

# INFORME ANUAL CIESOL

CIESOL ANNUAL REPORT

# 2019



Solar Energy Research Center  
Centro de Investigación en Energía Solar



UNIÓN EUROPEA  
*"Una manera de hacer Europa"*



Empresas





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## 1. EXECUTIVE SUMMARY

### 1.1 INTRODUCTION AND WELCOME

The Solar Energy Research Center, CIESOL, is a joint institute of the University of Almería (UAL) and the Almería Solar Platform (PSA), which designs and develops new applications in solar energy. At CIESOL, researchers from the Solar Platform and from the University are working together to get the most out of solar radiation, encompassing energy use, water treatment and the study of air conditioning and thermal comfort in buildings.

At the center, we carry out international research, transfer, dissemination and training on various aspects of solar energy.

We collaborate with companies and institutions in our quest to serve society. In the field of training, we are proud of our Official Master's Degree in Solar Energy, a clear example of understanding between the two institutions that form CIESOL (<http://cms.ual.es/UAL/estudios/masteres/MASTER7106>).

Welcome to CIESOL, we appreciate your interest in our work and on the following pages, we will try to provide you , with relevant information as well as the contact details for the groups that are the life and soul of the center.



Edificio CIESOL

### 1.2 CIESOL DESCRIPTION

CIESOL is located in a building on the campus of the University of Almería which was specifically designed for studying the use of solar radiation in buildings. Thus, in addition to its laboratories, scientific equipment and pilot plants, the center is actually a scientific facility in itself.

It comprises a total area of about 1700 m<sup>2</sup>, with a warehouse of 200 m<sup>2</sup> and a courtyard of 300 m<sup>2</sup>. There is also 1 workshop, an external laboratory, 3 cold storage rooms, 1 meteorological station, 7 laboratories, 5 offices, 1 dining room, 1 study room , 1 work room, a classroom/meeting room. The solar heating and cooling system covers most of the center's demand as the building is designed to employ passive strategies and maximize solar resources. We have advanced equipment to carry out our research projects, as reflected in section 3, where we talk about the facilities in detail.

During 2019, 93 researchers participated in projects and contracts assigned to CIESOL (57 men and 36 women), 23 of them (10 men and 13 women) with their permanent base at its laboratories and offices during this period. The activities carried out by these researchers form part of 16 projects from official competitive calls (National Research Plan and the Program for Incentives to Agents of the Andalusian Knowledge System ), 2 contracts with companies and institutions, 14 European projects and 9 networks (4 Spanish, 1 Ibero-American and 4 European).

In addition , the center's units have hosted 36 international research stays from 12 different countries, most notably from Mexico, Brazil, France and Italy.



### 1.3 RESEARCH LINES IN CIESOL

#### What is done in CIESOL?

Our work is carried out in different areas, all of them focused on knowledge of solar resources and various applications, which we can classify into two lines: one related to the energy use of solar radiation, and the other to the development of solar technologies for treatment of water.

Committed to preserving the environment, CIESOL research centres on two essential areas for life, water and energy, both linked by the use of solar radiation.

#### How is CIESOL progressing in the use of energy?

The first thing we need to know about using solar energy is its availability, which is why new methods are being investigated to evaluate and predict solar resources and the optimization of sky cameras to track and predict cloudiness.

Monitoring, modeling and automatic control of solar installations are also important, at very different scales, from large solar thermal plants to generate electricity, to electric vehicles powered by solar energy using the photoelectric effect, better known as photovoltaic energy.



Solar cooling installation

In addition, thermal solar energy allows the production of what is called "solar cooling" through phase change, compression and decompression systems. Research is being carried out on "solar air conditioning", the building that houses CIESOL being an example of this. Work is also being done on the design and optimization of solar heating and cooling plants, both for domestic and industrial use, with the study of energy efficiency and comfort control in buildings being especially important. The introduction of smart energy grids is also proving to be a very significant saving factor.

Research is also underway on the development of new water-soluble substances with photochemical activity, with the aim of paving the way towards new, more environmentally sustainable photovoltaic cells.

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### How is CIESOL making advances in water treatment?

We must protect water resources, as vital as they are scarce, whose value for life increases in line with with quality. For this purpose, CIESOL is developing new clean technologies for decontamination based on solar irradiance, both for toxic waters that cannot be treated by conventional biological methods, and treated wastewater, which still has small amounts of persistent pollutants, which affect the aquatic environment.

Among the solar wastewater treatment methods, a new process based on microalgae is emerging, taking advantage of photosynthesis for decontamination, with lower energy consumption and generating useful biomass for other industrial sectors.



Triple TOF 5600

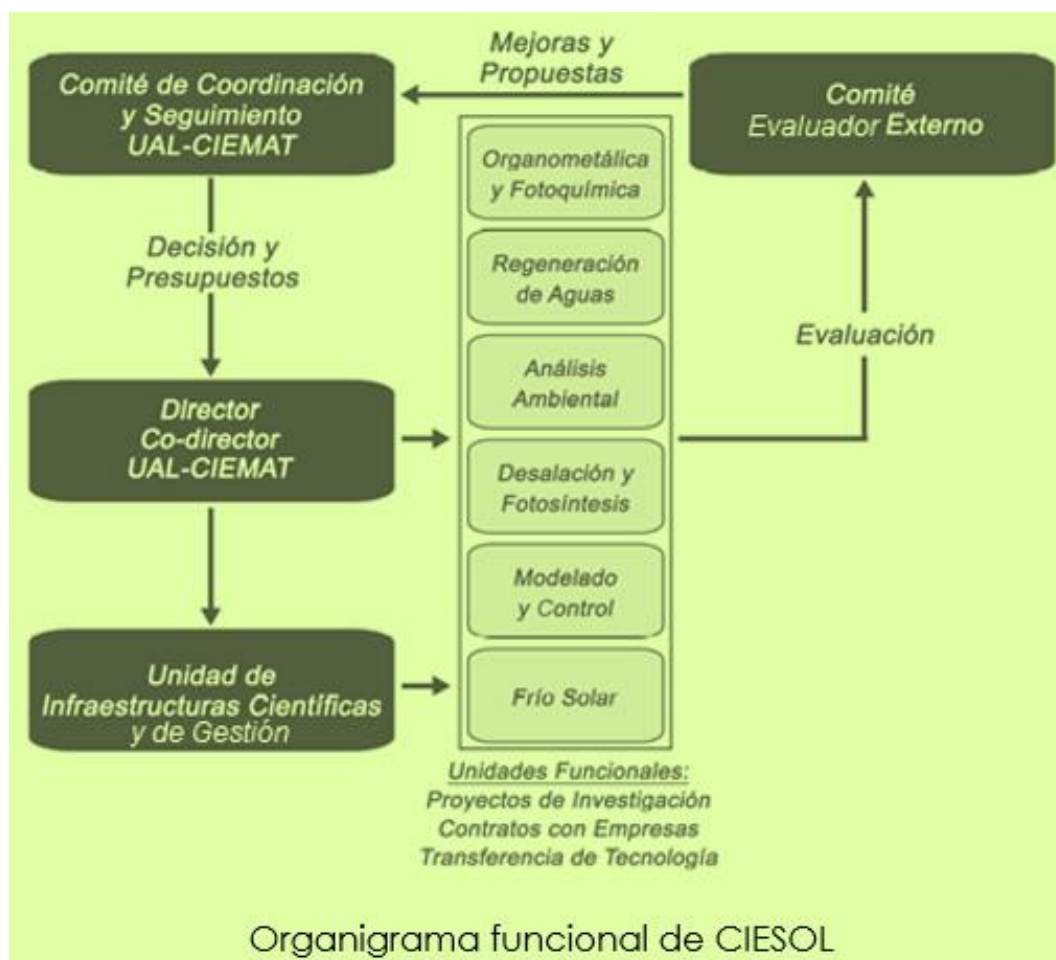
Once purified, water can have a new use, especially for irrigation. As such, it is necessary to inactivate the pathogenic microorganisms that still remain in the water. Disinfection by solar photocatalysis of treated wastewater is especially efficient. In all these processes, studying the influence of the treatments on the quality of the purified waters and the evaluation of the impact derived from their use plays a crucial role. The development of advanced chemical analysis methods is vital for measuring the presence of contaminants at a very low concentration, up to one billionth of a gram per liter (nanogram/liter). However, when the water shortage is pressing, desalination is required to generate new fresh water. Desalination of seawater, or brackish water, using solar energy is a much-needed alternative. In this regard, the combination of membrane distillation, which requires less heat input than other processes, and the use of solar energy to provide that heat, is proposed as an alternative solution to conventional technologies.

## 1.4 CIESOL ORGANISATION

### How does CIESOL work?

CIESOL's functional structure is made up of a Coordination and Monitoring Committee, CCS, its highest decision-making and management body; a Management Team and a set of 6 Functional Units that group researchers from institutions by different specific subject areas. It should be noted that CIESOL also has an External Evaluation Committee, CEE, with four members of recognized prestige as well as both national and

international impact. This annually assesses and supervises the scientific output of its different functional units as well as the development of the center. There is also a Scientific and Management Infrastructure Unit, made up of specialist technicians, who are responsible for the maintenance and operation of the center's equipment.



#### Who comprises the Coordination and Monitoring Committee and what does it do?

The Coordination and Monitoring Committee, CCS, is made up of two researchers from the UAL, one of whom must be the Vice-rector for Research, Development and Innovation at the university and two researchers from the PSA, one of whom must be the Director of the Almería Solar Platform. Currently, the CCS is made up of Diego Valera (Vice-Rector for Research), Manuel Berenguel from the UAL, Julián Blanco (Director of the Almería Solar Platform) and Eduardo Zarza from the PSA.

The Coordination and Monitoring Committee is in charge of ensuring the good governance of the Research Center and its main function is to evaluate and monitor the progress of the center's activities and their suitability for the planned objectives.

#### Who comprises the Management Team and what does it do?

The Management Team consists of a director and an assistant director, belonging to the UAL and PSA (and vice versa). Currently, the director is Sixto Malato Rodríguez from the PSA and the assistant director is José Antonio Sánchez Pérez from the UAL. They are responsible for the allocation of spaces and resources for the

different projects and work groups, the supervision of technical personnel, the maintenance of CIESOL and, in general, everything that affects the day to day operations of the center.

### **Who comprises the External Evaluation Committee and what does it do?**

The External Evaluation Committee, CEE, is made up of Ana María Amat Payá, Professor at the Polytechnic University of Valencia, Angela Fernández Curto, Deputy Assistant Director General for Large Scientific Technical Infrastructures (Ministry of Science, Innovation and Universities, Government of Spain), David Serrano, Director of IMDEA ENERGÍA in Madrid and Professor at the King Juan Carlos University and finally Sebastián Dormido, Professor at the UNED (Honorary Doctorate from the UAL).

The CEE is in charge of evaluating the scientific quality of CIESOL and proposing improvements. Among its duties are the evaluation of work proposals and strategic lines of action for CIESOL, new projects or collaborations, as well as the scientific evaluation of the work carried out. The CEE meets once a year with CIESOL researchers, visits its facilities and issues a report on its activity.

### **What are CIESOL's Functional Units?**

**Solar Resources and Solar Cooling.** Its main activity is the evaluation and prediction of the solar resources, and its main researcher is Francisco Javier Batlles Garrido (UAL). It also works on remote sensing and optimization of sky cameras, as well as in the design and optimization of solar heating and cooling plants. Trigeneration.

**Modeling and Control.** Led by Manuel Berenguel Soria (UAL) and Lidia Roca Sobrino (PSA), the group works on the modeling and control of solar thermal plants, photoreactors and photobioreactors, while studying energy efficiency and comfort control in buildings, including intelligent energy networks.

**Organometallics and Photochemistry.** Led by Antonio Manuel Romerosa Nieves (UAL) and Christoph Richter (DLR-PSA), it works on the development of new homo and hetero-nuclear ruthenium complexes, soluble in water and with photocatalytic activity in processes of high added value molecule synthesis, as well as in new photovoltaic cells.

**Water Treatment.** It focuses its activity on the study of solar photocatalysis for the decontamination of toxic waters and the elimination of micro-contaminants and disinfection of treated wastewaterurified water (regeneration). The main researchers are José Antonio Sánchez Pérez (UAL) and Inmaculada Polo López (PSA).

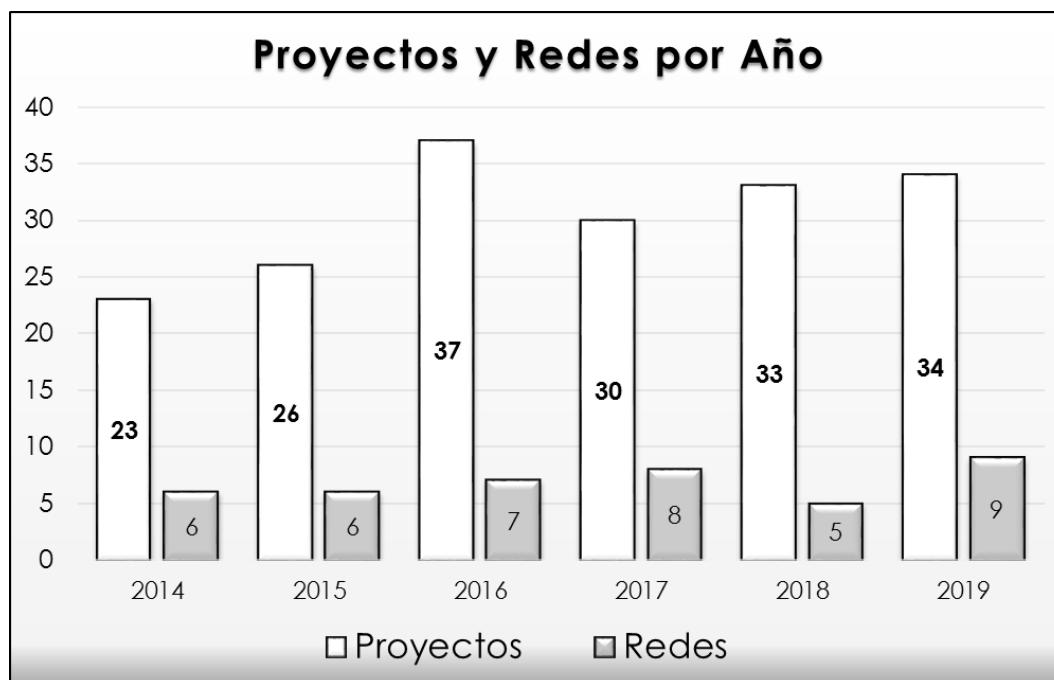
**Environmental Analysis.** It is focused on the development of advanced analytical methods in complex effluents and their application to the monitoring of organic micro-contaminants as well as the identification of transformation products generated during water treatment. The main researchers are Ana Agüera López (UAL) and Isabel Oller Alberola (PSA).

**Photosynthesis and Desalination.** The group performs two parallel lines of work, desalination and water treatment using membrane systems, as well as the production of microalgae and products of interest. The main researchers are José M. Fernández Sevilla (UAL) and Guillermo Zaragoza del Águila (PSA).

## **1.5 CENTER ACTIVITIES IN 2019**

The research center kept up its research activity during 2019 via the 34 research projects in progress. In addition, 33 new projects were applied for requested. The figure shows the progress in terms of the number

of projects in the last six years, showing an average of 31 projects being carried out each year. As for the networks, 4 national and 5 international ones were participated in. The financing obtained through the aforementioned projects amounted to € 3,871,986 in 2019.



Regarding the scientific output corresponding to 2019, a total of 113 publications indexed in the Journal Citation Report was reached. All units participated in national (10) and international (38) scientific congresses and meetings with a total of 86 contributions. The figure shows the progress in terms of the number of international scientific publications in the JCR over the last six years. An average of 101 articles per year can be observed.



Regarding doctoral theses, in the UAL-PSA collaboration during 2019, 12 were defended.

## Recognitions and awards received during 2019:

During 2019, the following awards and recognitions were forthcoming :

- Manuel Berenguel Soria, named "Honorary Visiting Professor" by the University of Brescia, Italy, May 20, 2019.
- CERTIFICATE Best Paper Award 2019 (3rd place) for the paper entitled "A Comparison of Energy Consumption Prediction Models based on Neural Networks of a Bioclimatic Building" Energies. H.R. Khosravani, M. Castilla, M. Berenguel, A. Ruano and P.M. Ferreira..
- Jesús Galdeano López and José Gabriel Martínez Hernández (tutors: Manuel Berenguel Soria and José Luis Guzmán Sánchez). First prize in the National Control Engineering Contest awarded by the Spanish Automation Committee in the XL edition of the Automation Conference held in Lugo, Spain, September 2019.
- Francisco Rodríguez Díaz. Award for Excellence in a Teaching Career. Docentia Program 2019. University of Almería.
- Álvaro Ramajo and Rubén González (tutors: José Carlos Moreno and Antonio Giménez Fernández). Third place in the National Humanoid Robots Competition 2019, awarded by the Spanish Automation Committee in the XL edition of the Automation Conference held in Lugo, Spain, September 2019.



- José Carlos Moreno Úbeda, Antonio Giménez Fernández. Award for Excellence in Multimodal Subjects for the subject "Robotics Applied to Rehabilitation" from the Masters in Nervous System Sciences, awarded at the Teaching Innovation and Professional Experiences Conference organised by the University of Almería.

**Research dissemination and transfer activities:**

Regarding transfer and dissemination activities, numerous national and foreign visits interested in our scientific activity and our facilities were welcomed. There was a strong presence in the local media and an important contribution was made to the European Night of Researchers and also at the Almeria agriculture fair, "InfoAgro EXHIBITION" with a stand, a conference and participation on a round table on Collaborative R&D. Likewise, CIESOL participated in the III Summer School of the International PhD School on Advanced Oxidation Processes, held in Alcoy, Alicante, where the functional units of Environmental Analysis and Regeneration of waters played a highly relevant role in the teaching of specialized courses.. .



The Center has been a member of the "International PhD School on Advanced Oxidation Processes" since its creation, <http://www.aops-school.com>, with Prof. Sixto Malato being the regional coordinator for Europe.

important contribution was made to the European Night of Researchers and also at the Almeria agriculture fair, "InfoAgro EXHIBITION" with a stand, a conference and participation on a round table on Collaborative R&D. Likewise, CIESOL participated in the III Summer School of the International PhD School on Advanced Oxidation Processes, held in Alcoy, Alicante, where the functional units of Environmental Analysis and Regeneration of waters played a highly relevant role in the teaching of specialized courses.. .



In January 2019, the third phase of the European project H2020 'Solar Facilities for the European Research Area', SFERA-III, in which CIESOL is a partner, started. This project promotes research stays in the best scientific facilities for solar energy in Europe. 15 European institutions are participating with a total budget of € 9,102,630.75, and CIESOL's share amounts to € 236,416.25.

The activities in which each unit participated are detailed below.

## 2. ACTIVITIES OF CIESOL

### 2.1 ACTIVITIES OF "ORGANOMETALLICS AND PHOTOCHEMISTRY"

#### 2.1.1 Functional unit description

In 2016 the unit was constituted by 10 members (three university professors, five researchers, two predoctoral contract and one postdoctoral contract) most of them pertaining to the research team FQM-317 entitled "Coordination/Organometallic Chemistry and Photochemistry" that is constituted by researchers from U. Almería, La Laguna and Cádiz and a researcher at the German Aerospace Centre - Plataforma Solar de Almería (DLR-PSA-CIEMAT). The group has research collaborations with PAI (Andalusian Research Plan) groups and CIESOL groups as well as with other Andalusian universities. The unit has not stopped growing in both projects (regional, national and international) and scientific production (> 220 articles in international journals chemical impact). The initial interest of the team, the synthesis of metal catalysts for photochemical reactions in water, has been extended to other areas such as photo-hydrogen-generation, conversion of small molecules by solar radiation and production of electricity by solar light.

#### 2.1.2 Main research lines

- New water soluble homo- and hetero-metal-polymers with photocatalytic activity in the synthesis of high impact molecules and production of electricity.
- White phosphorus transformation mediated by visible-light irradiation.

#### 2.1.3 Main researchers

**Antonio Manuel Romerosa Nievas** (ORCID ID = 0000-0002-6285-9262; Scopus Author ID 6603792206)

Antonio Romerosa was born in Granada (Spain) in 1964. He graduated in 1987 (University of Granada) and received his PhD (Universitat Autònoma de Barcelona) in January 1992. In the same year he undertook a postdoctoral research at the former ISSECC CNR, now ICCOM CNR, (Florence, Italy), before becoming Lecture Professor (1997) and finally Full Professor (2009) at the University of Almería (Spain). His research interests range over homogeneous catalysis and organometallic chemistry in water, phosphorus chemistry, photo-inorganic-chemistry, bioinorganic chemistry and natural stones. He has authored of more than 150 international refereed papers, 15 Spanish and international patents and made more than 250 presentations at national and international meetings. He has been responsible for more than 20 national research regional and European projects, was supervisor of 19 PhD and is supervising 3 more. He is responsible of the Junta de Andalucía research team FQM-317.

**Christoph Richter** (ORCID ID = 0000-0001-8386-1882; Scopus Author 55439554100)

PhD in Physical Chemistry from the University of Cologne in 1993. In 1994 he began to work in the Department DLR (German Aerospace Center) is at the Plataforma Solar de Almería (PSA-CIEMAT) in Spain, the largest test center for research and development in solar concentrating technologies at high temperatures. Initially working as a project manager in the area of solar chemistry in development projects photochemical applications of solar energy in water treatment and fine chemical synthesis. Currently working on different aspects of the operation of solar thermal plants, including heat storage, cooling and environmental impact, and is responsible for administration and infrastructure department of DLR in Almería. Since March 2008, is the Secretary General of Solar PACES.

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#### 2.1.4 Summary of the functional unit's activities carried out in CIESOL during 2019

During 2019 the research team has been partially renewed due to the arrival of new BSc and MSc students and two researchers hired through "youth employment" funding. The group also followed the training of PhD students. The main activities of the group were the student training, the publication of articles in the best journals in the area of chemistry, inorganic chemistry and materials, as well as the realization of invention patents. Additionally, the AACI project granted in 2017 was extended, has been obtained for the development of Latin American countries that, together with contracts with companies, will allow it to continue its research activity in the coming years.

#### 2.1.5 Collaboration with other functional units of CIESOL during 2019

In 2019 started a collaboration with the Water Treatment Unit. Results are being evaluated.

#### 2.1.6 Human resources of the Functional Unit

##### Visits and research stays in CIESOL:

- Nazanin Kordestani; University of Isfahan, Iran; 01/11/2018 – 31/06/2019

##### Research stays of CIESOL researchers in other institutions:

- Antonio Manuel Romerosa Nievas; Universidad de Debrecen, Debrecen, Hungría; 20/07 al 8/08/2019

##### Students in curricular internships

- Belen Lopez Sanchez, PhD Thesis in Chemistry
- Jose Veiga del Pino, PhD Thesis in Chemistry
- Andrés Alguacil Alarcón, PhD Thesis in Chemistry
- Juan Alfredo Cayuela Castillo, Master Thesis in Chemistry
- Alverto Barros Pardo, Master Thesis in Chemistry

#### 2.1.7 Scientific production

##### Papers

- Neutron Scattering in Coordination Chemistry. John A. Stride, Wendy L. Queen and Antonio Romerosa. European Journal of Inorganic Chemistry Número especial sobre neutrones y química de coordinación, 2019, 1057–1059. DOI: 10.1002/ejic.201801283
  - Molecular insights into bulk and porous  $\kappa$ 2P,N-PTA metal-organic polymers by simultaneous Raman spectroscopy and inelastic neutron scattering. Franco Scalambra, Svemir Rudić, Antonio Romerosa. European Journal of Inorganic Chemistry, Número especial sobre neutrones y química de coordinación, 2019, 1155-1161., DOI: 10.1002/ejic.201801283
  - The interaction of water with cis and trans  $\{Ru(bpy)_2(PTA)_2\}^{2+}$  (PTA = 1,3,5-triaza-7-phosphaadamantane) studied by neutron scattering and ab initio calculations. VIP paper. Franco Scalambra, Nicole Holzmann, Leonardo Bernasconi, Silvia Imberti, Antonio Romerosa. European Journal of Inorganic Chemistry Número especial sobre neutrones y química de coordinación. Selecte as VIP, 2019, 1162-1169. DOI: 10.1002/ejic.201801499
  - New Findings in Metal Complexes with Antiproliferative Activity Containing 1,3,5-triaza-7-phosphaadamantane (PTA) and Derivative Ligands. Franco Scalambra, Pablo Lorenzo-Luis, Isaac de los Ríos, Antonio Romerosa. European Journal of Inorganic Chemistry Número especial sobre "Fósforo en 2019", 2019, 1529-1538. DOI: 10.1002/ejic.201801426
  - Isomerization of Allylic Alcohols in Water Catalyzed by Transition Metal Complexes. Franco Scalambra, Pablo Lorenzo-Luis, Isaac de los Ríos, Antonio Romerosa. Coordination Chemistry Review Número especial dedicado al Prof. Armando Pombeiro, 2019, 393, 118-148. doi.org/10.1016/j.ccr.2019.04.012.
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- Novel Ruthenium-Silver PTA-Based Polymers and Their Behavior in Water. Benjamin Sierra-Martin, Manuel Serrano-Ruiz, Franco Scalambra, Antonio Fernandez-Barbero, Antonio Romerosa. *Polymers Special Issue "Selected Papers from ECIS 2018"*, 2019,11, 1249-1257. doi:10.3390/polym11081249
- CpRu-complexes containing water soluble phosphine PTA and natural purines adenine, guanine and theophylline: synthesis, characterization and antiproliferative properties. Lazhar Hajji, Cristobal Saraiba-Bello, Gaspar Segovia-Torrente, Franco Scalambra, Antonio Romerosa. *European Journal of Inorganic Chemistry*, 2019, 4078–4086

#### Congress assistance

- XXXVII Biental de la Real Sociedad Española de Química. 26 - 30 de mayo de 2019. San Sebastián, España.
- 1<sup>st</sup> International Conferences on Noncovalent Interactions (ICNI-2019), September 2-6, 2019, Lisbon, Portugal.

#### Congress contributions

- Agua en sistemas químicos desafiantes. Franco Scalambra, Nicole Holzmann, Leonardo Bernasconi, Silvia Imberti, Svemir Rudić y Antonio Romerosa. XXXVII Biental de la Real Sociedad Española de Química. 26-30 de mayo de 2019, San Sebastián, España. ORAL, S8, OC 03, pp 234.
- Isomerización catalítica de 2-ciclohexenol catalizada por [RuClCp(PTA)<sub>2</sub>] y [RuCp(PTA)<sub>2</sub>(H<sub>2</sub>O-κO)](CF<sub>3</sub>SO<sub>3</sub>)·3.5H<sub>2</sub>O. Franco Scalambra, Belén López y Antonio Romerosa. XXXVII Biental de la Real Sociedad Española de Química. 26-30 de mayo de 2019, San Sebastián, España. FLASH. S8, FP 01, pp 238.
- Estudio de las propiedades ópticas del complejo hidrosoluble cis-[Ru(DcBpyH)<sub>2</sub>(PTAH)<sub>2</sub>]Cl<sub>2</sub>. José M. Veiga del Pino, Franco Scalambra y Antonio Romerosa. XXXVII Biental de la Real Sociedad Española de Química. 26-30 de mayo de 2019, San Sebastián, España. FLASH, S8, FP 03, pp 240.
- Complejos metálicos carbeno solubles en agua con PTA y derivados (PTA = 1,3,5-triaza-7-fosfaadamantano).. Belén López, Jose M. Veiga del Pino, Antonio Romerosa, Franco Scalambra, Isaac de los Rios, Pablo Lorenzo-Luis. XXXVII Biental de la Real Sociedad Española de Química. 26-30 de mayo de 2019, San Sebastián, España. Poster, S8, P 39, pp 701.
- Neutron Scattering: a Valuable Procedure to study the Interaction of Water Molecules with Catalytic Intermediates. Antonio Romerosa, Franco Scalambra, Belen López-Sánchez, Nicole Holzmann, Silvia Imberti, Leonardo Bernasconi. 1<sup>st</sup> International Conferences on Noncovalent Interactions (ICNI-2019), September 2-6, 2019, Lisbon, Portugal. KL16.
- Study of catalytic intermediate states in water by X-ray Pair Distribution Function (XPDF). Antonio Romerosa, Franco Scalambra, Belen López-Sánchez. 1<sup>st</sup> International Conferences on Noncovalent Interactions (ICNI-2019), September 2-6, 2019, Lisbon, Portugal. P6.

#### Congress organization

- Sesión S8 in XXXVII Biental de la Real Sociedad Española de Química. 26-30 may 2019, San Sebastián, España.
- 25<sup>th</sup> SolarPACES Conference, 1-4 October 2019. Daegu, Corea del Sur.

#### Book Chapters

- Recent Advances in Transition metal-mediated transformations of white phosphorus. Franco Scalambra, Maurizio Peruzzini, Antonio Romerosa. *Advances in Organometallic Chemistry*. 2019, 72 (Pages 1-222), 173-222.

#### PhD Thesis

- OBTENCIÓN DE CARBÓN ACTIVADO DE CÁSCARA DE ARROZ Y SUS POSIBLES APLICACIONES EN DESCONTAMINACIÓN DE AGUAS. DOCTORANDO: Freddy Alberto Pereira Guanuche. Universidad de Almería. Facultad de Ciencias Experimentales 24/10/2019. Sobresaliente CUM LAUDE Unanimidad.

NUEVOS COMPLEJOS DE COORDINACIÓN CON EL LIGANDO DMOPTA: AVANCES EN LA CAPACIDAD ANTIPROLIFERATIVA. Elisabet Zenaida Mendoza Nozeman. Universidad de La Laguna. Departamento de Química. 05/11/2019 Sobresaliente CUM LAUDE Unanimidad. Tesis Europea.

## 2.1.8 Staff members

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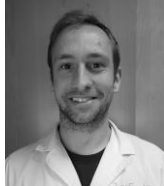
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**Ana Belén Bonhome Espinosa**



PhD Researcher  
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## 2.1.9 Ongoing projects in 2019

### 2.1.9.1 Water soluble fluorescent heterometallic polymers.

**Participants:**

Grupo de Inv. "Química de Coordinación, Organometálica y Fotoquímica". Universidad de Almería (FQM-317)

**Contacts:**

A. Romerosa Nievas (romerosa@ual.es)

**Funds:**

Ministerio de Economía y Competitividad. FEDER 2013 (CTQ2015-67384-R)

**Time Period:**

January 2016 – June 2019

**Current situation:**

In progress.

**Summary**

The project is targeted to the design of new heterometallic polymers with gel and fluorescent properties in water, which can be confined in a matrix that increase their respond to environment variations.

**Objectives.**

The ultimate goal is to obtain sensors that are able to tune their optical response against common explosives both in dissolution and vapours.

### 2.1.8.2 Water purification using activated charcoal from rice husk.

**Participants:**

Grupo de Inv. "Química de Coordinación, Organometálica y Fotoquímica". Universidad de Almería (FQM-317)

**Contacts:**

A. Romerosa Nievas (romerosa@ual.es)

**Funds:**

H. Consejo Universitario de Ecuador N° 396/2016

**Time Period:**

November 2017 – November 2018

**Current Situation:**

In progress.

**Summary**

Water is fundamental for life and therefore having quality water is essential for the proper development of the population. This project is devoted to obtain a method that allows the rice husk to be converted into activated charcoal that will be used for water purification. The whole process should be ecological, would not produce tangential contamination and would be respectful of the productive and social means of the community where it will be developed. The participation of one of the most important Rice Cooperatives of the region (PROASEM) guarantees adequate access to the raw material and shows the interest of the economic fabric of the area.

**Objectives**

The project aims to avoid two serious problems of the population of the Machala region (Ecuador): the elimination of rice husk produced and the access to quality water.

### 2.1.10 Participation in networks during 2019

The research network "REDESMA" ([www.redesma.es](http://www.redesma.es)) evolve 15 research teams involved in the study of metal complexes in wáter.

### 2.1.11 Transfer and Complementary Activities

Special Issue devoted to Neutron Scattering in Coordination Chemistry in European Journal Inorganic Chemistry. John A. Stride, Wendy L. Queen, Antonio Romerosa. Neutron Scattering in Coordination Chemistry. European Journal of Inorganic Chemistry, 2019, 1057–1059 (Guest Editors). DOI: 10.1002/ejic.201801283

Franco Scalambra, Nicole Holzmann, Leonardo Bernasconi, Silvia Imberti, Antonio Romerosa. The interaction of water with cis and trans  $\{Ru(bpy)_2(PTA)_2\}^{2+}$  (PTA = 1,3,5-triaza-7-phosphaadamantane) studied by neutron scattering and ab initio calculations. *VIP paper*. European Journal of Inorganic Chemistry, 2019, 1162-1169. *VIP*. Número especial sobre neutrones y química de coordinación. *Selecte as VIP*.

### 2.1.12 Dissemination activities

Especial I+D+i number published in ABC, 6/5/2019 (<https://www.guiadeprensa.com/suplementos/idi-mayo-2019-abc/>).

### 2.1.13 Project's applications in 2019

- CONVOCATORIA 2019 DE PROYECTOS I+D+i "RETOS INVESTIGACIÓN" DEL PROGRAMA ESTATAL DE I+D+i ORIENTADA A LOS RETOS DE LA SOCIEDAD. Reference: PID2019-110206RB-I00. Center: CIESOL CENTRO MIXTO DE INVESTIGACIÓN EN ENERGÍA SOLAR UAL-CIEMAT. Title: COMPLEJOS HETEROMETÁLICOS CON EL LIGANDO 3,7-DIMETIL-1,3,7-TRIAZA-5-FOSFABICICLO[3.3.1]NONANO (DMOPTA): PROPIEDADES ANTIPROLIFERATIVAS Y CATALÍTICAS. Universidad de Almería
- Equipamiento FEDER, solicitado por la Universidad bajo solicitud del grupo.
- Ayudas B. Galindo, solicitada por la Universidad bajo solicitud del grupo.

