímica de la RSEQ and XV Encontro Ibérico de Electroquímica
Venue: Valencia, Spain
Date: 15-17 July 2013
Organizer: RSEQ; University of Valencia

19. Title: *Óxidos metálicos modificados superficialmente para supercondensadores mejorados*
Authors: Chávez-Capilla, T.; Epifani, M.; Arbiol, J.; Andreu, T.; Palma, J.; Morante, J.R.; Díaz, R.
Congress: XXXIV Reunión del grupo de Electroquímica de la RSEQ and XV Encontro Ibérico de Electroquímica
Venue: Valencia, Spain
Date: 15-17 July 2013
Organizer: RSEQ; University of Valencia

20. Title: *Enhancing the life-cycle environmental performance of an energy system for the coproduction of synthetic biofuels and electricity*
Authors: Iribarren, D.; Susmozas, A; Dufour, J.
Congress: Life Cycle Management (LCM 2013)
Venue: Gothenburg, Sweden
Date: 25-28 August 2013
Organizer: The Swedish Life Cycle Center (CPM)

21. Title: *Biosynfuel production via slow or fast pyrolysis? A life-cycle energy demand and global warming approach*
Authors: Peters, J.; Iribarren, D.; Dufour, J.
Congress: Life Cycle Management (LCM 2013)
Venue: Gothenburg, Sweden
Date: 25-28 August 2013
Organizer: The Swedish Life Cycle Center (CPM)

22. Title: *Modelo para la generación de datos de consumo energético residencial basado en un enfoque probabilístico*
Authors: Gruber, J.K.; Prodanovic, M.
Congress: XXXIV Jornadas de Automática
Venue: Terrassa, Spain
Date: 4-6 September 2013
Organizer: Polytechnic University of Cataluña

23. Title: *Numerical modeling of solar thermochemical reactor for kinetic analysis*
Authors: Bellan, S.; Alonso, E; Pérez, C.; González-Aguilar, J.; Romero, M.
Congress: SolarPACES 2013
Venue: Las Vegas, USA
Date: 17-20 September 2013
Organizer: SolarPACES

24. Title: *100-Wh Multi-purpose particle reactor for thermochemical heat storage in concentrating solar power plants*
Authors: Álvarez de Miguel, S.; González-Aguilar, J.; Romero, M.
Congress: SolarPACES 2013
Venue: Las Vegas, USA
Date: 17-20 September 2013
Organizer: SolarPACES

25. Title: *Analysis of net zero-energy building in Spain. Integration of PV, solar domestic hot water and air-conditioning systems*
Authors: Gallo, A.; Téllez, B.; Prodanovic, M.; González-Aguilar, J.; Romero, M.
Congress: International Conference on Solar Heating and Cooling for Buildings and Industry (SHC 2013)
Venue: Freiburg, Germany
Date: 23-25 September 2013
Organizer: PSE AG

26. Title: *Life cycle approach to sustainability evaluation of energy technologies*
Authors: Hernández, P.; Maiztegi, A.; Velte, D.; Arrizabalaga, E.; Mabe, L.; Lechón, Y.; Cabal, H.; Caldes, N.; de la Rúa, C.; Santamaría, M.; Iribarren, D.
Congress: I Simposio de la Red Española de ACV
Venue: CIEMAT, Madrid, Spain
Date: 15 October 2013
Organizer: IMDEA Energy Institute; CIEMAT

27. Title: *Nuevas estrategias para la adición covalente y no covalente de quinonas sobre carbones*
Authors: Isikli, S.; Méndez, A.; Díaz, R.
Congress: XII Reunión del grupo español del carbón
Venue: Madrid, Spain
Date: 20-23 October 2013
Organizer: Grupo Español del Carbón

28. Title: *Phase change and heat transfer numerical analysis during solidification on an encapsulated phase change material*
Authors: Ramos Archibold, A.; Rahman, M.M.; González-Aguilar, J.; Goswami, D.Y.; Stefanakos, E.K.; Romero, M.
Congress: Solar World Conference 2013 (ISES)
Venue: Cancún, Mexico
Date: 04-07 November 2013
Organizer: ISES; ANES

training and dissemination activities

annual report 2013

9.1. Organization of conferences and courses

The IMDEA Energy Institute has been involved in the organization of the following conferences, courses, masters, workshops and congresses:

1. 2nd Workshop RESTONE: Últimos avances en la producción de combustibles limpios a partir de residuos agroforestales y oleaginosos
Members of the Organizer Committee: David Serrano, Juan M. Coronado, Víctor de la Peña, Javier Dufour
Venue: IMDEA Energy Institute, Móstoles, Madrid, Spain
Date: 23-24 May 2013
Organizer: IMDEA Energy Institute, Rey Juan Carlos University

conferences and courses

2. European Solar Day-2013. Global overview on R&D and markets trends in Solar Energy
Speakers: José Herrero, José Ignacio Arjona, Manuel Romero, José González-Aguilar
Venue: EOI, Madrid, Spain
Date: 14 May 2013
Organizer: EOI, IMDEA Energy Institute, AEDES

3. SolarPACES 2013
Member of the Scientific Committee: Manuel Romero
Venue: Las Vegas, USA
Date: 17-20 September 2013
Organizer: SolarPACES

4. Course: Thermophysical properties of advanced materials
Speakers: Ramon Arauz, Stephan Knappe, André Lindemann
Venue: IMDEA Energy Institute, Móstoles, Madrid, Spain
Date: 26-27 September 2013
Organizer: Netzsch, IMDEA Energy Institute

5. Meeting and Workshop RENAISSANCE: Shortening the long way between R&D and industry
Member of the Organizer Committee: Rebeca Marcilla
Venue: IMDEA Energy Institute, Móstoles, Madrid, Spain
Date: 14-15 October 2013
Organizer: Netzsch, IMDEA Energy Institute

6. I Symposium of the Spanish Network of Life Cycle Assessment. ACV & Bioenergy
Technical Programme Chair: Javier Dufour
Venue: CIEMAT, Madrid, Spain
Date: 15 October 2013
Organizer: IMDEA Energy Institute, CIEMAT

7. HIA30 International Energy Agency
Member of the Organizer Committee: Javier Dufour
Venue: IMDEA Energy Institute, Móstoles, Madrid, Spain
Date: 16-17 October 2013
Organizer: IMDEA Energy Institute

8. Workshop Energy 2013
Venue: IMDEA Energy Institute, Móstoles, Madrid, Spain
Date: 17 October 2013
Organizer: IMDEA Energy Institute, CSIC

9. Congress: 7th International Symposium on Feedstock Recycling of Polymeric Materials 2013 (ISFR)
Member of the Scientific Committee: David Serrano
Venue: Nueva Delhi, India
Date: 23-26 October 2013
Organizer: CSIR, FSRJ

10. TCSPower project meeting and mid-term review meeting
Venue: IMDEA Energy Institute, Móstoles, Madrid, Spain
Date: 29-31 October 2013
Organizer: IMDEA Energy Institute

11. Congress: Solar World Conference 2013 (ISES)
Members of the Scientific Committee: Manuel Romero and José González-Aguilar
Venue: Cancún, Mexico
Date: 04-07 November 2013
Organizer: ISES, ANES

12. Congress: Smart Cities
Venue: IMDEA Energy Institute, Móstoles, Madrid, Spain
Date: 6 November 2013
Organizer: The City Hall of Mostoles

13. Innpulso Network Assembly. Network of 51 cities for science and innovation
Venue: IMDEA Energy Institute, Móstoles, Madrid, Spain
Date: 7 November 2013
Organizer: The City Hall of Mostoles

14. II Workshop on Smart Grids
Panel discussion: Consumo bajo demanda en Smart Grids
Speakers: Prodanovic M., Marin F.
Venue: IFEMA, Madrid, Spain
Date: 15 November 2013
Organizer: Tecma Red Group

15. International Workshop: Energy Management in Smartgrids
Venue: IMDEA Energy Institute, Móstoles, Madrid, Spain
Date: 25 November 2013
Organizer: IMDEA Energy Institute

16. Kick-off meeting of European project CASCATBEL
Venue: IMDEA Energy Institute, Móstoles, Madrid, Spain
Date: 3 December 2013
Organizer: IMDEA Energy Institute

17. Madrid Network–University of California Davis Research Workshop: Renewable Energy: Science, Technology, Markets and Policy
Venue: Colegio Oficial de Arquitectos de Madrid, Spain
Date: 9-10 December 2013
Organizer: IMDEA Energy Institute, Madrid Network, University of California Davis

18. 2nd Annual Workshop of Young Researchers of IMDEA Energy
Venue: IMDEA Energy Institute, Móstoles, Madrid, Spain
Date: 13 December 2013
Organizer: IMDEA Energy Institute

9.2. Organization of lectures and seminars

The IMDEA Energy Institute has been involved in the organization of the following lectures and technical seminars:

1. Oral presentation: Oxidoreductases for lignocellulosic bioethanol production
Speaker: David Moreno (IMDEA Energy Institute)
Date: 11 January 2013

2. Oral presentation: A novel solar reactor to reduce non-volatile metal oxides
Speaker: Elisa Alonso (IMDEA Energy Institute)
Date: 1 March 2013

3. Oral presentation: Development of new redox chemistries and design of low-cost electrolytes for application in redox flow battery technologies
Speaker: Laura Sanz (IMDEA Energy Institute)
Date: 5 April 2013

