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UNA DÉCADA SACANDO
PARTIDO AL SOL

CIESOL

Centro de Investigación en Energía Solar

SOLAR ENERGY RESEARCH CENTER

El SOL es la única
SOLución
SOLvente y
SOLidaria
CIESOL
Joaquín Arcaño



Instituto Mixto UAL-PSA-CIEMAT
JOINT INSTITUTE UAL-PSA-CIEMAT



INFORME ANUAL 2015

ANNUAL REPORT 2015

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1. INTRODUCTION AND EXECUTIVE SUMMARY

In 2015 CIESOL (joint research center of the University of Almeria and the Center for Environmental and Technological Energy, CIEMAT, Ministry of Economy and Competitiveness) celebrated its tenth year of operation. During this time the center has become a hallmark of the University of Almería.

The center, located in the northern part of the Campus of the University of Almería, has occupied an operational building since January 2006, and was built with funding from FEDER. It is also a research-demonstrator collector for different active and passive techniques implemented and studied throughout the development period (2006 - 2012) of the National Singular and Strategic Project on Bioclimatic Architecture and Solar Cooling (ARFRISOL) aimed at reducing energy consumption in buildings.

The scope of research activities at CIESOL enables it to:

- a) Participate in calls for the European Union and the National Plan for R & D, in both research projects and demonstration.
- b) Encourage collaboration with companies related to energy and the environment.
- c) Develop technological innovation patents that facilitate industrial development of Almeria and, in turn, the Levante area as a whole (the eastern region of the Iberian Peninsula, on the Spanish Mediterranean coast).
- d) Conduct seminars and workshops dedicated to different topics related to the use of solar energy, such as: electricity generation, evaluation and prediction of solar resources, development of new materials, water treatment, photocatalysis, photochemical reactions and organometallic chemistry.
- e) Any other activities that could help to achieve the pursued goals.

Consequently, research and technology transfer related to the applications of solar energy at CIESOL is carried out in the following areas: sustainable chemistry, decontamination and water regeneration, environmental analysis, photosynthesis and desalination, modeling and automatic control of solar systems, energy efficient home automation, solar cooling and solar resource assessment. CIESOL laboratories are equipped with resources generated by the center itself and stand out for their quality and capability, making them highly attractive for other international researchers. In particular, the SFERA II European program is worthy of mention, in which CIESOL participates prominently in a consortium of leading European research centers from Italy, Germany, Switzerland, France, and Portugal, led by the Plataforma Solar de Almería.

During 2015, 68 researchers participated in projects and contracts assigned to CIESOL, 48 of them with working on a permanent basis in its laboratories and offices. The activities of these researchers have been framed in 20 official competitive calls for projects (National Research Plan and Incentive Programme for Agents of the Andalusian Knowledge System), 8 contracts with companies and institutions and 4 European project patents.

As for scientific production it reached a total of 89 publications indexed in the Journal Citation Report. All units participated in Congress as well as national and international scientific meetings (18) and (79) along with transfer activities, some of them regarding specific contracts or the formation of consortia together with subsequent participation in national (12) or international calls (16) to be completed throughout 2016.

Also noteworthy is the financing obtained by the above projects, which totalled around 1,337,711 euros in 2015 (Ministry of Economy and Competitiveness 757.105,00 €; Andalusian 100.599,00 €; contracts with companies 181.219,00 €; 239,788 € European Commission, 50,000.00 € CDTI, CIEMAT 9.000,00 €), generating indirect costs close to 55,000 €. None of this would have been possible without the joint efforts of UAL and CIEMAT.

It should not be overlooked that one of the most important fruits the UAL-PSA collaboration during 2015 was the reading by 6 students of their UAL Doctoral Theses co-directed by researchers from UAL and PSA. This ensures continuity and dissemination of knowledge generated, especially as CIESOL trained PhDs are working in prestigious research centers in different countries around the world.

In addition to the detailed information that will be shown in the following chapters by the functional and technical units, in this initial Abstract of activities the following milestones from 2015 stand out:

X Aniversario (November 2015):



On 19th November 2015 an official ceremony was held to mark the tenth anniversary of the UAL-CIEMAT joint center. The event was attended by the Director of the Energy Department of CIEMAT, D. Ramón Gavela González and the Rector of the University of Almería, D. Carmelo Rodríguez Torreblanca. D. Joaquín Araujo Ponciano, the prestigious science communicator and disseminator, gave a lecture entitled "An energy model of solidarity".

During the ceremony, the protocol signing for the extension of the CIEMAT-UAL collaboration agreement for another decade, namely the CIESOL joint venture took place, with the firm belief that the collaboration between the two institutions would be as fruitful as the previous ten years. During this event the importance of this institution in the field of solar energy research was also underlined.

On the occasion of our anniversary, Nova Science magazine published a special issue dedicated to CIESOL. Also, both the local press and various web publications reported the news.

Awards received in 2015:

Outstanding awards were received by several members of CIESOL, as follows: Prize for the best work in the Automatic Control Engineering XXXVI Jornadas de Automática para la Unidad de Modelado y Control; Scholarship to support young researchers from the IBERDROLA SPAIN Foundation, as part of the Call for Grants for Research in Energy and Environment for Dr. María del Mar Castilla from the Modeling and Control Unit; Prize for the best work in the Energy session at the VIII Congreso Ibérico de Agroingeniería 2015; Extraordinary award for a PhD from UNED for Alberto de la Calle Alonso; Prize for the Best Doctoral Thesis 2015 on applications for environment for Elisabet Ortega Gómez (European Advanced oxidation Processes PhD School).