### 2.1.14 Others

#### Final degree and master projects

- Helena Hernández Martínez (Chemistry degree -Plan 2009). Final degree project. Síntesis, caracterización y estudio de nuevos complejos de Ru(II):  $[RuCp(dmoPTA)(PPh_3)(PTA)]^+$  y sus derivados heterometálicos con Zn y Co./ Synthesis, characterization and study of new Ru(II) complexes:  $[RuCp(dmoPTA)(PPh_3)(PTA)]^+$  and its heterometallic derivatives with Zn and Co  
Date: 25/09/2019  
Tutor(es): Antonio Manuel Romerosa Nievas, Franco Scalambra  
Calification: NOTABLE (8.6)
- Andrés Alguacil Alarcón (Advanced Chemistry Master) Master project. Síntesis, caracterización y estudio de nuevos compuestos de coordinación con fosfinas solubles en agua y propiedades anticancerígenas./Synthesis, characterization and study of new coordination compounds with water soluble phosphines and anticancer properties.  
Date: 22/07/2019  
Tutor(es): Antonio Manuel Romerosa Nievas, Franco Scalambra.  
Calification: Sobresaliente (9.4).

#### PhD Theses (under development)

- Belén López Sánchez, PhD in Chemistry. Supervisors: Antonio Manuel Romerosa Nievas, Franco Scalambra.
  - Jose Veiga del Pino, PhD in Chemistry. Supervisors: Antonio Manuel Romerosa Nievas, Franco Scalambra.
  - Andrés Alguacil Alarcón, PhD in Chemistry. Supervisors: Antonio Manuel Romerosa Nievas, Franco Scalambra.
-

**Other scientific activities**INVITED CONFERENCES

- Procesos Químicos Activados con Radiación Solar. Conferencias de la Univesidad Politécnica del Valle de México. Universidad Politécnica del Valle de México, Tultitlán, Estado de México. 20 de marzo de 2019
- Uso de la Radiación Solar. Conferencia en la FES-UNAM-Aragón. Univesidad Nacional Autónoma de México (UNAM). Celebradas en la FES-UNAM-Aragón, Nezahualcoyotl, Estao de México. 21 de marzo de 2019
- Química organometálica en agua: Nuevos compuestos químicos para un mundo más saludable. Conferencias del Departamento de Química Inorgánica y Nuclear de la Facultad de Química de la UNAM. Univesidad Nacional Autónoma de México (UNAM). Ciudad Universitaria, Cd. México. 22 de marzo de 2019.
- PTA a surprising ligand. Organometallic and Catalysis Confrence (dedicated to Prof. Ferenc Joó's 70<sup>th</sup> birthday). Center of Debrecen Regional Committee of the Hungarian Academy of Sciences, Debrecen, Hungary. 17 mayo de 2019.



## 2.2 ACTIVITIES OF " ENVIRONMENTAL ANALYSIS"

### 2.2.1 Functional unit description

The staff of the Unit is made up of researchers from the Department of Chemistry and Physics at the University of Almeria and the Unit of *Solar Water Treatments* from the Plataforma Solar de Almería (CIEMAT). The collaboration between the two centres dates back to 1998, the year in which the first joint work is published. Since then the group has been actively involved in national and international projects and has more than 40 joint publications. Currently, members of both centres are part of the research group "Environmental Analysis and Water Treatment (FQM-374)" of the Andalusian Research Plan (PAI).

### 2.2.2 Main research lines

The activity of the group is focused on the development, optimization and analytical assessment of advanced wastewater treatment processes applied to complex effluents in order to get their regeneration and enable their reuse. The strategic lines of action include:

- Development of advanced analytical methods for characterizing complex effluents and its application to monitoring of organic micro-contaminants during wastewater treatment to ensure its elimination.
- Identification of transformation products generated during wastewater treatments and establishment of routes of degradation.
- Study of the influence of treatments on the quality of reclaimed water and evaluating the impact of their reuse in agriculture.

### 2.2.3 Main researchers

**Agüera López** (ORCID ID: 0000-0003-2649-6772; Scopus Author ID: 6701415534)

Full professor at the University of Almeria. Degree in Chemistry (1987). PhD in Chemistry (1995). She has more than 28 years of experience working in the development and validation of analytical method based on chromatographic technique coupled to mass spectrometry for the analysis of organic contaminants in food and environmental matrices. She has participated in 23 national and international competitive R&D Projects. She is co-author of 2 patents and 155 scientific publications in indexed international journals (h-index = 55, January 2020). She has also co-authored more than 160 conference papers, 3 books and 12 book chapters, and has participated in the organization of 8 international conferences. She has supervised 10 doctoral theses.

**Isabel Oller Alberola** (ORCID ID: 0000-0002-9893-6207; Scopus Author 8415190600)

Researcher at the Solar Treatment of Water Unit at the Plataforma Solar de Almería (CIEMAT), degree in Chemical Engineering (2002) and PhD in Chemical Engineering (2008). Dr. Isabel Oller scientific career is focused in the industrial and urban wastewater treatment and reuse by using advanced oxidation processes (with and without solar energy) and their combination with physic-chemical pre-treatment systems and advanced biological processes. She has developed this activity under her participation in several I+D national and European Projects (5th, 6th & 7th EU Framework programs). Her scientific production it is worthy to mention she is author of 4 National Editorial book and co-author of 18 International Editorial books chapters. Furthermore, she is co-author of 117 publications in indexed scientific international journals and more than 130 contributions to different International Congresses and Symposiums (until January 2018). She



has also participated as teacher in some national and international courses and masters related with Advanced Treatment of Wastewater. H-index (December 2019): 37.

#### **2.2.4 Summary of the functional unit's activities carried out in CIESOL during 2019**

This year, two of the ongoing projects, the P12-RNM-1739 project and the SOLFENDIS project, have been completed. The first ended in July and culminated with the defense, in September 2019, of the doctoral thesis of Ms. Ana Ruiz Delgado. As reflected in the corresponding final report of the project, the proposed objectives have largely been achieved. As a summary, the project has determined that the treatment of cork boiling wastewater by chemical oxidation must be carried out to the most advanced state of mineralization, in order to subsequently combine with a refining treatment in a nanofiltration membrane system that allows to obtain a permeate flow with sufficient quality to be reused in the cork cooking process. On the other hand, acute and chronic toxicity tests, based on different microorganisms, showed high toxicity values at the end of the proposed treatment line, except in the permeate stream. This fact increases the interest in deepening the knowledge of the contaminants, degradation products or metabolites that could be generated. The proposed treatment line for landfill leachate is based on the combination of a physical-chemical pre-treatment (coagulation / flocculation), an AOP (solar photo-Fenton) and an aerobic biological reactor, with a final stage of refining based on membrane systems (membrane distillation) for nutrient recovery and possible reuse. From the analytical point of view, considering the difficulty of the matrices, the techniques developed have allowed us to provide relevant information for the evaluation of complex effluent treatments and their applicability has been studied in industrial wastewater of different origin.

Also in 2019 the SOLFENDIS project has been completed. A summary of the activities carried out was presented at the scientific-technical monitoring sessions held in Madrid, and a positive report was received as a result of its evaluation. In December, the thesis of Ms. Marina Celia Campos Mañas was defended, which includes part of the results achieved, especially from the analytical point of view within the framework of the project.

Regarding the activities derived from the LIFE PureAgroH2O project, we have continued collaborating with CITRICOS del Andarax, S.A., in the characterization and adaptation of the effluent to be treated with the NFPR reactor. The water generated with a new advanced washing system installed in the company, has been characterized and pretreatment processes have been tested by coagulation with  $Al_2(SO_4)_3$  and  $FeCl_3$ . With none of the options evaluated, the effluent quality has been improved to the levels required for treatment with the reactor (COD <50 mg/L). As an alternative, the effluent from the biological treatment plant (MBR), which provides adequate levels of COD, has been characterized, but it is still necessary to evaluate if its conductivity can be a limitation for the adequate reactor operation.

During 2019, two new projects have also been initiated, the LIFE Ulises and the UAL-Feder AMBAGENS project.

#### **2.2.5 Collaboration with other Functional Units of CIESOL during 2019**

In 2019 the collaboration with the Water Regeneration unit has been maintained, with which joint projects are being carried out: SOLFENDIS (CTQ2016-78255-R), LIFE PureAgroH2O (LIFE17 ENV/GR/000387) y LIFE Ulises (LIFE18 ENV/ES/000165).

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### 2.2.6 Human resources of the Functional Unit

Dña. Ana Lorenzo Flores, Dña. Laura Ponce Robles and Dña Elisa García Gómez have left the Functional Unit and Dña. Carmen María Morales Álvarez has been incorporated with a one-year contract.

#### Postdoctoral contracts:

- Ana Belén Martínez Piernas. March, 2019. Postdoctoral research contract under project LIFE17 ENV / GR / 000387.
- Ana Ruiz Delgado. January, 2019. Predoctoral research contract.

#### Visits and research stays in CIESOL

- Melisa Portilla Sangabriel. Universidad Nacional Autónoma de México, México (01/05/2019-31/08/2019).
- José Alberto Macías Vargas. Universidad Nacional Autónoma de México, México (21/10/2019-21/12/2019).

#### Students in curricular internships

- Mirco Raso . Chemistry Degree.
- Rocío López Domene. Chemistry Degree.

### 2.2.7 Scientific production

#### Papers

- TiO<sub>2</sub> photocatalysis under natural solar radiation for the degradation of the carbapenem antibiotics imipenem and meropenem in aqueous solutions at pilot plant scale. A. Cabrera-Reina, A.B. Martínez-Piernas, Y. Bertakis, N.P. Xekoukoulotakis, A. Agüera, J.A. Sánchez Pérez, *Water Research*, 166, art. no. 115037, 2019. DOI: 10.1016/j.watres.2019.115037
- On the design and operation of solar photo-Fenton open reactors for the removal of contaminants of emerging concern from WWTP effluents at neutral pH. P. Soriano-Molina, J.L. García Sánchez, S. Malato, P. Plaza-Bolaños, A. Agüera, J.A. Sánchez Pérez. *Applied Catalysis B: Environmental*, 256, art. no. 117801, 2019. DOI: 10.1016/j.apcatb.2019.117801
- Effect of solar photo-Fenton process in raceway pond reactors at neutral pH on antibiotic resistance determinants in secondary treated urban wastewater. A. Fiorentino, B. Esteban, J.A. Garrido-Cardenas, K. Kowalska, L. Rizzo, A. Agüera, J.A. Sánchez Pérez. *Journal of Hazardous Materials*, 378, art. no. 120737, 2019. DOI: 10.1016/j.jhazmat.2019.06.014
- Determination of pesticide levels in wastewater from an agro-food industry: Target, suspect and transformation product analysis. M.C. Campos-Mañas, P. Plaza-Bolaños, A.B. Martínez-Piernas, J.A. Sánchez-Pérez, A. Agüera. *Chemosphere*, 232, pp. 152-163, 2019. DOI: 10.1016/j.chemosphere.2019.05.147
- Reclamation of Real Urban Wastewater Using Solar Advanced Oxidation Processes: An Assessment of Microbial Pathogens and 74 Organic Microcontaminants Uptake in Lettuce and Radish. Y. Aguas, M. Hincapie, A.B. Martínez-Piernas, A. Agüera, P. Fernández-Ibáñez, S. Nahim-Granados, M.I. Polo-López. *Environmental Science and Technology*, 53 (16), pp. 9705-9714, 2019. DOI: 10.1021/acs.est.9b00748
- Assessment of solar raceway pond reactors for removal of contaminants of emerging concern by photo-Fenton at circumneutral pH from very different municipal wastewater effluents. P. Soriano-Molina, P. Plaza-Bolaños, A. Lorenzo, A. Agüera, J.L. García Sánchez, S. Malato, J.A. Sánchez Pérez. *Chemical Engineering Journal*, 366, pp. 141-149, 2019. DOI: 10.1016/j.cej.2019.02.074
- Oxidation mechanisms of amoxicillin and paracetamol in the photo-Fenton solar process. M.M. Hinojosa Guerra, I. Oller Alberola, S. Malato Rodríguez, A. Agüera López, A. Acevedo Merino, A. Egea-Corbacho Lopera, J.M. Quiroga Alonso. *Water Research*, 156, pp. 232-240, 2019. DOI: 10.1016/j.watres.2019.02.055
- Natural chelating agents from olive mill wastewater to enable photo-Fenton-like reactions at natural Ph. A. Ruiz-Delgado, M.A. Roccamante, I. Oller, A. Agüera, S Malato. *Catalysis Today*, 328, pp. 281-285, 2019. DOI: 10.1016/j.cattod.2018.10.051

- Identification of opioids in surface and wastewaters by LC/QTOF-MS using retrospective data analysis. M.C. Campos-Mañas, I. Ferrer, E.M. Thurman, J.A. Sánchez Pérez, A. Agüera. *Science of the Total Environment*, 664, pp. 874-884, 2019. DOI: 10.1016/j.scitotenv.2019.01.389
- Identification of transformation products of carbamazepine in lettuce crops irrigated with Ultraviolet-C treated water. A.B. Martínez-Piñas, S. Nahim-Granados, M.I. Polo-López, P. Fernández-Ibáñez, S. Murgolo, G. Mascolo, A. Agüera. *Environmental Pollution*, 247, pp. 1009-1019, 2019. DOI: 10.1016/j.envpol.2019.02.001
- Organic Microcontaminants in Tomato Crops Irrigated with Reclaimed Water Grown under Field Conditions: Occurrence, Uptake, and Health Risk Assessment. A.B. Martínez-Piñas, P. Plaza-Bolaños, P. Fernández-Ibáñez, A. Agüera. *Journal of Agricultural and Food Chemistry*, 2019. DOI: 10.1021/acs.jafc.9b01656.
- Environmental assessment of solar photo-Fenton processes in combination with nanofiltration for the removal of micro-contaminants from real wastewaters. *Science of the Total Environment*. A. Gallego-Schmid, R.R. Zepon Tarpani, S. Miralles-Cuevas, A. Cabrera-Reina, S. Malato, Adisa Azapagic. 650, 2210–2220, 2019.
- Optimization of electrocatalytic H<sub>2</sub>O<sub>2</sub> production at pilot plant scale for solar-assisted water treatment. I. Salmerón, K.V. Plakas, I. Sirés, I. Oller, M.I. Maldonado, A.J. Karabelas, S. Malato. *Applied Catalysis B: Environmental*, 242, 327–336, 2019.
- Commercial fertilizer as effective iron chelate (Fe<sup>3+</sup>-EDDHA) for wastewater disinfection under natural sunlight for reusing in irrigation. S. Nahim-Granados, I. Oller, S. Malato, J.A. Sánchez Pérez, M.I. Polo-Lopez. *Applied Catalysis B: Environmental*, 253, 286–292, 2019.
- Photo-Fenton treatment of saccharin in a solar pilot compound parabolic collector: Use of olive mill wastewater as iron chelating agent, preliminary results. K. Davididou, E. Chatzisyneon, L. Perez-Estrada, I. Oller, S. Malato. *Journal of Hazardous Materials*, 372, 137–144, 2019.
- EDDS as complexing agent for enhancing solar advanced oxidation processes in natural water: Effect of iron species and different oxidants. S. Miralles-Cuevas, I. Oller, A. Ruíz-Delgado, A. Cabrera-Reina, L. Cornejo-Ponce, S. Malato. *Journal of Hazardous Materials*, 372, 129–136, 2019.
- Inactivation of *E. coli* and *E. faecalis* by solar photo-Fenton with EDDS complex at neutral pH in municipal wastewater effluents. I. García-Fernández, S. Miralles-Cuevas, I. Oller, S. Malato, P. Fernández-Ibáñez, M.I. Polo-López. *Journal of Hazardous Materials*, 372, 85–93, 2019.
- Microbiological evaluation of combined advanced chemical-biological oxidation technologies for the treatment of cork boiling wastewater. L. Ponce-Robles, I. Oller, M.I. Polo-López, G. Rivas-Ibáñez, S. Malato. *Sci. Tot. Environ.* 687, 567–576, 2019.
- Improved landfill leachate quality using ozone, UV solar radiation, hydrogen peroxide, persulfate and adsorption processes. R. Poblete, I. Oller, M.I. Maldonado, E. Cortes. *Journal of Environmental Management*, 232, 45-5, 2019.
- Contaminants of emerging concern removal from real wastewater by UV/free chlorine process: A comparison with solar/free chlorine and UV/H<sub>2</sub>O<sub>2</sub> at pilot scale. G. Cerreta, M.A. Roccamante, I. Oller, S. Malato, L. Rizzo. *Chemosphere*, 236, 124354, 2019.

#### **Congress assistance**

- 3<sup>rd</sup> European Summer School on “Environmental Applications of AOPs. Alcoy, Valencia, España. 03/06/2019-07/06/2019.
  - 6<sup>th</sup> European Conference on Environmental Applications of Advanced Oxidation Processes (EAAOP6). 26/06/2019-30/06/2019. Portorov. Eslovenia.
  - 20<sup>th</sup> Symposium on Health-Related Water Microbiology (HRWM). Vienna, Austria. 15/09/2019-20/09/2019.
  - Congreso Internacional en Energía, Eficiencia y Sustentabilidad Ambiental (CEES 2019). 16/10/2019-18/10/2019. La Serena. Chile.
  - Young water professional congress. Madrid. 12/11/2019-15/12/2019.
  - IV Iberoamerican Conference on Advanced Oxidation Technologies (IV CIPOA). 18/11/2019-22/11/2019. Natal. Brasil.
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### Congress contributions

- ZeroValent Iron technology at Neutral pH assisted with iron complexes to remove pesticides in natural water. Roccamante, M., Miralles-Cuevas S., A. Cabrera-Reina, I. Oller, S. Malato. 3<sup>rd</sup> European Summer School on "Environmental Applications of AOPs. Alcoy, Valencia, España. 03/06/2019-07/06/2019. Short-oral.
- Industrial Wastewater Treatment by combining AOPs, biological and membrane technologies: ammonium recovery. Ana Ruiz-Delgado, I. Oller, Adrián M.T. Silva, Sixto Malato, Ana Agüera. 6<sup>th</sup> European Conference on Environmental Applications of Advanced Oxidation Processes (EAAOP6). 26/06/2019-30/06/2019. Portorov. Eslovenia. Oral-keynote.
- Solar driven processes to reclaim wastewater from fresh-cut industry: assessment of pathogens and microcontaminants in water and raw-eat crops. S. Nahim-Granados, E. García-Gómez, P. Plaza-Bolaños, J.A. Sánchez Pérez, A. Agüera, M.I. Polo-López. 6<sup>th</sup> European Conference on Environmental Applications of Advanced Oxidation Processes (EAAOP6). 26/06/2019-30/06/2019. Portorov. Eslovenia. Oral and poster.
- Solar photo-fenton process evaluation through simulation: the influence of location on process performance and treatment cost. Alejandro Cabrera-Reina, Sara Miralles-Cuevas, Lorena Cornejo-Ponce, Isabel Oller, Sixto Malato. 6<sup>th</sup> European Conference on Environmental Applications of Advanced Oxidation Processes (EAAOP6). 26/06/2019-30/06/2019. Portorov. Eslovenia. Oral.
- Advanced Treatment of Municipal Wastewater effluents by UVC/free Chlorine process: Contaminants of emerging concern removal, trihalomethanes formation and comparison with UV/H<sub>2</sub>O<sub>2</sub> process. Giusy Cerreta, Melina Roccamante, I. Oller, Patricia Plaza-Bolaños, Ana Agüera, Luigi Rizzo, Sixto Malato. 6<sup>th</sup> European Conference on Environmental Applications of Advanced Oxidation Processes (EAAOP6). 26/06/2019-30/06/2019. Portorov. Eslovenia. Oral.
- Strategies to increase the treatment capacity by solar photo-Fenton at neutral pH operated in continuous mode. Sandra Arzate, Marina Celia Campos Mañas, Sara Miralles Cuevas, José Luis García Sánchez, Ana Agüera, José Antonio Sánchez Pérez. 6<sup>th</sup> European Conference on Environmental Applications of Advanced Oxidation Processes (EAAOP6). 26/06/2019-30/06/2019. Portorov. Eslovenia. Poster.
- Evaluation of different sources of zero valent iron to remove pesticides in natural water at neutral pH. Roccamante, M., Miralles-Cuevas S., A. Cabrera-Reina, I. Oller, S. Malato. 6<sup>th</sup> European Conference on Environmental Applications of Advanced Oxidation Processes (EAAOP6). 26/06/2019-30/06/2019. Portorov. Eslovenia. Poster.
- Fresh-cut wastewater disinfection by solar processes with iron-chelate (Fe<sup>3+</sup>-EDDHA). M.I. Polo-López, S. Nahim-Granados, J.A. Sánchez-Pérez, I. Oller, S. Malato. 20<sup>th</sup> Symposium on Health-Related Water Microbiology (HRWM). Vienna, Austria. 15/09/2019-20/09/2019. Short-oral.
- Engineering aspects of solar photo-Fenton: process simulation as scaling-up tool. Cabrera-Reina, A., Miralles-Cuevas S., Cornejo, L., Malato, S., Oller, I. Congreso Internacional en Energía, Eficiencia y Sustentabilidad Ambiental (CEES 2019). 16/10/2019-18/10/2019. La Serena. Chile. Oral.
- Evaluation of ozone as an alternative treatment to chlorine in the fresh-cut industry: disinfection, microcontaminants elimination and agricultural reuse of treated wash-water. S. Nahim-Granados, G. Rivas-Ibañez, I. Oller, P. Plaza-Bolaños, S. Malato, J.A. Sánchez-Pérez, A. Agüera, M.I. Polo-López. Young water professional congress. Madrid. 12/11/2019-15/11/2019. Oral
- Evaluation of different sources of zero valent iron to remove pesticides in natural water at neutral pH. Roccamante, M., Miralles-Cuevas S., A. Cabrera-Reina, I. Oller, S. Malato. Young water professional congress. Madrid. 12/11/2019-15/11/2019. Short-oral.
- Assessment of organic micro-contaminants and microbial of emerging concern: From solar treated fresh-cut wastewater to irrigated crops. M.I. Polo-Lopez, S. Nahim-Granados, I. Oller, S. Malato, E. García-Gómez, P. Plaza-Bolaños, J.A. Sánchez Pérez, A. Agüera. IV Iberoamerican Conference on Advanced Oxidation Technologies (IV CIPOA). 18/11/2019-22/11/2019. Natal. Brasil. Oral

### Book Chapters

- Economic Assessment and Possible Industrial Application of a (Photo) catalytic Process: A Case Study. In: Heterogeneous Photocatalysis: Relationships with Heterogeneous Catalysis and Perspectives. J. Giménez, S. Esplugas, S. Malato and J. Peral. Giuseppe Marci, Leonardo Palmisano (eds.). Elsevier, Amsterdam, Netherlands. ISBN: 978-0-444-64015-4. Chapter 8, pp. 235-267, 2019.

### PhD Thesis

- "Integración de procesos fotoquímicos solares con otras técnicas avanzadas de análisis para el tratamiento y valorización de aguas residuales complejas" Ana Ruiz Delgado. 26/09/2019. Sobresaliente "Cum Laude" . International mention.
- "Determination of organic microcontaminants and transformation products in surface water and wastewater by low- and high-resolution mass spectrometry" Marina Celia Campos Mañas. 13/12/2019. Sobresaliente "Cum Laude". International mention.

### 2.2.8 Staff members

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**Sixto Malato Rodríguez**



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**Ricardo Sánchez**



Senior Researcher OPI  
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Post-doc Researcher  
UAL

**Azahara Martínez García**



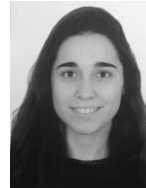
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CIEMAT-PSA**Dennis Deemter**PhD Student  
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## 2.2.9 Ongoing projects in 2019

### 2.2.9.1 Characterization and treatment of wastewater from various sources (landfill leachate and effluent of the cork industry)

**Participants:**

Functional Unit of "Environmental Analysis"

**Contacts:**

A. Agüera (aaguera@ual.es)  
I. Oller (Isabel.oller@psa.es )

**Funds:**

Junta de Andalucía. Proyecto de Excelencia. Convocatoria 2012. (P12-RNM-1739)

**Time Period:**

January 2014 - January 2019. Extended

**Current Situation:**

Finalized

**Summary:**

The project aims to address the treatment of complex wastewaters integrating different advanced oxidation processes (AOPs) (photo-Fenton and solar  $O_3/H_2O_2$ ) with biotreatment (Bio). The strategies of treatment will include combinations of both PAO/Bio and Bio/PAO, depending on biodegradability characteristics of the water to be treated. Two types of wastewater, landfill leachate and effluents from the cork industry, will be used. Due to the complexity of these waters, advanced analytical techniques (LC-MS, GC-MS), global parameters (TOC, COD, biodegradability, etc. ) and batteries of bioassays will be applied in the initial characterization of the waters and during the monitoring of the evolution of treatments.

**Objectives:**

1. Characterization of wastewaters from different origin by wide spectrum analytical protocols including extraction procedures and combined analytical techniques.
2. Establishment of a comprehensive methodology for determining the biocompatibility and detoxification of wastewater treated by advanced processes, by comparing different methods for measuring toxicity and biodegradability.
3. Selecting the best choice among different advanced oxidation treatments (photo-Fenton,  $O_3/OH-O_3/H_2O_2$ ) and its combination with biological treatment.

### 2.2.9.2 Disinfection of WWTP secondary effluents by solar photo-Fenton process in raceway pond reactors. Effect on antibiotic resistance transfer. (SOLFENDIS).

**Participants:**

Functional Units: "Water Treatments" and "Environmental Analysis"

**Contacts:**

J. A. Sánchez (jsanchez@ual.es)

A. Agüera (aaguera@ual.es)

**Funds:**

Ministerio de Economía y Competitividad. (CTQ2013-46398-R)

**Time Period:**

December 2016 – December 2019.

**Current Situation:**

Finalized

**Summary:**

Disinfection of secondary effluents using solar photo-Fenton has been reported; mainly at lab scale and only a few papers deal with pilot plant scale in tubular reactors equipped with Compound Parabolic collectors (CPC). Despite the interest in that water reclamation for irrigation in Spain, no experiences at large scale and cost evaluation are known, mainly due to the recent nature of these investigations. For any of the different uses for which the reuse of treated wastewater is allowed (RD 1620/2007), it is necessary to reduce the content of pathogenic microorganisms in reclaimed water. In this regard, the applicant team has investigated the use of raceway pond reactors for the removal of organic micropollutants with promising results that have aroused the interest of the scientific community. However, to the best of our knowledge, this kind of reactor has never been used for water disinfection. Another aspect that has not been evaluated is its ability to reduce the risk of spreading antibiotic resistance (AR). The antibiotic resistance is today one of the most pressing problems worldwide for public health. Spain is recognized as a country with a high prevalence of resistance, especially in species that cause infections mainly: Pneumococcus, meningococcus, Haemophilus influenzae, Campylobacter, Salmonella sp or E. coli. Spain is also one of the countries with the highest consumption of antibiotics per capita. There is evidence that conventional disinfection processes of wastewater are not effective in controlling the spread of AR. In this context, the generation of disinfection by-products has also been investigated and the need for sophisticated analytical monitoring using advanced techniques has been reported. Finally, the economic assessment and cost minimization are key to bringing this technology to the commercial scale, ultimate goal of the proposed research.

The hypothesis of this project is that raceway pond reactors can be used to disinfect water by the solar photo-Fenton process without generating toxic by-products, improving control of the spread of antibiotic resistance and reducing costs substantially.

**Objectives:**

- The study of the operating variables of raceway pond reactors for water disinfection, dosing of reagents and liquid depth, at pilot plant scale
  - The analytical monitoring of micropollutants and their transformation products, improving and validating new analytical methods.
  - Evaluating the effect of treatments on the transfer of AR, through the inactivation of ARB and ARG.
  - The economic optimization of the proposed process at pilot plant scale to facilitate decision-making for implementation on a larger scale and pre-commercialization of the developed technology.
-

### 2.2.9.3 Pollutant Photo-NF remediation of Agro-Water (LIFE PureAgroH2O)

**Participants:**

Functional Units: "Water Treatments" and "Environmental Analysis"

**Contacts:**

A. Agüera (aaguera@ual.es)

**Funds:**

LIFE Environment and Resource Efficiency, EU. (LIFE17 ENV/GR/000387)

**Time Period:**

July 2018 – December 2021

**Current Situation:**

In progress

**Summary:**

The SFERA-II project (<http://sfera2.sollab.eu>), in which CIESOL is third party of CIEMAT-PSA, finances research stays of European groups in our facilities. During 2014, the functional units of "Analytical evaluation of water treatment and environmental analysis" and "Advanced Technologies for water regeneration" have welcomed the group of Prof. Nikos Xekoukoulotakis, Department of Environmental Engineering, Technical University of Crete (Greece). The approved project was related to the study of the photochemical degradation under solar radiation of two  $\beta$ -lactam antibiotics, meropenem of the subgroup of carbapenems and cefotaxime of the subgroup of cephalosporins, in aqueous solutions, in ultrapure water (UPW) and wastewater (WW).

**Objectives:**

- Develop analytical protocols for the determination of the two antibiotics in the matrices tested.
- Study the photolytic and photocatalytic degradation by photo-Fenton.
- Identification of the main degradation products generated in both processes.

### 2.2.9.4 Upgrading wastewater treatment plants by Low cost Innovative technologies for energy Self-Sufficiency and full recycling. (LIFE ULISES, LIFE18 ENV/ES/000165)

**Participants:**

Functional Units: "Water Treatments" and "Environmental Analysis"

**Contacts:**

J. L. Casas López (jlucasas@ual.es)

**Funds:**

LIFE Environment and Resource Efficiency, EU. (LIFE18 ENV/ES/000165)

**Time Period:**

July 2019 – July 2022

**Current Situation:**

In progress

**Summary:**

The LIFE ULISES project aims to improve conventional reclamation processes through a set of innovative technologies that allow the production of value-added resources from wastewater, such as vehicular biofuel, agricultural biofertilizers and water suitable for reuse. The project seeks to reduce energy consumption and the carbon footprint associated with water treatment, increasing the efficiency of a conventional wastewater treatment plant (WWTP) by integrating different technologies in each of the main lines (water, gas and mud).

During the project, the following low-cost technologies will be implemented at the El Bobar WWTP (Almería):

- Biogas enrichment with ABAD Bioenergy® system to produce a renewable biofuel for vehicles. (Aqualia, Energylab)
- PUSH anaerobic pretreatment combined with advanced aeration control to reduce energy consumption by half in the purification process. (Aqualia)



- Photo-Fenton solar disinfection treatment to produce regenerated water to be reused in irrigation. (Ciesol - UAL)
- Mud enzymatic hydrolysis treatment to obtain a quality agricultural biofertilizer (CETIM, Aqualia)
- Struvite recovery system of concentrates by means of direct osmosis-based process (CETIM)

All these innovative technologies will reduce the electrical consumption of the El Bobar sewage plant and, therefore, minimize its environmental impact and carbon footprint.

**Objectives:**

The main objective of the LIFE ULISES project is to demonstrate the viability of a set of technologies to improve the resources efficiency of the wastewater treatment plants. This will include: an anaerobic aeration pretreatment process to reduce energy demand, an upgrade process to increase biogas production, an enzymatic hydrolysis and membrane-based struvite precipitation for the use of sludge as fertilizer and a tertiary treatment based in solar energy for water reuse.

All these processes will be tested and validated in a pilot plant located in El Bobar, Almerá, Spain.

**2.2.9.5 Reutilización de agua regenerada en cultivos reales de agricultura intensiva: evaluación de la transmisión de antibióticos, bacterias y genes resistentes en el nexo agua-suelo-planta (AMBAGENS)**

**Participants:**

Functional Unit: "Environmental Analysis"

**Contact:**

A. Agüera (aaguera@ual.es)

**Funds:**

Programa Operativo FEDER-Andalucía 2014-2020

**Time Period:**

01/10/2019-31/09/2021

**Current Situation:**

In progress

**Summary:**

The water scarcity is especially noticeable in arid and semi-arid areas such as southern Spain and Andalusia. In the search for alternative resources, unconventional resources such as urban wastewater, represent an effective alternative that can be used in various activities. However, it has been shown that regenerated WW may contain relevant concentrations of antibiotics and their transformation products (TPs), while acting as propagators of resistant bacteria and genes (ARB and ARG). It is necessary, therefore, an adequate evaluation of reuse practices, especially in applications as sensitive as the irrigation of crops intended for consumption, to ensure the protection of both the environment and the consumer. The ANBAGENS project will address the study of chemical and microbiological contamination in a complete reuse scheme under real field conditions, by monitoring an intensive tomato crop, typical of the province of Almería irrigated with real regenerated WW. The project encompasses the development of analysis methods for the determination of antibiotics and their TPs, ARB and ARG. Antibiotics widely used in Spain and reported in treated WWTPs will be considered; as well as the WHO Priority Pathogen List for bacteria and antibiotics that have Critical or High Priority, such as *Acinetobacter baumannii* (resistant to carbapenems), *Pseudomonas aeruginosa* (resistant to carbapenems), Enterobacteriaceae (resistant to carbapenems and cephalosporins of 3rd generation). The results obtained will contribute to fill the current information gap in aspects such as the effectiveness of the regeneration treatments in the elimination of ARB and ARG and the possible regrowth along the irrigation system (storage and transport), the effect of long term exposure to mixtures of antibiotics or to their potentially toxic TPs or the behavior of pollutants under real culture conditions.

**Objectives:**

- Provide validated and standardized analytical protocols for the detection and quantification of antibiotics, ARB and ARG in water, soil and plant, which guarantee the quality of the results obtained.
-

- Contribute to the improvement of WW treatments and reuse schemes, detecting critical points and contributing to a better chemical and microbiological quality of irrigation waters.
- Provide solid and realistic information on the possible risks to public health arising from the reuse of reclaimed water for irrigation, by conducting field studies in real growing conditions.

#### 2.2.10 Participation in networks during 2019

Participation in the "Iberoamerican Solar Water Treatment Network (REDES180149)". Program to Support the Formation of International Networks between Research Centers, Call 2018. International Cooperation Program of CONICYT. Universidad de Tarapacá (Chile).

#### 2.2.11 Transfer and Complementary Activities

Edition of the special issue of the SPEA10 congress: Sixto Malato, Isabel Oller, J.A. Sánchez Pérez "SPEA10". Catalysis Today Vol. 328, 2019. 44 articles

#### 2.2.12 Dissemination activities

The group has participated with a stand at the European Night of Researchers 2019, an activity developed within the framework of the European scientific dissemination OpenResearchers project approved by the European Commission in the call for actions Marie Skłodowska-Curie.

Additionally, the functional unit has participated in activities prior to the European Researchers' Night through dissemination activities in of research in secondary education institutes.

Members of the group have participated as teachers in the 3rd European Summer School of Environmental Applications on Advanced Oxidation Processes. 3-7 June 2019, Alcoy.