4. Lecture: C/N-materials for energy storage, conversion, and artificial photosynthesis
Speaker: Dr. Markus Antonietti (Max Planck Institute of Colloids and Interfaces, Germany)
Date: 6 May 2013

5. Oral presentation: Hydrotreating of methyl esters to maximize green diesel production by controlling the catalysts acidity and the operation temperature
Speaker: Cristina Ochoa (IMDEA Energy Institute)
Date: 10 May 2013

6. Lecture: Research on High Temperature Processes at PROMES
Speaker: Dr. Gabriel Olalde (CNRS, France)
Date: 22 May 2013

7. Oral presentation: Contribution to the thermal characterization of ceramic volumetric absorbers for solar tower receivers
Speaker: Fabrisio Gómez (IMDEA Energy Institute)
Date: 07 June 2013

8. Lecture: Diseño del biodiesel ideal que disminuya las emisiones contaminantes y favorezca las prestaciones del motor diesel
Speaker: Dr. María Pilar Dorado (University of Cordoba)
Date: 19 July 2013

9. Oral presentation: 2nd generation biofuels based on pyrolysis and hydroupgrading
Speaker: Jens Peters (IMDEA Energy Institute)
Date: 26 July 2013

10. Lecture: Ceramic membranes - they allowed the USA to produce the atomic bomb but what else can they do?
Speaker: Prof. Marc Anderson (IMDEA Energy Institute)
Date: 31 July 2013

11. Oral presentation: Improving of Na-Mn based thermochemical cycles for water splitting
Speaker: Alicia Bayón (IMDEA Energy Institute)
Date: 6 September 2013

12. Oral presentation: An approach to artificial photosynthesis: Design of active photocatalytic systems
Ponente: Laura Collado (IMDEA Energy Institute)
Date: 11 October 2013

13. Oral presentation: Environmental evaluation of hydrogen production via biomass gasification
Speaker: Ana Susmozas (IMDEA Energy Institute)
Date: 8 November 2013

9.3. Participation in conferences, courses and seminars

The following list includes invited lectures and conferences in courses, masters, technical seminars and workshops given by researchers of the IMDEA Energy Institute:

1. Master: Renewable Energies and Environment
Module: Solar thermal power plants
Speaker: Romero, M. (Coordinator) and González-Aguilar, J.
Venue: UPM, Madrid, Spain
Date: 1 January-30 June 2013
Organizer: Polytechnic University of Madrid

2. Master: Renewable Energies and Energy Market
Module: Solar Energy
Speaker: Romero, M. (Coordinator) and González-Aguilar; J.
Venue: EOI, Madrid, Spain
Date: 1 January-30 June 2013
Organizer: EOI

3. Seminar within the framework of SOLGEMAC project: Hydrogen technologies
Conference: The SOLGEMAC project in the context of hydrogen technologies
Speaker: Romero, M.
Venue: Móstoles, Madrid, Spain
Date: 21 January 2013
Organizer: Rey Juan Carlos University

4. Course: Design and evaluation of biorefineries
Conference: PPP-Biobased. The European commitment by an economy based in bio-products
Speaker: Ballesteros, M.
Venue: Jaén, Spain
Date: 8-9 April 2013
Organizer: University of Jaén

5. Summer School: Saving, efficient management and energy production. Geostrategic necessity and employment. Panel discussion on Renewable Energies
Speaker: Dufour, J.
Venue: Madrid, Spain
Date: 27 June 2013
Organizer: CEU Business School. University CEU-San Pablo

6. Summer School: The energy challenges to 2020: Renewable electricity and clean fuels. Panel discussion on Solar Thermal and Photovoltaic Energy
Speaker: Romero, M.
Venue: Aranjuez, Spain
Date: 10 July 2013
Organizer: URJC Foundation

7. Summer School: Contamination, climate impact and role of alternative energy
Conference: Renewable energy in the current energy situation and its potential in reducing air emissions
Speaker: González-Aguilar, J.
Venue: Ciudad Real, Spain
Date: 10-12 July 2013
Organizer: University of Castilla La Mancha

8. Summer School: The energy challenges to 2020: Renewable electricity and clean fuels. Panel discussion on the current situation and prospects of renewable energies
Speaker: Dufour, J.
Venue: Móstoles, Madrid, Spain
Date: 8 August 2013
Organizer: Rey Juan Carlos University

9. Seminar within the framework of SOLGEMAC project: Taking advantage of the sun: the Disco-Stirling
Conference: How to generate power concentrating sunlight
Speaker: González-Aguilar, J.
Venue: Torrejón de Ardoz, Madrid, Spain
Date: 14 November 2013
Organizer: INTA

10. Seminar within the framework of SOLGEMAC project: Taking advantage of the sun: the Disco-Stirling
Conference: The SOLGEMAC program, a commitment of the Community of Madrid for the development of solar concentration systems
Speaker: Romero, M.
Venue: Torrejón de Ardoz, Madrid, Spain
Date: 14 November 2013
Organizer: INTA

11. Master: Renewable Energies, Hydrogen and Fuel Cells
Module: Solar Energy
Speakers: Romero, M. (Coordinador) and González-Aguilar, J.
Venue: Madrid, Spain
Date: 20 November-21 December 2013
Organizer: CSIC-UIMP

12. Invited conference at Instituto de Microelectronica de Madrid
Speaker: Victor de la Peña
Venue: Madrid, Spain
Date: 11 December 2013
Organizer: Instituto de Microelectrónica de Madrid

9.4. Participation in science dissemination activities

The main science dissemination events in which IMDEA Energy has been involved in 2013 are listed below:

1. Researchers' night 2013
Activity: Science and...¡action¡
IMDEA Units: TCPU, ECPU, HTPU, BTPU, ELSU, SAU
Venue: IMDEA Energy Institute, Móstoles, Madrid, Spain
Date: 27 September 2013
Organizer: IMDEA Energy Institute

2. Science Week of Comunidad de Madrid (2013)
Activity: GYMKANA: In search of a sustainable world
IMDEA Units: TCPU, ECPU, HTPU, BTPU, ELSU, SAU
Venue: IMDEA Energy Institute, Móstoles, Madrid, Spain
Date: 14 November 2013
Organizer: IMDEA Energy Institute

science dissemination activities

9.5. Training activities

IMDEA Energy has been involved during 2013 in training activities devoted to undergraduated students. Those activities are very interesting for the Institute that has signed an important number of educational agreements with national and international universities.

1. Cabañas, Miguel
B. Sc. in Chemical Engineering, Rey Juan Carlos University
Project title: Modelling of an electrochemical reactor
Supervisor: Enrique García-Quismondo and Jesús Palma, ECPU
Date of defense: June 2013

2. Cabascango, Jenny E.
M. Sc. in Renewable Energy, University Carlos III
Project title: Development of a building automation system for energy efficiency improvement
Supervisor: Jorn Gruber, ELSU
Date of Defence: September 2013

3. Castillo, Noemí
B. Sc. in Chemical Engineering, Rey Juan Carlos University
Project title: Advanced postcombustion CO_2 capture in energy conversion systems
Supervisor: Javier Dufour and Fontina Petrakopoulou, SAU
Date of defense: January 2013

4. Cren, Laurent
B. Sc. Industrial Engineering, Nantes University
Internship work: Analysis on net zero-energy building integration renewable energies
Supervisor: José González, HTPU
Period: July-September 2013

5. Cruz, Pedro L.
B. Sc. in Chemical Engineering, Rey Juan Carlos University
Internship work: Calculations of exergy in energy systems
Supervisor: Javier Dufour, SAU
Period: February-July 2013

6. Cruz, Pedro L.
B. Sc. in Chemical Engineering, Rey Juan Carlos University
Project title: Study of the energy efficiency of combined cycle power plants and its influence on CO_2 emissions
Supervisor: Javier Dufour and Fontina Petrakopoulou, SAU
Date of defense: January 2013

7. del Hoyo, Alejandro
B. Sc. in Energy Engineering, Rey Juan Carlos University
Internship work: Mechanical performance of materials after high-temperature thermal treatment
Supervisor: Dr. José González, HTPU
Period: July-September 2013

8. David, Alexander
B. Sc. in Mechanical Engineering, ETH
Project title: Experimental and theoretical analysis of the directional intensity in a solar simulator
Supervisor: José González (HTPU) and Aldo Steinfeld
Date of defense: December 2013

9. Estirado, Eva M.
B. Sc. in Chemistry, Autonoma University of Madrid
Internship work: Flow batteries
Supervisor: Jesús Palma, ECPU
Period: September-December 2013

10. Fernández, Joaquín
B. Sc. in Energy Engineering, Rey Juan Carlos University
Project title: Thermochemical energy storage based on mixed oxides of manganese and iron: experimental study and simulation
Supervisor: Patricia Pizarro and Alfonso Carrillo, TCPU
Date of defense: September 2013

11. Gallardo, Víctor
B. Sc. in Energy Engineering, Rey Juan Carlos University
Internship work: Analysis on high-temperature solid-oxide electrolyser cell into solar tower plant for hydrogen production
Supervisor: Manuel Romero, HTPU
Period: April-July 2013

12. García, Álvaro
B. Sc. in Energy Engineering, Rey Juan Carlos University
Project title: Modelling of an electrochemical reactor
Supervisor: Enrique García-Quismondo (ECPU) and J.A. Calles
Date of defense: June 2013

13. Gentilini, Matheus
B. Sc. in Environmental Engineering, Autonoma University of Madrid
Internship work: Study about analysis of strengths, weaknesses, opportunities, threats of renewable energies in Spain
Supervisor: Javier Dufour and Tadhg O'Mahony, SAU
Period: June-July 2013