Dissemination and research transfer:

With an interest in the dissemination and transfer of research, during 2015 CIESOL actively participated in the organization of an international workshop, and other international activities, related to the field of solar energy, such as:

- Workshop on: "Metal, Water and Sun 2015", Almería, May 2015.
- 3rd IFAC Internet Based Control Education, Brescia, Italy November 2015 Manuel Berenguel Soria.
- Organization of Training Network course "Robótica en Agricultura" ceiA3 2015. Modeling and Control Unit.
- Participation in the European project: Researchers' Square (RESSQUA) regarding the organization of the European Researchers' Night, September 2015.

Activities related to repair and maintenance of CIESOL facilities:

- Request to the Directorate General of Infrastructure for routine maintenance operations at Ciesol: July 2015
- Repairing roof gutter: September 2015
- Removing the metal structure from the courtyard: October 2015
- Siding (roofing) compressors: November 2015
- Renovation of the cold storage facilities: December 2015

Document for basic workplace advice and access to the center:

During 2015 a document summarizing the workplace and access rules for the CIESOL building was produced. This document was made public at the briefing held on 13th November 2015 in order to properly inform all center staff.

2. ACTIVITIES IN CIESOL

2.1 ACTIVITIES OF "ORGANOMETALLICS AND PHOTOCHEMISTRY"

2.1.1 Funcional unit description

In 2015 the unit was constituted by 12 members (three university professors, six researchers and three predoctoral contracts) 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, CTAP and Tecnova, 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 (> 180 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 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 125 international refereed papers, 13 Spanish and international patents and made more than 220 presentations at national and international meetings. He has been responsible for more than 19 national research regional and European projects, was supervisor of 15 PhD and is supervising 3 more. He is responsible of the Junta de Andalucía research team FQM-317.

Christoph Richter (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 chemical 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 Almeria. Since March 2008, is the Secretary General of Solar PACES.

2.1.4 Summary of the activities carried out during 2015

During 2015 the group has undergone a profound transformation, first, a professor from the University of Cadiz was incorporate as well as PhD and master students, which were partially lost. As achievements to point out are three PhD thesis, articles in the best journals in chemistry, inorganic chemistry and materials, and two patents. Also, the team organized the first edition of the congress "Metal, water and Sun" that was held by researchers from various European countries and USA, who were interested in organometallic chemistry, catalysis and photocatalysis in water. It should also be noted that the group achieved a MINECO project and industrial contracts. The obtained fund will allow to the team to continue its research activity next years.

2.1.5 New staff: pre and post-doctoral fellowships, contracts, scholarships

The group incorporated a permanent professor from the U. de Cádiz, two PhD students and one master student. Unfortunately for the group, master's student left it after obtaining a scholarship grant in another CIESOL-PSA group, which was obviously very positive for the student. The group also received two Tunisian students for 6 months and an Ecuadorian student for two months.

2.1.6 Publications (Journal articles, doctoral theses, conference communications, book chapters etc.)

Papers

- Metal backbone polymers $[M(\text{isn-jNpy})_4(\text{l-SiF}_6\text{-jF,F0})]_n$ ($M = \text{Cu, Co, Ni}$; isn = isonicotinamide) containing an unusual hexafluoridosilicato bridge. *Inorganica Chimica Acta*, 2015, 427, pp 198-202.
- First Water-Soluble Backbone Ru–Ru–Ni Heterometallic Organometallic Polymer. *Macromol. Rapid Commun.* 2015, 36, pp 689-693.
- Ruthenium(II) complexes containing benzimidazolic tripodal ligands. *Inorganica Chimica Acta*, New advances in Coordination Chemistry, special issue 2015, 431, pp 258-265.

Book Chapter

- Book: Non-covalent Interactions in the Synthesis and Design of New Compounds. Chapter: Non-covalent interactions of water with metal complexes in solution. John Wiley & Sons, Inc. 2015. ISBN: 978-1-119-10989-1.

Congress

- XIX SEMANA CIENTÍFICA "Antonio González", 6 - 9 October 2015, La Laguna, Tenerife, Spain.
- Molecular Spectroscopy Science Meeting 2015, 29-30 January 2015, Cosener's House, Abingdon.
- 12th European Workshop on Phosphorus Chemistry. 1-18 March 2015, Kassel, Germany.
- Metal, Water and Sun 2015, 21-22 May 2015, Almeria, Spain.
- 2nd European Conference on Smart Inorganic Polymer. 24-26 September, 2015. Uppsala, Sweden.

Patents

Title: Células solares constituida por agua y complejos de rutenio con fosfinas acuosolubles: un nuevo tipo de células solares.

No: P201500602 (P2015-91000000557) (22/07/2015)

Applicant: University of Almería

Congress Organization

Title: Metals, Water and Sun (MWS2015)

http://www.ual.es/Congress/MWS-2015/index_en.html

INTERNATIONAL

Date: 21-22/05/2015

Location: Almería (Spain)

2.1.7 Staff

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2.1.8 Ongoing projects in 2015

2.1.8.1 New smart and sostenible factory for demilitarization and defence technologies. SIXTREMS

Participants:

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

Contacts:

A. Romerosa Nievas (romerosa@ual.es)

Source of funding:

Ministerio de Economía y Competitividad. FEDER 2013 (ITC-20132016)

Duration:

January 2013 – July 2015

Status:

Ended

Abstract

The project is targeted to obtain a procedure to transform white phosphorus, coming from weapons demilitarization, into red phosphorus, more stable and secure. Solar radiation will be used as the energy source to promote the transformation.