#### 2.2.13 Project's applications in 2019

- "Regeneración de agua residual urbana mediante Nuevos mAteriales y tecnologías solares aVanzadas: evaluación de nuevos Indicadores de cAlidad del tratamiento (NAVIA)" Convocatoria 2019 «Proyectos de I+D+i». In evaluation.
- "Evaluación de un sistema real de regeneración de agua y reutilización en riego agrícola: selección y seguimiento de indicadores de calidad químicos y microbiológicos (CIRCULARWATER)". Convocatoria 2019 - «Proyectos de I+D+i», modalidad de Jóvenes Investigadores. In evaluation.
- "Adquisición de un equipo de cromatografía de gases acoplado a espectrómetro de masas de tipo triple cuadrupolo con automuestreador de altas prestaciones (EQC2019-006683-P). Convocatoria para la adquisición de equipamiento científico-técnico (2019) Ministerio de Ciencia, Innovación y Universidades. GRANTED. 213.000 euros.
- "Innovative cost-effective multibarrier treatments for reusing water for agricultural irrigation (LIFE PHOENIX)". LIFE19 ENV/ES/000278. 2019 LIFE call for proposals for traditional projects - Environment and resource efficiency. Under evaluation.
- "Plantas de aprovechamiento de aguas residuales: Afrontando el estrés hídrico con un cambio de paradigma en los métodos de gestión de efluentes (WATERVAL)". Interreg Sudoe Projects. Under evaluation.

#### 2.2.14 Others

##### Final degree projects

- Alvaro Jesus Gilabert Belmonte: "QuEChERS extraction for the determination of organic microcontaminants in wastewater by liquid chromatography coupled to mass spectrometry".

### **PhD Theses (under development)**

- Melina Roccamante (Sixto Malato and Sara Miralles)

### **Attendance at Transfer and Dissemination Workshops**

- Circular Economy in Water Management of the Agrifood Industries. 09/04/2019. Centro Tecnológico AINIA, Paterna, Valencia.
- JORNADA DE TRANSFERENCIA DE EXPERIENCIAS MODELO AGRICOLA ALMERIENSE: AGUA – ENERGÍA – ALIMENTOS. 15 /5/2019. Diputación de Almería. Almería.
- "Master's Degree in Sustainable Management and Water Technology". University of Alicante. January 21, 2019.

### **Other scientific activities**

- Conference in "International Course-Workshop on ODP Update: New Environmental Developments of Advanced Oxidation Processes". University of Caldas, in Manizales - Caldas (Colombia). April 29 to May 3, 2019
  - Conference in "International workshop-workshop on updating in PAOs: New environmental developments of Advanced Oxidation Processes": "Monitoring of treatment and reuse of industrial wastewater through advanced analytical and microbiological techniques". University of Caldas, in Manizales - Caldas (Colombia). April 29 to May 3, 2019
  - Presentation (Novel trends in photo-Fenton). 3rd European Summer School on Environmental Applications of Advanced Oxidation Processes. Alcoy, Spain, June 3-7, 2019.
  - Presentation (Real examples: tertiary treatment). 3rd European Summer School on Environmental Applications of Advanced Oxidation Processes. Alcoy, Spain, June 3-7, 2019.
  - Presentation (Novel trends in chromatography). 3rd European Summer School on Environmental Applications of Advanced Oxidation Processes. Alcoy, Spain, June 3-7, 2019.
  - Oral Communication at the INTERSOLAR Connecting Solar Business in Europe Congress in München. INTERSOLAR 2019. May 14-16, 2019.
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## 2.3 ACTIVITIES OF "ADVANCED TECHNOLOGIES FOR WATER REGENERATION"

### 2.3.1 Functional unit description

The Functional Unit has been formed during 2019 by 12 researchers, with a cathediatric professor, an OPI principal researcher, a researcher hired from OPI, two university professors, four doctors hired in charge of projects, two doctors hired Juan de la Cierva and two predoctoral researchers. The group works on the decontamination of water contaminated with persistent toxics, removal of microcontaminants and disinfection of treated wastewater for reuse. It has basic analytical equipment located in the laboratories 1 and 2 of the center, as well as pilot plants for biological and photochemical water treatments, in the test yard.

### 2.3.2 Main research lines

Study of solar photocatalysis for the removal of toxic substances and water disinfection and its combination with advanced biological methods. The strategic lines of action are:

- Use of solar photo-Fenton for decontamination of toxic water
- Use of solar photo-Fenton for micropollutant removal from treated wastewater
- Use of solar photo-Fenton for treated wastewater disinfection (regeneration)
- Combination of solar photo-Fenton and membrane bioreactor (pre-and post-treatment)
- Optimization of the operation and development of new technology for photo-Fenton
- Economics of water treatment processes

### 2.3.3 Main researchers

**José Antonio Sánchez Pérez** (ORCID ID: 0000-0001-5635-3137; Scopus Author ID 57195586656)

Full Professor. Department of Engineering. Degree in Chemical Engineering by Univ. of Granada (1988); PhD by the Univ. of Granada (1992). He has been involved in 22 national and international R&D projects and has leaded 11 of them, as well as in a 12 contracts with private companies. He has directed 17 PhD theses in different fields such as biotechnology of microalgae, filamentous fungi fermentation and water treatment and is co-author of four patents and more than 150 scientific publications in international journals.

**Inmaculada Polo López** (ORCID ID: 0000-0002-2505-721X; Scopus Author ID 26032688800)

OPI hired researcher. Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT), Almería Solar Platform. Graduated in biology from the University of Granada in 2006 and PhD in Chemical Engineering from the University of Almería (2012). He has carried out 15 national and international R&D projects, currently leading 2 of them. He has directed/co-directed two doctoral theses and is currently directing two other ongoing doctoral theses in the field of solar water treatment and reuse. Author and co-author of 65 publications in international journals with a high impact index, author of 1 book and co-author of 9 other book chapters.

### 2.3.4 Summary of the activity developed in CIESOL during 2019

The year 2019 has been marked by the completion of the SOLFENDIS project and the start of the Life Ulises project. At the end of 2019, the UAL-Feder AQUELOO project concession was announced. Among the different and diverse activities carried out this year, it is worth highlighting the intense research work carried out in the continuous operation of the RPR (Raceway Pond Reactor) in order to treat secondary effluents

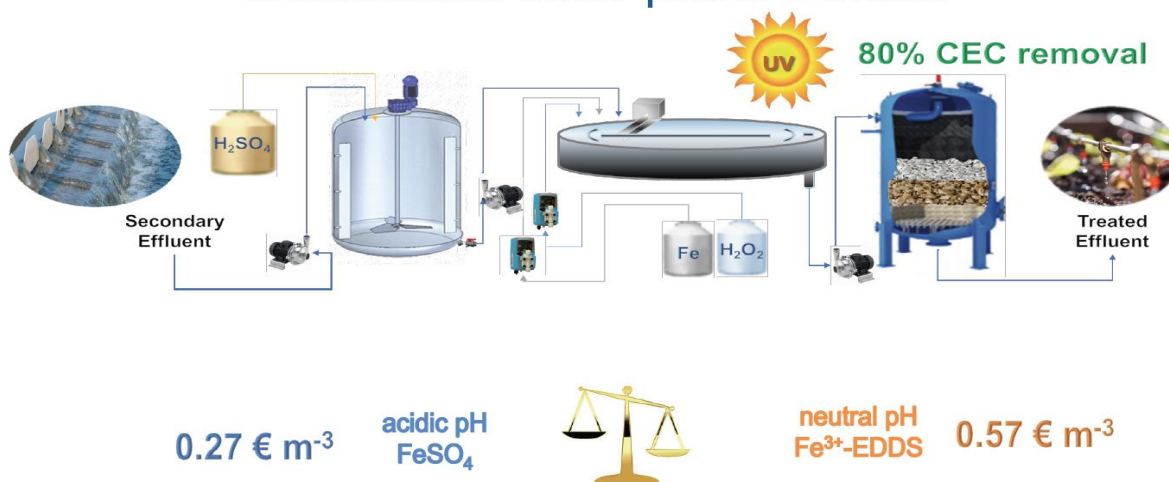
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from WWTP using solar photo-Fenton . The group is a pioneer in continuous operation and has studied different treatment alternatives for disinfecting and removing emerging pollutants in secondary effluents for reuse in agriculture. The treatment of photo-Fenton at neutral pH has been studied using the Fe (III)-EDDS complex and, alternatively, the Fe (III)-NTA complex, or precipitates of ferric hydroxides formed from the oxidation of ferrous sulfate . At the same time, in order to use more oxidizing conditions that allow the elimination of antibiotic resistance genes, continuous operation at acid pH (2.8) with subsequent neutralization in calcium carbonate columns from by-products of the marble industry. This last option has been proposed to reduce neutralization costs and the retention of precipitated iron.

During 2019, three international doctoral theses have been defended, corresponding to Paula Soriano Molina, Irene de la Obra Jiménez and Marina Celia Campos Mañas, the latter shared with the Environmental Analysis Functional Unit.

Regarding mobility, during 2019 we welcomed Dr. Kacper Szymansky and Dr. Sylwia Mozia from the West Pomeranian University of Technology (Szczecin, Poland) within the H2020 SFERA-III project, between the months of September and October. A second stay was also carried out by the doctoral student Amal Mehri, from the Water Research and Technology Center of the University of Cartago, (Soliman, Tunisia), for three months, from May to July.

## Continuous solar photo-Fenton



Conceptual diagram of the operation of the photo-Fenton solar process in continuous mode for water treatment at acidic and neutral pH.

### 2.3.5 Collaboration with other CIESOL Functional Units during 2019

There is close collaboration with the group "Analytical evaluation of water treatment and environmental analysis", complementing and strengthening the main current lines of work, sharing the SOLFENDIS (CTQ2016-78255-R), Life PureAgroH2O (LIFE17 ENV/GR/000387) and Life Ulises (LIFE18 ENV / ES / 000165) projects. The collaboration with the "Modeling and Control Unit", has started for the implementation of control systems for the disinfection and decontamination process using photo-Fenton solar operated in continuous mode.

### 2.3.6 Human resources of the Functional Unit.

During 2019 the PhD student Sandra Yazmin Arzate Salgado left the Functional Unit due to the end of her FPI contract, although she is planning to defend her doctoral thesis in March 2020.

#### Visits and research stays in CIESOL

- Dr. Kacper Szymansky. West Pomeranian University of Technology (Szczecin, Polonia) (15/09/2019-15/10/2019)
- Dra. Sylwia Mozia. West Pomeranian University of Technology (Szczecin, Polonia) (22/09/2019-28/09/2019)
- Amal Mehri. Centro de Investigación y Tecnología del Agua de la Universidad de Cartago, (Soliman, Túnez) (2/05/2019-31/07/2019)
- Luca Falco. Univerisdad de Nápoles Federico II, Italia (01/04/2019-15/07/2019)
- Marisa Frattura. Univerisdad de Nápoles Federico II, Italia (01/04/2019-15/07/2019)

#### Research stays of CIESOL researchers in other institutions:

- Dra. Sara Miralles Cuevas. Laboratorio de Investigaciones Medioambientales en Zonas Áridas (LIMZA), Univeridad de Tarapacá, Chile (01/07/2019-31/10/2019).

#### Students in curricular internships

- Marta Domenech Cuevas (12/11/2018-26/01/2019). Grado en Ingeniería Química Industrial (Plan 2010).
- Francisco José Valenzuela Rodríguez (7/10/2019-20/12/2019). Grado en Ingeniería Química Industrial (Plan 2010).
- Francisco Gabriel López Martínez (7/10/2019-20/12/2019). Grado en Ingeniería Química Industrial (Plan 2010).
- Alba Ruíz Espín (14/11/2019-28/01/2020). Grado en Ingeniería Química Industrial (Plan 2010).
- Juan Miguel Serrano Rodríguez (18/02/2019-02/05/2019). Grado en Ingeniería Electrónica Industrial.
- Jesús Galdeano López. (18/02/2019-02/05/2019). Grado en Ingeniería Electrónica Industrial
- Pedro Jose Martinez Valdivia. (18/02/2019-02/05/2019). Grado en Ingeniería Electrónica Industrial.
- Rafael Antonio Cid Prior (13/11/2018-28/01/2019) Grado en Ingeniería Química Industrial (Plan 2010).

### 2.3.7 Scientific production

#### Papers.

- Environmental assessment of solar photo-Fenton processes in combination with nanofiltration for the removal of micro-contaminants from real wastewaters. A. Gallego-Schmid, R. Zepon Tarpani, S. Miralles-Cuevas, A. Cabrera-Reina, S. Malato, A. Azapagic. *Science of the Total environment*, 650, 2210-2220, 2019 <https://doi.org/10.1016/j.scitotenv.2018.09.361>
- Comparison of different detoxification pilot plants for the treatment of industrial wastewater by solar photo-Fenton: are raceway pond reactors a feasible option?. A. Cabrera Reina, S. Miralles, G. Rivas, J. A. Sánchez Pérez. *Science of the Total Environment* 648: 601-608, 2019. <https://doi.org/10.1016/j.scitotenv.2018.08.143>
- Identification of opioids in surface and wastewaters by LC/QTOF-MS using retrospective data analysis. M.C. Campos-Mañas, I. Ferrer, E. M. Thurman, J. A. Sánchez Pérez, A. Agüera. *Science of the Total Environment* 664: 874-884, 2019. <https://doi.org/10.1016/j.scitotenv.2019.01.389>
- Continuous flow disinfection of WWTP secondary effluents by solar photo-Fenton at neutral pH in raceway pond reactors at pilot plant scale. I. De la Obra, B. Esteban García, G. Rivas, J. L. Casas López, J. A. Sánchez Pérez. *Applied Catalysis B: Environmental* 247: 115-123, 2019. <https://doi.org/10.1016/j.apcatb.2019.01.093>
- Assessment of solar raceway pond reactors for removal of contaminants of emerging concern by photo-Fenton at circumneutral pH from very different municipal wastewater effluents. P. Soriano Molina, P. Plaza-Bolaños, A. Lorenzo, A. Agüera, J. L. García Sánchez, S. Malato, J. A. Sánchez Pérez.

Chemical Engineering Journal 366: 141-149, 2019. <https://doi.org/10.1016/j.cej.2019.02.074>

- Commercial fertilizer as effective iron chelate (Fe<sup>3+</sup>-EDDHA) for wastewater disinfection under natural sunlight for reusing in irrigation. S. Nahim-Granados, I. Oller, S. Malato, J. A. Sánchez Pérez, M. I. Polo-López. *Applied Catalysis B: Environmental* 253: 286-292, 2019. <https://doi.org/10.1016/j.apcatb.2019.04.041>
  - Kinetic assessment of antibiotic resistant bacteria inactivation by solar photo-Fenton in batch and continuous flow mode for wastewater reuse. I. De la Olla, J. L. Casas López, G. Rivas, B. Esteban García, J. A. Sánchez Pérez. *Water Research* 159: 184-194, 2019. <https://doi.org/10.1016/j.watres.2019.04.059>
  - Determination of pesticide levels in wastewater from an agro-food industry: target, suspect and transformation product analysis. M.C. Campos-Mañas, P. Plaza-Bolaños, A. B. Martínez-Piernas, J. A. Sánchez Pérez, A. Agüera. *Chemosphere* 232: 152-163, 2019. <https://doi.org/10.1016/j.chemosphere.2019.05.147>
  - On the design and operation of solar photo-Fenton open reactors for the removal of contaminants of emerging concern from WWTP effluents at neutral pH. P. Soriano Molina, J. L. García Sánchez, S. Malato, P. Plaza-Bolaños, A. Agüera, J. A. Sánchez Pérez. *Applied Catalysis B: Environmental* 256: 117801, 2019. <https://doi.org/10.1016/j.apcatb.2019.117801>
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## Congress

- 3<sup>rd</sup> European Summer School on “Environmental Applications of AOPs. 03/06/2019 - 07/06/2019. Alcoy, Valencia, España.
- 6<sup>th</sup> European Conference on Environmental Applications of Advanced Oxidation Processes (EAAOP6). 26/06/2019 - 30/06/2019. Portorov. Eslovenia.
- 20<sup>th</sup> Symposium on Health-Related Water Microbiology (HRWM). 15/09/2019-20/09/2019. Vienna, Austria.
- Congreso Internacional en Energía, Eficiencia y Sustentabilidad Ambiental (CEES 2019). 16/10/2019 - 18/10/2019. La Serena. Chile.
- Young water professional congress. 12/11/2019 - 15/11/2019. Madrid. España.
- IV Iberoamerican Conference on Advanced Oxidation Technologies (IV CIPOA). 18/11/2019 - 22/11/2019. Natal. Brasil.

## Congress contributions

- ZeroValet Iron technology at Neutral pH assisted with iron complexes to remove pesticides in natural water. Roccamante, M., Miralles-Cuevas S., A. Cabrera-Reina, I. Oller, S. Malato. 3<sup>rd</sup> European Summer School on “Environmental Applications of AOPs. Alcoy, Valencia, España. 03/06/2019 - 07/06/2019. Short-oral.
- Assessment of two strategies of solar photo-Fenton at neutral pH for simultaneous disinfection and microcontaminant removal in secondary WWTP effluents. Paula Soriano Molina, Belén Esteban García, José Antonio Sánchez Pérez. 6<sup>th</sup> European Conference on Environmental Applications of Advanced Oxidation Processes (EAAOP6). 26/06/2019 - 30/06/2019. Portorov. Eslovenia. Oral.
- Inactivation of ARB in WWTP secondary effluents by continuous flow solar photo-Fenton process at pilot plant scale. Irene de la Olla Jiménez, Belén Esteban García, Gracia Rivas Ibáñez, José Luis Casas López, José Antonio Sánchez Pérez. 6<sup>th</sup> European Conference on Environmental Applications of Advanced Oxidation Processes (EAAOP6). 26/06/2019 - 30/06/2019. Portorov. Eslovenia. Oral.
- Solar driven processes to reclaim wastewater from fresh-cut industry: assessment of pathogens and microcontaminants in water and raw-eat crops. S. Nahim-Granados, E. García-Gómez, P. Plaza-Bolaños, J.A. Sánchez Pérez, A. Agüera, M.I. Polo-López. 6<sup>th</sup> European Conference on Environmental Applications of Advanced Oxidation Processes (EAAOP6). 26/06/2019 - 30/06/2019. Portorov. Eslovenia. Oral and poster.
- Solar photo-fenton process evaluation through simulation: the influence of location on process performance and treatment cost. Alejandro Cabrera-Reina, Sara Miralles-Cuevas, Lorena\_Cornejo-Ponce, Isabel Oller, Sixto Malato. 6<sup>th</sup> European Conference on Environmental Applications of Advanced Oxidation Processes (EAAOP6). 26/06/2019 - 30/06/2019. Portorov. Eslovenia. Oral.
- E. coli K-12 inactivation by UV-A LED driven photo-Fenton process in continuous flow mode. Belén Esteban, Sara Miralles Cuevas, Irene de la Olla Jiménez, José Luis Casas López, José Antonio Sánchez Pérez. 6<sup>th</sup> European Conference on Environmental Applications of Advanced Oxidation Processes (EAAOP6). 26/06/2019 - 30/06/2019. Portorov. Eslovenia. Poster.
- Strategies to increase the treatment capacity by solar photo-Fenton at neutral pH operated in continuous mode. Sandra Arzate, Marina Celia Campos Mañas, Sara Miralles Cuevas, José Luis García Sánchez, Ana Agüera, José Antonio Sánchez Pérez. 6<sup>th</sup> European Conference on Environmental Applications of Advanced Oxidation Processes (EAAOP6). 26/06/2019 - 30/06/2019. Portorov. Eslovenia. Poster.
- Elimination of thiabendazole in aqueous systems by photo-Fenton process at circumneutral pH using ZVI nanoparticles. Jorge Plaza, Amaya Arencibia, José Antonio Sánchez Pérez, María José López Muñoz. 6<sup>th</sup> European Conference on Environmental Applications of Advanced Oxidation Processes (EAAOP6). 26/06/2019 - 30/06/2019. Portorov. Eslovenia. Poster.
- Evaluation of different sources of zero valent iron to remove pesticides in natural water at neutral pH. Roccamante, M., Miralles-Cuevas S., A. Cabrera-Reina, I. Oller, S. Malato. 6<sup>th</sup> European Conference on Environmental Applications of Advanced Oxidation Processes (EAAOP6). 26/06/2019 - 30/06/2019. Portorov. Eslovenia. Poster.



- Fresh-cut wastewater disinfection by solar processes with iron-chelate (Fe<sup>3+</sup>-EDDHA). M.I. Polo-López, S. Nahim-Granados, J.A. Sánchez-Pérez, I. Oller, S. Malato. 20<sup>th</sup> Symposium on Health-Related Water Microbiology (HRWM). Vienna, Austria. 15/09/2019-20/09/2019. Short-oral.
- Engineering aspects of solar photo-Fenton: process simulation as scaling-up tool. Cabrera-Reina, A., Miralles-Cuevas S., Cornejo, L., Malato, S., Oller, I. congreso Internacional en Energía, Eficiencia y Sustentabilidad Ambiental (CEES 2019). 16/10/2019 - 18/10/2019. La Serena. Chile. Oral.
- Evaluation of ozone as an alternative treatment to chlorine in the fresh-cut industry: disinfection, microcontaminants elimination and agricultural reuse of treated wash-water. S. Nahim-Granados, G. Rivas-Ibañez, I. Oller, P. Plaza-Bolaños, S. Malato, J.A. Sánchez-Pérez, A. Agüera, M.I. Polo-López. Young water professional congress. Madrid. 12/11/2019 - 15/11/2019. Oral
- Towards a smart & integral treatment of natural radioactivity in water provision services. I. M. Rodríguez Ruano, F.J. Martínez Rodríguez, J.L. Casas López, M.G. Pinna-Hernández, M. Gómez Rincón, N. Martín Sánchez. Young water professional congress. Madrid. 12/11/2019 - 15/11/2019. Oral
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- Disinfection of WWTP secondary effluents by continuous flow solar photo-Fenton process. Scaling up from lab to pilot scale. José Antonio Sánchez Pérez, Irene de la Olla Jiménez, Belén Esteban García, Paula Soriano Molina, José Luis Casas López. IV Iberoamerican Conference on Advanced Oxidation Technologies (IV CIPOA). 18/11/2019 - 22/11/2019. Natal. Brasil. Oral.
- Bacterial inactivation by UV-A LED driven photo-Fenton process operating in continuous flow mode. J.L. Casas López, S. Miralles Cuevas, B. Esteban García, I. De la Olla Jiménez, J.A. Sánchez Pérez. IV Iberoamerican Conference on Advanced Oxidation Technologies (IV CIPOA). 18/11/2019 - 22/11/2019. Natal. Brasil. Oral.
- Assessment of organic micro-contaminants and microbial of emerging concern: From solar treated fresh-cut wastewater to irrigated crops. M.I. Polo-Lopez, S. Nahim-Granados, I. Oller, S. Malato, E. García-Gómez, P. Plaza-Bolaños, J.A. Sánchez Pérez, A. Agüera. IV Iberoamerican Conference on Advanced Oxidation Technologies (IV CIPOA). 18/11/2019 - 22/11/2019. Natal. Brasil. Oral
- Design of open reactors for the removal of contaminants of emerging concern by two strategies of continuous solar photo-Fenton. José Antonio Sánchez Pérez, Paula Soriano Molina, Sandra Arzate Salgado, Irene de la Olla Jiménez, Sara Miralles Cuevas, José Luis García Sánchez. IV Iberoamerican Conference on Advanced Oxidation Technologies (IV CIPOA). 18/11/2019 - 22/11/2019. Natal. Brasil. Poster.
- E.coli inactivation and concurrent elimination of micropollutants by solar photo-Fenton in urban wastewater, mediated by iron oxides in Raceway Pond Reactors. Irene de la Olla Jiménez, José Luis Casas López, Paula Soriano Molina, Sandra Arzate, José Antonio Sánchez Pérez. IV Iberoamerican Conference on Advanced Oxidation Technologies (IV CIPOA). 18/11/2019 - 22/11/2019. Natal. Brasil. Poster.

#### **Book Chapter**

- Chapter 15: Solar Water Detoxification: Fundamentals and Applications. Cabrera-Reina, A., Miralles-Cuevas, S., Santos-Juanes, L., SPRINGER (2019). 341-351. ISBN: 18653529  
[https://doi.org/10.1007/978-3-319-97484-2\\_15](https://doi.org/10.1007/978-3-319-97484-2_15)

#### **PhD Thesis**

- MODELADO CINÉTICO DEL PROCESO FOTO-FENTON SOLAR PARA LA ELIMINACIÓN DE MICROCONTAMINANTES PRESENTES EN EFLUENTES DE DEPURADORA CON REACTORES DE BAJO COSTE. Paula Soriano Molina. Universidad de Almería 21 de mayo 2019. Sobresaliente cum Laude por unanimidad
  - DESINFECCIÓN DE EFLUENTES SECUNDARIOS DE EDAR MEDIANTE EL PROCESO FOTO-FENTON SOLAR OPERANDO EN FLUJO CONTINUO A PH NEUTRO. ELIMINACIÓN DE CONTAMINANTES DE PREOCUPACIÓN EMERGENTE Y BACTERIAS RESISTENTES A LOS ANTIBIÓTICOS. Irene de la Olla Jiménez. Universidad de Almería 31 de mayo 2019. Sobresaliente cum Laude por unanimidad
  - DETERMINACIÓN DE MICROCONTAMINANTES ORGÁNICOS Y PRODUCTOS DE TRANSFORMACIÓN EN AGUAS SUPERFICIALES Y RESIDUALES MEDIANTE ESPECTROMETRÍA DE MASAS DE BAJA Y ALTA RESOLUCIÓN. Marina Celia Campos Mañas. Universidad de Almería 13 de diciembre 2019. Sobresaliente cum Laude por unanimidad
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### 2.3.8 Staff members

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### 2.3.9 Ongoing projects in 2019

#### 2.3.9.1 Disinfection of WWTP secondary effluents by solar photo-Fenton process in raceway pond reactors. Effect on antibiotic resistance transfer. (SOLFENDIS).

**Participants:**

Functional Units: "Water Treatments" and "Environmental Analysis"

**Contacts:**

J. A. Sánchez (jsanchez@ual.es)

A. Agüera (aaguera@ual.es)

**Funds:**

Ministerio de Economía y Competitividad. (CTQ2013-46398-R)

**Time Period:**

December 2016 – December 2019.

**Current Situation:**

Finalized

**Summary:**

Disinfection of secondary effluents using solar photo-Fenton has been reported; mainly at lab scale and only a few papers deal with pilot plant scale in tubular reactors equipped with Compound Parabolic collectors (CPC). Despite the interest in that water reclamation for irrigation in Spain, no experiences at large scale and cost evaluation are known, mainly due to the recent nature of these investigations. For any of the different uses for which the reuse of treated wastewater is allowed (RD 1620/2007), it is necessary to reduce the content of pathogenic microorganisms in reclaimed water. In this regard, the applicant team has investigated the use of raceway pond reactors for the removal of organic micropollutants with promising results that have aroused the interest of the scientific community. However, to the best of our knowledge, this kind of reactor has never been used for water disinfection. Another aspect that has not been evaluated is its ability to reduce the risk of spreading antibiotic resistance (AR). The antibiotic resistance is today one of the most pressing problems worldwide for public health. Spain is recognized as a country with a high prevalence of resistance, especially in species that cause infections mainly: Pneumococcus, meningococcus, Haemophilus influenzae, Campylobacter, Salmonella sp or E. coli. Spain is also one of the countries with the highest consumption of antibiotics per capita. There is evidence that conventional disinfection processes of wastewater are not effective in controlling the spread of AR. In this context, the generation of disinfection by-products has also been investigated and the need for sophisticated analytical monitoring using advanced techniques has been reported. Finally, the economic assessment and cost minimization are key to bringing this technology to the commercial scale, ultimate goal of the proposed research.

The hypothesis of this project is that raceway pond reactors can be used to disinfect water by the solar photo-Fenton process without generating toxic by-products, improving control of the spread of antibiotic resistance and reducing costs substantially.

**Objectives:**

- The study of the operating variables of raceway pond reactors for water disinfection, dosing of reagents and liquid depth, at pilot plant scale
- The analytical monitoring of micropollutants and their transformation products, improving and validating new analytical methods.
- Evaluating the effect of treatments on the transfer of AR, through the inactivation of ARB and ARG.
- The economic optimization of the proposed process at pilot plant scale to facilitate decision-making for implementation on a larger scale and pre-commercialization of the developed technology.

### 2.3.9.2 Toward a smart & integral treatment of natural radioactivity in water provision services (LIFE ALCHEMIA) (LIFE16 ENV/ES/000437)

#### Participants:

CIESOL. Unidad funcional "Tecnologías avanzadas para la regeneración de aguas"  
 Fundación CARTIF (Coordinadores)  
 Diputación de Almería  
 Tallinn University of Technology  
 University of Tartu  
 Viimsi Vesi Ltd (Estonia)

#### Contacts:

J. L. Casas López (jlicasas@ual.es)

#### Funds:

Unión Europea. Programa LIFE (LIFE16 ENV/ES/000437)

#### Time Period:

October 2017 - December 2020

#### Current Situation:

In progress

#### Summary:

The Life Alchemia project tackle one of the current challenges in the treatment of water for human consumption, such as the presence of natural radioactivity. There is a notable lack of knowledge on the part of those involved in water management and despite current legislation (Directive 2013/51 / Euratom), radioactivity is not a parameter that is being systematically monitored at European level. In this regard, it should be noted that this project has the support of 43 of these actors, including the highest national authorities of the 2 member countries of the consortium: the Estonian Ministry of Environment and the Spanish Nuclear Safety Council. It is an environmental problem that cannot be solved at the source, since it is generated by the dilution in groundwater of minerals rich in radioactive isotopes, mainly uranium (U), radium (RA) and thorium (TH). Therefore, new systems capable of providing a sustainable elimination of radioactivity from the point of view of profitability and sustainability are needed. Reverse osmosis (RO) is the most used treatment for this application; However, the carbon footprint of this process is very high and generates large volumes of water rejection with radioactivity that needs additional treatment. The LIFE Alchemia project offers a breakthrough to this problem from two angles. First, with the use of filter bed based treatment systems that will reduce the cost of water treatment up to five times. Second, considering the entire life cycle of radioactivity, including the management of generated waste.

#### Objectives:

- Demonstrate the technical and economic feasibility of filter beds that will be optimized to eliminate water radioactivity and minimize the generation of natural radioactive materials (NORM). Four pilot plants will be operated, three in Spain and one in Estonia, with different strategies to prevent the generation of NORM waste.
- Replicate Life Alchemia solutions in facilities in five other European countries (Italy, Poland and Finland, among others).
- Promote the transfer to other facilities and members of the EU.
- Encourage the active participation of interested parties in the implementation of Directive 2013/51 / Euratom to minimize the environmental impact of radionuclide treatment on water supply services.

During the execution of the project, the specific stakeholders of the target sectors (water suppliers, manufacturers, policy makers) will ensure compliance with the aforementioned objectives.

### 2.3.9.3 Pollutant Photo-NF remediation of Agro-Water (LIFE PureAgroH2O)

**Participants:**

Functional Units: "Water Treatments" and "Environmental Analysis"

**Contacts:**

A. Agüera (aaguera@ual.es)

**Funds:**

LIFE Environment and Resource Efficiency, EU. (LIFE17 ENV/GR/000387)

**Time Period:**

July 2018 – December 2021

**Current Situation:**

In progress

**Summary:**

The SFERA-II project (<http://sfera2.sollab.eu>), in which CIESOL is third party of CIEMAT-PSA, finances research stays of European groups in our facilities. During 2014, the functional units of "Analytical evaluation of water treatment and environmental analysis" and "Advanced Technologies for water regeneration" have welcomed the group of Prof. Nikos Xekoukoulotakis, Department of Environmental Engineering, Technical University of Crete (Greece). The approved project was related to the study of the photochemical degradation under solar radiation of two  $\beta$ -lactam antibiotics, meropenem of the subgroup of carbapenems and cefotaxime of the subgroup of cephalosporins, in aqueous solutions, in ultrapure water (UPW) and wastewater (WW).

**Objectives:**

- Develop analytical protocols for the determination of the two antibiotics in the matrices tested.
- Study the photolytic and photocatalytic degradation by photo-Fenton.
- Identification of the main degradation products generated in both processes.

### 2.3.9.4 Upgrading wastewater treatment plants by Low cost Innovative technologies for energy Self-Sufficiency and full recycling. (LIFE ULISES, LIFE18 ENV/ES/000165)

**Participants:**

Functional Units: "Water Treatments" and "Environmental Analysis"

**Contacts:**

J. L. Casas López (jlcasas@ual.es)

**Funds:**

LIFE Environment and Resource Efficiency, EU. (LIFE18 ENV/ES/000165)

**Time Period:**

July 2019 – July 2022

**Current Situation:**

In progress

**Summary:**

The LIFE ULISES project aims to improve conventional reclamation processes through a set of innovative technologies that allow the production of value-added resources from wastewater, such as vehicular biofuel, agricultural biofertilizers and water suitable for reuse. The project seeks to reduce energy consumption and the carbon footprint associated with water treatment, increasing the efficiency of a conventional wastewater treatment plant (WWTP) by integrating different technologies in each of the main lines (water, gas and mud).

During the project, the following low-cost technologies will be implemented at the El Bobar WWTP (Almería):

- Biogas enrichment with ABAD Bioenergy® system to produce a renewable biofuel for vehicles. (Aqualia, Energylab)

- PUSH anaerobic pretreatment combined with advanced aeration control to reduce energy consumption by half in the purification process. (Aqualia)
- Photo-Fenton solar disinfection treatment to produce regenerated water to be reused in irrigation. (Ciesol - UAL)
- Mud enzymatic hydrolysis treatment to obtain a quality agricultural biofertilizer (CETIM, Aqualia)
- Struvite recovery system of concentrates by means of direct osmosis-based process (CETIM)

All these innovative technologies will reduce the electrical consumption of the El Bobar sewage plant and, therefore, minimize its environmental impact and carbon footprint.

**Objectives:**

The main objective of the LIFE ULISES project is to demonstrate the viability of a set of technologies to improve the resources efficiency of the wastewater treatment plants. This will include: an anaerobic aeration pretreatment process to reduce energy demand, an upgrade process to increase biogas production, an enzymatic hydrolysis and membrane-based struvite precipitation for the use of sludge as fertilizer and a tertiary treatment based in solar energy for water reuse.