14. Ghinassi, Giulia
B. Sc. in Internship work: Leonardo Da Vinci Trainee
Supervisor: Juan Coronado, TCPU
Period: September-December 2013

15. Gómez, David
B. Sc. in Energy Engineering, Rey Juan Carlos University
Internship work: CO_2 valorisation by photocatalytic processes
Supervisor: Víctor de la Peña, TCPU
Period: February-August 2013

16. Hernández, Juan
M. Sc. in Technology and Energy Resources, Rey Juan Carlos University
Project title: Adsorption/desorption of water in vapour phase for thermochemical energy storage
Supervisor: David Serrano and Juan Coronado, TCPU
Date of defense: September 2013

17. Hernández, Yolanda
B. Sc. in Chemical Engineering, Rey Juan Carlos University
Project title: Optimization of bioethanol production from microalgae: carbohydrate accumulation during cultivation in photobioreactors
Supervisor: Marie Demuez (BTPU) and Javier Dufour (SAU)
Date of defense: May 2013

18. Köhl, Maximiliam
M. Sc. in Applied Physics, Complutense University of Madrid
Project title: Life cicle assessment of bioethanol production form microalgae
Supervisor: Javier Dufour, SAU
Date of defense: June 2013

19. Manzanares, Ana M.
B. Sc. in Energy Engineering, Rey Juan Carlos University
Internship work: CO_2 valorisation by photocatalytic processes
Supervisor: Víctor de la Peña, TCPU
Period: July-December 2013

20. Manzanares, Ana M.
B. Sc. in Energy Engineering, Rey Juan Carlos University
Project title: Design and implementation of system for automatic control of CO_2 photovalorization process
Supervisor: Víctor de la Peña and David Serrano, TCPU
Date of defense: September 2013

21. Martín, Mario
B. Sc. in Chemical Engineering, Rey Juan Carlos University
Internship work: Life cycle assessment of high- and low-enthalpy geothermal systems
Supervisor: Javier Dufour and Diego Iribarren, SAU
Period: February-July 2013

22. Martín, Mario
B. Sc. in Chemical Engineering, Rey Juan Carlos University
Project title: Life cycle assessment of high- and low-enthalpy geothermal systems
Supervisor: Javier Dufour and Diego Iribarren, SAU
Date of defense: May 2013

23. Martín, Tania
B. Sc. in Chemistry Engineering, Rey Juan Carlos University
Internship work: Bio-oil production from microwave liquefaction of lignocellulosic biomass
Supervisor: Juan Coronado, TCPU
Period: September-December 2013

24. Mata, Cristina
B. Sc. in Chemistry Engineering, Rey Juan Carlos University
Internship work: Water splitting
Supervisor: Víctor de la Peña and Prabhas Jana, TCPU
Period: March-June 2013

25. Méndez, Mynor A.
M. Sc. in Renewable Energy and Fuels for the Future, Autonoma University of Madrid
Project title: Modification of carbon electrodes with organic redox compounds and their use in Supercapacitors
Supervisor: Raúl Díaz, ECPU
Date of defense: June 2013

26. Mínguez, José Luis
M. Sc. in Technology and Energy Resources, Rey Juan Carlos University
Project title: Optimization of energy supply locally
Supervisor: Jorn Gruber, ELSU
Date of defense: May 2013

27. Molina, Antonio
B. Sc. In Chemistry, Autonoma University of Madrid
Internship work: Study of electrochemical properties of carbonaceous materials in ionic liquids
Supervisor: Rebeca Marcilla, ECPU
Period: September 2013-January 2014

28. Montero, Eric
B. Sc. in Energy Engineering, Rey Juan Carlos University
Internship work: Development of a prototype management system for smart home
Supervisor: Milan Prodanovic, ELSU
Period: June-July 2013

29. Montero, Eric
B. Sc. in Energy Engineering, Rey Juan Carlos University
Project title: Optimal mix of energy technologies for health centres in Afric
Supervisor: Dr. Milan Prodanovic (ELSU) and Dr. Javier Dufour (SAU)
Date of defense: September 2013

30. Moyano, Edelweiss
B. Sc. in Chemistry Engineering, Rey Juan Carlos University
Internship work: CO_2 valorisation by photocatalytic processes
Supervisor: Víctor de la Peña and Patricia Pizarro, TCPU
Period: January-July 2013

31. Navalpotro, Paula
M. Sc. in Renewable Energy and Fuels for the Future, Autonoma University of Madrid
Project title: Development of optimized ionic liquid based electrolytes and their use in Supercapacitors
Supervisor: Rebeca Marcilla, ECPU
Date of defense: June 2013

32. Nieva, David
B. Sc. in Energy Engineering, Rey Juan Carlos University
Project title: Steam-iron process for hydrogen production
Supervisor: Javier Dufour and Abel Sanz, SAU
Date of defense: September 2013

33. Ortíz, Héctor
B. Sc. in Technical Industrial Engineering, Rey Juan Carlos Univesity
Internship work: Support for energy management of IMDEA Energy Institute
Supervisor: Silvia Mateo, ADM
Period: February-August 2013

34. Oro, Carlos
B. Sc. in Materials Engineering, Rey Juan Carlos University
Internship work: Synthesis of sol-gel methods of different metal oxides
Supervisor: Jesús Palma, ECPU
Period: February-September 2013

35. Orozco, Sandra
B. Sc. in Chemical Engineering, Rey Juan Carlos University
Internship work: Thermal and mechanical characterisation of materials for solar thermochemistry
Supervisor: José González, HTPU
Period: January-April 2013

36. Orozco, Sandra
B. Sc. in Chemical Engineering, Rey Juan Carlos University
Project title: Feasibility of membrane reactor in "Water Gas Shift" reaction for hydrogen production
Supervisor: Javier Dufour, SAU
Date of defense: September 2013

37. Otero, Javier
B. Sc. Chemical Engineering, Rey Juan Carlos University
Internship work: Electrodes for metal-air battery
Supervisor: Rebeca Marcilla, ECPU
Period: October 2013-January 2014

38. Palomo, María
B. Sc. in Chemistry Engineering, Rey Juan Carlos University
Internship work: Water splitting
Supervisor: Víctor de la Peña and Patricia Pizarro, TCPU
Period: November 2013-January 2014

39. Pescador, Rocío
B. Sc. in Sociology, University of Salamanca
Internship work: Social impact analysis
Supervisor: Javier Dufour and Tadhg O'Mahony, SAU
Period: May-September 2013

40. Prieto, Mercedes
B. Sc. in Chemical Engineering, Rey Juan Carlos University
Project title: Synthesis and characterization of different microporous materials for electrochemical energy storage
Supervisor: Raúl Díaz (ECPU) and Gisela Orcajo
Date of defense: June 2013

41. Ruiz, Andrés J.
B. Sc. in Materials Engineering, Rey Juan Carlos University

Internship work: Study of the electrochemical properties of electrodes based on carbon nanotubes
Supervisor: Rebeca Marcilla, ECPU
Period: June-October 2013

42. Sánchez, Rubén
B. Sc. in Chemistry Engineering, Rey Juan Carlos University
Internship work: HDO of vegetable oils
Supervisor: Juan Coronado and Patricia Pizarro, TCPU
Period: January-July 2013

43. Sánchez, Yaiza R.
B. Sc. in Industrial Chemistry, Rey Juan Carlos University
Project title: Preliminary study of the environmental feasibility of recycling processes for low-density polyethylene
Supervisor: Javier Dufour and Diego Iribarren, SAU
Date of defense: June 2013

44. Santos, Cleis
M. Sc. in Renewable Energy and Fuels for the Future, Autonoma University of Madrid
Project title: Development of materials for capacitive deionization (CDI) applied to wastewater treatment and energy storage
Supervisor: Enrique García-Quismondo, ECPU
Date of defense: June 2013

45. Soria, Jorge
B. Sc. in Energy Engineering, Rey Juan Carlos University
Internship work: Preparation of electrodes for capacitive deionization system
Supervisor: Enrique García-Quismondo, ECPU
Period: April-September 2013

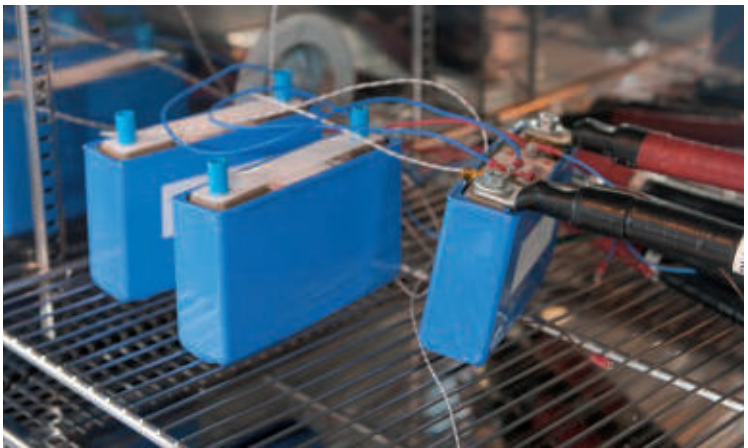
46. Tamayo, Sergio
B. Sc. in Energy Engineering, Rey Juan Carlos University
Internship work: Determination of optical performance of volumetric absorbers using ray tracing techniques
Supervisor: José González, HTPU
Period: January-April 2013