2.1.9 Activities and Courses, technical capacity

Workshop Metals, water and Sun 2015

In 2015 the group organized the first edition of the meeting entitled "Metal, water and Sun" (http://www.ual.es/Congress/MWS-2015/index_en.html), an international conference that brought together the most important research teams in coordination chemistry / organometallic catalysis and photocatalysis in water. The obtained congress success advises to held a new version in future as it can become the international platform to present and discuss new findings in the area.



2.1.10 Project's applications in 2015

During 2015 was submitted to the Spanish National call in the Retos section the project entitled "POLIHETEROORGANOMETALICOS FLUORESCENT POLYMERS water soluble." which was awarded.

2.2 ACTIVITIES OF "ANALYTICAL EVALUATION OF WATER TREATMENT AND ENVIRONMENTAL ANALYSIS"

2.2.1 Funcional unit description

The staff of the Unit is made up of researchers from the Department of Chemistry and Physics at the University of Almería 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

Ana Agüera López (Scopus Author 6701415534)

Full professor at the University of Almería. Degree in Chemistry (1987). PhD in Chemistry (1995). She has 25 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 more than 20 national and international competitive R&D Projects. She is co-author of 2 patents and 117 scientific publications in indexed international journals (h-index = 45, March 2016). She has also co-authored more than 150 conference papers, 3 books and 11 book chapters, and has participated in the organization of 7 international conferences. She has supervised 7 doctoral theses.

Isabel Oller Alberola (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 1 National Editorial book and co-author of 7 International

Editorial books chapters. Furthermore, she is co-author of 74 publications in indexed scientific international journals and 270 contributions to different International Congresses and Symposiums (until March 2016). She has also participated as teacher in some national and international courses and masters related with Advanced Treatment of Wastewater. H-index (March 2016): 27.

2.2.4 Summary of the activities carried out during 2015

Overall, the Unit has worked on projects in progress. It has been proposed a specific strategy as baseline for the treatment and reuse of cork boiling wastewater (CBW) based on the combination of an optimized physicochemical pre-treatment with an AOP (solar photo-Fenton) and a final purification stage through a nanofiltration system, to increase the quality of the effluent so that it can be reused in the own cork boiling process, meaning a reduction in the use of fresh water. In addition, despite of the complexity of the raw water matrix, unknown positive masses were monitored in a LC-QTOF/MS system operated in full scan mode. Acute and chronic toxicity were also monitored throughout the proposed treatment line. This strategy recommends the use of a nanofiltration membrane at the end of AOPs with the main objective of retaining possible contaminants present in the treated effluent (responsible for chronic toxic results) and so obtaining a final permeate with a high enough quality for reuse purposes.

We have also worked on the improvement and development of new analytical methodologies for the determination of contaminants that expand the range of compounds that can be identified and monitored during wastewater treatments. It has also worked on the development of protocols for the identification of transformation products (TPs). In this sense, we have collaborated with the University of Cranfield in identifying TPs of the herbicide Quinmerac and with the Department of Chemical Engineering and Physical Chemistry of the University of Extremadura (Badajoz), welcoming the predoctoral stay of D. Rafael Rodriguez Solis in CIESOL laboratories. The doctoral candidate has carried out the work entitled "Identification of oxidation by-products coming from the photocatalytic ozonation of contaminants in water by liquid chromatography coupled with high resolution mass spectrometry (LC-MS-QTOF)" during the period from 01.03.2015 to 04.30.2015.

It has been launched a new line of research, in collaboration with PSA, intended to evaluate the environmental impact of the use of reclaimed water in irrigation practices. In this sense, we have developed a multiresidue method for determining contaminants of emerging concern in soil, plant and fruit. Laboratory tests have been conducted to evaluate the accumulation and translocation of pollutants in different parts of the plant.

Finally, it hosted the three-month stay of Dr. Adriana Freitas, of the University of Technology Federal de Minas Gerais (Brazil), the result of which, in collaboration with the Functional Unit of Water Treatment, a new research line focused on the assessment of the acute and chronic toxicity of treated water has been initiated.

2.2.5 New staff: pre and post-doctoral fellowships, contracts, scholarships

In October 2015 the call for Research Personnel in training, linked to the research projects of the Junta de Andalucía 2012, was resolved. The selected candidate was Ms. Ana Ruiz Delgado who will begin her predoctoral training in CIESOL under the direction of Dr. Ana Agüera and Dra. Isabel Oller.

Dña. Marina Celia Campos Manas was hired under the project REAQUA. She is under the direction of Dr. Ana Agüera and Dr. José Antonio Sánchez.

Mrs. Estefania Torres and Mrs. Lucia del Pilar Prieto have left the group, the latter currently engaged in the Andalusian Stone Technology Centre (CTAP).

During this year, the Unit has also supported the request for two research contracts on the Juan de la Cierva and Ramón y Cajal calls.