All these processes will be tested and validated in a pilot plant located in El Bobar, Almerá, Spain.

**2.3.9.5 Water regeneration for irrigation using solar energy in low-cost reactors operated continuously (AQUELOO)**

**Participants:**

Functional Unit: "Regeneración de aguas"

**Contacts:**

J. A. Sánchez (jsanchez@ual.es)

**Funds:**

Proyectos de I+D de la Universidad de Almería en el marco del programa operativo FEDER Andalucía 2014-2020, convocatoria 2018.

**Time Period:**

October 2019 – September 2021.

**Current Situation:**

In progress

**Summary:**

The AQUELOO project addresses the development of technical solutions based on the use of solar energy for the regeneration of irrigation water in agriculture, thus promoting the use of unconventional water resources. In this project, the photo-Fenton solar process is considered because its efficiency has been demonstrated to eliminate up to 80% of micro-contaminants and 6 log of CFU/mL of pathogenic microorganisms present in effluents from secondary WWTP treatments. On the other hand, the use of low-cost raceway type reactors (RPR) helps to drastically reduce both investment and operating costs. The disinfection of residual waters will be addressed by photo-Fenton solar in continuous mode at TRH of 30 to 60 min, with a liquid depth of between 5 and 15 cm (depending on local radiation) on a pilot scale as well as cost reduction of operation, minimizing the use of chemical reagents. The challenge will be to reduce up to 80% the microcontaminants present and achieve an inactivation of the E. coli bacteria below the detection limit (1 CFU/mL) according to the reuse requirements established for irrigation in Spain (RD 1620/2007). Likewise, the AQUELOO project will help to bridge the gap between validated treatments on a laboratory scale and their application in real conditions on a pilot scale and in continuous flow.

**Objectives:**

In this project, the continuous operation of solar photocatalysis reactors with residence times (30 - 60 min) shorter than those currently used with chlorination (90 min) is proposed. The general objectives of the project can be synthesized in:

- a) Optimize the continuous operation variables of the raceway reactors for the regeneration of wastewater on a pilot scale by photo-Fenton solar at neutral pH.
- b) Carry out the conceptual design of a commercial scale reactor and estimate costs.

### 2.3.10 Participation in Networks during 2019

Participation in the "Iberoamerican Solar Water Treatment Network". Support Program for the Formation of International Networks between Research Centers, 2018 Call. CONICYT International Cooperation Program.

Participation in the European COST Action entitled: 'NEW AND EMERGING CHALLENGES AND OPPORTUNITIES IN WASTEWATER REUSE (NEREUS)' (<http://www.nereus-cost.eu/>). In October 2018, the final meeting of the project took place in Limassol (Cyprus), which was coincided XENOWAC II Conference.

### 2.3.11 Dissemination activities

European Night of Researchers 2019, activity carried out within the framework of the European OpenResearchers scientific dissemination project approved by the European Commission in the Marie Skłodowska-Curie call for actions. The functional unit has participated through two stands. One of them dedicated to the activities carried out in the LIFE Alchemia project and entitled "Natural radioactivity in waters for human consumption. In search of a sustainable treatment ". The other stand entitled "On water and its reuse through treatments with solar technology" has focused on showing the latest advances in solar treatments to decontaminate and disinfect wastewater to be reused for agricultural purposes.

XXV Conference of the Parties to the United Nations Convention on Climate Change (COP25), held in Madrid from December 2<sup>nd</sup> to 15<sup>th</sup>. Members of the functional unit have participated in the citizen space, meeting and environmental awareness of COP25 with which Spain wants to contribute to facilitate the participation of all civil society, through the exhibition of the most innovative solar technologies that are investigated in the units applied to wastewater treatment on December 11, 12 and 13.

Additionally, the functional unit has participated in activities prior to the European Night of Researchers through the dissemination of research in secondary education institutes.

### 2.3.12 Projects requested during 2019

- Design, construction and operation of a pilot solar photocatalysis plant for the disinfection and elimination of emerging pollutants from secondary effluents from the WWTP, ERASOL project, presented at the 2018 call Proyectos de I+D de la Consejería de Conocimiento, Investigación y Universidad de la Junta de Andalucía.. Project presented in December 2018. Currently under evaluation.
- Regeneration of urban wastewater by means of New Materials and Advanced Solar Technologies: evaluation of new Treatment Quality Indicators (NAVIA). 2019 call for proyectos de I+D+i, Ministerio de Ciencia e innovación. Coordinated project: UAL (Coordinator), PSA, UPV.
- Innovative cost-effective multibarrier treatments for reusing water for agricultural irrigation. (LIFE Phoenix, LIFE19 ENV / ES / 000278). Call LIFE Environment and Resource Efficiency, EU, 2019. In June 2019 the Concept Note of the project was presented, which was satisfactorily evaluated and reported in October 2019. The presentation of the project in the second phase has been carried out in February 2020. The proposal is being led by AQUALIA and includes companies and technology centers such as

NEWLAND, Aguas de Portugal and CETIM, and public bodies such as the Guadalquivir Hydrographic Confederation, the Almería Provincial Council and the Solar Energy Research Center, CIESOL.

- Development of new modeling strategies for advanced oxidation processes for the control and optimization of water treatment, the COPTAGUA project. CYTED, Chile, 2019 call. Currently under evaluation.

### 2.3.13 Others

#### Final degree projects

- Pedro Jose Moises Martinez Valdivia. (Degree in Industrial Electronic Engineering). Puesta en marcha y desarrollo de un sistema de supervisión para el proceso foto-Fenton.
- Alumno: Ruben Diaz Gonzalez (Chemical engineer). Diseño de una planta regeneradora de agua para la edar de el toyo en el proceso foto-fenton solar en reactor raceway operado de modo continuo
- Luca Falco y Marisa Frattura. (Master in Environmental and Territory Engineering, Universidad Federico II, Nápoles) Pesticides removal in low concentration using peroxidisulfate activated by microspheres of zero valent iron and solar light

#### PhD Theses (under development)

- Sandra Yazmin Arzate Salgado (Supervisor: José Antonio Sánchez Pérez)
- Melina Roccamante (Supervisors: Sixto Malato and Sara Miralles)
- Samira Nahim-Granados (Supervisors: M. Inmaculada Polo López and Jose Antonio Sánchez Pérez)

#### Attendance at Transfer and Dissemination Workshops

- PROCESOS AVANZADOS DE OXIDACIÓN: FUNDAMENTOS Y APLICACIONES CON ÉNFASIS EN LOS PROCESOS SOLARES. 29/04/2019-03/05/2019, Universidad de Caldas, Manizales, Colombia.
- Economía Circular en la Gestión del Aguas de las Industrias Agroalimentarias. 09/04/2019. Centro Tecnológico AINIA, Paterna, Valencia.
- JORNADA DE TRANSFERENCIA DE EXPERIENCIAS MODELO AGRICOLA ALMERIENSE: AGUA – ENERGÍA – ALIMENTOS. 15 de mayo de 2019. Diputación de Almería. Almería.





## 2.4 ACTIVITIES OF “MODELING & AUTOMATIC CONTROL” UNIT

### 2.4.1 Functional unit description

This functional unit is composed by researchers of the group “Automatic Control, Robotics and Mechatronics (TEP197, arm.ual.es) of the University of Almería (UAL) and the Automatic Control Unit of the Plataforma Solar de Almería (PSA). The group has among its areas of interest: intensive agriculture, solar energy, biotechnology and bioengineering, in addition to control education, mechanization and robotics in general. Collaborative activities between the group and the PSA have been developing continuously over the past 25 years, with remarkable participation of UAL researchers in developing some of the SCADA (Supervisory Control And Data Acquisition) system involved in test facilities located in the PSA. Following the experience gained in the ARFRISOL project, the group also has a research line linked to applications of control systems to achieve thermal, visual and air quality comfort and energy efficiency in buildings.

### 2.4.2 Main research lines

The main research lines of the group are:

- Modeling and control of thermosolar plants.
- Modeling, control and robotics in agro-industry.
- Energy efficiency and comfort control in buildings.
- Engineering education.
- Modeling and control of photobioreactors.
- Electric vehicles.
- Energy smart grids
- Predictive, hierarchical and robust control.
- Supervisory systems and industrial communications.
- Artificial intelligence in solar energy applications.

### 2.4.3 Main researchers

**Manuel Berenguel Soria** (ORCID 0000-0002-3349-7506, Scopus Author ID 6701834872)

Manuel Berenguel received the industrial engineering and Ph.D. degrees from the University of Seville, Spain. He is Full Professor of automatic control and systems engineering with the University of Almería, Spain. His research interests include control education and in predictive and hierarchical control, with applications to solar energy systems, agriculture, and biotechnology. He has been Vice-Rector of ICT at University of Almería (2007-2012) and is the head of the research group “Automatic Control, Robotics and Mechatronics” (arm.ual.es) from 2000. He is co-author of the books *Advanced Control of Solar Plants* (Springer, 1997), *Control of Solar Energy Systems* (Springer, 2012), *Comfort Control in Buildings* (Springer, 2014) and *Modeling and Control of Greenhouse Crop Growth* (Springer, 2014). He has been director and co-director of 15 PhD Thesis in these lines. He is co-author of 138 international journal papers, 179 papers in international conferences and 5 patents. H-index: 42 (Google Scholar), 34 (Scopus), 30 (Web of Science). He has participated in the International Program Committee of 10 international conferences (in one as IPC Chair) and 5 national conferences, where he has been chairman in many occasions. He is reviewer of more than 15 renowned international journals (more than 100 reviews) and from 2013 is adjoint-director of the journal *Revista Iberoamericana de Automática e Informática Industrial* (indexed in SCI). He has been member of the board of Governors of the Comité Español de Automática (main Spanish Association in Automatic Control) from 2003 to 2008 and 2012-2016, member of IEEE Control System Society from 2000 (Senior Member from 2012)

and member of the IFAC Technical Committees TC 8.01 Control in Agriculture, TC 6.3. Power and Energy Systems and TC 8.4 Biosystems and bioprocesses and member of the Coordination and management committee of the Mixed R&D Center CIESOL between the University of Almería and CIEMAT- Spanish Research Center in Energy, Environment and Technology (from 2005) and member of Scientific Committee of IMDEA Energy from 2015 and of its board of governors since 2019. He was the organizer of the XXVII Jornadas de Automática (the annual meeting of the Spanish Automatic Control Committee) in 2006.

**Lidia Roca Sobrino** (ORCID 0000-0002-8724-5136, Scopus Author ID 23467603800)

Lidia Roca received the academic degree in Electronic Engineering by the University of Granada (2004), Master's in Solar Energy by the University of Almería (2007) and the PhD. degree in by the University of Almería (2009). Her PhD. dissertation, which was a contribution of control strategies for a solar Multi-effect Distillation plant coupled to a double effect LiBr-H<sub>2</sub>O absorption heat pump, was granted with a PhD. award in Engineering by the University of Almería. From 2012, she is a researcher at CIEMAT being her scientific career focused in modeling, optimization and advanced control strategies for solar thermal processes such as solar desalination processes, absorption heat pumps, hydrogen production, thermal storage and hybrid CSP plants. Currently, she belongs to the Solar Desalination Unit at the Plataforma Solar de Almería. She has been involved in 16 national and international R+D projects, she is co-author of 36 publications in SCI Impact Factor Journals and 2 books and she has 35 contributions to different International Conferences.

#### 2.4.4 Summary of the functional unit's activities carried out in CIESOL during 2019

- Control and optimal management of heterogeneous Resources in agroindustrial production districts integrating renewable energies
- Modelling and control of the combined process of microalgae production and wastewater treatment with industrial reactors
- Modeling and control of solar desalination plants. Modeling and optimization for efficient management of resources in solar desalination.
- Development of models and controllers for fertigation and humidity control in greenhouses and coupling to a solar desalination plant.
- Control of greenhouse crop growth optimizing sustainability, energy and economic criteria.
- Multi-objective optimization of air conditioning and lighting systems for comfort achievement in sustainable buildings.
- Simulation and control of thermosolar plants with parabolic troughs in industrial and refrigeration applications.
- Modeling and optimization for efficient management of resources in solar thermal technology.
- Kinematic and dynamic modeling and control of electrical vehicles focusing on energy efficiency using solar energy.
- Control of unmanned aerial vehicles (UAV).
- Development of interactive tools and virtual and remote laboratories for automatic control.
- Robot design and control.

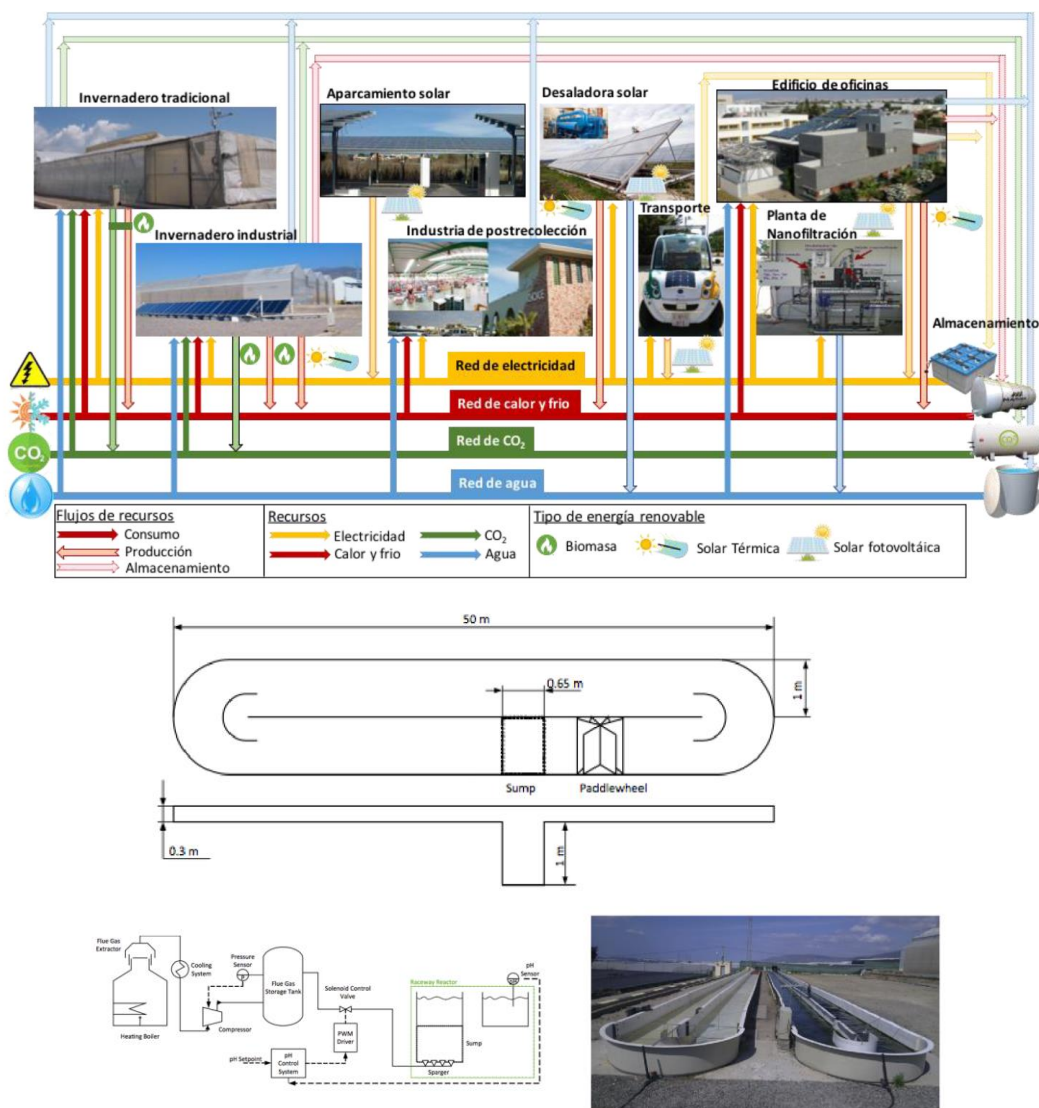


Fig. 2.4.1 Various examples of the activity of the modeling and control unit

#### 2.4.5 Collaboration with other functional units of CIESOL during 2019

In 2019 the Modeling and Control Unit has maintained collaborations with the following CIESOL Functional Units:

- Desalination and Photosynthesis: European projects (SABANA), national plan projects, joint publications (desalination, photobioreactors, greenhouses, ...) Joint management of TFG, TFM and Doctoral Theses. Collaboration within the scope of the Sfera 3 project.
- Environmental Analysis: collaboration at the joint management level of TFG and TFM. Appearance in local press. Collaboration within the scope of the Sfera 3 project.
- Water Regeneration: collaboration at the joint management level of TFG and TFM. Planning of joint publications. Collaboration within the scope of the Sfera 3 project.

In addition, collaborations with PSA are maintained in the following areas:

- Master in Solar Energy

- The research group "Automatics, Robotics and Mechatronics" of the University of Almeria together with CIEMAT have collaborated in the research line of R+D of Automatics in solar thermal plants in the framework of several national projects: DPI2004-07444-C04-04, DPI2007-66718-C04-04, DPI2010-21589-C05-02, DPI2014-56364-C2-R, DPI2017-85007-R.
- Collaboration with the CIEMAT Energy Efficiency in Buildings Unit UIE3. The collaboration established on the basis of the ARFRISOL project, already concluded, has opened up new options for the development of joint activities of common interest in the field of the dynamic characterisation of the thermal properties of materials and elements.

#### 2.4.6 Human resources of the Functional Unit

##### Visits and research stays in CIESOL:

- Marchi, Leticia de Araujo. Universidad Federal de Santa Catarina (UFSC), Brasil (01/02/2019-31/07/2019).
- Meza, Roberto. Universidad Nacional Autónoma de México (UNAM), México (09/09/2019-31/10/2019).
- Polanco, Luis. Universidad de Guanajuato, México (11/12/2019-24/06/2020).
- Román, Caio. Universidad Federal de Santa Catarina (UFSC), Brasil (01/09/2019-28/02/2020).
- Vázquez, Laura. Universidad Nacional Autónoma de México (UNAM), México (02/09/2019-31/10/2019).

##### Research stays of CIESOL researchers in other institutions:

- Manuel Berenguel Soria. Universidad de Brescia, Italia (18/05/2019-01/06/2019).
- Juan Diego Gil Vergel. Plataforma Solar de Almería, España (01/02/2019-30/04/2019).
- Luis José Yebra Muñoz. Estancia como profesor/investigador invitado por el Dpto. de Automática de la Universidad de Alcalá, España (10/02/2019-18/06/2019).

##### Students in curricular internships

- Ación Zapata, Salvador. Grado en Ingeniería Informática (14/11/2019-28/01/2020).
- Aguilera López, Raúl. Grado en Ingeniería Mecánica (14/02/2019-28/04/2019).
- Asensio Amador, Carlos. Grado en Ingeniería Electrónica Industrial (03/10/2019-17/12/2019).
- Berenguel Sánchez, Juan Jesús. Grado en Ingeniería Electrónica Industrial (19/11/2018-02/02/2019).
- Chinchilla Pérez, Juan Manuel. Grado en Ingeniería Electrónica Industrial (18/02/2019-02/05/2019).
- Galdeano López, Jesús. Grado en Ingeniería Electrónica Industrial (18/02/2019-02/05/2019).
- Giménez Miralles, Adrián. Grado en Ingeniería Electrónica Industrial (12/05/2019-26/08/2019).
- Kalmutskyy Kalmutskyy, Georgiy. Grado en Ingeniería Electrónica Industrial (19/11/2018-03/02/2019).
- López Martínez, Francisco Gabriel. Grado en Ingeniería Electrónica Industrial (07/10/2019-20/12/2019).
- Martínez Valdívila, Pedro José. Grado en Ingeniería Electrónica Industrial (18/02/2019-02/05/2019).
- Otálora Berenguel, Pablo. Grado en Ingeniería Electrónica Industrial (18/02/2019-02/05/2019).
- Ramajo Ballester, Álvaro. Grado en Ingeniería Electrónica Industrial (08/11/2019-22/01/2020).
- Serrano Rodríguez, Juan Miguel. Grado en Ingeniería Electrónica Industrial (18/02/2019-02/05/2019).

#### 2.4.7 Scientific production

##### Papers

- Multiobjective control architecture to estimate optimal set points for user comfort and energy saving in buildings. Martell, M., F. Rodríguez, M. Castilla, M. Berenguel. *ISA Transactions*, in press, 2020. Available online 22 October 2019. DOI: 10.1016/j.isatra.2019.10.006.
- Apparent delay analysis for a flat-plate solar field model designed for control purposes. Ampuño, G., L. Roca, J.D. Gil, M. Berenguel, J.E. Normey-Rico. *Solar Energy*, 177, 241-254, 2019. DOI: 10.1016/j.solener.2018.11.014.

- Incremental state-space model predictive control of a Fresnel solar collector. Camacho, E.F., A.J. Gallego, A.J. Sánchez, M. Berenguel. *Energies*, 13, 3, 2019. DOI: 10.3390/en12010003.
- Parabolic trough collector field dynamic model: Validation, energetic and exergetic analyses. Carballo, J.A., J. Bonilla, M. Berenguel, P. Palenzuela. *Applied Thermal Engineering*, 148, 777-786, 2019. DOI: 10.1016/j.applthermaleng.2018.11.093.
- New approach for solar tracking systems based on computer vision, low cost hardware and deep learning. Carballo, J.A., J. Bonilla, M. Berenguel, J. Fernández-Reche, G. García. *Renewable Energy*, 133, 1158-1166, 2019. DOI: 10.1016/j.renene.2018.08.101.
- Design of a parallel genetic algorithm for continuous and pattern-free heliostat field optimization. Cruz, N.C., S. Salhi, J.L. Redondo, J.D. Álvarez, M. Berenguel, P.M. Ortigosa. *Journal of Supercomputing*, 75(3), 1268-1283, 2019. DOI: 10.1007/s11227-018-2404-8.
- Gain-scheduling model predictive control of a Fresnel collector field. Gallego, A.J., G.M. Merello, M. Berenguel, E.F. Camacho. *Control Engineering Practice* 82, 1-13, 2019. DOI: 10.1016/j.conengprac.2018.09.022.
- Biomass estimation of an industrial raceway photobioreactor using an extended Kalman filter and a dynamic model for microalgae production. García-Mañas, F., J.L. Guzmán, M. Berenguel, F.G. Acién. *Algal Research-Biomass Biofuels and Bioproducts*, 37, 103-114, 2019. DOI: 10.1016/j.algal.2018.11.009.
- Optimal thermal energy management of a distributed energy system comprising a solar membrane distillation plant and a greenhouse. Gil, J.D., J.D. Álvarez, L. Roca, J.A. Sánchez-Molina, M. Berenguel, F. Rodríguez. *Energy Conversion and Management*, 198, 111791, 2019. DOI: 10.1016/j.enconman.2019.111791.
- Daytime/Nighttime event-based PI control for the pH of a microalgae raceway reactor. E. Rodríguez-Miranda, M. Beschi, J.L. Guzmán, M. Berenguel, A. Visioli. *Processes*, 7(5), 1-16, 2019. DOI: 10.3390/pr7050247.
- Development of an empirical tomato crop disease model: a case study on gray leaf spot. H. Wang, J.A. Sánchez-Molina, M. Li, M. Berenguel. *European Journal of Plant Pathology*, 2019. DOI: 10.1007/s10658-019-01897-7.
- Evaluation of a dehumidifier in a mild weather greenhouse. J.M. Zapata, J.A. Sánchez-Molina, F. Rodríguez-Díaz, J.C. López-Hernández. *Applied Thermal Engineering*, 146, 92-102, 2019. DOI: 10.1016/j.applthermaleng.2018.09.107.
- Cost function optimization for predictive control of a five-phase IM drive. M. Ruiz-Arahal, C. Martín-Torres, A. Kowal-Gornig, M.M. Castilla-Nieto, F.J. Barrero-García. *Optimal Control Applications & Methods*, 1-10, 2019. DOI: 10.1002/oca.2499.
- Uncertainty-Aware Calibration of a Hot-Wire Anemometer With Gaussian Process Regression, R.A. García, J.L. Blanco-Claraco, J. López-Martínez, A.J. Callejón-Ferre. *IEEE Sensors Journal*, 19(17), 7515-7524, 2019. DOI: 10.1109/JSEN.2019.2915093.
- Benchmarking Particle Filter Algorithms for Efficient Velodyne-Based Vehicle Localization. J.L. Blanco-Claraco, F. Mañas-alvarez, J.L. Torres-Moreno, A. Gimenez-Fernandez, F. Rodriguez-Diaz. *Sensors*, 19, 2019. DOI: 10.3390/s19143155.
- Modelling of Batteries for Application in Light Electric Urban Vehicles. F. Gomez, L.J. Yebra-Muñoz, A. Gimenez-Fernandez, J.L. Torres-Moreno. *Revista Iberoamericana de Automática e Informática Industrial*, 16(4), 2019. DOI: 10.4995/riai.2019.10609.
- Cost Function Optimization for Multi-phase Induction Machines Predictive Control. M. Ruiz-Arahal, A. Kowal-Gornig, F.J. Barrero-García, M.M. Castilla-Nieto. *Revista Iberoamericana de Automática e Informática Industrial*, 16(1), 48-55, 2019. DOI: 10.4995/riai.2018.9771.
- Automated system for soil wind erosion studies. A. Gimenez-Fernandez, F.J. Lozano-Cantero, J.A. Torres-Arriaza, C.M. Asensio-Grima. *Computers and Electronics in Agriculture*, 164, 104889, 2019. DOI: 10.1016/j.compag.2019.104889.
- Optimal processing of greenhouse crop residues to use as energy and CO<sub>2</sub> sources. J.V. Reinoso, M.G. Pinna, M.D. Fernández, J.A. Sánchez-Molina, F. Rodríguez, J.C. Hernández, F.G. Acién. *Industrial Crops and Products*, 135, 662-671, 2019. DOI: 10.1016/j.indcrop.2019.04.074.

- Improving the performance of vegetable leaf wetness duration models in greenhouses using decision tree learning. Wang, H., J.A. Sánchez-Molina, M. Li, F. Rodríguez. *Water*, 1(11), 158-170, 2019. DOI: 10.3390/w11010158.
- Design and analysis of a constant-force bench press. Sánchez-Salinas, S., C. Núñez, J. López, J. García-Vallejo, J.M. Muyor. *Mechanism and Machine Theory*, 142, 103612, 2019. DOI: 10.1016/j.mechmachtheory.2019.103612.
- Robust QFT-Based Feedback Linearization Controller of the Greenhouse Diurnal Temperature Using Natural Ventilation. A. Hoyo, J. C. Moreno, J. L. Guzmán, F. Rodríguez. *IEEE Access*, 7, 64148- 64161, 2019.
- Evaluation of photosynthetic light integration by microalgae in a pilot-scale raceway reactor. M. Barceló-Villalobos, P. Fernández-del Olmo, J. L. Guzmán, J. M. Fernández-Sevilla, F.G. Ación *Bioresource Technology*, 280, 404-411, 2019.
- Event-based feedforward control of linear systems with input time-delay. E. Aranda-Escolástico, C. Rodríguez, M. Guinaldo, J. L. Guzmán, S. Dormido. *International Journal of Applied Mathematics & Computer Science*, 29(3), 541-553, 2019.
- Linear Active Disturbance Rejection Control for a Raceway Photobioreactor. J.J. Carreño-Zagarra, J. L. Guzmán, J. C. Moreno, R. Villamizar. *Control Engineering Practice*, 85, 271-279, 2019.
- Machine learning for solar trackers. J.A. Carballo, J. Bonilla, M. Berenguel, J. Fernández-Reche, G. García, AIP Conference Proceedings SolarPACES Conference, October Casablanca, Morocco, 2018. Vol. 2126, No. 1, p. 030012, 2019. DOI: <https://doi.org/10.1063/1.5117524>.
- Hybrid NMPC applied to a solar-powered membrane distillation system. J.D. Gil, P.R.C Mendes, G.A. Andrade, L. Roca, J.E. Normey-Rico. M. Berenguel. 12<sup>th</sup> Symposium on Dynamics and Control of Process Systems, including Biosystems (DYCOPS 2019). *IFAC-PapersOnLine*, 52(1), 124-129, 2019.
- Control system for pH in raceway photobioreactor based on Wiener model. A. Pawlowski, J.L. Guzmán, M. Berenguel, F. G. Ación. 11<sup>th</sup> IFAC Symposium on Dynamics and Control of Process Systems, including Biosystems - DYCOPS-CAB 2019. *IFAC-PapersOnLine*, 52(1), 928-933, 2019.
- Greenhouse Models as a Service (GMaaS) for Simulation and Control. Muñoz-Rodríguez, M., J.L. Guzmán, J.A. Sánchez-Molina, F. Rodríguez, M. Torres. 6<sup>th</sup> IFAC Conference on Sensing, Control and Automation Technologies for Agriculture AGRICONTROL 2019. *IFAC-PapersOnLine*, 52(30), 190-195, 2019. DOI: 10.1016/j.ifacol.2019.12.520.

### Congress assistance

- 8<sup>th</sup> International Work-Conference on the Interplay between Natural and Artificial Computation (IWINAC 2019), 2019.
- Global IoT Summit (GIoTS 2019), 2019.
- European Control Conference, Naples, Italy, 2019.
- 6<sup>th</sup> IFAC Conference on Sensing, Control and Automation Technologies for Agriculture AGRICONTROL 2019, Sydney, Australia, 4-6 December 2019.
- 15<sup>th</sup> Workshop on Time Delay Systems, Sinaia, Romania, 9-1 September 2019.
- 2<sup>nd</sup> IWA Conference on Algal Technologies for Wastewater Treatment and Resource Recovery, Valladolid, Spain, 1-2 July 2019.
- 12<sup>th</sup> Symposium on Dynamics and Control of Process Systems, including Biosystems (DYCOPS 2019), 2019.
- 11<sup>th</sup> IFAC Symposium on Dynamics and Control of Process Systems, including Biosystems - DYCOPS-CAB 2019. Florianopolis, Brazil, 2019.
- Solar World Congress, Santiago de Chile, November 4, 2019.
- International Conference on Mechanical Models in Structural Engineering, 23-25 October 2019, Alicante, Spain.
- Aportando valor al CO<sub>2</sub>, 1-2 October, 2019, Technology Lab de Repsol, Móstoles, Madrid, Spain.
- International Conference on Concentrating Solar Power and Chemical Energy Systems, 2019, Daegu, Korea, 01-04 October, 2019.

- IEEE 23<sup>rd</sup> International Conference on Intelligent Engineering Systems, Godollo, Hungary, 25-27 April, 2019.
- X Congreso Ibérico de Agroingeniería, 3-6 Septiembre 2019. Escuela Politécnica Superior, Campus Huesca de la Universidad de Zaragoza, Huesca, España.
- XL Jornadas de Automática, 3-5 Septiembre 2019, Ferrol, España.
- EUROSIM 2019. 10<sup>th</sup> Congress of the Federation of European Simulation Societies. Special Session on Trends and Perspectives of Machine Learning in Automation, 1-5 July, 2019. Logroño, Spain.
- Jornadas de Innovación Docente y Experiencias Profesionales en la Universidad de Almería. Curso 2019. 19 September, 2019, Almería, Spain.
- XXX Jornadas de Paralelismo, Cáceres, Spain, 18-20 September, 2019.
- EDULEARN19, the 11<sup>th</sup> annual International Conference on Education and New Learning Technologies, 1-3 July 2019, Palma de Mallorca, Spain.
- Congresso de Métodos Numéricos em Engenharia, 1-3 July, 2019, Guimaraes, Portugal.

### Congress contributions

- An Indoor Illuminance Prediction Model based on Neural Networks for Visual Comfort and Energy Efficiency Optimization Purposes. M. Martell, M. Castilla, F. Rodríguez y M. Berenguel. En 8th International Work-Conference on the Interplay between Natural and Artificial Computation (IWINAC 2019), 2019.
- An IoT Control System for a Solar Membrane Distillation Plant used for Greenhouse Irrigation. J.D. Gil, M. Muñoz, L. Roca, F. Rodríguez y M. Berenguel. En Global IoT Summit (GloTS 2019), 2019.
- Application of a Symmetrical-Send-On-Delta event-based controller for a microalgal raceway reactor. E. Rodríguez-Miranda, J.L. Guzmán, M. Berenguel, F.G. Ación, A. Visioli. European Control Conference, Naples, Italy, 2019.
- Greenhouse Models as a Service (GMaaS) for Simulation and Control. Muñoz-Rodríguez, M., J.L. Guzmán, J.A. Sánchez-Molina, F. Rodríguez, M. Torres. 6<sup>th</sup> IFAC Conference on Sensing, Control and Automation Technologies for Agriculture AGRICONTROL 2019, Sydney, Australia, 4-6 December 2019.
- Predictive Active Disturbance Rejection Control for Insulin Infusion in Patients with T1DM. J.J. Carreño-Zagarrá, R. Villamizar, J.C. Moreno, J.L. Guzmán. 15th Workshop on Time Delay Systems, Sinaia, Romania, 9-1 September 2019.
- A feedback control strategy of dissolved oxygen in raceway reactors. M. Barceló-Villalobos, J.L. Guzmán, F.G. Ación. 2nd IWA Conference on Algal Technologies for Wastewater Treatment and Resource Recovery, Valladolid, Spain, 1-2 July 2019.
- A graphical tool to simulate raceway photoreactors. A. Hoyo, J.L. Guzmán, F.G. Ación, M. Berenguel, J.C. Moreno. 2nd IWA Conference on Algal Technologies for Wastewater Treatment and Resource Recovery, Valladolid, Spain, 1-2 July 2019.
- Diurnal and Nocturnal pH control in Microalgae Raceway Reactors. E. Rodríguez-Miranda, J.L. Guzmán, M. Berenguel, F.G. Ación, A. Visioli. 2nd IWA Conference on Algal Technologies for Wastewater Treatment and Resource Recovery, Valladolid, Spain, 1-2 July 2019.
- Hybrid NMPC applied to a solar-powered membrane distillation system. J.D. Gil, P.R.C. Mendes, G.A. Andrade, L. Roca, J.E. Normey-Rico. M. Berenguel. 12th Symposium on Dynamics and Control of Process Systems, including Biosystems (DYCOPS 2019), 2019.
- Control system for pH in raceway photobioreactor based on Wiener model. A. Pawlowski, J.L. Guzmán, M. Berenguel, F. G. Ación. In 11th IFAC Symposium on Dynamics and Control of Process Systems, including Biosystems - DYCOPS-CAB 2019. Florianopolis, Brazil, 2019.
- A Software for Dimensioning of Small Microgrids with PV-Battery Systems. Torres, J.L., J.A. Carballo, J. Bonilla, A. Giménez-Fernández. Solar World Congress, Santiago de Chile, November 4, 2019.
- A topological entropy-based approach for damage detection of civil engineering structures. Jiménez-Alonso, J.F., J. López-Martínez, J.L. Blanco-Claraco, R. González, A. Sáez-Pérez. International Conference on Mechanical Models in Structural Engineering, 23-25 October 2019, Alicante, Spain.