47. Tello, Pilar
M. Sc. In Technology and Energy Resources, Rey Juan Carlos University
Project title: Life cycle assessment of CO_2 transport and storage
Supervisor: Dr. Javier Dufour and Dr. Diego Iribarren, SAU
Date of defense: May 2013

48. Velasco, Mario
B. Sc. in Chemical Engineering, Rey Juan Carlos University
Project title: Biogas production from algal residue obtained after ethanol production
Supervisor: Cristina González (BTPU) and Javier Dufour (SAU)
Date of defense: June 2013

49. Zazo, Lydia
B. Sc. in Chemical Engineering, Rey Juan Carlos University
Internship work: Bio-oil production from microvawe lignification of lignocellulosic biomass
Supervisor: Juan Coronado and Dr. Patricia Pizarro, TCPU
Period: March-August 2013

50. Zazo, Lydia
B. Sc. in Chemical Engineering, Rey Juan Carlos University
Project title: Thermochemical Energy Storage using manganese oxides: experimental study and simulation
Supervisor: Patricia Pizarro, TCPU
Date of defense: September 2013



scientific highlights

10

annual report

2013

high-flux solar

High-Flux Solar Simulators: A tool for indoor testing of CSP components

a tool for indoor testing of CSP components

Developing efficient and commercially viable industrial processes based on the use of concentrated solar energy requires following a series of analyses of increasing complexity associated with the scaling up. Industrial-scale solar thermoelectric and thermochemical processes require concentrations that allow producing temperatures between 300 and 2200 °C (or even higher) in the range of tens or hundreds of MW thermal. The irradiance required in concentrated photovoltaic systems is significantly lower, but it can exceed 100 kW/m^2.

High-flux solar simulators are devices that recreate in the laboratory the high flux densities met in solar concentrating systems in well-defined conditions without regard to external perturbations due to the intermittency of the solar resource. It is a tool used in the analysis of elements and systems in the range of thermal powers below 50 kW contributing in the process development at early stages. In the lowest thermal power domain, the use of high flux solar simulators is mainly aimed at research in Materials Science, Chemistry and Physics. Here materials are subject to high irradiances in order to characterize its chemical or physical properties under extreme conditions or modify their superficial physicochemical properties. It is also applied in synthesis of materials or commodities and the studies conducting to establish the kinetic mechanisms involved. As the power increases, the HFSS application is led to characterize devices of which design is representative of the end process scale (i.e. testing concentration photovoltaic solar or solar lighting modules, solar receivers and reactors).

Various HFSS has been already reported. Among others, it can be mentioned the high-flux solar simulator for the study of high temperature and flux measurements established at Lawrence Berkeley Laboratory (peak fluxes up to 16 MW/m^2 [1], the high-power linear Ar arc (200 kW electrical input) enclosed by an elliptical trough mirror, designed by ETH-Zurich (this device was capable of delivering up to 75 kW of continuous radiative power at peak fluxes exceeding 4250 kW/m^2) [2], and the high-flux solar simulator facil-

simulators

ity comprising an array of ten Xe arcs, installed at the Paul Scherrer Institute, that can deliver over 50 kW of radiative power at peak fluxes exceeding 11 MW/m2 [3]. DLR has a facility composed of ten 6 kW xenon short-arc lamps with elliptical reflectors. Daniel S. Codd in Massachusetts Institute of Technology used seven 1.5 kW metal halide outdoor stadium lights to simulate concentrating solar power heliostat output for studying optical melting and light absorption behaviour of molten salts [4]. University of Minnesota designed a high-flux solar simulator consisting of seven 6.5 kWe xenon arc lamp. It can deliver radiative power of approximately 9.2 kW over a circular area of 60-mm-diameter located in the focal plane [5, 6]. University of Florida built a 56 kWe facility providing peak flux levels in excess of 5000 kW.

Since 2013, the IMDEA Energy Institute has a new 42kWe high-flux solar simulator. This facility that complements the 7kWe HFSS already installed in 2009 increases the laboratory capabilities covering thermal powers between 1 to 15 kW thermal. Figure 1 illustrates a sketch of the HFSS (internally called KIRAN42). This is composed of seven independent units distributed at the vertices and center of a regular hexagon. Each unit consists of an elliptical aluminum reflector and a 6kWe short-arc Xenon lamp mounted on a common support, which provides two degrees of freedom in azimuth and elevation. This configuration provides a great flexibility since it allows different aiming point strategies (and therefore various flux density distributions) on the sample. KIRAN42 is installed inside one of the two chambers of an enclosure constructed in order to confine the radiation produced during the trials. The second room contains the positioning table with a load capacity of 300 kg

The flux distribution is axisymmetric with 3,600 kW/m2 of peak flux and a circular area of 20-mm-diameter in which the flux exceeds 3,000 kW/m2. The power density within a focal area with diameter of 30 mm is about 2,700 kW/m2, and the cumulative power is about 2,000 W. For the diameter of 60 mm, the cumulative power is 5,300 W, and the power density is about 1,860 kW/m2, which correspond to stagnation temperature achieving 2,400 K. Within the focal area of 200-mm-diameter, the cumulative power can reach 14,000 W.

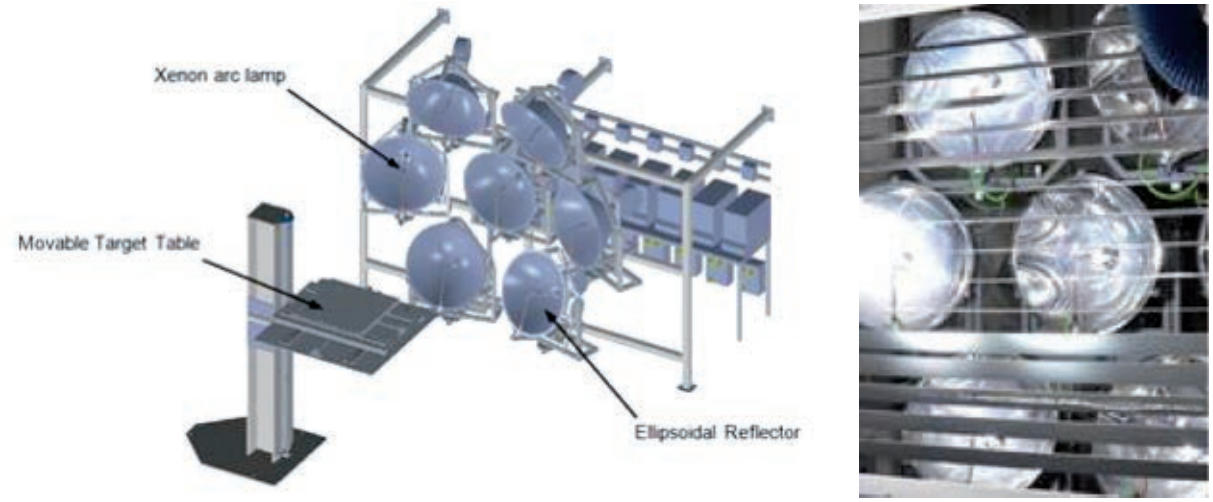


Figure 1. (Left) Scheme of the 42kWe High-Flux Solar Simulator installed at IMDEA Energía Institute. (Right) View of the HFSS lamps in operation through the HFSS shutter.

References

[1] Kuhn, P.; Hunt, A. "A new solar simulator to study high temperature solid-state reactions with highly concentrated radiation". Solar Energy Materials, **1991**, *24*, 742-750.

[2] Hirsch, D.; Zedtwitz, P.V.; Osinga, T.; Kinamore, J.; Steinfeld, A. "A new 75 kW high-flux solar simulator for high-temperature thermal and thermochenical research". Journal of Solar Energy Engineering, **2003**, *125*, 117-120.

[3] Petrasch, J.; Coray, P.; Meier ,A.; Brack, M. *et al*. "A novel 50 kW 11,000 suns high-flux solar simulator based on an array of Xenon Arc Lamps". Journal of Solar Energy Engineering, **2007**, *129*, 405-411.

[4] Codd, D.S.; Carlson, A.; Rees, J.; *et al*. "A low cost high flux solar simulator". Solar Energy, **2010**, *84*, 2202-2212.

[5] Krueger, K.R.; Davidson, J.H.; Lipinski, W. "Design of a new 45 kWe high-flux solar simulator for high-temperature solar thermal and thermochemical research". Journal of Solar Energy Engineering, **2011**, *133*, 011013.

[6] Krueger, K.R.; Lipinski, W.; Davidson, J.H. "Operational performance of the university of Minnesota 45 kWe high-flux solar simulator". Journal of Solar Energy Engineering, **2013**, *135*, 044501.


Nederman

metal-air

Metal-Air Batteries: The Promise of High Energy Density

the promise of high energy density

Even when fully developed, the highest energy storage that Li-ion batteries can deliver is too low to meet the demands of key markets, such as transport, in the long term. Metal-air batteries are a type of battery distinguishable by the fact that one of the electro-active materials (oxygen) does not need to be stored. This technology has the potential to attain the highest specific energy of any known battery technology (see Figure 1). Zn-air and Li-air batteries have attracted the most attention but other metals such as magnesium, sodium or aluminum are also promising for this technology [1].