2.2.6 Publications (Journal articles, doctoral theses, conference communications, book chapters etc.)

Papers

- Fate of micropollutants during sewage sludge disintegration by low-frequency ultrasound, *Chemical Engineering Journal*, 2015, 280, pp. 575-587.
- Cross-Contamination of Residual Emerging Contaminants and Antibiotic Resistant Bacteria in Lettuce Crops and Soil Irrigated with Wastewater Treated by Sunlight, *Environmental Science and Technology*, 2015, 49 (18), pp. 11096-11104.
- Removal of microcontaminants from MWTP effluents by combination of membrane technologies and solar photo-Fenton at neutral pH. *Catalysis Today*, 2015, 252, pp. 78-83
- Benefits and limitations of using Fe(III)-EDDS for the treatment of highly contaminated water at near-neutral pH. *Journal of Photochemistry and Photobiology A: Chemistry*, 2015, 303-304, pp. 1-7.
- Application of high intensity UVC-LED for the removal of acetamiprid with the photo-Fenton process. *Chemical Engineering Journal*, 2015, 264, pp. 690-696.
- Detailed treatment line for a specific landfill leachate remediation. Brief economic assessment (2015). *Chemical Engineering Journal*, 2015, 261, pp. 60-66.
- Degradation and monitoring of acetamiprid, thiabendazole and their transformation products in an agro-food industry effluent during solar photo-Fenton treatment in a raceway pond reactor. *Chemosphere*, 2015, 130, pp. 73-81.
- Modelling of the operation of raceway pond reactors for micropollutant removal by solar photo-Fenton as a function of photon absorption. *Applied Catalysis B: Environmental*, 2015, 178, pp. 210-217.
- Microcontaminant degradation in municipal wastewater treatment plant secondary effluent by EDDS assisted photo-Fenton at near-neutral pH: An experimental design approach. *Catalysis Today*, 2015, 252, pp. 61-69.

Book Chapter

- Book: Mass detectors. Mass spectrometry for the analysis of pesticide residues and their metabolites. Chapter: Recent developments in liquid-chromatography mass spectrometry: Wiley. 2015, ISBN: 978-1-118-500017-0.

Congress

- SETAC Europe 25th Annual Meeting, 3-7 May, 2015, Barcelona, Spain.
- 4th European Conference on Environmental Applications of Advanced Oxidation Processes – EAAOP4, 21-24 October, 2015, Atenas, Greece.
- VIII Encontro sobre aplicações ambientais de processos oxidativos avançados, 3-6 November, 2015, Belo Horizonte, Brasil.

2.2.7 Staff

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2.2.8 Ongoing projects in 2015

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

Participants:

"Environmental Analysis" Functional Unit

Contacts:

A. Agüera (aaguera@ual.es)

I. Oller (Isabel.oller@psa.es)

Source of funding:

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

Duration:

January 2014 - January 2019. Ampliado

Status:

In progress

Abstract:

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:

- Characterization of wastewaters from different origin by wide spectrum analytical protocols including extraction procedures and combined analytical techniques.
- 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.
- 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.

2.2.8.2 Cost reduction of solar photo-Fenton process using extensive open reactors for water regeneration (REQUA)

Participants:

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

Contacts:

J. A. Sánchez (jsanchez@ual.es)

A. Agüera (aaguera@ual.es)

Source of funding:

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

Duration:

January 2014 – December 2016

Status:

In progress

Abstract:

The removal of low concentrations of pollutants by photo-Fenton presents new challenges, scientifically and technically. It must be delved into reactions mechanisms and detection of generated transformation products.

Furthermore, the irradiation needs are fewer, reaching a point of kinetic saturation at high irradiances (light excess), so light distribution inside the reactor is especially important. Thus, we lay out a study of new treatment plants where the photoreactor surface and treated water volume per surface area are taken into account.

In addition to the technical development, an economic assessment has become essential to turn the photo-Fenton process into a commercial treatment. We propose the use of open reactors, "raceway" type, due to their low cost and the fact that they allow changing the optical path as a function of incident solar radiation. We expect to minimize total costs, maximizing reclaimed water volume per surface area.

Analytical assessment is especially important to monitor micro-contaminants and detect their transformation products during the treatment. For this purpose, highly sensitive and selective analytical techniques, based on mass spectrometry, will be used. It will also be proposed the development of simpler and faster detection strategies, which use pollution tracers.

Objectives:

- Show the technical and economic feasibility of "raceway" reactors for decontamination, disinfection and wastewater reclamation at pilot plant scale.
- Obtain the best operating conditions for the proposed system
- Improve and validate new analytical methods based on mass spectrometry which allow an adequate evaluation of the treated water
- Ensure effective removal of micro-contaminants and their transformation products during treatment, to obtain effluent suitable for reuse in different applications.

2.2.9 Activities and Courses, technical capacity

Working group "WG5: Wastewater reuse"

(<http://www.norman-network.net/?q=node/106>) of NORMAN (No. W604002510) network - Network of reference laboratories, research centers and related organizations for monitoring of emerging environmental substances (<http://www.norman-network.net/>). It is working on a campaign of detection of antibiotic resistant's genes in effluents of sewage treatment plant in Europe. New activities for 2016 include:

- Address the validation of the results of the 2014 and 2015 screening campaigns, the aim being to design and agree on a harmonized method for antibiotic resistance detection and quantification.
- Address the drafting of minimum quality criteria for reuse of treated wastewater for groundwater aquifer recharge and agriculture irrigation. That will include: biological tests, associated with trigger values; priority chemical contaminants; measurement of antibiotic resistance; recommendations for monitoring schemes.