- Gestión económica del enriquecimiento carbónico de un invernadero de tomate con diferentes fuentes de CO<sub>2</sub>. Rodríguez, F., J. Ramos-Teodoro, M. Berenguel, P. Lorenzo. Aportando valor al CO<sub>2</sub>, 1-2 October, 2019, Technology Lab de Repsol, Móstoles, Madrid, Spain.
- Pilot scale hybrid cooling system for optimizing the water consumption at CSP plants. Palenzuela, P., L. roca, G. García-Navajas, J.. Liria, A. Caron, A. Faisal, P. Kumar. International Conference on Concentrating Solar Power and Chemical Energy Systems, 2019, Daegu, Korea, 01-04 October, 2019.
- Control and optimal management of a heliostat field for solar power tower systems. Cruz, N.C., J.D. Álvarez, J. López-Redondo, M. Berenguel, P. Ortigosa, R. Klempous. IEEE 23rd International Conference on Intelligent Engineering Systems, Godollo, Hungary, 25-27 April, 2019.
- Modelado de producción, consumo y almacenamiento de recursos heterogéneos de un distrito agroindustrial con energías renovables. Ramos-Teodoro, J., F. Rodríguez, M.M. Castilla, M. Berenguel. X Congreso Ibérico de Agroingeniería, 3-6 Septiembre 2019. Escuela Politécnica Superior, Campus Huesca de la Universidad de Zaragoza, Huesca, España.
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- Jornada "Transición del sector eléctrico español hacia un mercado mayoritariamente renovable en 2030". 16/05/2019. Universidad de Almería, España.
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- HIGH-PERFORMANCE COMPUTING FOR OPTIMIZING THE DESIGN AND CONTROL OF SOLAR POWER TOWER PLANTS. Nicolás Calvo Cruz. Universidad de Almería 24/10/2019, sobresaliente cum laude.
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Hired researcher  
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**Pablo Otálora Berenguel**



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Arizona State University, USA

**Dr. Francisco Javier Cabrera Corral**



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**Dr. Ricardo Silva**



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## 2.4.9 Ongoing projects in 2019

### 2.4.9.1 Internet of Food and Farm IoF2020

**Participants:**

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72 International partners

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**Source of funding:**

H2020 Call for proposals: H2020-IOT-2016-2017 (H2020-IOT-2016). Proposal: 731884 — IoF2020. IoT-01-2016 — Large Scale Pilots. Innovation action.

**Duration:**

January 2017 – December 2020

**Status:**

Under development

**Abstract:**

The European Project Internet of Food & Farm 2020 (IoF2020, Internet of Food and Farming) aims to investigate and promote the large-scale implementation of the Internet of Things (IoT, Internet of Things) in the agricultural and food sector European. With a budget of 30 million euros, co-financed by the European Union, the project has the potential to introduce a paradigm shift in this area, drastically improving productivity and sustainability. The added value of networks and smart websites of interconnected objects, sensitive to the context and that can be identified, equipped with sensors and remotely controlled in the agri-food sector, will be demonstrated. The project has begun on January 1, 2017 and will last for four years. IoF2020: 5 trials, 19 case studies: IoT has the potential to be a true transforming element of agriculture. Recent initiatives have demonstrated the sector's interest in taking advantage of the opportunities offered by Information and Communication Technologies (ICT), networks and data-oriented technologies. However, the current available applications remain fragmentary and are used mainly by a small group of innovative users.

The IoF2020 project will offer solutions and facilitate the large-scale adoption of IoT, addressing the organizational and technological challenges facing the European agricultural and food sector. IoT can be used for example to optimize the quality of meat in the European Union (EU) while minimizing the possibilities of fraud through an increase in transparency and traceability. Another example: in global figures, the EU wine industry has the highest proportion of EU agricultural income. To stay competitive internationally, both

conventional and organic viticulture, the technologies associated with the IoT can be used to obtain a higher quality environmental sustainability, together with the reduction of production costs. The project, which focuses on 19 case studies spread across Europe, offers solutions to 5 agri-food areas: herbaceous agricultural crops, dairy products, meat, vegetables and fruits and takes into account their own needs and obstacles.

IoF2020 involves all the actors in the food chain: from farmers, cooperatives, suppliers of equipment and logistics, food processing companies, to consumer organizations and including ICT developers.

The project will develop innovative IoT solutions encouraging co-creation in iterative improvement cycles focused on user acceptability and business models to improve technology and market acceptance. End users are the core of the IoF2020 model and will participate in the evaluation and improvement of the technologies at stake, ensuring that they meet the requirements and expectations of the sector.

#### 2.4.9.2. SOLWARIS - Solving Water Issues for CSP Plants.

**Participants:**

Centro de Investigaciones en Energía Solar CIESOL (España), centro mixto UAL-CIEMAT  
Plataforma Solar de Almería  
Research group "Automatic Control, Robotics & Mechatronics". Universidad de Almería (TEP 197)

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**Source of funding:**

Horizon 2020 Framework Programme. Grant Agreement number: 792103.

**Duration:**

30/09/2019-30/04/2022.

**Status:**

Under development

**Abstract:**

SOLWARIS is a project funded by the European Union's Horizon 2020 research and innovation programme, coordinated by TSK ELECTRÓNICA Y ELECTRICIDAD SA, Spain.

The objective of SOLWARIS is to significantly reduce the water used by CSP plants. The project aims to demonstrate the efficiency of innovations in solar field cleaning, power block cooling, water recycling system and plant operation strategy.

#### 2.4.9.3 – PARTICIPATION - Sustainable Algae Biorefinery for Agriculture and Aquaculture SABANA

**Participants:**

CIESOL-Universidad de Almería,

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**Source of funding:**

Horizon 2020. European Union's Horizon 2020 Research and Innovation Program under Grant Agreement No. 727874 SABANA.

**Duration:**

01/12/2016 – 30/11/2020

**State:**

Under development

**Summary:**

SABANA aims to develop a large-scale integrated biorefinery based on microalgae for the production of biostimulants, biopesticides and feed additives, in addition to biofertilizers and aquafeeds, using only marine water and wastewater nutrients (wastewater, central water and pig manure). The objective is to achieve a zero waste process in a demonstration of up to 5 ha, both environmentally and economically sustainable. A

Demonstration Center of this biorefinery will be operated to demonstrate the technology, evaluate the operating characteristics of the system, evaluate the environmental impacts and collaborate with the potential customers for its use. The Modeling and Control unit collaborates in the design of data acquisition and control systems.

#### 2.4.9.4 – PARTICIPATION – SFERA 3 Solar Facilities for the European Research Area

**Participants:**

CIESOL-Universidad de Almería,

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**Sources of funding:**

European Commission-DG RTD Horizon 2020 Framework Programme H2020-INFRAIA-2018-2020 (H2020-INFRAIA-2018-1)

**Duration:**

01/01/2019 – 31/12/2022

**Status:**

Under development

**Abstract:**

SFERA III is a Horizon 2020 project funded under the Research Infrastructure Programme. The consortium is coordinated by CIEMAT-PSA and is made up of a total of 15 partners from 9 EU member countries. The project runs from January 2019 to December 2022 and will receive a grant of 9,103 million euros from the EC over these 4 years. The overall objective of this project is to continue the work done over the last 8 years in the SFERA 1 and SFERA 2 projects and to strengthen the sustainability of European advanced concentrating solar energy research infrastructure activities.

These activities will comprise: (i) networking activities to further develop cooperation between research infrastructures, the scientific community, industries and other stakeholders; (ii) transnational access activities aimed at providing all European researchers, both from academia and industry, with access to unique scientific and technological solar research infrastructures; and (iii) joint research activities with the sole objective of improving the integrated services provided by the infrastructure.

#### 2.4.9.5 Micro-grids for solar self-supply of isolated productive environments MICROPROD-SOLAR

**Participants:**

Centro de Investigaciones en Energía Solar CIESOL (España), centro mixto UAL-CIEMAT  
Centro de Tecnologías para Energía Solar CSET (Chile) centro mixto Fundación Fraunhofer  
Inventive Power (México), empresa fabricante de captadores solares cilindroparabólicos para aplicaciones industriales

**Contacts:**

Manuel Pérez (mperez@ual.es)

**Funding source:**

2018 ERANET LAC. P918PTE0258

**Duration:**

01/01/2019 – 31/12/2021

**State:**

Under development

**Summary:**

The objective of this project is to develop a set of analysis and decision-making tools that justify and favor the implementation of distributed energy micro-grids for the self-supply of isolated productive enclaves in Ibero-America. The type of supply to be considered will include both electricity and process heat and industrial cold, in both cases of solar origin, without prejudice to other renewable contributions in those cases where the available resource permits. This objective will be developed through an initial intensification in the following productive activities, selected based on the experience and capabilities of the consortium members: 1) the energy self-sufficiency of small industries or communities dedicated to the elaboration of

wine and spirits, 2 ) cattle farms dedicated to the treatment and conservation of milk and its derivatives and 3) canning industries traditional crops (asparagus, beans, ...).

#### 2.4.9.6 PROBIOREN Control and optimization for the biomass production from microalgae as renewable energy source

**Participants:**

Research group "Automatic Control, Robotics & Mechatronics". University of Almería (TEP 197)  
Department of Informatics and Automatic Control – UNED -Madrid

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**Source of funding:**

Ministerio de Economía y Competitividad. Plan Nacional 2010. (DPI2014-55932-C2-1-R)

**Duration:**

01/01/2015 – 30/06/2019

**Status:**

Under development

**Abstract:**

The project deals with the application of modelling and control approaches for the optimal biomass/biofuel production in raceway photobiorreactors to be competitive in the energy sector market. The main goal consists in reaching a near optimal environment for microalgae to grow, multiply, and produce biomass, together with an assessment of the balance between the requested energy to maintain an optimal microalgae growth, the injected CO<sub>2</sub>, and the recovered costs through biomass-biofuel. According to the nonlinear dynamics, and the complex and hierarchical nature of these processes, different control approaches will be evaluated to reach the proposed objectives. Event-based, reset, and fractional control approaches together with hierarchical model predictive control algorithms will be used to achieve an efficient microalgae biomass production in raceway photobiorreactors. Moreover, nonlinear models, estimators and predictors of the main photobiorreactor variables will be developed.

**Objectives**

The main objectives of the coordinated project are:

1. Development of a modelling framework to obtain nonlinear dynamical models for microalgal biomass production based on raceway photobiorreactors to be used for renewable energy purposes. The resulting models will be used for reactor design and control design purposes.
2. Development of low-level and high-level control strategies (mainly event-based, reset fractional, and model predictive control algorithms) for the optimal biomass production in raceway photobiorreactors looking for reducing costs and being competitive in the energy sector market, and contributing at the same time in the mitigation of the environment pollution.
3. Implementation and validation of the developed modelling and control strategies in different experimental plants with clear industrial relevance. Concretely, two industrial raceway photobiorreactors will be mainly considered for this purpose.

This proposal constitutes the continuation of a new research line on biomass production from microalgae in photobiorreactors, that was opened for the applicant control engineering groups in a previous research project focused on tubular photobiorreactors. The applicant groups have had a strong collaboration during the last years through research projects and joint publications. The team has a remarkable experience in control systems backed by many papers published in some of the most cited scientific journals. On the other hand, the multidisciplinary nature of the group is complemented with researchers with strong background in microalgal biomass production by photobiorreactors. Moreover, the international collaboration is fostered in the project because three relevant researchers from two European universities (Swedish and Italian) and one researcher from Arizona State University (USA) belonging to the control engineering field take part in the proposal. On the other hand, the project topic belongs to the strategic research lines of the European Union



and the National Research Plan, within the challenge on Secure, Efficient and Clean Energy and thus being a hot research topic. Hence, the fulfilment of the proposed objectives would be a significant contribution in this emerging renewable energy field and it would have a real impact in the energy market competitiveness of this type of processes. Consequently this proposal has risen the interest of different companies and research centers such as Acciona, AlgaEnergy or CIESOL.

#### **2.4.9.7 CALRESI – Modeling and control of the combined process of microalgae production and wastewater treatment with industrial reactors**

**Participants:**

Grupo de Inv. “Automática, Robótica y Mecatrónica”. Universidad de Almería (TEP 197)  
Departamento de Informática y Automática de la UNED

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**Source of funding:**

Ministry of Economy, Industry and Competitiveness DPI2017-84259-C2-1-R)

**Duration:**

01/01/2018 – 31/12/2020

**Status:**

Under development

**Abstract:**

The project deals with the analysis, study and application of modeling and control strategies for the optimization of the wastewater treatment process and the production of microalgae biomass in large-scale industrial photobioreactors. The main objective is to achieve the optimal working conditions that allow an efficient synergy of the combined process of the optimal growth of microalgae and the treatment of wastewater, trying to reach an adequate balance between the energy required for said process, the injection of CO<sub>2</sub> for the maximization of microalgae production and the recovery of costs through the resulting derived products. Microalgae use nutrients derived from wastewater (carbon, nitrogen and phosphorus), thus avoiding the use of chemical fertilizers. The adequate combination of microalgae with wastewater will allow achieving an adequate energy balance for this type of process and in the same way contributing to mitigate the emission of gases into the environment. Note that the presence of microalgae, bacteria and organic matter makes this type of systems have highly complex dynamics and a strongly non-linear character.

**Goals:**

1. Proposal and development of modeling, estimation and identification strategies for the combined process of microalgae production and wastewater treatment in raceway reactors.
2. Development and proposal of different control strategies for the efficient production of biomass and wastewater treatment in order to contribute to the reduction of costs and reduction of environmental impact.
3. Implementation and validation of the modeling and control strategies developed in two large-scale industrial raceway photobioreactors.

#### **2.4.9.8 CHROMAE – Control and Optimal Management of Heterogeneous Resources in Agroindustrial production districts integrating renewable Energies**

**Participants:**

Grupo de Inv. “Automática, Robótica y Mecatrónica”. Universidad de Almería (TEP 197)

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**Source of funding:**

Ministry of Economy, Industry and Competitiveness (DPI2017-85007-R)

**Duration:**

January 2018 – December 2020

**Status:**

Under development

**Abstract:**

Currently there is a growing concern about the overexploitation of energy resources and non-renewable materials, associated with climate change and the need to maintain the modern economy and the quality of life. This proposal aims to contribute, from the discipline of automatic control, to the optimal management of these resources in a way that ensures equitable access, efficiency and sustainability in the fields of water, energy and others using renewable energy. Specifically, the project addresses the problem of optimal resource management in agroindustrial districts, consisting of agricultural holdings, processing companies and supply of inputs located in a specific territory. All these elements have different industrial objectives, therefore they present different needs of heterogeneous resources, both energy (electricity and heat / cold) and materials (water and CO<sub>2</sub>). In this framework of collaboration, characterized by the heterogeneity in demand, it is necessary to conveniently manage the efficient use of resources in each of the systems, and to coordinate the flow among the elements of the district, especially if renewable energies are used. , establishing as a premise that the result of optimal management produces an environmental impact as small as possible. Taking into account these considerations, the main objectives of this proposal are:

- Characterization and modeling of the flows of resources and interrelations between the elements of the district that determine the productive activity, whether with the role of consumer, producer or warehouse thereof, based on the paradigm of distributed and multi-generation multi-generation systems. Energy. A simulation environment of consumption and production of heterogeneous resources for agri-food districts is proposed as a priority result of the project (although it can be easily extrapolated to any other) to analyze specific cases, test new management approaches and make decisions that optimize their use.
- Development of control strategies for the descriptive variables of operation of the elements of the district so that they can meet their objectives by meeting certain technical specifications, but also minimizing the use of the resources necessary for this, mainly using predictive control techniques.
- Development of control strategies and comprehensive and optimal management of heterogeneous resources necessary for the operation of the elements that make up an agro-industrial district using control techniques (centralized and / or distributed predictive, optimal controllers or controllers based on rules, among others) that consider economic and environmental aspects as well as the efficient use thereof.

The fulfillment of these objectives represents a significant contribution with real impact in this kind of processes, as shown by the collaboration in the project of Institutions such as the Cajamar Foundation and the IFAPA and the interest that has awakened in different companies interested in the results. which are expected to be applicable in the medium term. The proposal is a natural continuation of previous project activities, in which considerable experience in the control of energy systems was acquired, with numerous articles published in prestigious journals and relations with international research groups.

**Goals:**

The main objective of this proposal is the development of integrated management strategies, coordinated and optimal heterogeneous resources such as energy and materials, necessary for the operation of the elements that make up an agro-industrial district using automatic control techniques that consider both economic and environmental aspects as the efficient use of them.

#### 2.4.9.9 CARBON4GREEN Optimization of integral heating system and carbon enrichment in greenhouses

**Participants:**

CIESOL-Universidad de Almería,

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**Sources of funding:**

Proyectos de investigación orientados a los retos de la Sociedad Andaluza. Programa Operativo FEDER Andalucía 2014-2020. Convocatoria 2018 de Proyectos I+D+i en el Marco del Programa Operativo FEDER-Andalucía 2014-2020 (resolución de 23 de marzo de 2018, del Rector de la Universidad de Almería, BOJA nº 59 de 26 de marzo de 2018). Referencia UAL18-TEP-A055-B.

**Duration:**

01/10/2019-30/09/2021

**Status:**

Under development

**Summary:**

The project objective is the development, optimization, evaluation and demonstration under real conditions, of a previously patented process of heating and carbon enrichment in greenhouses. Using the plant residues produced in the production of vegetables in these greenhouses. Fundamental aspects are addressed such as:

1. The optimisation of operating conditions and absorbent materials for greater process efficiency.
2. The development of reference frameworks for the modelling, control and monitoring of CO<sub>2</sub> storage and enrichment processes, addressing the problem of interoperability and integration with already installed commercial systems.

#### 2.4.9.10 Open and scalable system for monitoring, efficient energy management and comfort control of the unique strategic CIESOL building

**Participants:**

CIESOL-Universidad de Almería,

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**Sources of funding:**

Convocatoria de incentivos a los agentes del sistema andaluz de conocimiento, ayudas a infraestructuras y equipamientos de I+D+i (orden de 7 de abril de 2017, convocatoria 2017). Referencia proyecto: 5447-20 (153.320 €).

**Duration:**

Pending start (01/2020-12/2021)

**Status:**

Granted

**Summary:**

The aim of this infrastructure aid is to provide the CIESOL Joint Centre with a new monitoring and control system incorporating the latest technologies in data acquisition, IoT, monitoring, etc.

#### 2.4.9.11 Sustainable, Autonomous, Connected and Open Intensive Farming System (AgroConnect).

**Participants:**

CIESOL-Universidad de Almería,

**Contacts:**

Manuel Berenguel (beren@ual.es)

**Sources of funding:**

Ayudas para la adquisición de equipamiento científico-técnico del subprograma estatal de infraestructuras de investigación y equipamiento científico-técnico (Plan Estatal I+D+i 2017-2020), convocatoria 2019. Centro Mixto de Investigación en Energía Solar UAL-CIEMAT (CIESOL). Referencia proyecto: EQC2019-006658-P (308.850 €).

**Duration:**

Pending start (01/2020-12/2021)

**Status:**

Granted

**Summary:**

The aim of this infrastructure aid is to acquire infrastructure that will enable an agricultural production system to be set up with water and energy management under the paradigm of the circular economy. It incorporates two desalination plants supported by solar energy, a greenhouse and photobioreactors. It is a further step towards the creation of a centre of competence in water and energy.

**2.4.10 Participation in networks during 2019****Thematic Network Automática ES**

## Participants:

Research group "Automatic Control, Robotics & Mechatronics". Universidad de Almería (TEP 197)  
14 Universidades Españolas

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## Sources of Funding:

Dynamisation actions "Research Networks". Ministry of Science, Innovation and Universities. RED2018-102688-T. IP. Carlos Balaguer Bernaldo de Quirós (UC3M)

## Duration:

01/01/2019-31/12/2021

## Status:

Under development

**Thematic Network in Control Engineering**

## Participants:

Research group "Automatic Control, Robotics & Mechatronics". Universidad de Almería (TEP 197)  
10 Spanish Universities

## Contacts:

José Luis Guzmán (joseluis.guzman@ual.es)

## Source of funding:

Dynamisation Actions "Networks of Excellence". Ministry of Economy, Industry and Competitiveness. DPI2017-90823-REDT. **IP Ramón Vilanova i Arbós (UAB)**

## Duration:

01/01/2017-31/12/2019

## Status:

Under development

**Thematic Network on Robotics**

## Participants:

Research group "Automatic Control, Robotics & Mechatronics". Universidad de Almería (TEP 197)  
12 Spanish Universities

## Contacts:

Antonio Giménez (agimfer@ual.es)

## Sources of funding:

Dynamisation actions "Research Networks". Ministry of Science, Innovation and Universities. DPI2017-90853-REDT. IP. Miguel Ángel Salichs Sánchez-Caballero.

## Duration:

01/07/2018-30/06/2020

## Status:

Under development

**Operating groups**

- Go Invernconec: From the crop to the final consumer.  
[http://www.coexphal.es/wp-content/uploads/2018/10/GOINVERCONEC\\_Cartel.pdf](http://www.coexphal.es/wp-content/uploads/2018/10/GOINVERCONEC_Cartel.pdf)

- ES-Agri – Sustainable energy for protected agriculture.  
<http://www.coexphal.es/grupos-operativos-autonomicos/>
- A4P. Agrodota 4 Prediction.  
<http://www.coexphal.es/grupos-operativos-autonomicos/>
- Artificial Intelligence and Big Data to improve the profitability of the Andalusian farmer.  
<http://unicagroup.es/bigdata/>

#### 2.4.11 Transfer and Complementary Activities

##### Contracts with companies

Advice on the development of models for the design of photovoltaic greenhouses based on external conditions within the framework of the European project SUN4GREEN GA nr. 756006. RUFEP A TECNOAGRO S.L. Ref. 001388. IP. Jorge Antonio Sánchez Molina. 01/11/2018-31/12/2019. Number of researchers: 6. AGRONAUTA, automation of agronomic work in intensive agricultural operations through robotics Agricultural News, S.A. IP. Francisco Rodríguez Díaz. 19/06/2017-18/12/2018.

##### Agreement with University of Brescia

The agreement includes co-tutela of Thesis, exchange of Erasmus students, double degree in Mechatronics for industrial automation, etc. As a result of the agreement, Prof. Manuel Berenguel has co-directed, together with Prof. Antonio Visioli, the thesis of Manuel Beschi and Prof. José Luis Guzmán is co-directing with Prof. Visioli the doctoral thesis of Enrique Rodríguez Miranda. The group of the University of Brescia made a stay (Domenico Gorni and Antonio Visioli) in the scope of the Sfera 2 project, dedicated to the simplified modeling of rooms in buildings and another room (Luca Merigo) dedicated to the development of event-based control algorithms .

##### Collaboration in ERASMUS+ KA 107 Programme

###### Participants:

- Modeling and Automatic Control Unit
- International Relationship Office of UAL

###### Contacts:

- Manuel Pérez García (mperez@ual.es)
- María del Mar Sánchez (sri@ual.es)

###### Objectives:

The Erasmus + KA 107 program is a student and teacher exchange program aimed at collaborating with partner countries. In it, stays of professors and students of master's and doctorate that include research activities are admitted. Throughout the year 2017, collaborations have been carried out within the framework of this program with the International University of Rabat and the University of the Republic of Uruguay.

##### Collaboration with the STUDY ABROAD Programme

###### Participants:

- Modeling and Automatic Control Unit
- International Relationship Office of UAL

###### Contacts:

- Manuel Pérez García (mperez@ual.es)
- María del Mar Sánchez (sri@ual.es)

Objectives:

The summer program STUDY ABROAD of the UAL offers a complete package that includes tuition and accommodation and a set of cultural services to international students who offer specialized courses of 80 hours to be taught in the month of July organized by departments and research centers of the University of Almería. The Modeling and Automatic Control Unit has coordinated the course called "Energy Transfer Processes in Solar Thermal Installations. Modeling and applications to design".

**Collaboration with IMDEA Energy**Participants:

- Modeling and Automatic Control Unit

Contacts:

- Luis José Yebra Muñoz (luis.yebra@psa.es)

Objectives

Collaboration in the Sun2Liquid european project from IMDEA Energía, in modelling and control of a heliostat field aimed at solar fuel production in a chemical reactor. The modelling works are focused mainly in the mechanical modelling of a heliostat different from those usually operated at PSA. This heliostat type need a detailed model for its operation and its experimental calibration to accomplish the strict requested aiming point operation specifications. Activities not performed so far in the thermo-fluid modelling domain are being afforded in this one, as the real time model based control of heliostats in the operation of the facility.

**Collaboration in PIMA Programme**Participants:

- Automatic Modeling and Control Unit
- International Relations Service of the University of Almería

Contacts:

- Manuel Pérez García (mperez@ual.es)

Objectives:

Exchange of students from the UAL and the Federal University of Santa Catarina (Brazil).

**2.4.12 Dissemination activities**

- Qualifying Tournament of the FIRST Lego League
- III Conference on Automation, Robotics and Mechatronics
- Challenge Robotics Club of the University of Almería
- Night of the Researchers, Almería
- Week of Science, Almería
- Robotics Club
- Window of Science
- European Robotics Week
- Girls Technology Campus
- Computer Week
- Visit your University
- Classroom Exhibition Company La Salle 2018
- Scientific News in Almería

### 2.4.13 Project's applications in 2019

- SAFEMPC: Safe and Reliable Energy Management of Microgrids integrating Demand Response Techniques and Stochastic Model Predictive Control – R+D+I Projects Challenges Research. Topic: Industrial production, civil engineering and engineering for society. Proposal acronym: SAFEMPC. IP: Carlos Bordons (US, ES), Ascensión Zafra (US, ES).
- Sustainable Mediterranean Greenhouse for smart and safe horticulture (Greenhouse 2.0) Convocatoria PRIMA 2019. IP Francisco Rodríguez.
- Next Generation Training on Intelligent Greenhouses (NGHTRA). Convocatoria Erasmus +. IP Francisco Rodríguez.
- Development of a greenhouse cluster in the agricultural area of the region of Imereti (Georgia) led by the Group Develops to the call Agricultural Project's Management Agency of Georgia Government. IP Francisco Rodríguez
- Simulator for the management and optimization of endogenous resources (water and energy) in farms (AGRO-SIMULATOR). PNDR call from the Ministry of Agriculture, Fisheries and Food. IP Francisco Rodríguez.
- Greenhouse dehumidifier-air conditioner. Regional call of the Generalitat Valenciana together with the University Miguel Hernández. IP Francisco Rodríguez.
- IoT System for Climate and Irrigation Telemanagement in Intensive Agricultural Operations. Call of the Andalusian Government aimed at boosting the relations of the educational centres dependent on the Ministry of Education and Sport with the productive sectors, in the Autonomous Community of Andalusia, modality "Strategic Environments Centres-Businesses". IP Francisco Rodríguez.
- Automation and ICTs in Agriculture Research Network (ATICA) together with 11 other Universities, 2019 IP Francisco Rodríguez
- Collaborative robot for intelligent transport inside greenhouses with support in AGRICOBOT IoT (AGRICultural COLlaborative roBot inside the IOT). Call: PROGRAMME OF AID FOR R+D+i, IN THE REGIME OF COMPETITIVE COMPETITION, IN THE AREA OF THE ANDALUSIAN PLAN FOR RESEARCH, DEVELOPMENT AND INNOVATION (PAIDI 2020) (Order of 7 April 2017, BOJA no. 71, of 17 April 2017). IP José Carlos Moreno. Not granted.
- MULTISOL Multifunctional solar thermal concentrator. Project of Excellence of the Junta de Andalucía. IP José Domingo Álvarez, Manuel Pérez. Not granted.
- Empowering African Food and Nutrition Systems (EAF) Topic: LC-SFS-34-2019, Food System Africa. IP Jorge Antonio Sánchez Molina.
- GO INVERCONEC - CONNECTED GREENHOUSE. From the cultivation to the final consumer. Application for support for the implementation of innovation projects by task forces. Submeasure 16.2 of the PNDR 2014-2020 co-financed by the EAFRD. IP Jorge Antonio Sánchez Molina.
- Presentation of a project proposal to the call "R+D+i Projects, Research Challenges" of the National Plan of the Ministry of Science, Innovation and Universities for the year 2019. The proposal was coordinated, with the participation of the Madrid Energy Institute (IMDEA ENERGIA), the CENER Foundation and CIEMAT (Plataforma Solar de Almería centre). The title of the coordinated project is "Improvement in optical efficiency of high concentration solar systems (OPHICAST)". Our objective in the project is to research advanced model-based control techniques for the IMDEA ENERGY VHCST central receiver plant and TCP-100 of the PSA-CIEMAT. It is important to mention that, in addition to the researchers and technicians from the above-mentioned organizations, the University of Alcalá also participates in this project by contributing the dedication of three professors from the Department of Automation to the CIEMAT sub-project with the title: "ADVANCED AUTOMATIC MODELING AND CONTROL OF THE TCP-100 THERMOSOLAR PLANT". IP Luis José Yebra Muñoz.

### 2.3.14 Others

#### Final degree projects

- Aliaga Rodríguez, José Antonio. Kinematic and dynamic modeling of the ABB IRB140 robot for the implementation of control algorithms. End of Master's work. Master in Industrial Engineering. University of Almería. Director: José Luis Torres Moreno. Date of defense: 26/09/2019.

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- Aguilera López, Raul. Development of state estimators using the physical simulation library SIMBODY. End of degree work. Degree in Mechanical Engineering. University of Almeria. Directors: José Luis Blanco Claraco, Javier López Martínez. Date of defense: 12/12/2019.
  - Battles Sánchez, José Miguel. Design of a solar tracker for a 5kW photovoltaic installation. End of degree work. Degree in Mechanical Engineering. University of Almeria. Director: José Luis Torres Moreno. Date of defence: 21/06/2019.
  - Bretones Castillo, Laura. Design and programming of a robotic cell for polishing compact surfaces. End of Master's work. Master in Industrial Engineering. University of Almeria. Director: José Luis Guzmán Sánchez. Reading date: 25/09/2019. Bretones Ortiz, María Dolores. Control basado en reglas del confort térmico y la calidad de aire en un edificio bioclimático. Trabajo Fin de Grado. Grado en Ingeniería Electrónica Industrial. Universidad de Almería. Directors: José Domingo Álvarez Hervás, Manuel Berenguel Soria. Fecha de defensa: 24/09/2019.
  - Cabrera Merlos, Juan José. Diseño y fabricación de protecciones y accesorios de bajo coste para sensores agrometeorológicos. Trabajo Fin de Grado. Grado en Ingeniería Mecánica. Universidad de Almería. Directors: José Luis Torres Moreno, Jorge Antonio Sánchez Molina. Date of defense: 23/09/2019.
  - Cantos Alcántara, Gabriel José. Development of models to predict resource consumption in greenhouses. End of Master's work, Master in Solar Energy. University of Almeria. Directors: Francisco Rodríguez, Manuel Berenguel. Date of defense: 15/07/2019.
  - Caro López, José Ismael. Design of a system for monitoring the growth and transpiration of hydroponic crops in greenhouses with weight measurements. End of degree work. Degree in Mechanical Engineering. University of Almeria. Directors: José Luis Torres Moreno, Jorge Antonio Sánchez Molina. Date of defense: 21/06/2019.
  - Casas García, Francisco José. Design of a hydrofoil for windsurfing. End of degree work. Degree in Mechanical Engineering. University of Almeria. Director: Javier López Martínez. Date of defense: 30/01/2019.
  - Díaz Lozano, Beatriz. Development of interactive practice material for mechanism theory using Jupyter Notebook End of Grade Project. Degree in Mechanical Engineering. University of Almería. Directors: José Luis Blanco Claraco, José Luis Torres Moreno. Date of defense: 01/07/2019.
  - Di Salvatore , Marco. 2D vision systems for automated micro-manipulation: component sorting method End of Grade work. Degree in Industrial Electronic Engineering. University of Almeria. Double Degree in "Mechatronics for Industrial Automation" between University of Almeria (Spain) and University of Brescia (Italy). Director: Francisco De Asís Rodríguez Díaz, Giovanni Legnani. Date of defense: 26/06/2019.
  - Escamilla Sánchez, José Joaquín. Study of the potential use of concentrated solar power for process heat generation in an industry in the province of Almeria. End of degree work. Degree in Mechanical Engineering. University of Almeria. Director: Manuel Pérez García. Date of defense: 20/06/2019.
  - Fenoy Illacer, Pedro José. Development of a disposable device for monitoring the traceability of the cold chain in real time for agricultural goods. End of Master's work. Master in Industrial Engineering. University of Almeria. Director: Jorge Antonio Sánchez Molina. Date of defense: 09/07/2019.
  - García Chica, Antonio. Resizing and calculation of an ammonia extraction installation. End of degree work. Degree in Mechanical Engineering. University of Almeria. Director: Antonio Giménez Fernández. Date of defense: 16/12/2019.
  - García Mañas, Francisco. Development of condition estimators for tomato growth in greenhouses End of Master's work. Master in Industrial Engineering. University of Almeria. Directors: Manuel Berenguel Soria, Francisco Rodríguez Díaz. Date of defense: 25/09/2019.
  - Gil Vergel, Juan Diego. An overall optimal operating strategy for commercial membrane distillation plants. End of Master's work. Master's Degree in Industrial Engineering. University of Almeria, Director: José Domingo Álvarez Hervás. Date of defense: 20/12/2019.
  - Giménez Miralles, Adrián. Design of a graphic interface for the modelling and analysis of energy hubs. End of degree work. Degree in Industrial Electronic Engineering. University of Almeria. Directors: Francisco De Asís Rodríguez Díaz, Jerónimo Ramos Teodoro. Date of defense: 16/12/2019.
  - Gómez Fernández, Antonio. Sub-millisecond synchronization of sensor networks using GPS. End of degree work. Degree in Industrial Electronic Engineering. University of Almeria. Director: José Luis Blanco Claraco. Date of defense: 26/06/2019.