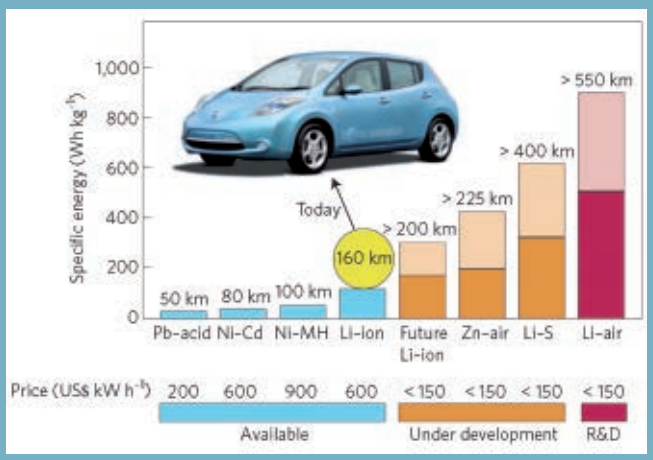


Figure 1: Practical specific energies for some rechargeable batteries, along with estimated driving distances and pack prices [2].

Simply put, metal-air batteries consist of an exposed porous carbon electrode –the air cathode, which traps oxygen gas– separated from the metal anode by an electrolyte (Figure 2). While low-capacity metal-air batteries that are already on the market are relatively low-cost, electrical recharging is difficult and inefficient; secondary (rechargeable) batteries under development currently have a lifetime of a few hundred cycles and typically attain only 50% cycle efficiency. The efforts should be mounted in such a way that all

of the five major components (anode, separator/membrane, electrolyte, air cathode, and packaging) of the metal–air cell will be investigated and developed concurrently [3,4]. A list of the key areas of development, which will assist evolving metal–air cell into a valuable chemical power source, is presented:

- Development of air cathodes with hierarchical pore structure, which will maintain adequate transport of oxygen and Me^{n+} towards the active, electron-conducting surfaces.
- Development of efficient bi-functional cathode catalysts to reduce the charge over-voltage.
- Development of a stable electrolyte in oxygen-rich electrochemical conditions.
- Oxygen selective membranes for purer oxygen supply from air.

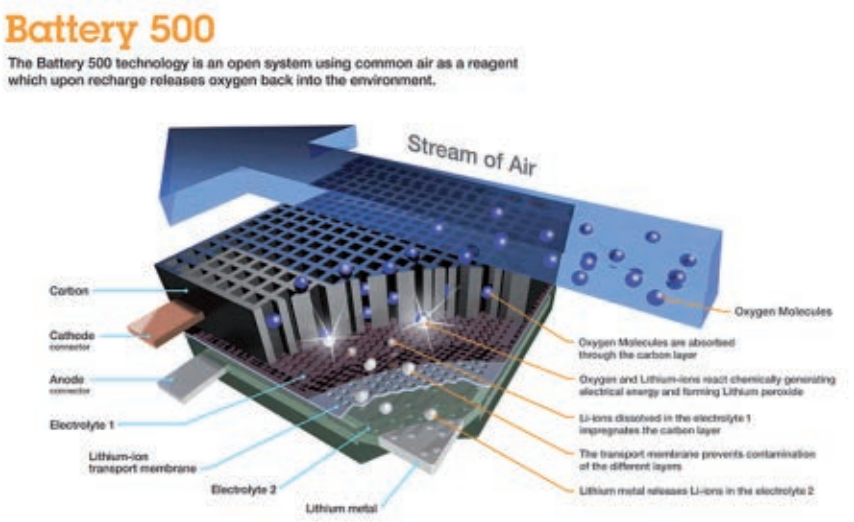


Figure 2: Schematic configuration of a Li-air cell [5].

Despite the difficulties, our society needs energy-storage devices with much higher levels of energy storage than ever before. Metal-air batteries are among the few technologies that can exceed the stored energy of Li-ion. At present, automotive propulsion batteries are just beginning the transition from nickel metal hydride to Li-ion batteries, after nearly

35 years of research and development on the latter. The transition to rechargeable metal-air batteries (if successful) should be viewed in terms of a similar development cycle.

Therefore, in the Electrochemical Processes Unit it is believed that we must devote more intensive research to overcome the existing limitation of the metal-air batteries. The current work at the ECPU is oriented towards (a) the search for advanced electrolytes where the reduction of the Me^{n+} ions could be possible under stable conditions, and (b) the development of new air electrodes in which both the oxygen evolution and the oxygen reduction reactions occur with the lowest possible hysteresis smaller voltage hysteresis, better rate, and better reversibility.

References

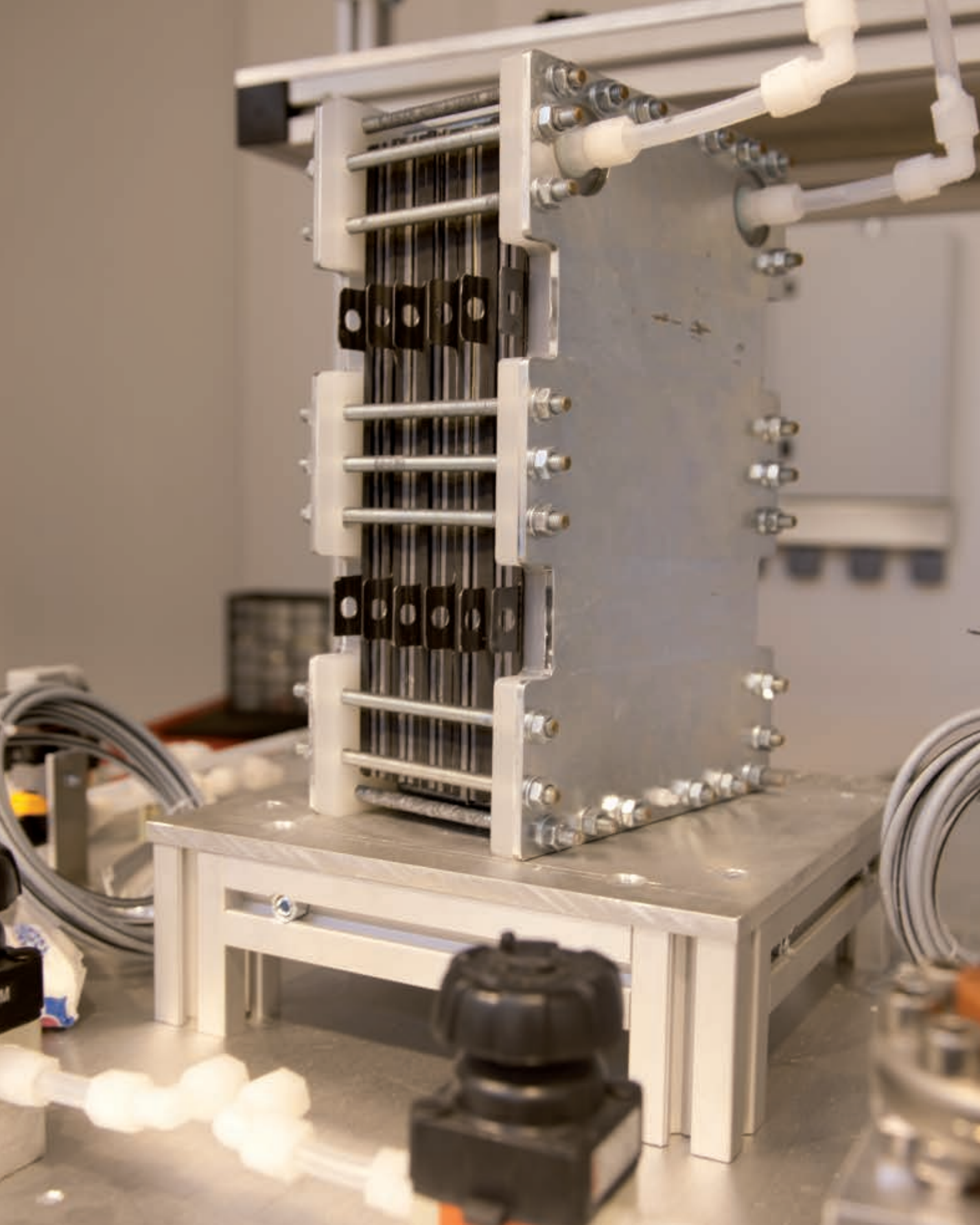
[1] Lee, J.-S. *et al.* "Metal-Air batteries with high energy density: Li-Air versus Zn-Air". Advanced Energy Materials, **2011**, *1*, 34-50.

[2] Bruce, P.G.; Freunberger, S. A.; Hardwick, L.J.; Tarascon, J.M. "Li-O_2 and Li-S batteries with high energy storage". Nature Materials, **2012**, *11*, 19-29.

[3] Kraytsberg, A.; Ein-Eli, Y. "Review on Li-air batteries-Opportunities, limitations and perspective". Journal of PowerSources, **2011**, *196*, 886-893.

[4] Balaish, M.; Kraytsberg, A.; Ein-Eli, Y. "A critical review on lithium-air battery electrolytes". Physical Chemistry Chemical Physics, **2014**, *16*, 2801-2822.

[5] The Battery 500 Project. at http://www.ibm.com/smarterplanet/us/en/smart_grid/article/battery500.html



power electroni

Power Electronics Applications for Electricity Networks

for electricity networks

In recent decades power electronics systems have proliferated to industrial environments, transport and energy systems predominantly as a result of significant advances in semiconductor switching devices seeing their cost and size reduced and their performance improved. Power electronics systems play a key role in reducing energy consumption and offering control flexibility: serving as power interface for renewable energy systems, improving efficiency in generation systems and electricity networks, providing applications leading to increased network reliability and enabling implementation of ancillary services [1].