European COST Action entitled: 'NEW AND EMERGING CHALLENGES AND OPPORTUNITIES IN WASTEWATER REUSE (NEREUS)'

(<http://www.nereus-cost.eu/>). The action's main objective is to develop a multidisciplinary network to determine which of the current challenges related to wastewater reuse are the most concern to public health and environmental protection, and how they can be overcome. The group is actively involved in the action through working groups on "Uptake and translocation of organic microcontaminants and ARB&ARG in crops" (WG2) and "Technologies efficient/economically viable to meet the current wastewater reuse challenges" (WG4). During the past 29-30 October 2015, it took place the "**3rd Management Committee and Working Groups Meeting**" in Belval, Luxembourg, in which Dra. Ana Agüera made a presentation entitled "Validation and application of a multiresidue method to the evaluation of plant uptake of pharmaceuticals from recycled water".

CONSOLIDER TRAGUA NETWORK

(CTM2014-53485-REDC), MINECO. The first meeting of the Network took place on January 14, 2015 in Zaragoza. The meeting was entitled "NEW SOURCES: WATER REUSE IN THE CONTEXT OF SUSTAINABLE MANAGEMENT" and was framed as a side event at the Annual Conference 2015 of UN-Water. Dra. Ana Agüera, as coordinator of the group "Control and Evaluation of Water Quality", made a presentation with the activities of the group in recent years.

1st Summer School on Environmental Applications of Advanced Oxidation Processes

that took place at the University of Salerno (Fisciano, Italy) on 15-19 June 2015 and was organized by the "European PhD School on Advanced Oxidation Processes" to which several members of this research unit belong. Two guest lectures were made at the associated Workshop titled "Water and wastewater treatment by Advanced Oxidation Processes: state of art and perspectives".

2.2.10 Project's applications in 2015

1. Interreg MED Programme, 2014-2020. Closing the Urban Water Cycle in the Mediterranean area through sustainable utilization of urban wastewater. RE-WATER-MED. Lead by Technical University de Crete, School of Environmental Engineering (TUC). Participants: CIESOL (Spain); University of Cyprus, Nireas International Water Research Center (UCY, Nireas); Region of Crete, Directorate of Environment and Spatial Planning (RegCrete), Greece; Municipal Wastewater Treatment Plant (WWTP, Creta, Greece); Rudjer Boskovic Institute, Division for Marine and Environmental Research (RBI), Croatia; Jožef Stefan Institute (JSI), Slovenia; Institute of Environmental Protection and Sensors (IOS), Slovenia; Università degli Studi di Salerno, Department of Civil Engineering (UNISA), Italy; Water Services Corporation, Malta (WSC, Malta); Research Institute for Development (IRD), UMR 5569 HydroSciences, Montpellier (HSM), France; BIO-UV, <http://www.bio-uv.com/>, France.
2. LIFE+ Projects. European Union. Depuration of Pesticide-contaminated Effluents: Lowering the Environmental Impact Of fruit-PACKaging plants, PELOPAS. Lead by University of Thessaly (Greece). Participants: CIESOL (Spain), Aeiforia (Italy), Cítricos Andarax SA (Spain), The Cyprus Phassouri Co. LTD (Cyprus), Sanifrutta (Italy), Spyros Nikolitsas S.A. (Greece) y Talos (Cyprus), Agricultural Research Institute (Cyprus), Benaki Phytopathological Institute (Greece) and University of Thrace (Greece).
3. Plan Estatal de Investigación Científica y Técnica y de Innovación 2013-2016. Modalidad 3: Proyectos de I+D+I para jóvenes investigadores. MINECO. "Development of advanced analytical tools for the evaluation of the effect of the reuse of regenerated water in agriculture: microcontaminants and transformation products" REAGRICONT. Participants: Patricia Plaza Bolaños; Ana Agüera.
4. Programa Estatal de Fomento de la Investigación Científica y Técnica de Excelencia, Subprograma Estatal de Generación de Conocimiento, modalidad 3: Acciones de dinamización "Redes de Excelencia", convocatoria de 2015. New materials and photocatalytic reactors for the removal of micro-contaminants and pathogens" FOTOCAT. Participants: Universidad Rovira i Virgili, U. Extremadura, U. Ramon Llull, U. Rey Juan Carlos, U. Politécnica de Valencia, U. Almería, PSA-CIEMAT and ICRA

2.3 ACTIVITIES OF "WATER TREATMENT"

2.3.1 Funcional unit description

The staff of the research group is also part of the group of the Andalusian Research Plan (PAI) "Bioprocess Engineering and Water Technologies, BIO263" created in 1999 within the Department of Chemical Engineering at the University of Almería (UAL). During these years, the group has increased its scientific activity in the field of biotechnology of microalgae, in the fermentation of filamentous fungi and, currently, in the purification and decontamination of water contaminated with persistent toxics. There is a close collaboration with the group "Analytical evaluation of water treatment and environmental analysis", complementing and strengthening the main lines of current work.