- González Cravio, Francisco Javier. Automation, improvement and modelling of the main fuel grinding of a cement factory. End of Master's work. Master in Industrial Engineering. University of Almeria. Directors: José Luis Guzmán Sánchez, José Carlos Moreno Úbeda. Date of defense: 17/12/2019.
- González Ruiz, Fátima. Virtual two-tank lab with Ejs. End of Grade Work. Degree in Industrial Electronic Engineering. University of Almeria. Directors: José Luis Guzmán Sánchez, María Del Mar Castilla Nieto. Date of defense: 16/12/2019.
- Heredia Vicente, Galo José. Automatic characterization and control of DC motors. Test bench implementation. End of degree work. Degree in Electrical Engineering. University of Almeria. Directors: Manuel Berenguel Soria, José Luis Torres Moreno. Date of defense: 26/06/2019.
- Huesa Amat, Ramón. Microcontroller-based Wireless Pedometer Prototype Design. End of Degree Work. Degree in Industrial Electronic Engineering. University of Almeria. Director: José Luis Blanco Claraco. Date of defense: 26/06/2019.
- Lachguer, Abdallah. Development of an interactive tool for the design of cascade control strategies End of Degree Work. Degree in Industrial Electronic Engineering. University of Almeria. Directors: José Luis Guzmán Sánchez, Manuel Berenguel Soria. Date of defense: 29/01/2019.
- Lara Morales, Daniel. Multi-function gym machine for people with reduced mobility. End of degree work. Degree in Mechanical Engineering. University of Almeria. Director: José Luis Torres Moreno. Date of defense: 19/09/2019.
- Leal Rueda, Marta. Analysis and Tuning of Cascade Control Schemes End of Degree Project. Degree in Industrial Electronic Engineering. University of Almeria. Directors: José Luis Guzmán Sánchez, Ángeles Hoyo Sánchez. Date of defense: 16/12/2019.
- Llena Velarde, Sara. Design of a ski binding with automatic gearbox. End of degree work. Degree in Mechanical Engineering. University of Almeria. Directors: José Luis Blanco Claraco, Javier López Martínez. Date of defense: 25/09/2019.
- Machado Mañas, Javier. Development and implementation of a SCADA system for the demonstrative installation of microalgae cultures of the SABANA project. End of Degree work. Degree in Industrial Electronic Engineering. University of Almeria. Directors: Francisco Rodríguez Díaz, Jorge Antonio Sánchez Molina. Date of defense: 28/01/2019.
- Mañas Álvarez, Francisco José. Modeling and multivariable control of the urban electric vehicle UAL-eCARM. End of Master's work. Master in Industrial Engineering. University of Almeria. Directors: José Luis Blanco Claraco, Francisco Rodríguez Díaz. Date of defense: 26/09/2019.
- Marchi, Letícia de Araújo. Modeling of an agro-food district under the paradigm of cyber-physical systems. End of Degree Project. Degree in Industrial Electronic Engineering. University of Almeria. Director: Francisco Rodríguez Díaz. Date of defense: 20/06/2019.
- Martín Gálvez, Moisés. Resonance prediction and test fundamentals in agricultural tyres. End of Grade work. Degree in Mechanical Engineering. University of Almeria. Director: Antonio Giménez Fernández. Date of defense: 04/02/2019.
- Martín Puertas, Antonio José. Modeling, control and creation of a didactic unit of the Temperature Control Lab system. End of Grade work. Degree in Industrial Electronic Engineering. University of Almeria. Director: José Luis Guzmán Sánchez. Date of defense: 16/12/2019.
- Martínez Castro, Francisco. Resonator control of a parabolic trough concentrator End of Grade work. Degree in Industrial Electronic Engineering. University of Almeria. Directors: José Domingo Alvarez Hervás, Manuel Berenguel Soria. Date of defense: 16/12/2019.
- Martínez González, Juan José. Implementation of biorefinery and model calibration of a raceway photobioreactor. End of degree work. Degree in Industrial Electronic Engineering. University of Almeria. Directors: José Luis Guzmán Sánchez, Francisco De Asís Rodríguez Díaz. Date of defense: 20/09/2019.
- Martínez Valdívía, Pedro Jose Moises. Implementation and development of a monitoring system for the photo-Fenton process. End of degree work. Degree in Industrial Electronic Engineering. University of Almeria. Directors: José Luis Guzmán Sánchez, José Luis Casas López. Date of defense: 13/12/2019.
- Martos Pérez, Ramón. Design of a motorcycle chassis for the Motostudent competition. End of Grade work. Degree in Mechanical Engineering. University of Almeria. Director: Javier López Martínez. Date of defense: 20/09/2019.

- Mínguez Pérez, Agustín Noé. Development of an automatic box palletizing system in a juice production line. End of degree work. Degree in Industrial Electronic Engineering. University of Almeria. Director: Francisco De Asís Rodríguez Díaz. Date of defense: 26/06/2019.
- Mínguez Rodríguez, Jorge. Assembly and control of a solar tracker prototype for the optimization of the battery charge. End of degree work. Degree in Industrial Electronic Engineering. University of Almeria. Directors: José Carlos Moreno Úbeda, José Luis Guzmán Sánchez. Date of defense: 18/12/2019.
- Molina Martínez, Alberto. Condition monitoring applied to the Silestone production process. Final Master's work. Master in Advanced and Industrial Computing. University of Almeria. Director: José Luis Guzmán Sánchez. Date of defense:
- Nache Romo, Carlos. Techno-economic analysis of thermal storage configurations for central receiver solar thermal plants. End of Master's work. Master in Industrial Engineering. University of Almeria. Director: Manuel Pérez García. Date of defense: 27/02/2019.
- Otálora Berenguel, Pablo. Control of a salt recuperator in a hybrid solar thermal plant. End of degree work. Degree in Industrial Electronic Engineering. University of Almeria. Directors: José Luis Guzmán Sánchez, Lidia Roca Sobrino. Date of defense: 25/09/2019.
- Palacios Góngora, Inmaculada. Dynamic model with experimental adjustment of a solar collector system. End of degree work. Degree in Industrial Technologies Engineering. Carlos III University of Madrid. Directors: Alberto Sánchez González, Luis José Yebra Muñoz. Date of defense: 09/2019.
- Peralta Moreno, Gabriel. Integrated contact center management application. End of degree work. Degree in Mechanical Engineering. University of Almeria. Director: José Luis Torres Moreno. Date of defense: 26/06/2019.
- Poyatos Bakker, Aaron Raúl. Integration and characterization of the photovoltaic system in the UAL-eCARM vehicle. End of degree work. Degree in Mechanical Engineering. University of Almeria. Directors: José Luis Blanco Claraco, José Luis Torres Moreno. Date of defense: 30/09/2019.
- Ramírez Escobar, Miguel Ángel. Development of a remotely operated underwater vehicle (ROV) using OpenRov and 3D printing. End of Degree work. Degree in Industrial Electronic Engineering. University of Almeria. Directors: Francisco De Asís Rodríguez Díaz, Julián Manuel García Donaire. Date of defense: 28/01/2019.
- Ramón Urrutia, Miguel. Estimation of the state of tomato cultivation in greenhouses using artificial vision. End of Master's work. Master in Industrial Engineering. University of Almeria. Director: Manuel Berenguel Soria. Date of defense: 20/12/2019.
- Rodríguez Escudero, Eduardo. Enhancement design of a roll-up plastic-mesh greenhouse roof window. End of grade work. Degree in Mechanical Engineering. University of Almeria. Director: Javier López Martínez. Date of defense: 12/12/2019.
- Rodríguez Maldonado, Víctor José. Hybrid app for the monitoring and control of farms. End of degree work. Degree in Computer Engineering. University of Almeria. Directors: José Joaquín Cañadas Martínez, Jorge Antonio Sánchez Molina. Date of defense: 30/09/2019.
- Romero Coronel, Rodrigo. Calibration of tyre rolling machines. End of grade work. Degree in Mechanical Engineering. University of Almeria. Director: Antonio Giménez Fernández. Date of defense: 23/09/2019.
- Sáinz Cantero Paredes, José Antonio. Assembly and programming of a robotic orthosis for hand rehabilitation. End of degree work. Degree in Industrial Electrical Engineering. University of Almeria. Directors: José Carlos Moreno Úbeda, José Luis Guzmán Sánchez. Date of defense:
- Sánchez López, Ismael. Modeling and characterization of lithium batteries for the energy management of smart micro grids. End of degree work. Degree in Industrial Electrical Engineering. University of Almeria. Director: José Luis Torres Moreno. Date of defense: 18/12/2019.
- Sánchez Ruiz, José Alejandro. Design and analysis of a tilting agricultural trailer End of degree work. Degree in Mechanical Engineering. University of Almeria. Director: José Luis Torres Moreno. Date of defense: 20/06/2019.
- Serrano Rodríguez, Juan Miguel. Start up of a laboratory for learning and research in mobile robotics based in Duckietown. End of Grade work. Degree in Industrial Electronic Engineering. University of Almeria. Directors: José Carlos Moreno Ubeda, Francisco De Asís Rodríguez Díaz. Date of defense: 20/09/2019.

- Socías Morcillo, Juan José. Thermo-acoustic control laboratory with Rijke's tube. End of Grade work. Degree in Industrial Electronic Engineering. University of Almeria. Directors: José Domingo Alvarez Hervás, Manuel Berenguel Soria. Date of defense: 29/01/2019.
- Topa Gavilema, Alex Omar. Design and implementation of a fuzzy controller for a field of parabolic trough collectors End of Master's work, Master in Solar Energy. University of Almeria. Directors: Loreto Valenzuela, Manuel Berenguel. Date of defense: 23/09/2019.
- Torres Martínez, Sandra. Design and calculation of a scissor lift for vehicles End of degree work. Degree in Mechanical Engineering. University of Almeria. Director: José Luis Torres Moreno. Date of defense: 20/06/2019.
- Torres Zaguirre, José María. Design of a distributed, wireless and mobile acquisition system for measuring greenhouse irrigation parameters based on FIWARE-IoT technology. End of Master's work. Master in Advanced and Industrial Computing. University of Almeria. Directors: Jorge Antonio Sánchez Molina, Francisco Rodríguez Díaz. Date of defense: 24/09/2019.
- Varela Trinidad, Álvaro. Design of a solar thermal-photovoltaic solution in a building with almost no energy. Final Master's work, Master in Solar Energy. University of Almeria. Directors: Manuel Pérez, Diego César Alarcón. Date of defense: 15/07/2019.

#### **PhD Theses (under development)**

- Alamin, Yaser (supervisors José Domingo Álvarez, María del Mar Castilla, Antonio Ruano)
- Barceló Villalobos, Marta (supervisors Francisco Gabriel Acién, José Luis Guzmán).
- Carreño Zagarra, José (supervisors José Carlos Moreno, José Luis Guzmán).
- García Mañas, Francisco (supervisors Francisco Rodríguez, Manuel Berenguel).
- García Ruiz, Rubén Antonio (supervisors José Luis Blanco Claraco, Javier López Martínez).
- Gil Vergel, Juan Diego (supervisors Manuel Berenguel, Lidia Roca).
- Gómez Navarro, Francisco José (supervisors Luis José Yebra, Antonio Giménez).
- Hoyo Sánchez, Ángeles (supervisors José Luis Guzmán, José Carlos Moreno Úbeda).
- Márquez García, Francisco Manuel (supervisors Pedro Zufiría, Luis José Yebra)
- Montoya Ríos, Ana Paola (supervisors: Francisco Rodríguez Díaz, José Luis Guzmán Sánchez).
- Muñoz Rodríguez, Manuel (supervisors Jorge Antonio Sánchez-Molina, Manuel Torres).
- Otálora Berenguel, Pablo (supervisor José Luis Guzmán).
- Pataro, Igor (supervisors Manuel Berenguel, José Luis Guzmán).
- Ramos Teodoro, Jerónimo (supervisors Francisco Rodríguez, Manuel Berenguel).
- Ran, Liu (supervisors José Luis Guzmán, Li Ming).
- Rodríguez Miranda, Enrique (supervisors Antonio Visioli, José Luis Guzmán).
- Topa Gavilema, Alex Omar (supervisors José Domingo Álvarez, José Luis Torres).

#### **Attendance at Transfer and Dissemination Workshops**

- Jornadas Nacionales de Robotica 2019, Alicante (<http://jnr2019.ua.es/>)
- Jornadas Nacionales de Automática 2019, Ferrol (<https://www.jautomatica.es/2019/>)
- Semana de la Informática de la Universidad de Almería. 13-15/02/2019. Almería, España.
- Noche de los investigadores 2019 en la actividad "Automática, robótica y mecatrónica para todos" dentro del proyecto europeo denominado "Open researchers 2018/19" (Grant Agreement 818340), aprobado por la Comisión Europea en la convocatoria Marie Skłodowska-Curie Actions,
- Semana de la Ciencia 2019.
- Semana Europea de la Robótica 2019 (ERW2019). Coordinador y organizador Francisco Rodríguez.
- Concurso Desafío Club de Robótica 2018-2019 del "Programa de Actividades 2018-2019" de la UCC+i de la UAL.
- Taller "Programación básica de un robot humanoide", desarrollado en la III Feria Aula Empresa.

- Jornada "Transición del sector eléctrico español hacia un mercado mayoritariamente renovable en 2030". 16/05/2019. Universidad de Almería, España.
- Robótica submarina. Profesor: Pedro José Sanz Valero (Universidad Jaime I). Universidad de Almería, 26/05/2019.
- Optimal Control Problems and Pontryagin's Maximum Principle. Profesor: Joao Lemos (Instituto Superior Técnico de Lisboa, Portugal). Universidad de Almería, 6-7/6/2019.
- Advances in PID Control. Profesor: Tore Hagglund (Universidad de Lund, Suecia). Universidad de Almería, 22-23/10/2019.
- Control Predictivo Centralizado, Distribuido y Coalicional en sistemas ciberfísicos. Profesor: José María Maestre (Universidad de Sevilla). Universidad de Almería, 13-15/11/2019.
- Ciberseguridad en Industria 4.0. Profesor: Manuel Domínguez (Universidad de León). Universidad de Almería 20-21/11/2019.
- Vehículos Autónomos. Profesor: Arturo de la Escalera (Universidad Carlos III de Madrid). Universidad de Almería, 28-29/11/2019.
- Digitalización en Agricultura: Tecnologías, Aplicaciones y cadena de valor. 10-12/07/2019. Almería. España.
- XVII Simposio de Ingeniería de Control y V seminario de innovación docente en automática. 30/01/2019 – 01/02/2019. Sevilla. España
- Jornadas de Innovación docente y experiencias profesionales en la Universidad de Almería. 19/09/2019. Almería. España.
- Google Cloud Platform Education Grants en el entorno universitario. 17/12/2018 – 26/01/2019. Almería. España.
- Machine learning aplicado a la investigación: Análisis de datos y desarrollo de software. 12/11/2019 – 22/11/2019. Almería. España

#### Awards during 2019

- Manuel Berenguel Soria, appointed as "Honorary Visiting Professor" by the University of Brescia, Italy, 20 May 2019.
- CERTIFICATE Best Paper Award 2019 (3rd place) for the paper entitled "A Comparison of Energy Consumption Prediction Models based on Neural Networks of a Bioclimatic Building" - Energies. H.R. Khosravani, M. Castilla, M. Berenguel, A. Ruano and P.M. Ferreira. Date awarded: March 2019.
- Jesús Galdeano López and José Gabriel Martínez Hernández (tutors Manuel Berenguel Soria and José Luis Guzmán Sánchez). First prize in the National Control Engineering Competition awarded by the Spanish Committee for Automation in the XL edition of the Conference on Automation held in Lugo, Spain, September 2019.
- Álvaro Ramajo and Rubén González (tutors José Carlos Moreno and Antonio Giménez Fernández). Third place in the National Humanoid Robot Competition 2019, awarded by the Spanish Committee for Automation in the XL edition of the Conference on Automation held in Lugo, Spain, September 2019.
- Francisco Rodríguez Díaz. Award for Excellence in Teaching Trajectory - Docentia 2019 program. University of Almería.
- José Carlos Moreno Úbeda, Antonio Giménez Fernández. Award of Excellence in Multimodal Subjects for the subject "Robotics Applied to Rehabilitation" of the Master in Sciences of the Nervous System, awarded at the Conference on Teaching Innovation and Professional Experiences of the University of Almería.

#### Other scientific activities

- Luis José Yebra Muñoz. Editor of the journal Mathematical Problems in Engineering (Hindawi) (Q3), and reviewer of several modeling, control and energy journals (all at JCR).
- Manuel Berenguel Soria. Executive Director of the Revista Iberoamericana de Automática e Informática Industrial (RIAI), published by UPV and indexed in JCR (Q3) and Associate Editor of the journal Energies.
- José Luis Blanco Claraco. Associate Editor of the IEEE Robotics and Automation Letters, International Journal of Robotics Research



## 2.5 ACTIVITIES OF “SOLAR RESOURCE ASSESSMENT AND SOLAR COOLING”

### 2.5.1 Functional unit description

Solar Resource Assessment and Solar Cooling unit is composed of the members of the groups “Solar Energy Resources Assessment and Climatology (TEP165)” and “Interdisciplinary Group of Complex Fluids (FQM230)”. TEP 165 is a stable group since its creation in 1997 within the Andalusian Research Plan of Junta de Andalucía, being responsible since its founding Francisco Javier Batlles Garrido. The group has been considered on numerous occasions as an Excellence Group within the Andalusian Research Plan. It is composed of Ph.D. teachers from Applied Physics area and Computer Languages and Systems area, and three research fellows also Ph.D. FQM230 group was created in 1995, and its research lines are focused on the study of complex fluids. It is currently composed of seven Ph.D., all of them from the Applied Physics area, and it is directed by Manuel Servando Romero Cano.

### 2.5.2 Main research lines

The main research lines of the unit are the following:

- Evaluation and forecast of solar resource
- Tele detection
- Sky cameras
- Optimization of sky cameras
- Design and optimization of solar thermal cooling and heating systems
- Design and optimization of air-conditioning system coupled with shallow geothermal systems and ground-coupled heat exchanger
- Design and optimization of trigeneration systems
- Integration of the solar thermal and photovoltaic energy in the construction, warehouses or greenhouses
- Thermal energy storage through phase change materials (PCM)

### 2.5.3 Main researcher

**Francisco Javier Batlles Garrido** (Scopus Author 6602731047)

He received his physics degree and the Ph.D. from the University of Granada, Spain, in 1986 and 1995, respectively. He is a professor in the Department of Chemistry and Physics at the University of Almería, Almería, Spain. Since the beginning, he is the head of the research group “Solar Resource Assessment and Climatology” at the University of Almería. Member of the Scientific and Technological Evaluation Commission of Andalusia, within Andalusian Research Plan, from 2002 to 2005. International Evaluator of the National Accreditation Commission of Chile. His research interests include evaluation and forecast of the solar resource, design and optimization of the solar thermal cooling and heating systems. Professor Francisco Javier Batlles Garrido has been the Main Researcher in 7 projects of the Research National Plan, and 1 of the European Community. He has been the Main Researcher of 10 research projects funded by the Ministry of Science and Innovation and contracts with different companies such as GEMASOLAR 2006, S.L., Torresol

Energy O & M, S.A, Solar Millennium, German Aerospace Centre. He has authored and co-authored over 60 articles in international journals, about 150 conference papers, both national and international, as well as a National Book. He has directed 8 doctoral theses.

#### 2.5.4 Summary of the functional unit's activities carried out in CIESOL during 2019

We have studied during 2019 the thermal characterization of materials with liquid-solid phase transition (PCM). For this project, we have established several collaborations within the PCMSOL project: the group of Prof. Svetlana Ushak, from Universidad de Antofagasta -UA- (Chile), the group of Prof. Jacek Kasperski, from the Science and Technical University of Wroclaw -WUST- (Poland), the group of Prof. Marcos Luján, from Universidad Católica de Bolivia -UCB-, and the company Phase Change Technologies S.L. The collaboration with the group from the UA has focussed on the development of a methodology for the thermal characterization of materials used in the fabrication of PCM, used as thermal storage. With the group from the WUST, the cooperation allowed the design and installation of all components of the storage tanks based on PCM, as well as the calculation of refrigeration and heating demand of the building, considering the real facility. Finally, the cooperation with the group from the UCB implied extensive exchange of results intended to define and carry out the proper exergy analysis of the solar-assisted refrigeration system.

Continuing the allocation of the tanks for thermal storage in December'2018, the PCM containers were received in April, purchased from the English company PCMproducts. We selected a PCM for refrigeration, with a melting point of 10.8°C, and a different one for heating, with a melting temperature of 46°C. In each tank, 174 nodules with the PCM for refrigeration and 24 ones for heating were allocated (each nodule having a mass of 5 kg approximately). The tank was filled with ca. 1200 liters of additional water. The final installation of the tanks with the PCM nodules was carried out in May, and they were in full operation immediately afterwards. Figure 2.5.1. shows the general design with all connections and sensors, and two photographs showing the two tanks and the nodules in one of the tanks with the inlet pipe.

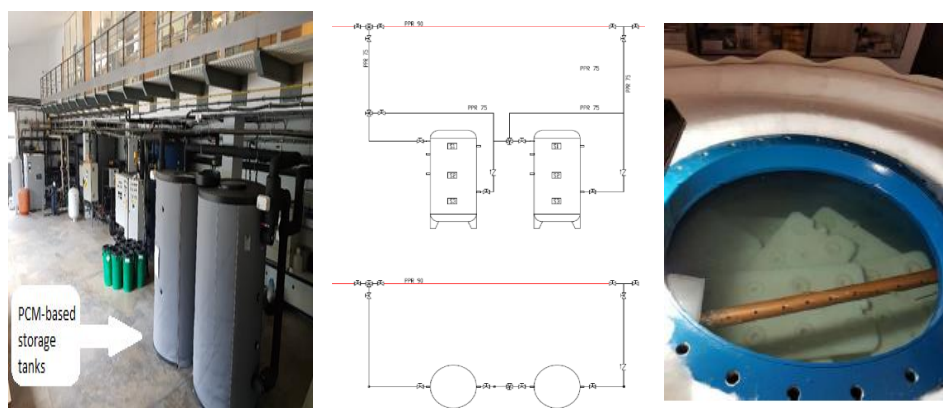


Fig. 2.5.1. General design of the storage tanks based on PCM and two photographs showing their location and the nodules.

During June, the overall facility was optimized after the two new tanks were in operation. The kinetics of charging and discharging the thermal energy were studied, and strategies were developed to allow an optimal storing of the thermal energy to recover and use it afterwards. Different strategies were proposed and tested in July and September, to measure the energy storing and the electricity consumption,

comparing the PCM tanks with water tanks, and with the case of conventional (compression) refrigeration without thermal storage. The results show that the new tanks can provide enough energy for more than three hours of refrigeration of the building when the tanks have been fully charged. With respect to electricity consumption, a reduction of more than 40% has been obtained, in comparison with conventional refrigeration without thermal storage.

Within the evaluation and forecast of solar resource research line the Solar Resource Assessment and Solar Cooling group has been actively collaborating with the University of Antofagasta and the University of Chile. In the aforementioned research stay, Professor Francisco Javier Battles Garrido collaborated on the production modelling of photovoltaic plants. Currently, a doctoral thesis is being co-directed between the University of Almería and the University of Antofagasta. The postdoctoral member Joaquín Alonso-Montesinos had an stay at University of Antofagasta, Chile, (September 2018) and is co-director of the PhD thesis of mexicain student. Also, a study about the characterization and influence of dust in the production of photovoltaic panels has been carried out. Moreover, during 2018 we presented the study related to the forecasting of power output from photovoltaic systems. The research done in this area resulted in one publication, which described the approach followed to set up a new forecasting method. A model to forecast (up to 3 hours ahead) the building integrated photovoltaic (BIPV) system's power output with the capacity of 9.324 kWp - installed on CIESOL's roof - was presented. The satellite images have been combined with Artificial Neural Networks (ANN) with the main goal to predict power output using the lowest number of input variables. In this work, real data of an existing operating BIPV system, combined with forecasted global incident radiation intensity from Second Generation Meteosat geostationary satellite images as well as the solar elevation angle and the solar azimuth, was used to derive an ANN system's model to predict the BIPV power output. In order to assess the accuracy of the neural model, the predicted results were compared statistically using five different parameters: the Root Mean Square Error, the normalized RMSE, Mean Bias Error, the Coefficient of Determination and the average absolute error. Results under all skies conditions demonstrate the accuracy ANN's predictions with an average absolute error for all skies conditions of less than 11 (W/m<sup>2</sup>) and practically null deviation, which can be considered very satisfactory. We also pointed out that future study in this field should focus on the use of the ANN to improve forecasts for the shortest horizons (0-1h ahead, where we obtained worst accuracy). The collaboration with the Antofagasta University has allowed to publish an article where a Multiple Linear Regression (MLR) model has been presented to determine the hourly PV production by using the Performance Ratio (PR) factor, according to different technologies: Cadmium Telluride (CdTe) and multicrystalline silicon (mc-Si). In this sense, data from several PV plants were studied in different Chile regions: San Pedro de Atacama and Antofagasta. With this study, it has been determined that the model can be extrapolated to different climatological emplacements, where generally, the root mean square error (RMSE) presents values lower than 16% in all cases, having the best result the CdTe technology. Moreover, another presented work analyses the influence of water vapor on the atmospheric transmission loss of solar radiation between heliostats and the receiver of solar power tower plants. To this purpose, an atmospheric transmission code (MODTRAN) is used to generate values of direct normal irradiance (DNI) reaching the mirror and the receiver under different geometries (including sun position, tower height, and mirror-to-receiver slant range) and atmospheric conditions related to water vapor and aerosols. These variables are then used as inputs to an artificial neural network (ANN), which is trained



to calculate the corresponding DNI attenuation. Two different aerosol scenarios are simulated: an ideal aerosol-free atmosphere, and a widely different one corresponding to semi-hazy conditions. The developed ANN model is then able to provide the DNI attenuation over a wide range of the input variables considered here, with root mean square differences of only 0.8%. The transmission loss due to water vapor is found to decrease with sun elevation. This is explained by the saturation effect in the incident irradiance at the mirror. The simplicity and accuracy of the algorithm are its great strengths, allowing its anticipated inclusion into the actual energy simulation codes currently used for solar tower plant design. We have also collaborated in the creation of a system to measure the atmospheric extinction. The aim of this work was to present the description of a novel measurement system for solar extinction at ground level based on two digital cameras and a Lambertian target. The first experimental results show that the system can measure solar extinction in the bandwidth 400-1000 nm with an accuracy of less than an absolute  $\pm 2\%$ . This measurement system is currently running on a daily basis at Plataforma Solar de Almería.

In addition, the design and execution of an experimental photovoltaic plant has been developed to characterize the losses that photovoltaic panels can suffer, in a Mediterranean coastal climate where there are precedents of frequent episodes of Saharan dust. To this end, different photovoltaic panels have been placed and different meteorological sensors have been installed which will be introduced into a common system of real time data acquisition. Specifically, 4 Atersa A-222P photovoltaic panels, 4 Shunts Shunts 15 A / 150 mV KL.0.5, 4 Atersa calibrated cells of 0-65 mV, a temperature and relative humidity sensor from Vaisala (HMP 60), a pressure sensor from Vaisala (model PTB110) and a dust sensor from Kipp & Zonen (Dust IQ) have been installed. In addition, in order to measure the temperature of each photovoltaic panel, 2 temperature sensors (pt100 at 4 wires) per photovoltaic module have been installed. All these devices have been installed, on a metallic structure manually adjustable in inclination and made of aluminum, on the roof of the Solar Energy Research Center (CIESOL) located in the northern part of the campus of the University of Almeria. All the sensors have been connected to a data acquisition server from the company Keysight, monitored by a computer server, making the data captures in an iterative way. Below are some images of the installation. Figure 2.5.2 shows the installations already completed.

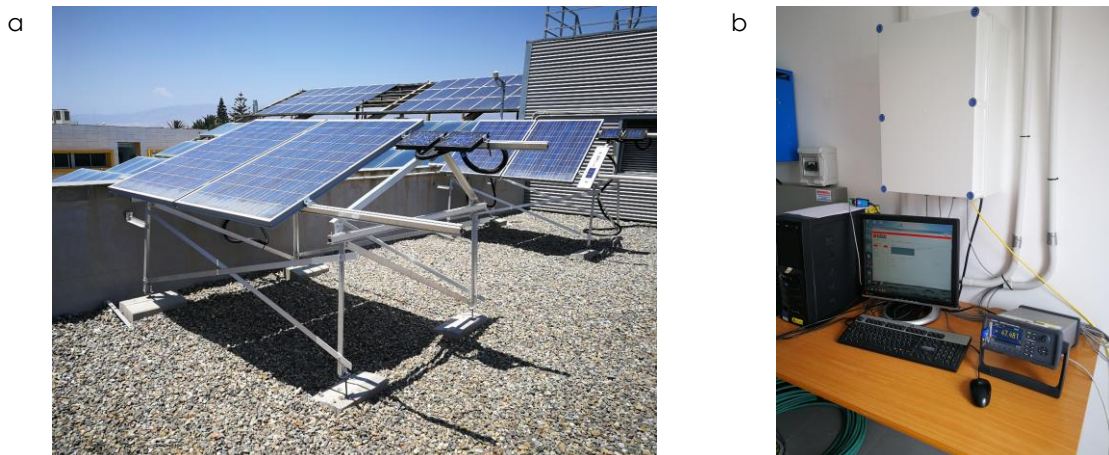


Fig. 2.5.2. a) Photovoltaic pilot plant with the sensors b) Photovoltaic pilot plant data acquisition system.

### 2.5.5 Collaboration with other functional units of CIESOL during 2019

During 2019 the Solar resource assessment and solar cooling functional unit collaborated with the Modeling and Control functional unit, led by Professor Manuel Berenguel Soria with the main goal to update the control of the presently installed in the CIESOL building solar-assisted air-conditioning system.

### 2.5.6 Human resources of the Functional Unit

#### Research stays of CIESOL researchers in other institutions:

- M Joaquín Alonso Montesinos. CDEA – Universidad de Antofagasta, Chile (02/10/2019 – 14/11/2019).

### 2.5.7 Scientific production

#### Papers

- Kinetics of freezing and melting of encapsulated phase change materials with effective convection: Experiments and simulations. M.S. Romero-Cano, A.M. Puertas, S. Rosiek, F.J. Batlles. *Numerical Heat Transfer, Part: Applications* 76, 909-924, 2019. <https://doi.org/10.1080/10407782.2019.1673649>
- Intra-hour energy potential forecasting in a central solar power plant receiver combining Meteosat images and atmospheric extinction. J. Alonso-Montesinos, R. Monterreal, J. Fernández-Reche, J. Ballestrín, E. Carra, J. Polo, J. Barbero, F.J. Batlles, G. López, R. Enrique, M. Martínez-Durbán, A. Marzo *Energy*, 188, 116034, 2019. <https://doi.org/10.1016/j.energy.2019.116034>
- Industrial food chamber cooling and power system integrated with renewable energy as an example of power grid sustainability improvement. S. Rosiek, M.S. Romero-Cano, A.M. Puertas, F.J. Batlles, *Renewable Energy* 138, 697-708, 2019. <https://doi.org/10.1016/j.renene.2019.02.010>
- Impact of DNI forecasting on CSP tower plant power production. J. Alonso-Montesinos, J. Polo, J. Ballestrín, F.J. Batlles, C. Portillo. *Renewable Energy*, 138, 368-377, 2019. <https://doi.org/10.1016/j.renene.2019.01.095>
- Simplifying the measurement of high solar irradiance on receivers. Application to solar tower plants. J. Ballestrín, M. Casanova, R. Monterreal, J. Fernández-Reche, E. Setien, J. Rodríguez, J. Galindo, F.J. Barbero, F.J. Batlles. *Renewable Energy*, 138, 551-56, 2019. <https://doi.org/10.1016/j.renene.2019.01.131>
- Physicochemical characterization of soiling from photovoltaic facilities in arid locations in the Atacama Desert. P. Ferrada, D. Olivares, V. del Campo, A. Marzo, F. Araya, E. Cabrera, J. Llanos, J. Correa-Puerta, C. Portillo, D. Román Silva, M. Trigo-Gonzalez, J. Alonso-Montesinos, G. López, J. Polo, F.J. Batlles, E. Fuentealba. *Solar Energy*, 187, 47-56, 2019. <https://doi.org/10.1016/j.solener.2019.05.034>
- One year of solar extinction measurements at Plataforma Solar de Almería. Application to solar tower plants. J. Ballestrín, E. Carra, R. Monterreal, R. Enrique, J. Polo, J. Fernández-Reche, J. Barbero, A. Marzo, J. Alonso-Montesinos, G. López, F.J. Batlles. *Renewable Energy*, 136, 1002-1011, 2019. <https://doi.org/10.1016/j.renene.2019.01.064>
- Hourly PV production estimation by means of an exportable multiple linear regression model. M. Trigo-González, F.J. Batlles, J. Alonso-Montesinos, P. Ferrada, J. del Sagrado, M.D. Martínez-Durbán, M. Cortés, C. Portillo, A. Marzo. *Renewable Energy*, 135, 303-312, 2019. <https://doi.org/10.1016/j.renene.2018.12.014>
- Prospective environmental and economic assessment of solar-assisted thermal energy recovery from wastewater through a sequencing batch biofilter granular reactor. I. Muñoz, F. Portillo, S. Rosiek, F.J. Batlles, J. Martínez-Del-Río, I. Acasuso, V. Piergrossi, M. De Sanctis, S. Chimienti, C. Di Iaconi. *Journal of Cleaner Production* Volume 212, 1, Pages 1300-1309, 2019. <https://doi.org/10.1016/j.jclepro.2018.12.074>
- Microservices and machine learning algorithms for adaptive green buildings. D. Rodríguez-Gracia, J.A. Piedra-Fernández, L. Iribarne, J. Criado, R. Ayala, J. Alonso-Montesinos, M.M. Capobianco-Uriarte. *Sustainability (Switzerland)*, 11 (16), art. no. 4320, 2019. <https://doi.org/10.3390/su11164320>

### Congress assistance

- Solar World Congress. Noviembre 2019. Santiago. Chile.
- EU PVSEC European PV Solar Energy Conference and Exhibition. Septiembre 2019. Marsella. Francia.