The back-to-back converter (Figure 1) has become the most common topology in applications where it is necessary to regulate bidirectional power flows and control reactive powers [2]. It consists of two AC/DC converters linked by a common DC bus. Principal features such as bidirectional power flows, sinusoidal (or arbitrary) output currents and unity power factor have made the back-to-back topology used frequently during last decades.

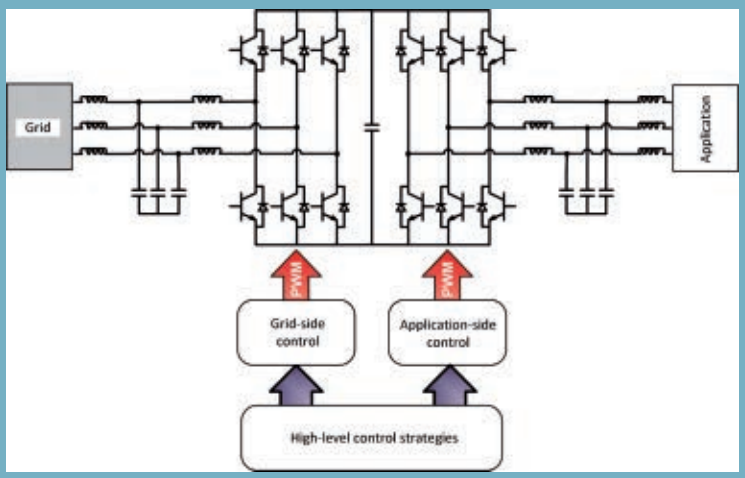


Figure 1. Back-to-back converter and traditional control structure.

cs applications

Back-to-back converters have been widely used in applications such as:

- Interface for variable-frequency systems. Nowadays, it is the most popular topology for large motor drives, grid integration of wind turbines, being also widely used as power interface in gas micro-turbines and diesel generators [3]. The bidirectional power flow feature is of particular interest for energy recuperation in motor drives and in creating startup conditions in generator application.

- Flexible AC Transmission Systems (FACTS). Based on power electronics, the FACTS are applied on transmission and distribution networks, increasing grid reliability and power supply efficiency. Common FACTS such as UPFC, UPQC, DVR or STATCOM are usually implemented using back-to-back converters [4].

- High-voltage DC (HVDC) transmission systems. HVDC technology is an economic alternative to long-distance power transmission, off-shore generation or submarine links. HVDC systems based on back-to-back converters are mainly oriented for providing short-distance links between heterogeneous grids [5].

- Interface for energy storage systems (ESS). The use of ESS in electricity networks improves power generation efficiency and provides to the system with elements that ensure reliability and power quality by using FACTS. Back-to-back converters are the most common interfaces for flywheels, universal power supplies (UPS) or hybrid power generation systems [3].

- Smart interfaces for distribution networks. Back-to-back converters are a topology of choice for applications in soft-normally open points (SNOP). A SNOP is a power electronics converter installed between two distribution networks that provides active and reactive power control and ancillary services without requiring a costly investment in infrastructure [6] and facilitates integration of distributed generation in low-voltage distribution networks.

Smart Grids can profit from application of back-to-back converters by exploiting active power management features, ancillary services and reconfiguration capabilities and also by implementing concepts such as SNOPs, integration of renewable resources or storage systems in distribution networks (Figure 2) with reasonable investment requirements [7].

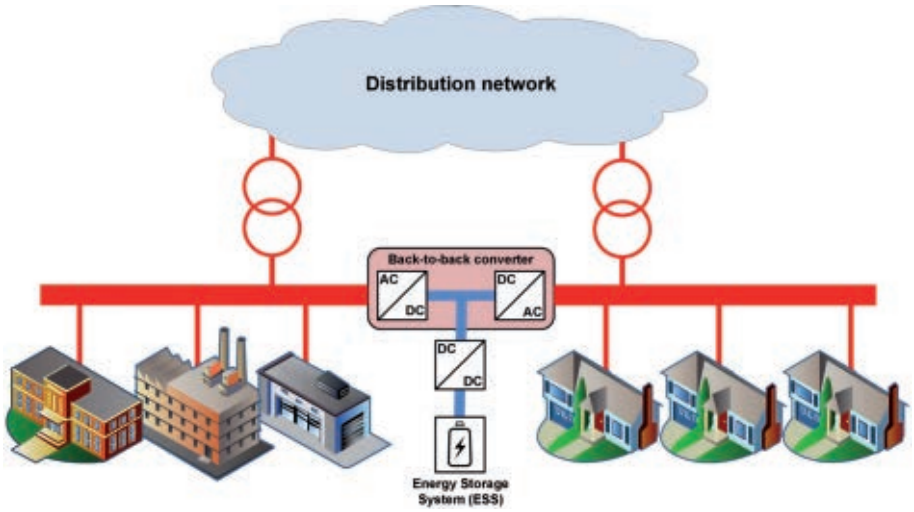


Figure 2. Back-to-back converter applied as a SNOP between two distribution networks and providing interface for an energy storage system.

In addition to these conventional applications of power electronics systems, their inherent control flexibility make them perfect candidates for any new energy scenario. Smart Grids assumes a new paradigm in which all the entities (now acting as agents) can play continuously changing roles and so they must be able to readjust their operation modes to satisfy specific energy demand and guarantee security and efficiency [8].

New times require new solutions. Traditionally back-to-back converter control has been tackled from a viewpoint in which both converter sides were decoupled and independently controlled [9]. That methodology has led to an inflexible control structure that normally serves only a specific application target. That leads to the converter components often oversized resulting in increased system costs. In Smart Grids applications, where flexibility and efficiency are key elements, it appears more adequate to select the control topology for back-to-back converters in a more general way and integrate both sides of the converter in a single control structure.

Development of novel control strategies for back-to-back converters and their respective applications in future electricity networks is one of the fundamental research lines of the Electrical Systems Unit of Institute IMDEA Energy. Novel control structures are being sought in order to ensure the system economic feasibility, guarantee the operation of ancillary services, provide a necessary degree of adaptability for automatic system reconfiguration (acting upon changing network conditions) and, finally, a quick integration of any new entities connected to the grid.

References

[1] Bose, B.K. "Global energy scenario and impact of power electronics in 21st century". IEEE Transactions on Industrial Electronics, **2013**, *60 (7)*, 2638-2651.

[2] Bueno, E.J. *et al.* "Design of a back-to-back NPC converter interface for wind turbines with squirrel-cage induction generator". IEEE Transactions on Energy Conversion, **2008**, *23 (3)*, 932-945.

[3] Kramer, W. *et al.* "Advanced power electronic interfaces for distributed energy systems. Part 1: Systems and topologies". Technical Report NREL/TP-581-42672, March **2008**.

[4] Hingorani, N.G.; Gyugyi, L. "Understanding FACTS: concepts and technology of flexible AC transmission systems. Wiley-IEEE press, **2000**.

[5] Flourentzou, N. *et al.* "VSC-based HVDC power transmission systems: An overview". IEEE Transactions on Power Electronics, **2009**, *24 (3)*, 592-602.

[6] Moslehi, K.; Kumar, R. "A reliability perspective of the Smart Grid". IEEE Transactions on Smart Grid, **2010**, *1 (1)*, 57-64.

[7] Brewin, B.O. *et al.* "New technologies for low voltage distribution networks". *2nd ISGT Europe*, **2011**.

[8] Liserre, M. *et al.* "Future Energy Systems". *IEEE Industrial Electronics Magazine*, **2010**.

[9] Kazmierkowski, M.P. *et al.* "Control in power electronics: selected problems". Academic Press, **2002**.

sun heat o

developing micro and mesoporous materials for ...

Sun Heat on Demand: Developing Micro and Mesoporous Materials for Thermochemical Energy Storage at low and high Temperature

Recently, energy roadmaps have placed great emphasis on the development of efficient thermal energy storage systems (TES), as a key factor to minimize the mismatch between energy supply and energy demand, for both domestic and industrial thermo solar applications. The concept is simple: the excess of heat generated by the solar radiation is stored throughout the day and then used during off-sun periods [1] [2].

There are three different types of thermal energy storage systems: sensible, latent and thermochemical [3].

Energy can be stored by means of sensible heat by increasing the temperature of a storing medium that could be either liquid (water, molten salts) or solid (concrete, rocks, sand). The stored heat per mass unit is directly proportional to its heat capacity and the temperature difference between its initial and final state. Sensible heat storage (SHS) is on an advanced stage of development and it has been already implemented in concentrated solar power (CSP) plants allowing a 24 hour energy production during many months of the year [4].

Latent heat storage (LHS) systems imply the phase change (crystallization, melting...) of the storage medium. Usually this type of TES can store more energy than the (SHS) as both specific and latent heat participate in the storing process. Materials used for LHS are called phase change materials (PCMs), like paraffin or eutectic salts, and can be packed in tubes, capsules or wall boards.

The third type of process, thermochemical heat storage (TCS), is based on reversible chemical reactions (e.g. reduction-oxidation) or reversible physicochemical processes (sorption-desorption). Both consist of three steps: charge, storage and discharge.

$$A + \text{heat} \leftrightarrow B + C \quad (1)$$

In the case of the former, during the charge the energy provided by the sun is used to carry out an endothermic reaction. The reaction products are stored independently and finally combined during discharge in order to release the stored energy, through an exothermic reaction.