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 wastewater disinfection
- Combination of solar photo-Fenton and membrane bioreactor (pre-and post-treatment)
- Optimization of the operation and development of new technology for photo-Fenton
- Water treatment economics

2.3.3 Main researchers

José Antonio Sánchez Pérez (Scopus Author ID 7006076735)

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 15 research projects (European and Spanish projects) and has led 8 of them. 12 Research contracts with private companies most of them related with the development of Solar Technologies applied to wastewater treatment. He has directed 13 PhD theses in different fields such as biotechnology of microalgae, filamentous fungi fermentation and water treatment, co-authored more than 100 peer-reviewed international papers.

Manuel Ignacio Maldonado Rubio (Scopus Author ID: 7102035826)

Degree in Chemistry by Univ. of Granada (1994); PhD by the Univ. of Almería (2001). Master in Environmental Sciences by the Instituto de Investigaciones Ecológicas (Málaga, 1999). Working for CIEMAT since 2002. Scientific production summary: co-authored more than 90 paper-reviewed international publications (h index 34), co-author of 6 books as well as 20 chapters in others, 116 communications to international congresses and 4 communications to national congresses. He has involved in 12 European Union research projects (4th, 5th and 6th Framework Programmes), 9 National research projects and 4 R&D Contracts with private companies related with the development of Solar Technologies applied to wastewater treatment.

2.3.4 Summary of the activities carried out during 2015

During 2015 we have worked on projects in progress, with special attention to the development of the solar photo-Fenton process raceway pond reactors and the study of the application of LED powered by

photovoltaic energy as a source of radiation. A new line of work that has been introduced in the group has been studying the toxicity of water with micropollutants and simultaneous removal by photo-Fenton. For that, the research group carried out two international collaborations. The first one, Dr. Adriana Freitas, Federal University of Technology of Minas Gerais (Brazil), made a stay at Ciesol for three months working on the evaluation of acute and chronic toxicity. The second one, the doctoral candidate Gracia Rivas Ibáñez made a three-month stay at the RECETOX center of the Czech Republic studying new methods for the evaluation of the toxicity using hormonal tests. The main findings of both studies are: the solar photo-Fenton process at initial neutral pH is able to significantly reduce toxicity, while eliminating the total charge of micropollutants in wastewater secondary effluent; and there are not available simple methods of determining toxicity with short response times and serve to monitor the efficiency of the implementation of tertiary treatment. Consequently, a new field of great interest come up. This task has been developed in collaboration with the group "Analytical evaluation of water treatment and environmental analysis."

Regarding the operation of raceway pond reactors, the group have worked on the kinetic modelling of the elimination of micropollutants considering factors such as temperature, optical properties and concentration of the absorbing species, and the optical path (reactor geometry) that affect on the rate of absorption of photons at optimum pH for this reaction (2.8). The model, developed at laboratory scale and validated at pilot plant, allowed to reproduce the experimental results adequately and predict the behavior of operating in continuous mode reactors, which experimental verification is currently running. To our knowledge, this is the first study on the application of the solar photo-Fenton process in continuous mode. It also has worked on the application at neutral pH by using complex Fe³⁺/EDDS in raceway reactors. The first results are very encouraging. This research with the complexed Fe was carried out in collaboration with the unit "Solar Water treatment" of the Solar Platform of Almería.

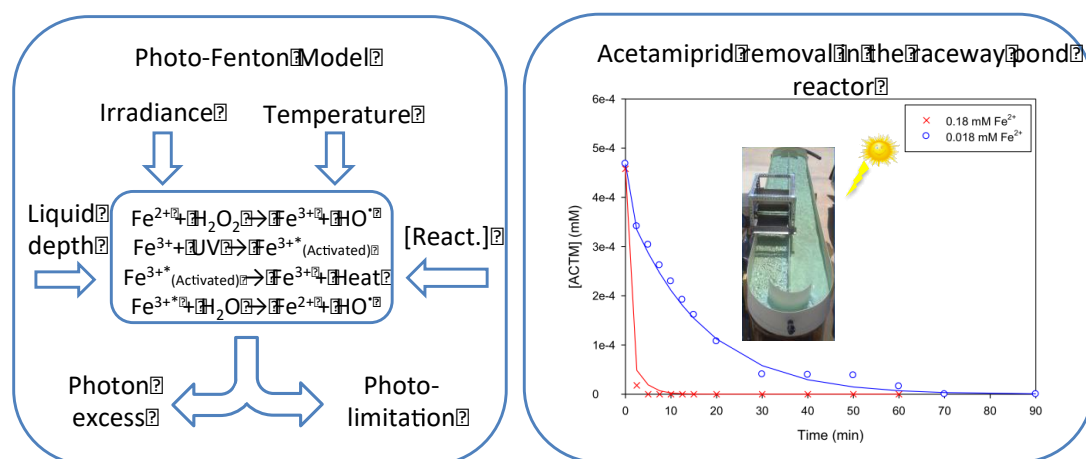


Figure. Schematic representation of modelling of the photo-Fenton process in raceway reactors and comparison of the simulation model (lines) with the experimental data (points) for two concentrations of iron.

Regarding the tasks performed with reactors based on LEDs different types of LEDs differentiated by its wavelength and energy efficiency were evaluated. In this sense, it has been shown that the most

energetic radiation with shorter wavelengths, leading to faster kinetics are not the most favourable to be applied to the photo-Fenton process from an economic point of view and energy efficiency.