### Congress contributions

- The use of solar radiation forecasting techniques and extinction measurements in solar power plant areas. J. Alonso-Montesinos. Solar World Congress. Noviembre 2019. Santiago (Chile). Conferencia invitada.
- Relevance analysis of atmospheric variables in the production of an experimental PV power plant considering dust deposition in the Mediterranean coast. J. Alonso-Montesinos, J. Barbero, F. J. Batlles, Francisco Rodríguez-Martínez, P. Ferrada, M. Cortés, J. Polo, N. Martín-Chivelet, N. Vela, M. Alonso, G. López, A. Marzo. Solar World Congress. Noviembre 2019. Santiago (Chile). Póster.
- Analysis of the Local Factors that Influence the Cementation of Soil and Effects on PV Generation at the Plataforma Solar Del Desierto De Atacama, Chile. Douglas Olivares, Mauricio Trigo-González, Aitor Marzo, Pablo Ferrada, Jaime Llanos, Francisco Araya, Gabriel López, Jesús Polo, Joaquín Alonso-Montesinos and Christian Gueymard. Solar World Congress. Noviembre 2019. Santiago (Chile). Oral.
- Characterization of PV soiling losses in urban Mediterranean environment. J. Polo, N. Martín-Chivelet, M. Alonso, C. Sanz, F. J. Batlles, G. López, H. Zitouni, J. Alonso-Montesinos, N. Vela, J. L. Bosch, J. Barbero. Solar World Congress. Noviembre 2019. Santiago (Chile). Póster.
- Effect of cloudiness on solar radiation forecasting. G. López, S. M. Sarmiento-Rosales, C. A. Gueymard, A. Marzo, J. Alonso-Montesinos, J. Polo, N. Martín-Chivelet, P. Ferrada, J. Barbero, F. J. Batlles, N. Vela. Solar World Congress. Noviembre 2019. Santiago (Chile). Póster.
- Ultraviolet irradiance modeling by using artificial neural networks in Atacama Desert. Gino Mondaca, Mauricio Trigo-González, Aitor Marzo, Joaquín Alonso-Montesinos, Javier Barbero, Germán Salazar, Douglas Olivares and Pablo Ferrada. Solar World Congress. Noviembre 2019. Santiago (Chile). Oral.
- Design of an application for the estimation of the PV power plant production in real-time. Joaquín Alonso-Montesinos, Javier Barbero, Francisco Javier Batlles, Gabriel López, Jesús Polo, Nuria Martín, Miguel Alonso, Nieves Vela. EU PVSEC European PV Solar Energy Conference and Exhibition. Septiembre 2019. Marsella (Francia). Póster.
- Characterization and modelling of the soiling effect on the PV generation under urban Mediterranean conditions. Nuria Martín, Jesús Polo, Miguel Alonso, Carlos Sanz, Francisco Javier Batlles, Gabriel López, Joaquín Alonso-Montesinos, Nieves Vela, Juan Luis Bosch, Javier Barbero. EU PVSEC European PV Solar Energy Conference and Exhibition. Septiembre 2019. Marsella (Francia). Póster.
- Assessing Spectral Mismatch Factors from Solar Spectral Measurements under Clear and Hazy Conditions. Gabriel López, Christian A. Gueymard, Jesús Polo, Nuria Martín, Joaquín Alonso-Montesinos, Aitor Marzo, Francisco Javier Batlles, Nieves Vela, Javier Barbero. EU PVSEC European PV Solar Energy Conference and Exhibition. Septiembre 2019. Marsella (Francia). Oral.
- PCMSOL: Thermal Energy Storage with Phase Change Materials for Solar Cooling and Heating. F.J. Batlles, B. Gil, M. Grageda, J. Kasperski, M. Luján, D. Maldonado, M. Nems, A. Nems, A.M. Puertas, M.S. Romero-Cano, S. Rosiek, S. Ushak. Solar World Congress. Noviembre 2019. Santiago (Chile). Póster.

### 2.5.8 Staff members

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UAL**Joaquín Alonso Montesinos**Post-doc Researcher  
UAL**Antonio Manuel Puertas López**Full Professor  
UAL**Manuel Servando Romero Cano**Full Professor  
UAL

## 2.5.9 Ongoing projects in 2019

### 2.5.9.1. Thermal energy storage with phase change materials for solar cooling and heating applications: A technology viability analysis (PCMSOL)

#### Participants:

University of Almería (Spain), University of Antofagasta (Chile), Technical University of Wrocław (Poland), University of Cochabamba (Bolivia), y Phase Change Technologies, S.L. (Spanish company)).

#### Project Leader:

Antonio M. Puertas (apuertas@ual.es)

#### Amount:

300.936 €

#### Funds:

European Commission (ERANET-LAC Joint call 2015-2016), MINECO (Ref. PCIN-2016-013)

#### Time Period:

December 2016 – December 2019

#### Current Status:

In progress

#### Summary:

Project PCMSOL is a coordinated project with the University of Antofagasta (Chile), Technical University of Wrocław (Poland), University of Cochabamba (Bolivia), and the company Phase Change Technologies, S.L. The project is intended to develop and test new phase change materials for the storage of thermal energy in a cooling/heating system based on solar energy. Due to the time mismatch between solar radiation and energy demand, this kind of technology requires the storage of energy. In our case, energy is saved in the form of thermal energy using materials with the liquid-solid phase transition in the appropriate temperature range. For winter, the phase transition should take place around 50°C, while the phase transition temperature

is sought around 5°C for the summer mode. In this project, we intend to study in the first place different materials that could be used for thermal storage. The materials must be characterized chemical and thermally, and using numerical simulations the kinetics of the melting is studied, to model the required storage system for a model building. Finally, storage tanks will be tested in CIESOL, to perform a viability analysis of the storage system based on phase change materials.

**Objectives:**

- Find new materials with potential use for thermal energy storage in both the winter and the summer mode (heating and cooling).
- Characterize the materials and model the kinetics of melting.
- Estimate a storage system for a cooling/heating system based on solar energy.
- Install the storage tanks and study the viability of the whole system.

**2.5.9.2 Short-term prediction of the production of energy in a photovoltaic plant and influence of fouling of the panels in the production of the same (PVCastSOIL)**

**Participants:**

University of Almería (Spain), University of Huelva (Spain), CIEMAT (Spanish researching center).

**Project Leader:**

Francisco Javier Batlles Garrido (fbatlles@ual.es)

**Amount:**

442.049,30 €

**Funds:**

Ministerio de Economía y Competitividad.

**Time Period:**

January 2018 – December 2020.

**Current Status:**

In progress.

**Summary:**

Photovoltaic solar energy (PV) is the technology for electric generation that shows the highest growth since 2002, experiencing an average annual increase of 48%. The prediction of the solar resource for a PV plant, connected to the grid, is absolutely necessary to ensure optimal capture and transformation of the available solar energy and reliable power production. The development of short-term forecasting methods for plant production is particularly important due to its growing incorporation into electricity grids and the variability of the solar resource, mainly due to the transitory phenomena caused by alternating clouds and clearings. The accumulation of dirt on the surface of photovoltaic modules has a significant impact on the production of a photovoltaic installation. This phenomenon, better known by the Anglo-Saxon term "soiling" is intimately related to the angle of inclination of the panel and weather conditions, such as the amount of aerosols present in the atmosphere, relative humidity, wind speed and direction and precipitation.

**Objectives:**

The fundamental objective of the present project is to develop a methodology capable of predicting in the short term, from one to three hours, the production of a photovoltaic plant, including the losses per soiling. This methodology is based on image processing and supervised learning techniques, such as Artificial Neural Networks.

### 2.5.9.3 Fortalecimiento de la calidad de sistemas solares industriales de torre mediante la medida de parámetros y estimación de la atenuación atmosférica con enfoque a entornos climáticos desértico

#### Participants:

Universidad de Antofagasta, Pontificia Universidad Católica de Chile, SERC Chile, Fraunhofer Chile, Universidad de Chile, Asociación Chilena De Energías Renovables, Universidad de Almería, Universidad de Huelva, DLR y CIEMAT.

#### Project Leader:

Aitor Marzo Rosa

#### Contact:

F.J. Batlles (fbatlles@ual.es) and Joaquín Alonso (joaquin.alonso@ual.es).

#### Amount:

\$218.467.166

#### Funds:

CORFO (Chile) .

#### Time Period:

October 2017 – December 2019 (posible extensión)

#### Current Status:

In progress.

#### Summary:

In order to strengthen the knowledge of the operating conditions of tower plants in the country, it is proposed as of general interest to create useful information on the losses that the lower layers of the atmosphere can generate in the production of the plants. To this end, it is essential to be able to strengthen the following aspects:

- Definition of a methodology for estimating atmospheric attenuation in the lower layers of the atmosphere
- Provision of a reliable long-term database with information on the variables involved in the phenomenon of extinction.
- To have a map with geographical information where the atmospheric attenuation is quantified as a function of the distance between the heliostat and the tower and the local atmospheric conditions

### 2.5.10 Transfer and Complementary Activities

- Participation of Dr. Joaquín Alonso in the IEA PVPS Task 16: Solar resource for high penetration and large scale applications. Santiago de Chile, november 2019.

### 2.5.11 Dissemination activities

- Press publication UAL NEWS: La UAL extiende sus colaboraciones en materia de energías renovable (entrevista a Joaquín Alonso)  
<https://news.ual.es/ciencia/la-ual-extiende-sus-colaboraciones-en-materia-de-energias-renovables>
- Press publication Noticias de la Ciencia y Tecnología (NCYT): Desarrollan una aplicación que predice con precisión los cambios meteorológicos en plantas solares:  
<https://noticiadelaciencia.com/art/34347/desarrollan-una-aplicacion-que-predice-con-precision-los-cambios-meteorologicos-en-plantas-solares>

### 2.5.12 Project's applications in 2019

Junta de Andalucía, Consejería de Conocimiento, Investigación y Universidad, Low Carbon Solution for sustainable food preservation system (SMARTcold), University of Almería, Total budget: 394.400,00€

### 2.5.13 Others

#### Final degree projects

- Francisco Rodríguez Martínez. Diseño e instalación de una planta fotovoltaica experimental y de una estación meteorológica de monitorización de variables atmosféricas para el estudio del rendimiento de los paneles bajo condiciones de ensuciamiento por polvo. Grado en Ingeniería eléctrica.



## 2.6 ACTIVITIES OF “DESALINATION AND PHOTOSYNTHESIS”

### 2.6.1 Functional unit description

The “Desalination and Photosynthesis” unit is made up of researchers from the Chemical Engineering Department of the Universidad de Almería and from the Plataforma Solar de Almería who have started a new independent research group “Desalination and Photosynthesis” (BIO-352) with synergies from two fields. The researchers of this unit are also adscribed to the Plan Andaluz de Investigación research groups “Desalación Solar, TEP026” and “Biotecnología de microalgas marinas, BIO173”. This unit was started in 2014 and focused its activity on the water-energy-food nexus, beginning with the set up and operation of new installations and facilities dedicated to water desalination with solar energy by using hydrophobic membranes, as well as the application of solar energy in biological microalgae-based depuration processes. Both lines present ample opportunities for synergy and for collaboration with other units within CIESOL which raise frequent colaborations.

### 2.6.2 Main research lines

The group works in two parallel lines dealing with solar energy application in desalination using membrane systems and microalgal cultivation particularly oriented to recycling by solar energy-driven synthesis of commodities such as biofertilizers or biodiesel and value products such as carotenoids and essential fatty acids. Seawater is the main raw material the research deals with although other types of feed, such as freshwater, brines, rackish waters or wastewaters are also considered. The main research lines ar:

- Development of membrane-based solar desalination and water treatment systems.
- Application of solar energy to the treatment of hypersaline media.
- Recovery of value compouds from brines and hypersaline effluents.
- Design of photobioreactors for the cultivation of microalgae.
- Applications of microalgae to the purification of wastewaters and industrial effluents
- Valorization of microalgal biomass obtained from wastewater.

### 2.6.3 Main researchers

**Jose M. Fernández Sevilla** (ORCID 0000-0002-0290-5810, Scopus Author 6602856181)

Is a Professor of Chemical Engineering at Universidad de Almeria, currently affiliated with the Engineering Department at Universidad de Almería. He obtaines a Degree in Industrias Chemistry (Químico Industrial) at Universidad de Granada in 1991 and a PhD. In Chemistry in 1995 at the Universidad de Almería. He has worked in in twelve I+D projects in the international and spanish national levels, as lead reseacher in five of them. He has participated also in 15 research contracts funded by companie, has also advised six PhD. Theses and is the co-author of seven patents and over one-hundred scientific publications in peer-reviewed international journals.

**Guillermo Zaragoza del Águila** (ORCID 0000-0002-4452-9980, Scopus Author 6701505211)

PhD in Applied Physics by the University of Granada, Spain (1996). Has held academic positions in the Consejo Superior de Investigaciones Científicas of Spain (CSIC), the University of Oxford, Estación Experimental “Las



Palmerillas" (Fundación Cajamar) and is currently a Senior Researcher in the Department of Energy of Spanish CIEMAT (Centre for Energy, Environment and Technology Research), at the Plataforma Solar de Almería (Solar Desalination Unit). Has published more than 80 papers in peer-reviewed international journals, presented more than 120 papers on international conferences, authored 8 book chapters and co-authored 4 books. Teaches in international courses on Solar Desalination organized by the European Desalination Society (EDS) and on the Master Course on Solar Energy organized by CIESOL. He is board director of the EDS and is currently coordinating the Renewable Energy Desalination Action Group of the European Innovation Partnership on Water of the European Commission, as well as the Working Group on the same subject in the European Water Platform WssTP.

#### **2.6.4 Summary of the functional unit's activities carried out in CIESOL during 2019**

In the microalgae production line different research lines are in progress, such as those related with the production of microalgae for high value applications, mainly food and feed but also the production of biostimulants and biopesticides, or those related with the treatment of residuals, mainly wastewaters both urban or animal, and flue gases. These includes ALQUABIOTIC with BIORIZON BIOTECH focused into the production of aquafeed for aquaculture, AL4BIO with UPC focused into the production of biostimulants from effluent after secondary treatment, ALGAE4CONTROL with BIORIZON BIOTECH focused to the production of biopesticides from microalgae, BLUECARE with BIORIZON BIOTECH focused to the production of cosmetics products from microalgae, SETEC with SYTCOM focused to the production of bioplastics from flue gases using microalgae, BIOREFINA with MIGUEL SANCHEZ E HIJOS focused into the production of biofertilizers from vegetable residuals, GREENFARM with Uva and focused into the treatment of animal wastewaters to produce agriculture related products, and SABANA financed by the EU Commission through the H2020 programme focused to the production of agriculture and aquaculture related products from microalgae using residuals. On this year, two additional research lines has been started in collaboration with other functional units from CIESOL such as the recovery of heat and CO<sub>2</sub> from flue gases to be used in greenhouses through the CARBON4GREN project financed by the UAL-FEDER programme, and the removal of emerging pollutants through the ULISES project financed by the LIFE programme from the EU.

Project RED Heat to Power finished in April with the demonstration of the pilot plant in the facilities of Fujifilm in Tilburg (The Netherlands). This combined a reverse electrodialysis stack with an advanced membrane distillation technology to regenerate the salinity gradient. The latter was responsibility of CIEMAT, and a membrane distillation system based on a multi-envelope spiral-wound module in vacuum-enhanced air-gap configuration with record heat efficiency (less than 50 kWh thermal energy consumed per m<sup>3</sup> of distillate produced). The REWACEM project concluded in September with the demonstration of the pilot plant installed at the facilities of the Electroníquel company in Gijón. This included a combination of diffusion dialysis, membrane distillation and reactive precipitation, and the results were 85-100% recovery of sulfuric acid and 85% of copper, obtaining also permeate of high quality (50-60 µS/cm), from the wastewater of a copper electroplating process. The activities on European project INSHIP (Integrating National Research Agendas on Solar Heat for Industrial Processes) continued with the evaluation of membrane distillation modules operating in batch recirculation mode for enhanced recovery. During 2019, Plataforma Solar de Almería has continued working in project WASCOP in the installation of a testing facility at PSA for the evaluation of a hybrid cooling system and its comparison with conventional cooling systems. A company to

do the engineering and mechanical assembly were contracted and the electrical connections, SCADA system and instruments installation was carried out by PSA staff. The facility was ready in July 2019 and an exhaustive test campaign at different hybrid cooling configurations and at different operation conditions has been performed until December 2019, when the project has already finished. This task has finished with successful results in terms of water consumption reduction and minimum electric consumption with respect to conventional cooling systems, which was the aim of the project. The Desalination unit has also continued the activities in the European project SOLWATT (now re-called SOLWARIS) that started in 2018. During 2019, the main activity has been focused in the optimum design of a multi-effect evaporator (MEE) unit to be installed at a real CSP plant (La Africana CSP plant located in Córdoba, Spain), which will treat water from different points of the CSP plant to be recovered and re-introduced again in the CSP plant. This plant is being manufactured by the Spanish company INDETEC. Also, the connection points for the integration of the MEE into La Africana have been decided after several visits to the CSP plant with the partners TSK and INDETEC. The instruments and control loops of the MEE unit have been decided together with INDETEC and the dynamic modelling of the plant has been started to be implemented in Modelica by researchers of the Desalination unit at PSA.

A new project called EERES4WATER (Promoting energy-water nexus resource efficiency through renewable energy and energy efficiency, INTERREG ATLANTIC AREA) started its activities in April 2019 and has a duration of four years. Main goal of the project is to provide Atlantic Area stakeholders with the tools and instruments needed to overcome the Energy-Water nexus challenges and increase its utilisation. PSA will be involved within the technical workpackages doing research in the field of membrane distillation and forward osmosis processes for desalination and salinity-gradient power generation.

#### **2.6.5 Collaboration with other functional units of CIESOL during 2019**

During 2019 we have continued the collaboration with the Functional Unit "Modeling and control", on modeling the operation of solar membrane distillation plants, working in another scientific publications to be published soon. A new project related with the reuse of heat and CO<sub>2</sub> from flue gases in greenhouses has been started on this year. Also we are collaborating with the Functional Unit "Water regeneration" into the LIFE ULISES project focused to removal of emerging pollutants combining photocataluysis and biological processes.

#### **2.6.6 Human resources of the Functional Unit**

- Alexia Martinez Aragón, EL Salvador - May-18 (6 months)
- Eleonora Antonucci, Italia - September-18 (6 months)
- Jannay Pinedo, Mexico - January-19 (11 months)
- Jendryk Klumparendt, Alemania - January-19 (6 months)
- Juan Pablo, Chile - February-19 (3 months)
- Leonardo Rörig, Brasil, April-19 (4 months)
- Stephani Aparicio, Valencia, April -19 (3 months)
- Lisa Maggioli, Italia, May-19 (4 months)
- Margarita Kuznetsova, Francia, May -19 (3 months)

- Suzanne Diaw, Francia, May -19 (3 months)
- Lesly Kompaoré, Francia, May -19 (3 months)
- Axel, Francia, May -19 (3 months)
- William NGUYEN, Francia, May -19 (3 months)
- Pedro SIQUEIRA ZATTA, Francia, May -19 (3 months)
- Joel Edh, Francia, May -19 (3 months)
- Mabi Darlyne Fatou Imelda, Francia, May -19 (3 months)
- Loreto Cavieres, Chile, July-19 (1 mes)
- Ernesto Flores, México, July -19 (1 mes)
- Luis Gilberto Torres Bustillos, México, July -19 (1 mes)
- Gema , España (Málaga), July -19 (3 months)
- Adib Moohebat Gall, España (Lleida), July -19 (3 months)
- Agustín Rearte, Argentina, August-19 (3 months)
- Eliaira Rodríguez, Venezuela, September-19 (3 months)
- Elihu Pinedo, México, September -19 (3 months)

#### **Alumnos en prácticas curriculares:**

- Lidia Alameda, Máster Ingeniería Química, España, October-18 (5 months)
- Alejandro de Arriba, Máster Ingeniería Química, España, October -18 (5 months)
- Rafa Cid, Grado ingeniería Química, España, January-19 (5 months)
- Salvador García, Grado Biotecnología, España, February-19 (4 months)
- German Jesús Gamarra Santos, Grado Biotecnología, España, February -19 (4 months)
- Maria Matamala, Grado Biotecnología, España, February -19 (2 months)
- Adrián Macías, Grado Biotecnología, España, February -19 (2 months)
- Laura Arbeloa, Grado Biotecnología, España, February -19 (2 months)
- Jannan LALCHANDANILAKHANI, Grado Biotecnología, España, February -19 (2 months)
- Joice Villachica, Máster Biotecnología, Perú, April-19 (3 months)
- Lesly Villachica, Máster Energía Solar, Perú, May-19 (3 meses)

### **2.6.7 Scientific production**

#### **Papers**

- Parabolic trough collector field dynamic model: Validation, energetic and exergetic analyses. J.A. Carballo, J. Bonilla, M. Berenguel, P. Palenzuela. Applied Thermal Engineering. 148, 777-786. 2019. DOI: <https://doi.org/10.1016/j.applthermaleng.2018.11.093>
- Towards the first proof of concept of a reverse electro dialysis – membrane distillation heat engine. M. Micari, A. Cipollina, F. Giacalone, G. Kosmadakis, M. Papapetrou, G. Zaragoza, G. Micale, A. Tamburini. Desalination, 253, 77-88. 2019. DOI: <https://doi.org/10.1016/j.desal.2018.11.022>
- Ideal performance of a self-cooling greenhouse. P.A. Davies, G. Zaragoza. Applied Thermal Engineering, 149, 502-511. 2019. DOI: <https://doi.org/10.1016/j.applthermaleng.2018.12.056>
- Evaluation of forward osmosis as a pretreatment process for multi stage flash seawater desalination. Thabit, M.S., A.H. Hawari, M.H. Ammar, S. Zaidi, G. Zaragoza, A. Altaee. Desalination, 461, 22–29. 2019. <https://doi.org/10.1016/j.desal.2019.03.015>

- Comparative evaluation of microalgae strains for CO<sub>2</sub> capture purposes. C. Sepulveda, C. Gómez, N. El Bahraoui, G. Ación. *Journal of CO<sub>2</sub> Utilization*, 30, 158–167, 2019.
- Impact of Membrane Orientation on the Performance of Dual Stage Pressure Retarded Osmosis. A. Altaee, A.O. Sharif, G. Zaragoza, J. Zhou. *Journal of Water Process Engineering*, 30, 100621. 2019. <https://doi.org/10.1016/j.jwpe.2018.05.001>
- Evaluation of Permeate Quality in Pilot Scale Membrane Distillation Systems. A. Ruiz-Aguirre, J.A. Andrés-Mañas, G. Zaragoza. *Membranes*, 9, 69. 2019. <https://doi.org/10.3390/membranes9060069>
- Evaluation of native microalgae from Tunisia using the pulse-amplitude-modulation measurement of chlorophyll fluorescence and a performance study in semi-continuous mode for biofuel production. A. Jebali, F.G. Ación, N. Jiménez-Ruiz, J.M. Fernández-Sevilla, S. Sayadi, E. Molina-Grima, *Biotechnol Biofuels* 12, 119. 2019. <https://doi.org/10.1186/s13068-019-1461-4>
- Monoalgal and mixed algal cultures discrimination by using an artificial neural network. B. Franco Ortellado, C. Gómez Serrano, F.G. Ación Fernández, L.M. Navas, C. Sepulveda. *Algal Research*, Volume 38, 101419. 2019.
- Variations of culture parameters in a pilot-scale thin-layer reactor and their influence on the performance of *Scenedesmus almeriensis* culture. M. Barceló-Villalobos, C. Gómez Serrano, A. Sánchez Zurano, L. Alameda García, S. Esteve Maldonado, J. Peña, F.G. Ación Fernández. *Bioresource Technology Reports* 6 190–197 2019.
- Control System for pH in Raceway Photobioreactors Based on Wiener Models. A. Pawlowski, J.L. Guzman, M. Berenguel, F.G. Ación Fernández. 12<sup>th</sup> IFAC Symposium on Dynamics and Control of Process Systems, including Biosystems, accepted January 2019
- Production of a biocrust-cyanobacteria strain (*Nostoc commune*) for large-scale restoration of dryland soils. B. Roncero-Ramos, R. Román, C. Gómez-Serrano, Y. Cantón, F. G. Ación. *Journal of Applied Phycology*, accepted January 2019.
- Evaluation of photosynthetic light integration by microalgae in a pilot-scale raceway reactor M. Barceló-Villalobos, P. Fernández-del Olmo, J.L. Guzmán, J.M. Fernández-Sevilla, F.G. Ación Fernández, *Bioresource Technology*, 280, pp. 404-411. 2019. DOI: 10.1016/j.biortech.2019.02.032
- Flashing light does not improve photosynthetic performance and growth of green microalgae. P.S.C. Schulze, C. Brindley, J.M. Fernández, R. Rautenberger, H. Pereira, R.H. Wijffels, V. Kiron. (2020) *Bioresource Technology Reports* Vol. 9, 100367, 2020. <https://doi.org/10.1016/j.biteb.2019.100367>
- Engineering strategies for the enhancement of *Nannochloropsis gaditana* outdoor production: Influence of the CO<sub>2</sub> flow rate on the culture performance in tubular photobioreactors. L. Moraes, G.M. Rosa, A. Morillas España, L.O. Santos, M.G. Morais, E. Molina Grima, J.A.V. Costa, F.G. Ación Fernández, *Process Biochemistry* Volume 76, Pages 171-177 2019. <https://doi.org/10.1016/j.procbio.2018.10.010>
- Evaluation of native microalgae from Tunisia using the pulse-amplitude-modulation measurement of chlorophyll fluorescence and a performance study in semi-continuous mode for biofuel production. A. Jebali, F.G. Ación, N. Jiménez-Ruiz, C. Gómez, J.M. Fernández-Sevilla, N. Mhiri, F. Karray, S. Sayadi, E. Molina-Grima. *Biotechnology for Biofuels*, 12:119. 2019.
- Effect of microalgae incorporation on the physicochemical, nutritional, and sensorial properties of an innovative broccoli soup. T. Lafarga, F.G. Ación-Fernández, M. Castellaric, S. Villaró, G. Bobo, Ingrid Aguiló-Aguayo. *LWT* Volume 111, Pages 167-174, 2019. <https://doi.org/10.1016/j.lwt.2019.05.037>
- Selection of biomass supply for a gasification process in a solar thermal hybrid plant for the production of electricity. M.G. Pinna-Hernández, I. Martínez-Soler, M.J. Díaz Villanueva, F.G. Acien Fernández, J.L.C. López. *Industrial Crops and Products* 137, pp. 339-346, 2019.
- Optimal processing of greenhouse crop residues to use as energy and CO<sub>2</sub> sources. J.V. Reinoso Moreno, G. Pinna-Hernández, M.D. Fernández Fernández, J.A. Sánchez Molina, F. Rodríguez Díaz, J.C. López Hernández, F.G. Ación Fernández. *Industrial Crops & Products* 137 662–671, 2019.
- BIO\_ALGAE 2: improved model of microalgae and bacteria consortia for wastewater treatment. A. Solimeno, C. Gómez-Serrano, F.G. Ación. *Environmental Science and Pollution Research*. 2019. <https://doi.org/10.1007/s11356-019-05824-5>

- Modelo de temperatura para reactores abiertos de microalgas. E. Rodríguez Miranda, F.G. Ación Fernández, J.L. Guzmán Sánchez, M. Berenguel Soria and A. Visioli. JA2019, 2019
- Potential of the microalgae *Nannochloropsis* and *Tetraselmis* for being used as innovative ingredients in baked goods. T. Lafarga, E. Mayre, G. Echeverría, M. Castellari, I. Aguiló-Aguayo. LWT 115,108439, 2019.
- Fibonacci-type tubular photobioreactor for the production of microalgae. J.P. Díaz, C. Inostroza, F.G. Ación Fernández. Process Biochemistry 86, pp. 1-8, 2019.
- Engineering strategies for the enhancement of *Nannochloropsis gaditana* outdoor production: Influence of the CO<sub>2</sub> flow rate on the culture performance in tubular photobioreactors L. Moraes, G. Martins da Rosa, A. Morillas España, L. Oliveira Santos, M. Greque de Morais, E. Molina Grima, J. Alberto Vieira Costa, F.G. Ación Fernández Process Biochemistry, Volume 76, Pages 171-177, 2019.
- Differential hydrolysis of proteins of four microalgae by the digestive enzymes of gilthead sea bream and Senegalese sole. A.J. Vizcaíno, M.I. Sáez, T.F. Martínez, F.G. Ación, F.J. Alarcón. Algal Research, Volume 37, Pages 145-153, 2019.
- Biomass estimation of an industrial raceway photobioreactor using an extended Kalman filter and a dynamic model for microalgae production. F. García-Mañas, J.L.Guzmán, M.Berenguel, F.G.Ación. Algal Research, Volume 37, Pages 103-114, 2019.
- In vitro protein hydrolysis of microalgae by digestive enzymes of farmed fish. A.J. Vizcaíno, M.I. Sáez, T.F. Martínez, F.G. Ación, S. Martínez-Llorens, F.J. Alarcón. Algal Research, 2019

#### **Congress assistance**

- AlgalBBB 2019: The 9<sup>th</sup> International Conference on Algal Biomass, Biofuels and Bioproducts. 17-29 June 2019. Boulder, Colorado USA.
- CURSO DE FORMACIÓN "Los residuos y su reciclaje: gestión y educación ambiental" RECAPACICLA, Almeria, Spain 2019.
- II Jornadas doctorales en energías renovables Jaen, Spain 2019
- Horizon 2020 Regional Seminar Addressing Euro-Mediterranean Common Challenges through Research and Innovation Cooperation Fees, Morocco 2019
- Congreso Nacional de Biotecnología, BIOTEC2019 Vigo, Spain
- EUALGAE Final Conference European Recent Advances in the Microalgae Field Madrid, Spain
- 27<sup>th</sup> European Biomass Conference and Exhibition, EUBCE 2019 Lisbon, Portugal
- CONAMA 2019 Toledo, Spain
- 9<sup>th</sup> Symposium on Microalgae and seaweed products in plant/soil systems Mosonmagyaróvár, Hungary
- International Conference on Advanced Production and Processing ICAPP2019 Novi Sad, Serbia
- Congreso Internacional I+D+i Sostenibilidad energética 2019 Quito, Ecuador
- AlgaEurope 2019 Paris, Francia
- Congress of microbiology and biotechnology MicroBiotrec 2019 Coimbra, Portugal

#### **Congress contributions**

- Small-Scale Renewable Polygeneration System for Off-Grid Applications: Desalination, Power Generation and Space Cooling. D. S. Ayou, G. Zaragoza, A. Coronas. 5<sup>th</sup> International Conference on Polygeneration, (ICP 2019). May 15-17, 2019. Fukuoka, Japan. Oral.
- Vacuum-enhanced air-gap membrane distillation as a viable solution for solar desalination. G. Zaragoza, J.A. Andrés-Mañas, F.G. Ación, A. Ruiz-Aguirre, 9<sup>th</sup> IWA membrane technology conference & exhibition on water and wastewater treatment and reuse, June 23 – 27 2019, Toulouse, France. Oral.
- Application of diffusion dialysis in separation of sulfuric acid and copper from electroplating wastewater. A. Ruiz-Aguirre, J. López, R. Gueccia, S. Randazzo, A. Cipollina, J. L. Cortina, G. Zaragoza,

- G. Micale, 9<sup>th</sup> IWA membrane technology conference & exhibition on water and wastewater treatment and reuse, June 23 – 27 2019, Toulouse, France. Oral.
- Commercial scale experiments of vacuum-enhanced air-gap MD for treating high salinity feeds, G. Zaragoza, J.A. Andrés-Mañas, EU-China Cooperation Conference on Membrane Technology Innovation. 9-10 julio 2019, Weihai, China, Oral.
  - Pilot Scale Hybrid Cooling System for Optimizing the Water Consumption at CSP Plants. Patricia Palenzuela, Lidia Roca, Ginés García, José Liria, Diego-César Alarcón-Padilla, Charles-André Lemarié, Adèle Caron, Faisal Asfand, Kumar Patchigolla. 25<sup>th</sup> SolarPACES conference. October 01-04, 2019. Daegu. South Korea. Póster.
  - Assessment of a Concentrating Solar Power plant coupled to a Multi-Effect Distillation unit with an Air-Cooled Condenser. Carlos Mata-Torres, Adriana Zurita, Patricia Palenzuela, Diego C. Alarcón-Padilla, and Rodrigo Escobar. 25<sup>th</sup> SolarPACES conference. October 01-04, 2019. Daegu. South Korea. Oral.
  - Vacuum-enhanced air-gap membrane distillation for maximum efficiency in solar desalination. G. Zaragoza, J.A. Andrés-Mañas, A. Ruiz-Aguirre. International Conference on Sustainable Water Treatment Technologies and Environment. October 14-16. Tlpasa, Algeria. Keynote presentation.
  - PURASOL project: Optimization of the effluent recycling rate in a microalgae-based pig manure depuration process. M. Ciardi, C. Gómez-Serrano, A.M. González Céspedes, F.G. Acién, J.M. Fernández-Sevilla. AlgalBBB 2019: The 9<sup>th</sup> International Conference on Algal Biomass, Biofuels and Bioproducts. 17-29 Junio de 2019. Boulder, Colorado USA. Poster.
  - A simple, algebraic model to optimize the light regime in raceway photobioreactors. P. Fernández del Olmo, F.G. Acién, J.M. Fernández-Sevilla. AlgalBBB 2019: The 9<sup>th</sup> International Conference on Algal Biomass, Biofuels and Bioproducts. 17-29 Junio de 2019. Boulder, Colorado USA. Poster.
  - Measuring the interactions of photosynthesis and respiration in microalgae-bacteria consortia for wastewater treatment. Sánchez Zurano, A., Gómez Serrano, C., Acién Fernández F. G., Molina Grima E. and Fernández Sevilla J.M. AlgalBBB 2019: The 9<sup>th</sup> International Conference on Algal Biomass, Biofuels and Bioproducts. 17-29 Junio de 2019. Boulder, Colorado USA. Poster.
  - A new coupled electrodynamic-hydrodynamic based productivity model of CO<sub>2</sub> to bio-materials conversion by cyanobacteria. Naoufel EL BAHRAOUI, Shuli SHU, Francisco Gabriel ACIÉN FERNANDEZ, Rodrigo RIVERA TINOCO, Jamal CHAOUKI. 22<sup>nd</sup> Conference Process Integration, Modelling and Optimisation for Energy Saving and Pollution Reduction. Crete, Greece 2019 Poster

### Book Chapters

- Concentrating Solar Power and Desalination Plants. In: "Solar Resources Mapping. Fundamentals and Applications". P. Palenzuela & D. C. Alarcón-Padilla. Springer. 2019. 2018. Chapter 14, 327-340. ISBN: 978-3-319-97483-5.
- Removal of contaminants of emerging concern by microalgae-based wastewater treatments and related analytical techniques. A. Agüera, P. Plaza-Bolaños, F.G Acién Fernández Current Developments in Biotechnology and Bioengineering: Emerging Organic Micro-pollutants (ISBN 9780128195949).
- Valorization of microalgae and energy resources. Cynthia V. González-López, Francisco García Cuadra, Natalia Jawiarczyk, Jose M. Fernández-Sevilla and Francisco G. Acién-Fernández Publisher: InTechOpen.
- Combining wastewater treatment with biofuel and bio-product production through microalgae in the frame of biorefinery. Alice Ferreira, Alberto Reis, Senka Curcin, Jelena Vlastic, Spyros Gkelis, Lusine Melkonyan, Gayane Avetisova, Roberta Congestri, Gabriel Acién, Raul Muñoz, Pierre Collet and Luisa Gouveia Springer
- New strategies for the design and control of raceway reactors to optimize microalgae production. Marta Barceló Villalobos, Francisco Gabriel Acién Fernández, José Luis Guzmán, Jose María Fernández Sevilla Algal Technologies Volumes of CRC Press.