The main advantage of TCS is its higher energy storage density, compared with the two other types, which implies a smaller volume of storage medium, involving almost no energy losses during the storing period. A second advantage is the wide variety of chemical reactions and processes that can be used, resulting in a broad interval of temperatures at which energy can be stored. This flexibility allows choosing the right material for the relevant working conditions, from low to high temperatures.

Of particular interest for domestic applications are the systems based on reversible water adsorption on porous solids. By applying heat, water can be desorbed from these materials. After this charging stage both components can be stored separately. Then, during the discharge, water and sorbent are brought together again resulting in a heat release. This process can be easily implemented and it is suitable for seasonal storage as the dry solid can be stowed for long periods at low relative humidity.

These reasons make TCS a promising concept to boost the efficiency of solar thermal and CSP technologies. For this purpose, the TCP Unit of IMDEA Energy is working on the development of porous materials for low and high temperature energy storage.

Low temperature heat storage research is carried out in collaboration with National Chemistry Institute of Slovenia (project STOREHEAT, MATERA-ERA-NET), and is based on water sorption-desorption processes of microporous materials. Among them, aluminophosphates (ALPO) and metalorganic-framework (MOF) materials (Figure 1) have been proposed as suitable candidates for this application. Both have been subjected to water adsorption-desorption cycles, under different conditions of temperature (50-200 ºC) and humidity, in order to check their stability during several charge-discharge loops.

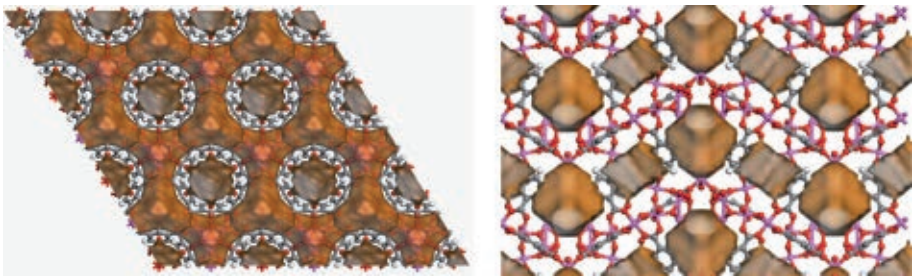


Fig.1. Different views of the structures of MOF MIL-96 showing in brown color the volume accessible to water molecules.

High temperature energy storage is focused on reduction-oxidation reactions of mesoporous metal oxides. In particular, Mn_2O_3 has been selected as a feasible material due to its inexpensive cost, low toxicity and favorable thermodynamics, as the redox reactions occur in the 600 – 1000 ºC temperature range (TCSPower). This interval will match the operation conditions of future CSP plants with central air receivers. This material stores and releases energy through the following reversible reaction [5]

$$\text{Charge (reduction)} \rightarrow$$
$$6Mn_2O_3 \leftrightarrow 4Mn_3O_4 + O_2 \quad (2)$$
$$\leftarrow \text{Discharge (oxidation)}$$

In spite of this redox couple meets some of the requirements to be a TCS material, others like kinetics and cycle stability must be improved in order to guarantee its complete feasibility. For this reason, the influence of the synthesis route on the reaction rate and the cyclability are subject of study as Figure 2 depicts. Results have demonstrated the very promising characteristics of these materials for TCS purposes.

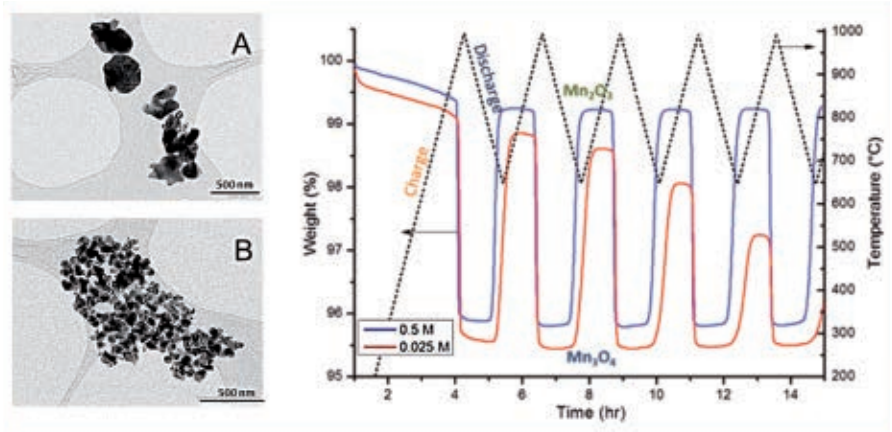


Fig.2. TEM images of Mn_2O_3 (left) showing the different particle size distribution of the samples prepared from 0.5 (A) and 0.025 (B) M precursor solution and the different stability of the Mn_2O_3-Mn_3O_4 redox cycles assays in air (right).

References

[1] "Technology Roadmap Concentrating Solar Power." [Online]. Available: http://www.iea.org/publications/freepublications/publication/csp_roadmap.pdf. [Accessed: 05-Mar-**2013**].

[2] "Technology Roadmap Solar Heating and Cooling." [Online]. Available: http://www.iea.org/publications/freepublications/publication/Solar_Heating_Cooling_Roadmap_2012_WEB.pdf. [Accessed: 05-Mar-**2013**].

[3] Abedin, A.; Rosen, M. "A critical review of thermochemical energy storage systems". The Open Renewable Energy Journal, **2011**, 42-46.

[4] "Torresol Energy-Gemasolar thermosolar plant." [Online]. Available: http://www.torresolenergy.com/TORRESOL/gemasolar-plant/en. [Accessed: 10-Dec-**2012**].

[5] Worner, A.; Binyami, S.; Giger, F.; Soupart, J.B.; Gonzalez-Aguilar, J.; Steinfeld, A.; Trettin, R. "The TCSPower Project Thermochemical Energy Storage for Concentrated Solar Power Plants" in *Solar Paces*, **2012**, no.September.

improving lignoce

saccharification using laboratory-produced...

Improving lignocellulosic biomass saccharification using laboratory-produced cocktails of fungal enzymes

Agricultural residues, such as wheat straw, are lignocellulosic raw materials that represent one of the most abundant and low cost feedstock for bioethanol production. The process is based on the enzymatic hydrolysis of polymers contained in lignocellulosic biomass to their monomer sugars (saccharification) and their conversion to ethanol by a fermentative microorganism. The improvements of bioethanol production process using lignocellulosic biomass and overall cost decrease are considered as the main current challenges.

The saccharification step is regarded as the key-limiting step. Since the production cost of hydrolytic enzymes is one of the major problems for industrial application, big efforts have been directed to the characterization and optimization of the enzymes produced by wood-degrading fungi. During this decade, research has been focused on the discovery of new xylanases and other accessory enzymes to increase the hydrolysis of all the components present in the lignocellulosic biomass. It has been shown that hydrolytic enzymes production is induced and affected by the nature of the substrate [1-2]. Therefore, the cultivation of fungus on a particular lignocellulosic material could induce different enzyme mixture with a composition and proportion especially suitable for the hydrolysis of this particular material. By finding a tailored enzymatic cocktail for the hydrolysis of certain material, the enzyme loading would be lowered and the efficiency of the process increased.

The Biotechnological Processes Research Unit aims at finding a suitable enzymatic cocktail for saccharification of pretreated wheat-straw, by following the induction and characterizing the enzyme production by two wild-type filamentous fungi: the thermophilic *Myceliophthora thermophila* CBS 173.70 and the mesophilic *Aspergillus aculeatus* CECT 20387. Those fungi are grown on different composition of pretreated wheat-straw namely water insoluble solids fraction (WIS) and whole slurry. Likewise, a model cellulosic substrate (Sigmacell) is also used for comparison purposes.

Up to now only *A. aculeatus* has been studied in the BTPU. Cellulolytic and xylanolytic enzymes production profiles obtained in the different substrates were compared (Fig 1 and 2). As expected, the results showed that *A. aculeatus* is a good producer of β-glucosidase and xylanase enzymes [4-5]. The use of different substrates compositions

led to the induction of distinctive cellulolytic and xylanolytic enzymes. On WIS fraction higher β-xylosidase production was induced than on slurry. This difference seems to be due to the presence of soluble compounds (inhibitory and sugars) in the liquid fraction of slurry. As a final stage, the hydrolysis efficiency of pretreated wheat straw will be assessed using the laboratory-produced enzymatic cocktail.

References

[1] Alvira, P.; Tomas-Pejo, E.; Ballesteros, M.; Negro, M.J. "Pretreatment technologies for an efficient bioethanol production process based on enzymatic hydrolysis: A review". Bioresources Technology, **2010**, *101*, 4851-4861.

[2] Duff, S.J.B.; Cooper, D.G.; Maynard Fuller, O. "Effect of media composition and growth conditions on production of cellulase and B-glucosidase by a mixed fungal fermentation". Enzyme and Microbial Technology, **1987**, *9*, 47-52.

[3] Manju, S.; Chadha B.S. "Production of hemicellulolytic enzymes for hydrolysis of lignocellulosic biomass". Biofuels: alternative feedstock and conversion processes. **2011**, Chapter 9, 203-228.

[4] Guimaraes, N.C.A. *et al.* "Xylanase production form *Aspergillus japonicus* var. aculeatus: Production using agroindustrial residues and biobleaching effect on pulp. Journal of Biocatalysis & Biotransformation, **2013**, *2*, 1.

[5] de Vries, R.; Visser, J. "*Aspergillus* enzymes involved in degradation of plant cell wall polysaccharides". Microbiology and Molecular Biology Reviews, **2001**, *65*, 497-522.