2.3.5 New staff: pre and post-doctoral fellowships, contracts, scholarships

During 2015 Dr. Elizabeth Gómez Ortega left the group in August, at the end of her predoctoral FPI contract and Dr. Alejandro Cabrera Reina in July, enjoying a postdoctoral position at the University of Tarapaca (Arica, Chile) - SERC Chile (Solar Energy Research Center) in the unit of Solar Water Treatment. On the other hand, Paula Soriano Molina with FPU predoctoral contract and Sandra Salgado Arzate with a predoctoral FPI contract have joined the group.

2.3.6 Publications (Journal articles, doctoral theses, conference communications, book chapters etc.)

Papers

- Removal of microcontaminants from MWTP effluents by combination of membrane technologies and solar photo-Fenton at neutral pH, *Catalysis Today* 2014, 252.
- Modeling the photo-Fenton oxidation of the pharmaceutical paracetamol in water including the effect of photon absorption (VRPA), *Applied Catalysis B: Environmental*, 2015, 166-167, pp 295-301.
- Biological oxygen demand as a tool to predict membrane bioreactor best operating conditions for a photo-Fenton pretreated toxic wastewater, 2015, *Journal of Chemical Technology & Biotechnology*, 2015, 90, pp 110-119.
- Supported-TiO₂ solar photocatalysis at pilot plant scale: degradation of pesticides found in citrus processing industry wastewater. Reactivity and influence of photogenerated species, *Journal of Chemical Technology & Biotechnology*, 2015, 90, pp 149-157.
- Application of high intensity UVC-LED for the removal of acetamiprid with the photo-Fenton process, *Chemical Engineering Journal*, 2015, 264, pp 690-696.
- Principal parameters affecting virus inactivation by the solar photo-Fenton process at neutral pH and μM concentrations of H₂O₂ and Fe^{2+/3+}, *Applied Catalysis B: Environmental*, 2015, 174.
- Application of solar photo-Fenton at circumneutral pH to nanofiltration concentrates for removal of pharmaceuticals in MWTP effluents, *Environmental Science and Pollution Research*, 2015, 22(2), pp 846-855.
- Modelling of the operation of raceway pond reactors for micropollutant removal by solar photo-Fenton as a function of photon absorption, *Applied Catalysis B: Environmental*, 2015, 178, pp 210-217.
- Degradation and monitoring of acetamiprid, thiabendazole and their transformation products in an agro-food industry effluent during solar photo-Fenton treatment in a raceway pond reactor, *Chemosphere*, 2015, 130, pp 73-81.
- Fate of micropollutants during sewage sludge disintegration by low-frequency ultrasound, *Chemical Engineering Journal* 2015 280, pp 575-587.

Books

- Application of the photo-Fenton process for the removal of persistent pollutants: operation parameters, Irene Carra Ruiz, José Antonio Sánchez Pérez, Sixto Malato Rodríguez, Ana Agüera López, José Luis Casas López, Editorial CIEMAT, 2015, ISBN: 978-84-7834-733-9.
- Inactivación de microorganismos presentes en aguas mediante foto-Fenton solar a pH neutro, Elisabet Ortega Gómez, José Antonio Sánchez Pérez, María de la Menta Ballesteros Martín, Pilar Fernández Ibáñez, Editorial CIEMAT, 2015, ISBN: 978-84-7834-744-5.
- Degradación de Contaminantes Emergentes mediante TiO₂ Inmovilizado e Irradiación Solar, M. I. Maldonado Rubio; S. Suárez Gil; N. Miranda García, Editorial CIEMAT 2015, ISBN: 978-84-7834-735-3.

- Desarrollo de Nuevas Estrategias Basadas en Fotocatálisis Solar para la Regeneración de una Industria Agro-alimentaria, M. I. Maldonado Rubio; M. Jiménez Tototzintle; I. Oller Alberola, M^a Aracely Hernández Ramírez, Editorial CIEMAT 2015, ISBN: 978-84-7834-742-1.

Congress

- 4th Conference on Environmental Applications of Advanced Oxidation Processes (EAAOP4), 21-24 October 2015, Athens, Greece.

Doctoral Theses

- Eliminación de micro-contaminantes mediante combinación de procesos de membrana (nanofiltración) y procesos avanzados de oxidación, Sara Miralles Cuevas, directors S. Malato Rodríguez, J.A. Sánchez-Pérez, Almería, 10 March 2015.
- Inactivación de microorganismos presentes en aguas mediante foto-Fenton solar a pH neutro, Elisabet Ortega Gómez, directors José Antonio Sánchez Pérez, Pilar Fernández Ibáñez, Menta Ballesteros Martín, Almería, 23 April 2015.
- Degradación de contaminantes emergentes mediante TiO₂ inmovilizado e irradiación solar, Noelia Miranda García, directors M. Ignacio Maldonado, Silvia Suárez Universidad de Almería. May 2015.
- Desarrollo de nuevas estrategias basadas en fotocatálisis solar para la regeneración de aguas de una industria agro-alimentaria, Margarita Jiménez Tototzintle, directores M. Ignacio Maldonado, Isabel Oller, M^a Aracely Hernández-Ramírez, Universidad de Almería. July 2015

2.3.7 Staff

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2.3.8 Ongoing projects in 2015

2.3.8.1 Combination of intensive technologies for improving the quality of aqueous effluents in SMEs. Integrated design process (AQUAPYME)