## 2.6.8 Staff members

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**Ismael Marín Cara**



Associate Researcher  
UAL

**Martina Ciardi**



Associate Researcher  
UAL

## 2.6.9 Ongoing projects in 2019

### 2.6.9.1 Conversion of low grade heat to power through closed loop reverse electro-dialysis (RED-HEAT-TO-POWER)

#### Participants:

WIP (D)  
 University of Palermo (IT)  
 FUJIFILM (NL)  
 REDSTACK (NL)  
 UNIVERSITY OF EDINBURGH (UK)  
 UNIVERSITAT POLITECNICA DE CATALUNYA (ES)  
 PSA-CIEMAT (ES)  
 Universidad de Almería (ES)

#### Contacts:

Dr. Guillermo Zaragoza (guillermo.zaragoza@psa.es)

#### Funds:

European Commission, Horizon 2020 programme

#### Time Period:

May 2015 – April 2019

#### Current situation:

Finished this year

#### Summary

The overall objective is to prove this revolutionary concept, develop the necessary materials, components and know-how for bringing it to the level of a lab prototype generating electricity from low-grade heat at higher efficiencies and lower costs than ever achieved to date. Specific objectives:

- Select the most suitable technologies for the regeneration process and the combinations of salts and solvents that can maximise the system performance.
- Create new knowledge for developing: membranes for the selected solutions; membrane manufacturing concepts that can be scaled-up for high volume and low-cost production; efficient stacks suitable for this application; energy efficient regeneration processes.
- Implement and validate a process simulation tool to analyse the performance under different configurations and operating conditions.
- Evaluate and improve the performance of the overall system through tests on a lab-prototype, identifying potential up-scaling and operational issues

#### Objectives

The specific objective of CIEMAT-PSA is to select the most suitable technologies for the regeneration process and the combinations of salts and solvents that can maximise the system performance.

### 2.6.9.2 Resource recovery from industrial waste water by cutting edge membrane technologies (REWACEM)

#### Participants:

Fraunhofer Institute (Germany)  
 CIEMAT-PSA (Spain)  
 AEE (Austria)  
 VDEH GmbH (Germany)  
 Universita Degli Studi Di Palermo (Italy)  
 Deutsche Edelstahlwerke GmbH (Germany)  
 SolarSpring GmbH (Germany)  
 AT&S (Austria)  
 Electroniquel SAU (Spain)  
 DEUKUM GmbH (Germany)  
 Associazione Italiana Zincatura (Italy)  
 Universitaet Stuttgart (Germany)



Tecnozinco Srl (Italy)  
PSE AG (Germany)

**Contacts:**

Dr. Guillermo Zaragoza (guillermo.zaragoza@psa.es)

**Funds:**

European Commission, Horizon 2020 programme

**Time Period:**

October 2016-October 2019

**Current situation:**

Finished this year

**Summary:**

The ReWaCEM project aims at reducing water, energy use and wastewater production, recovering valuable metal resources and decreasing water footprint by between 30-90% in the metal plating, galvanizing and printed circuit board industry. In order to achieve these goals, ReWaCem will adopt two cutting edge membrane technologies suitable for the requirements of closed material cycles approaches and recovery concepts in metal processing industry: Diffusion Dialysis (DD) and Membrane Distillation (MD) as an integrated hybrid process.

The main objective of the proposed project is the application and demonstration of innovative and efficient water treatment technologies with the effect of a significant reduction of water use, waste water production, chemical consumption and energy use for the metal production, processing and coating industries. By combination and integration of existing but highly innovative technologies valuable resources such as metals and process fluids will furthermore be recovered, thus reducing raw material consumption, closing process chain loops and bringing existing processes in the metallurgical industry a large step closer to sustainability.

**Objectives:**

Further specific objectives of the project are:

- Adaptation of a combined treatment system including proven membrane selective separation technologies for application in the metal processing industry for minimising their liquid waste streams by 70-90%, minimising water usage by 50-90% and maximizing the recovery of valuable resources, leading to environmental and economic benefits
- Utilization of available low grade waste heat at 70-90°C for the thermal powered membrane process
- Testing and evaluation of the technology in real conditions and integration into the production process demonstrating technical and economic performance
- Facilitate the market uptake of the project results by active engagement with the industry from an early stage, first taking their feedback during the development phase and then communicating effectively to them the project achievements and further opportunities for the exploitation of the project results
- Implementation of an effective communication and transfer of knowledge strategy aiming to policy making, business and to the general public

**2.6.9.3 Bio-Mimetic and Phyto-Technologies designed for low-cost purification and recycling of water (INDIA-H2O)**

**Participants:**

University of Birmingham  
Pandit Deendayal Petroleum University  
CIEMAT  
National Environmental Engineering Research Institute  
Aquaporin AS

Institute for Water Education IHE-Delft  
 LEITAT  
 Govind Ballabh Pant Krishi Evam Prodyogik Vishwavidyalaya  
 Modus research and innovation limited  
 Ben-Gurion University of the Negev  
 Davey products  
 Advanced Center for Water Resources Development & Management  
 Jadavpur University  
 Envirochem Services  
 CETIM  
 Aston University

**Contacts:**

Dr. Guillermo Zaragoza (guillermo.zaragoza@psa.es)

**Funds:**

European Commission, Horizon 2020 programme.

**Time Period:**

February 2019 – August 2023

**Current situation:**

Ongoing

**Summary**

INDIA-H2O will develop, design and demonstrate high-recovery, low-cost water treatment systems for saline groundwater and industrial wastewaters. The focus for developments is in the arid state of Gujarat, where surface water resources are very scarce. Solutions will be demonstrated in small-scale rurally relevant low-cost systems for brackish groundwater treatment for use as safe drinking water, which will be extended to include phyto-technology solutions for rural domestic wastewater treatment. Systems will remove salinity and emerging pollutants (e.g. agricultural chemicals), valorise rejected brines in halophytic crop cultivation.

For specific industrial wastewater in textile, desalination and dairy cost-effective high-efficiency hybrid technologies for water recycling with minimum liquid discharge will be developed and demonstrated using advanced membrane technologies to achieve the required water quality for recycling.

A centre of excellence will be established in water treatment membrane technologies, design operation and monitoring.

**Objectives**

Develop novel batch-reverse osmosis technology for a 10-fold reduction in specific energy consumption with high fractions of water recovery (80%) reducing /m<sup>3</sup> operating costs to below €0.35/m<sup>3</sup> (<30 rupees/m<sup>3</sup>).

Develop forward osmosis at pilot scale for use in wastewater recovery applications including hybrid arrangements with reverse osmosis for further reduction in energy consumption.

Develop business models to exploit the developed solutions to mutual EU/India economic advantage.

Produce policy briefs on economic models and governance arrangements for viable adoption of the developed systems

#### **2.6.9.4 Optimization of the treatment of purines with microalgae for the production of biofertilizers and feed for aquaculture. Study of the behavior of emerging pollutants (PURASOL)**

**Participants:**

Universidad de Valladolid (ES).  
 Universidad de Almería

**Contacts:**

JM Fernandez-Sevilla (jfernand@ual.es)

**Funds:**

Ministerio de Economía, Industria y Competitividad

**Time Period:**

31/12/2017 – 31/12/2020

**Current situation:**

Started 2018

**Summary:**

The aim of PURASOL is to optimize manure valorization by the use of microalgae. In this way, a water stream (suitable for irrigation) and a nutrient recovery (as bioproducts and bioenergy) are obtained. The lack of natural resources coupled with the increasing need of importing basic compounds makes livestock industry of major importance in our country. Manure production is closely related to it and the challenge of turning a potential source of environmental problems, as manure, into a renewable resource with a high economic value is one of the issues in Europe nowadays. Previous studies confirmed that it is possible to use manure as nutrient source for microalgae growth. However, there are still some issues to be optimized, namely microalgae productivity and water quality. Moreover, it was proved that microalgae biomass can be successfully converted into biofertilizers, animal feed or biofuels, but these processes need to be further optimized and validated.

**Objectives:**

PURASOL project aims at finding a solution to all those issues. More specifically:

- Different pretreatments will be studied in order to reduce manure turbidity, maximizing the light use by the microalgae.
- In order to increase water recovery, evaporation will be reduced by covering the thin-layer photobioreactors.
- Microalgae-bacteria consortia will be studied to determine their optimal valorization way, since it has been demonstrated that their composition depends on the environmental and operation conditions.
- Study the presence of emerging pollutants and heavy metals in treated water and microalgae biomass, which besides represent a risk for the environment and public health, influence the microbial populations in the system, treatment capacity and valorization ways.

#### 2.6.9.5 Sustainable Algae Biorefinery for Agriculture and Aquaculture (SABANA)

**Participants:**

MIKROBIOLOGICKY USTAV - AVCR, V.V.I., Czech Republic  
GEA WESTFALIA SEPARATOR GROUP GMBH, Germany  
UNIVERSITA DEGLI STUDI DI MILANO, Italy  
UNIVERSIDAD DE LAS PALMAS DE GRAN CANARIA, Spain  
SZECHENYI ISTVAN UNIVERSITY, Hungary  
KARLSRUHER INSTITUT FUER TECHNOLOGIE, Germany  
A.I.A. S.p.A., Italy  
FCC AQUALIA SA, Spain  
BIORIZON BIOTECH S.L., Spain  
CIB-CONSORZIO ITALIANO BIOGAS E GASSIFICAZIONE  
UNIVERSIDAD DE ALMERIA, Spain

**Contacts:**

F. Gabriel Ación (facien@ual.es)

**Funds:**

This project has received funding from the European Union's Horizon 2020 Research and Innovation program under the Grant Agreement No. 727874

**Time Period:**

December 2016 – November 2020

**Current situation:**

In progress.

**Summary:**

SABANA aims at developing a large-scale integrated microalgae-based biorefinery for the production of biostimulants, biopesticides and feed additives, in addition to biofertilizers and aquafeed, using only marine water and nutrients from wastewaters (sewage, centrate and pig manure). The objective is to achieve a zero-waste process at a demonstration scales up to 5 ha sustainable both environmentally and economically. A Demonstration Centre of this biorefinery will be operated to demonstrate the technology, assess the operating characteristics of the system, evaluate environment impacts and collaborate with potential customers for use.

**Objectives:**

The objective of SABANA is to develop and demonstrate an integrated microalgae-based sustainable biorefinery to produce a range of value-added products (biostimulants, biopesticides and aquafeed additives) and low-value products (biofertilizers, aquafeed) for agriculture and aquaculture, using marine water and recovering nutrients from wastewaters (sewage, centrate and pig manure), accomplishing market (quality, price, regulations) and social (acceptance, capacitation, skills) requirements. It provides a solution for three current key issues in the EU: (i) improvement of the safety and sustainability of food production in agriculture and aquaculture, (ii) contamination problems resulting from nutrients dissemination and scarcity (phosphorous), and (iii) minimization of greenhouse gas emissions from wastes (wastewater and flue gases).

**2.6.9.6 Bioplastics production from carbon captured in household waste incineration fumes (SETEC)****Participants:**

Universidad de Almería.  
SETEC Environnement (France)

**Contacts:**

F. Gabriel Acién Fernández (UAL), facien@ual.es

**Funds:**

Private contract

**Time Period:**

May 2016– May 2017.

**Current situation:**

Extended

**Summary:**

Setec Environnement has concluded a research and development contract (hereinafter referred to as « MAIN CONTRACT ») with Sycotom, the Paris Metropolitan Intercommunal household waste treatment and recycling Syndicate (hereinafter referred to as « Sycotom »), the purpose of which is to provide within the framework of the project for bioplastics production from carbon captured in household waste incineration fumes (hereinafter referred to as « PROJECT »)

Setec Environnement requests that the UNIVERSIDAD DE ALMERIA, which agrees, provide its support as a subcontractor for the implementation of experimental missions to select microalgae strains.

#### 2.6.9.7 Biorefinery at small scale of in-situ application in rural environments with mixed agricultural activity and livestock (BIOREFINA)

**Participants:**

Universidad de Almería.  
SISTEMA AZUD S.A.  
MIGUEL GARCÍA SÁNCHEZ E HIJOS, S.A.  
BIORIZON BIOTECH S.L.  
J. BOUZADA INGENIEROS S.L.U.  
Fundación Cajamar

**Contacts:**

F. Gabriel Acién Fernández (UAL), facien@ual.es

**Funds:**

INTERCONNECTA 2016, Ministerio de Economía y Competitividad

**Time Period:**

November de 2016– November 2018.

**Current situation:**

In progress

**Summary:**

The project aims to develop "bioREFINA" technology or agroindustrial waste treatment process for its transformation into bioproducts that can be reused in fruit and vegetable farms, according to the biorefinery model. The three bioproducts to be obtained are: a "functional" organic amendment to improve the quality of cultivated soil, a liquid fertilizer for fertigation and a biofertilizer rich in amino acids and plant hormones of microalgal base. In this way, the horticultural exploitation would go from buying fertilizers to third parties, to produce their own biofertilizers made from the waste generated, improving their economic and environmental sustainability. One of the characteristics of bioREFINA fertilizers will be its high hygienic quality, essential for the safety of fruits and vegetables sold in markets in central and northern Europe, especially demanding in this area. In addition, bioREFINA generates a biofuel, biogas, which will be used as a source of renewable heat to achieve the energy self-sufficiency of the transformation processes.

**Objective:**

The general objective of the project is to develop an agricultural biomass treatment plant based on the concept of biorefinery to be installed in fruit and vegetable farms, allowing the production and self-consumption of bioenergy and biofertilizers of low environmental footprint and high hygienic quality.

#### 2.1.9.8 Production of biopesticides from cyanobacteria for their use in agriculture (ALGAE4CONTROL)

**Participants:**

Universidad de Almería.  
BIORIZON BIOTECH S.L.  
Fundación Cajamar

**Contacts:**

F. Gabriel Acién Fernández (UAL), facien@ual.es

**Funds:**

RETOS COLABORACION 2017, Ministerio de Economía y Competitividad

**Time Period:**

October 2018– September 2021.

**Current situation:**

In progress

**Summary:**

The ALGAE4CONTROL project aims to develop biopesticide formulations based on the use of antimicrobial metabolites from Cyanobacteria (microalgae) for agricultural use as natural phytosanitary of biological and sustainable origin compared to phytopathogenic microbial agents. This is a research project implemented by the biotechnology company Bioripple Biotech S.L., which also includes two organizations of research such as the University of Almería and the Jamar Foundation. Biocurly Biotech S.L. specialises in the development and commercialization of new products of agricultural use that allow to improve the sustainability and profitability of intensive production under plastic, and other extensive crops, being the main European company in the development of biofertilizers and biostimulants from microalgae. In this line the company is interested in developing products based on inhibitory metabolites of the growth of phytopathogenic microbial agents for soils and plants. This type of biopesticide compounds present in some microalgae have been reported in bibliography but at this time there is not a single biopesticide product of these characteristics in the whole world market. This is because the source of raw material is difficult to access, and whose positive effect has not been sufficiently contrasted and shown in real conditions. That is why in the project ALGAE4CONTROL is intended to resolve these problems by approaching all stages of characterization, production and application of this type of extracts of cyanobacteria, demonstrating finally the advantages of this type of bioproducts in both the profitability and the sustainability of agricultural production.

**Objective:**

The general objective of the project is to develop new biopesticides from microalgae as alternative to chemical pesticides for prevention of disease in plants and crops protection.

### 2.6.9.9 Biorefinería sostenible de microalgas para la producción de extractos fotoprotectores para la industria cosmética y formulados sustitutivos de harinas de pescado en piensos de acuicultura – BLUECARE

**Participants:**

ALGAETECH INNOVATION  
Universidad de Almería

**Contacts:**

F. Gabriel Acién Fernández (UAL), facien@ual.es

**Funding:**

NEOTEC-CDTI, EXP - 00104234/SNEO-20171045

**Time period:**

1 Enero 2019 – 31 Diciembre 2021

**Current situation:**

In progress.

**Abstract**

The BLUECARE Project consists on the implementation of a new concept of Biorefinery for the complete use of algal biomass for the production of photoprotective formulations for the cosmetic industry from microalgae and the full use of biomass for the production of hydrolyzates as food formulations for aquaculture. This is a novelty in this sector that, according to previous tests, has been shown to improve the digestibility and quality of fish farmed in captivity. The technology to be developed is based on the identification of infection associated antigens that are differentially recognized in uninfected vaccinated animals.

**Objetivos.**

To develop new photobioreactors and biomass processing technologies to obtain products of cosmetic interest.

#### 2.6.9.10 Mejora de la calidad nutricional de alimentos para acuicultura mediante la incorporación de hidrolizados de microalgas enriquecidos en microorganismos probióticos - ALQUABIOTEC.

**Participants:**

Global Feed  
Biorizon Biotech SL  
DMC Research  
Universidad de Granada  
Universidad de Almería

**Contacts:**

F. Gabriel Acién Fernández (UAL), facien@ual.es

**Funding:**

FEDER-INTERCONNECTA 2018

**Time period:**

1 Enero 2019 – 31 Diciembre 2020

**Current situation:**

In progress.

**Abstract**

The ALQUABIOTIC project aims to develop a new feed for aquaculture in which part of the fishmeal has been replaced by a microalgae hydrolyzate enriched in probiotic microorganisms. Specifically, the project aims to develop high-quality food of sustainable origin, which guarantees not only the growth of organisms, but also increases their health, resistance to stress and disease-causing agents within farming systems. This is an applied research project led by the company GLOBAL FEED, in which the biotech companies DMC Research Center and Biorizon Biotech also participate, together with two public research organizations, the University of Almería and the University of Granada. GLOBAL FEED, as a leading company in animal feed products, is interested in the development of new products for its application in aquaculture. Biorizon Biotech, pioneer in the application and development of enzymatic hydrolyzates of microalgae, aims to diversify in applications of its products, such as The case of aquaculture, where DMC with extensive experience in the development of probiotic products and microorganisms with application in human and animal nutrition, has already developed additives for this aquaculture sector. The consortium constituted under the title ALQUABIOTIC is interested in applying these products to develop a line of differentiated aquaculture products for making sustainable use of natural resources, especially by replacing fishmeal with microalgae hydrolyzates, and with the application of probiotics, with the ultimate goal each of them to improve their position in the market with respect to the competition.

**Objetives.**

ALQUABIOTIC contemplates the development of a production process that includes the optimization of a microalgae hydrolyzate and the selection of probiotic microorganisms for use in feeding aquaculture species of commercial interest, combining basic and applied research. In this sense, it is intended to develop a hydrolysis process to obtain an algal preparation rich in partially hydrolyzed protein of high biological value that can be used as an alternative ingredient to fishmeal in aquaculture feed, as well as to know the bioavailability of essential amino acids, and other nutrients in it to have enough information on the Arthrospira hydrolyzate to assess its nutritional value compared to fishmeal.

#### 2.6.9.11 Microalgas para la Producción sostenible de bioproductos y agua regenerada (AL4BIO).

**Participants:**

Universidad Politecnica de Cataluña  
Universidad de Almería

**Contacts:**

F. Gabriel Acién Fernández (UAL), facien@ual.es

**Funding:**

Proyectos de I+D+i RETOS INVESTIGACIÓN 2018  
Ministerio de Ciencia, Innovación y Universidades

**Time period:**

1 Enero 2019 – 31 Diciembre 2021

**Current situation:**

In progress.

**Abstract**

The AL4BIO project aims at producing high-value bioproducts and reclaimed water in microalgae-based systems for tertiary wastewater treatment. The bioproducts include biopolymers, biological pigments, biostimulants, biopesticides and biogas, along with reclaimed water. This approach calls for a multidisciplinary research group, which is better suited by combining the expertise of two complementary groups in a coordinated proposal: the Environmental Engineering and Microbiology Research Group of the Universitat Politècnica de Catalunya (GEMMA-UPC, Subproject 1) and the Chemical Engineering Department of the Universidad de Almería (DIQUAL, Subproject 2).

**Objetives.**

DIQUAL has a large experience on the design, construction and operation of microalgae-based bioprocesses both for high-value applications and wastewater treatment. This group has different pilot and demonstrative plants to study the production of microalgae and downstream processing, and obtain high-value products under real conditions. The group also has a fully equipped laboratory to characterize and evaluate the microalgae-based processes. DIQUAL will have the following external collaborators: an expert in energy engineering (Universidad Politécnica de Madrid), an expert on valuable compounds extraction from microalgae (University of Jaen), and an expert on the evaluation of bioproducts for the enhancement of crops production and protection (Cajamar Foundation).

**2.6.10 Participation in networks during 2019**

- EUALGAE COST action supported by the EU Commission. From 2017 to 2019.
- EIP Water Action Group: "Renewable Energy Desalination" (G. Zaragoza is coordinator)
- Water Europe Working Group: "Renewable Energy and Desalination" (G. Zaragoza is leader)

**2.6.11 Transfer and Complementary Activities**

- "Capacidades para la desalación a través del uso de energías renovables", G. Zaragoza, 2º Blue Energy Lab "Capacidades e impacto de las energías renovables marinas en Andalucía", organized by Cluster Marítimo Marino de Andalucía, 30 January 2019, Almería (Spain)
- "Main challenges for the implementation of solar desalination", G. Zaragoza, Two-day intensive course on solar driven desalination and water purification Gathering the water and renewable energy Communities, organized by Centre de Recherche en Technologie des Semi-conducteurs pour l'Energetique, 25-26 March 2019, Algiers (Algeria).
- "Desalination with solar energy", G. Zaragoza and D.C. Alarcón-Padilla, international course organized by the European Desalination Society and CIEMAT, 1-4 April 2019, Almería (Spain).

**2.6.12 Project's applications in 2019**

- "Next generation water-smart management systems: large scale demonstrations for a circular economy and society " (WATERMINING) H2020-SC5-2018-2019-2020 (Greening the economy in line with the Sustainable Development Goals (SDGs))



- "Integrated sustainable desalination systems for enhancing water and energy efficiency in agriculture" (SmartDeSYS2), ENI CBC Mediterranean Sea Basin Programme
- "Optimal Management of Unconventional Water Sources" (OMUNWAS), ENI CBC Mediterranean Sea Basin Programme
- EUWADI: Modernization of Engineering Learning: Sustainable Energy for Water (EPPKA2 - Cooperation for innovation and the exchange of good practices)
- "A Mediterranean greenhouse model combining a network of innovative cross-sectorial technologies and control systems in organic horticulture" (GROWTH). PRIMA S1 2019 Farming Systems IA
- "Sustainable Water production and management system for crop irrigation" (SUSTAINWATER). PRIMA RIA Management of low-quality waters under water scarcity and climate change conditions
- "Algae for Nutrient recycle, Sustainable Water reuse and bioFertilizer pRoduction" (Algas para el reciclado de nutrientes, la reutilización sostenible del agua y producción de biofertilizantes) (ANSWER). Proyectos de I+D en el marco del Programa Operativo FEDER Andalucía 2014-2020. Jose m Fernández Sevilla.

### 3. INFRASTRUCTURES AND SCIENTIFIC-TECHNOLOGICAL CAPABILITIES OF THE CENTER

Since its creation, the center has gradually increased the number and capacities of its scientific-technological infrastructures. The extensive and advanced equipment that is available, gives the possibility of offering a quality service and high competitiveness.

Our center is continuously trying to improve, optimizing our facilities as much as possible and remodeling deteriorated or obsolete infrastructures.

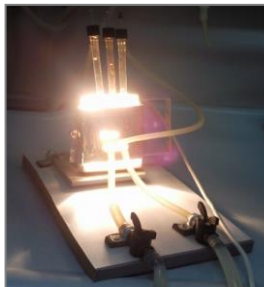
#### 3.1 FACILITIES AND INFRASTRUCTURES OF THE SOLAR ENERGY CHEMICAL USE AREA

##### **Autotrace.**

Autotrace is an automated solid-phase extraction (SPE) system for use with large samples (20 mL–20 L) to isolate trace organics in water or aqueous matrices. The compounds of interest are trapped on SPE adsorbents (cartridge or disk format), then eluted with strong solvents to generate an extract ready for analysis. AutoTrace instruments offer many advantages for sample preparation over traditional techniques including solid-phase extraction technology to save time, solvent, and labor.

##### **XcelVap.**

The XcelVap Automated Evaporation and Concentration System is a modern, compact nitrogen blow-down system that provides rapid, gentle evaporation of up to 54 sample extracts ranging in size up to 200-mL each. Evaporation is accomplished by combining consistent heat, controlled nitrogen flow, and active venting of the solvent vapors. With the XcelVap System, less time and attention are required to prepare reproducible extracts for chromatography analysis (GC/MS, LC/MS, GC, LC), improving laboratory productivity..

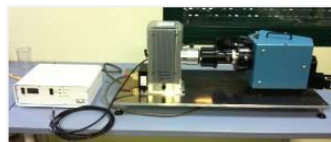


##### **Micromolar photochemical system.**

The micromolar photochemical reactor is a system that allows the controlled irradiation of small volumes containing photoactive species in both homogeneous and heterogeneous phases. Its irradiation source can be sunlight or an artificial halogen lamp and it is used to study photochemical reactions in real time, avoiding perturbations in the reaction medium and allowing external factors that might influence the reaction to be controlled.

##### **Spectrophotometers**

- Fluoromax-4 Horiba Jobin Yvon Fluorometer
- JASCO V650 UV-Vis spectrophotometer
- Hach Lange UV-Vis spectrophotometer



##### **Monochromator-coupled deuterium lamp.**

It is mainly used to study photochemical reaction mechanisms, identification of reaction intermediates and kinetics.

##### **Reaction carousels.**

Each one can host up to 12 reaction tubes with Teflon caps to work in different kinds of atmospheric conditions and temperatures. Condensation of vapour is permitted by a chilling circuit in the upper part of the system. The working temperature ranges are from room temperature up to 300°C.

They are mainly used to study catalytic reactions versus time and temperature along with varying the atmosphere

**UPLC Agilent Technologies series 1200.**

This equipment allows the analysis of substances present in aqueous and organic media with high precision and with a relatively short time analysis by reverse chromatography due to their ability to work at high pressure. This device is used for the detection of contaminants in water and allows the removal of these contaminants to be studied with the different processes studied in the CIESOL.

**SHIMADZU GC-2010 Gas chromatograph.**

The gas chromatograph is equipped with a capillary column Supelco SP-2330 with a FID detector, with the possibility of sample injection split/splitless. It is mainly used to separate and identify organic substances produced in catalytic processes with organometallic compounds and using sunlight and/or heat as the energy source.

**AB SCIEX QTRAP 5500 LC/MS/MS.**

The QTRAP is designed to excel at metabolite identification, detection and confirmation of low-level pesticides, It also houses a high sensitive ion trap along with offering ultra-fast scan speeds and full MS3 capabilities. Perform multiple reaction monitoring (MRM) scans for quantitation using this high-sensitivity triple quadrupole system. Identify, characterize, and quantify metabolites more quickly and easily. Enable high-sensitivity, full-scan MS, MS/MS, and MS3 with high-selectivity from true triple quadrupole precursor ion (PI) and neutral loss (NL) scans.

**TripleTOF™ 5600+.**

The TripleTOF 5600+ System is innovative in LC-MS/MS performance that uniquely integrates comprehensive, qualitative exploration, rapid profiling, and high-resolution quantification workflows on a single platform. It combines high-sensitivity detection, high resolution with fast acquisition speeds and stable mass accuracy over days of acquisition..

**BRUKER 320MS Mass spectrometer triple quadrupole coupled to BRUKER 450GC gas chromatograph.**

This chromatographic system complements the previously mentioned ones because it allows analysis of organic compounds of low/medium polarity. It is used especially for the determination of trace levels of contaminants such as synthetic fragrances, and pesticides, among others.

**Ion chromatograph (Metrohm 881 Compact IC Pro).**

This equipment allows the accurate analysis of anions or cations in concentrations from  $\mu\text{g/L}$  to  $\text{g/L}$ , with detection limits of  $<1 \mu\text{g/L}$ . This system is essential for the characterization of the aqueous effluents used for experimentation, since the presence of certain cations as phosphates and chlorides affects various processes of water decontamination conducted at CIESOL (Fenton and solar photo-Fenton).



**Total organic carbon analysers (TOC).**

These analysers allow the dissolved carbon and nitrogen to be determined. In the laboratory they are used for the determination of inorganic and organic carbon and nitrogen dissolved in liquid samples of wastewater to evaluate their purification when oxidative treatments are applied.

**Chemical oxygen demand analyzer (COD).**

It is used to estimate the amount of organic matter and its oxidation state. The combination of this measure with BOD and TOC allows good overall quality characterization of a wastewater.

**Analizador de la demanda química de oxígeno (DQO).** Se emplea para estimar la cantidad de materia orgánica presente y su estado de oxidación. La combinación de esta medida con la DBO y el TOC permite una buena caracterización global de la calidad de un agua residual

**Atlas Suntest cPS+ solar simulator.**

This device simulates the solar spectrum, allowing laboratory scale experimentation. It is essential in pre initial scale pilot tests.

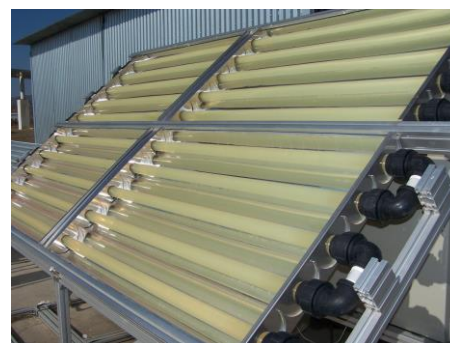
**Pilot plants.**

We have four pilot plants for contaminated water treatment by photo-Fenton (usually). They operate using solar irradiation and are equipped with radiometers to record the incident radiation. Pilot plant to evaluate the reuse of regenerated solar photocatalytic treatment water for irrigation. The plant is covered with an anti-pest 20x10 mm protector, and has twelve pots or containers with a mixture of coconut fibre and peat as substrate, where the tests are performed. It is equipped with two independent automated irrigation systems.

**Bioreactors.**

They are used to simulate different biological water purification processes

- Membrane bioreactor (MBR)
- Hollow fiber bioreactor (MBR)
- Batch bioreactor (SBR)
- SiClaro® 8PE Membrane bioreactor from Martin Systems AG



**Membrane distillation using solar energy test plant facility**, on the UAL central building rooftop.

### 3.2 FACILITIES AND INFRASTRUCTURES IN THE AREA OF SOLAR ENERGY USE

During 2019, the pilot module of the CIESOL yard corresponding to the scientific infrastructure project entitled "Multipurpose pilot module for evaluation, optimization and improvement of agri-food refrigeration systems with renewable energy" has been implemented (UNAM13-1E-2532) it was installed in the CIESOL courtyard. This installation is made up of three main modules that complement each other, and a common supervision and control room where an expert system for flexible data acquisition, monitoring and remote control was installed as a tool for managing, supervising and evaluating the tests carried out on carry out aimed at characterizing the sustainable model to be implemented. The installation is powered by an areogenerator and a photovoltaic system.



Fig. 3.2.2. Hybrid system consisting of a wind turbine (left) and PV system, installed opposite the main entrance of the CIESOL building and its courtyard respectively (right), forming an integral part of UNAM13-1E-2532 project..

The modeling and automatic control unit has the following equipment:

- Cameras and image processing systems: camera Marlin F-033C ½"; camera Intel VC4018/C; embedded data acquisition system with onboard image processing system National Instrument CompactRIO.
- Development environment for FPGA based embedded electronic systems from Altium Designer and Hard Real Time Systems development tools from Keil for 8, 16 and 32 bits processors.
- PC104 form factor development platform with soft real time operating systems: Embedded-Linux and WindowsXPEmbedded.
- Advanced tools for mathematical modelling and advanced control systems algorithms development: Dymola, Matlab/Simulink, NAG and Mathematica.
- Electronic instrumentation engineering desk, formed by:
  - Programmable power supply Metrix AX3222.
  - High accuracy multimeter Grundig DM100 and Metrix MTX3281 (portable).
  - Logic analyzer PC AT-LA500.
  - High accuracy timer and counter Pendulum CNT-90.
  - Welding station AOYUE 701.
  - Resistors decade box Chauvin & Arnoux P03197528A.
  - Tektronix TDS3014B Digital Oscilloscope.
  - Tektronix TDS2014 Digital Oscilloscope.
  - AFG3022C Function Generator.
- Cluster Beowulf formed by 13 nodes for distributed simulation and control in solar thermal power plants.

## 4 COMMITTEES AND ACTIVITY RESPONSIBLES.

### 4.1 CIESOL MANAGEMENT

<b>Director</b>	<b>Sixto Malato Rodríguez</b> OPI Researcher - PSA (CIEMAT) CIEMAT sixto.malato@psa.es
<b>Subdirector</b>	<b>José Antonio Sánchez Pérez</b> Full Professor University of Almería jsanchez@ual.es

### 4.2 ACTIVITY MANAGERS

Activity	University of Almería (UAL)	Plataforma Solar de Almería (PSA)
<b>Organometallics and Photochemistry</b>	<b>Antonio Romerosa</b> Full Professor UAL romerosa@ual.es	<b>Christoph Richter</b> DLR-PSA CIEMAT christoph.richter@dlr.de
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