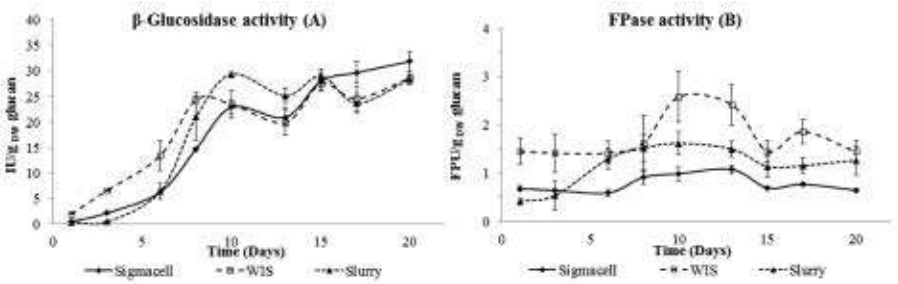


Figure 1. Time course profiles of celluloytic activity produced by A. aculeatus in submerged fermentation on Sigmacell, WIS and Whole Slurry.

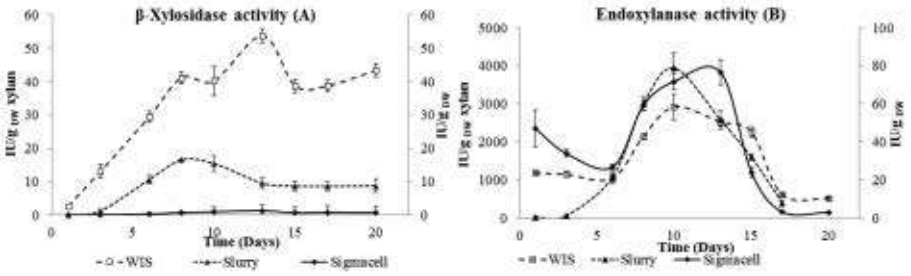


Figure 2. Time course profiles of xylanolytic activity produced by A. aculeatus in submerged fermentation on Sigmacell, WIS and Whole Slurry.

life cycle assessm

Life Cycle assessment of bioethanol production from microalgae

The interest in the use of microalgae as feedstock for biofuel production has strongly increased in the last years. This is partly due to numerous advantages of microalgae cultivation, namely extraordinary growth rate, high areal poductivity, high lipid or carbohydrate content, no lignin content, and CO_2 absorption during the growth stage [1,2]. However, an important drawback has to be overcome: unfavourable net energy balances, mainly due to energy-intensive dewatering techniques [3-5]. Co-producing ethanol has the potential to increase the overall energy production of microalgal systems, making them more viable [6]. Bioethanol can be produced from microalgae by reducing complex sugars to simple sugars through enzymatic or acidic hydrolysis. These sugars can be subsequently fermented in order to produce ethanol by means of yeast or bacteria. Since some microalgal strains can contain large amounts of carbohydrates, they even bear the potential for large-scale ethanol production.

The goal of the Life Cycle Assessment (LCA) study was to evaluate and contrast the life-cycle environmental performance of ethanol produced from *Chlorella vulgaris* microalgae. The functional unit (FU) was defined as 1 kg of microalgal bioethanol (99.7 %, at plant). A cradle-to-gate LCA approach was followed, covering from microalgae cultivation to the distillation of the final product. Although the productivity and viability of modern bioreactor systems is increasing more and more, *Chlorella vulgaris* microalgae were considered to be grown in oval open raceway ponds (0.1 ha) due to economic reasons [7]. Energy efficient harvesting techniques were considered, the algae-containing upper part of the cultivation medium (53.3 m^3 per pond) is pumped after sunset out of the pond. The algal solution containing 0.5 $g \cdot L^{-1}$ of microalgae is subsequently concentrated to 50 $g \cdot L^{-1}$ through flocculation and centrifugation. The previous concentration allows a low-energy concentration of the slurry to 50 $g \cdot L^{-1}$ by applying up to 3000 G [8]. The water overflow is in both steps pumped back to the culture pond. A key step of the system is the conversion of the carbohydrates into ethanol. The polysaccharides in the microalgae cannot be fermented directly, but they must be hydrolysed previously. While lignocellulosic biomass requires energy-intensive pretreatment, the polysaccharides of *Chlorella vulgaris* can directly be reduced to fermentable monosaccharides through dilute acid treatment.

ent of bioethanol

Water cooling is applied to cool the hydrolysate. Afterwards, the mix is transferred to a 500 L fermentation vessel and *Zymomonas mobilis* bacteria are inoculated together with monopotassium phosphate. The considered ethanol ratio was 5.88 kg·day^{-1}. Ethanol is separated from the remaining solution in the distillation section, which mainly involves vapour compression steam stripping (VCSS), vapour compression distillation (VCD), and a molecular sieve (MS) [9]. Pure (99.7 %) ethanol is obtained.

The environmental characterization of microalgal bioethanol was carried out through the implementation of the life-cycle inventory in SimaPro [22]. A set of five impact potentials were evaluated: global warming (GWP), cumulative energy demand (CED), land competition (LC), acidification (AP), and eutrophication (EP). The main processes responsible for the potential impacts were identified (Figure 1). Nutrient production and electricity production within the cultivation subsystem were found to be responsible for high contribution to GWP (along with construction), CED, and EP. Nutrient production also contributed significantly to AP (13 %). Nevertheless, the main contributor to this impact category was found to be chemical production, which explains the leading role of the hydrolysis subsystem regarding AP. The high contribution to LC was found to be linked to the land occupied by the cultivation facility itself.

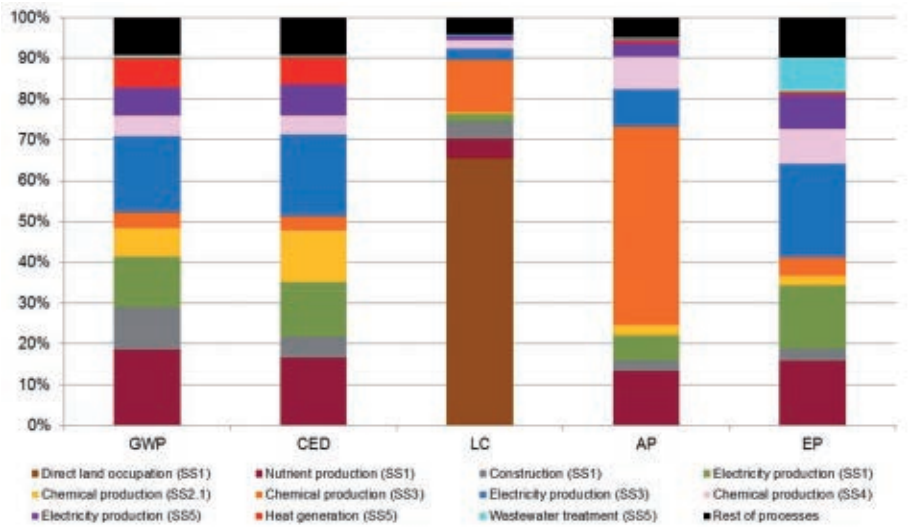


Figure 1: Process contribution to the potential environmental impacts of microalgal ethanol from Chlorella vulgaris.

When comparing biodiesel and bioethanol as alternative products from the same feedstock (*Chlorella vulgaris* microalgae), ethanol potentially arose as a more favourable option in terms of GWP, CED and, to a lesser extent, LC. However, it showed worse results regarding AP and EP, which is partly due to the different level of detail of the used inventories, with microalgal ethanol using a more detailed inventory.

References

[1] Chisti, Y. "Biodiesel from microalgae". Biotechnology Advances, **2007**, *25*, 294-306.

[2] Sheehan, J. "Engineering direct conversion of CO_2 to biofuel". Nature Biotechnology, **2009**, *27*, 1128-1129.

[3] Brentner, L.; Eckelman, M.J.; Zimmerman, J.B. "Combinatorial life cycle assessment to inform process design of industrial production of algal biodiesel". Environmental Science & Technology, **2011**, *45*, 7060-7067.

[4] Campbell, P.K.; Beer, T.; Batten, D. "Life cycle assessment of biodiesel production from microalgae in ponds". Bioresource Technology, **2011**, *102*, 50-56.

[5] Xu, L.; Brilman, D.W.F.; Withag, J.A.M.; Brem, G.; Kersten, S. "Assessment of a dry and a wet route for the production of biofuels from microalgae: energy balance analysis, Bioresource Technology, **2011**, *102*, 5113-5122.

[6] Sander, K.; Murthy, G.S. "Life cycle analysis of algae biodiesel". The International Journal of Life Cycle Assessment, **2010**, *15*, 704-714.

[7] Lardon, L.; Hélias, A.; Sialve, B.; Steyer, J.P.; Bernard, O. "Life-cycle assessment of biodiesel production from microalgae". Environmental Science & Technology, **2009**, *43*, 6475-6481.

[8] Evodos, www.evodos.eu [accessed 20 May **2013**].

[9] Luo, D.; Hu, Z.; Choi, D.G.; Thomas, V.M.; Realff, M.J.; Chance, R.R. "Life cycle energy and greenhouse gas emissions for an ethanol production process based on blue-green algae". Environmental Science & Technology, **2010**, *44*, 8670-8677.

editor
imdea energy institute

graphic design
base 12 diseño y comunicación

D.L.
M-15.902-2014