Participants:

Grupo de Inv. "Ingeniería de Bioprocesos y Tecnologías del Agua". Universidad de Almería (BIO-263)

Unidad de "Tratamientos Solares de Agua". PSA-CIEMAT

Contacts:

J. L. Casas (jlcasas@ual.es)

S. Malato (sixto.malato@psa.es)

Source of funding:

Junta de Andalucía. Proyecto de Excelencia 2010. (P10-RNM-5951)

Duration:

July 2011 – October 2016

Status:

In progress

Abstract:

Currently, there are new technologies for water reuse that return to water the quality appropriate to the intended destination (according to RD 1620/2007), however, the high costs and the different problems in their application indicating the need for further research on taking into account the minimization of energy cost and environmental risk to facilitate their implementation. Furthermore, it is also necessary to ensure the quality of reclaimed water, evaluate these treatments, including the study of potential risk associated with the reuse of treated water. The overall project objective is to study the combination of intensive sustainable technologies to improve the quality of water effluents in SMEs. To this end, a new integrated process design based on the use of anoxic membrane bioreactors and solar photocatalysis for the regeneration of industrial wastewater reuse permitting SMEs according to RD 1620/2007. In this regard, attention should be paid both to the disinfection of treated water to the elimination of persistent pollutants. Likewise, also be carried out the application of ultrasound to minimize the production of sludge.

Objectives:

- Evaluate the combination of different technologies based on sustainable intensive use of membranes and solar photocatalysis for the treatment of effluents from SMEs.
- Studying nutrient removal effluent IWWTP of SMEs through anoxic membrane bioreactor.
- Integrate ultrasound-based treatments to minimize the generation of sludge in membrane bioreactors.
- Assess the processes proposed from the standpoint of economic and quality assurance.

2.3.8.2 Design of new reactors for solar photo-Fenton applied to water regeneration. Economy, scaling and process control (SULAYR)

Participants:

Grupo de Inv. "Ingeniería de Bioprocesos y Tecnologías del Agua". Universidad de Almería (BIO-263)

Unidad de "Tratamientos Solares de Agua". PSA-CIEMAT

Contacts:

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P. Fernández (pfernandez@psa.es)

Source of funding:

Junta de Andalucía. Proyecto de Excelencia 2012. (P12-RNM-1437)

Duration:

January 2014 – January 2017

Status:

In progress

Abstract:

Many aspects about the photo-Fenton process have been studied in order to understand the factors that affect it and thus improve efficiency. An important factor is the type of photoreactor where the process takes place. These photoreactors were developed at pilot scale in parallel with other applications of solar energy and the use of plants based on compound parabolic trough solar collectors (CPC) is commonly accepted. The study of new treatment plants that take into account the surface (area) that photoreactors occupy and the volume of water that can be treated in this area arises. This concept was rarely studied in the development of the first plants because it was prioritized in the capacity of solar collection.

Objectives:

- Designing new solar to optimize both the solar radiation use and the volume of water treated per unit area.
- Designing new process control and automation.
- Studying the scaling up of the process considering the objectives of quality of treated water.
- Economic study of the implementation of the developed photoreactors for tertiary treatment of wastewater

2.3.8.3 Cost reduction of solar photo-Fenton process using extensive open reactors for water regeneration (REQUA)

Participants:

Unidad funcional "Tecnologías avanzadas para la regeneración de aguas"

Unidad funcional "Evaluación analítica de tratamientos de aguas y análisis ambiental"

Contacts:

J. A. Sánchez (jsanchez@ual.es)

Agüera (aaguera@ual.es)

Source of funding:

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

Duration:

January 2014 – December 2016

Status:

In progress

Abstract:

Information regarding this project can be found in section 2.2.8.2 of this report as it is a shared project.

2.3.8.4 Regeneration of wastewater from the nursery at the University of Almería using solar energy

Participants:

Grupo de Inv. "Ingeniería de Bioprocesos y Tecnologías del Agua". Universidad de Almería (BIO-263)

Unidad de "Tratamientos Solares de Agua". PSA-CIEMAT

Contacts:

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M. I. Maldonado (mignacio.maldonado@psa.es)

Source of funding:

Vicerrectorado de Infraestructuras, Campus y Sostenibilidad. Acuerdo de colaboración con la Universidad de Almería

Duration:

July 2010 – July 2015

Status:

In progress

Abstract:

The aim of this agreement is to treat the wastewater produced in the nursery of the University of Almería. To do this, a pilot plant to treat wastewater using advanced biological systems and then disinfect the treated water using solar photocatalytic methods has been installed.

2.3.9 Activities and Courses, technical capacity

1st Summer School on Environmental Applications of Advanced Oxidation Processes

It took place at the University of Salerno (Fisciano, Italy) on 15-19 June 2015 and was organized by the "European PhD School on Advanced Oxidation Processes" to which several members of this research unit belong. Two guest lectures were made at the associated Workshop titled "Water and wastewater treatment by Advanced Oxidation Processes: state of art and perspectives".

2.3.10 Project's applications in 2015

1. European Union LIFE+ project. Depuration of Pesticide-contaminated Effluents: Lowering the Environmental Impact Of fruit-Packaging plantS, PELOPAS. Lead by Universidad de Tesalia (Greece), Participants: CIESOL Almería (Spain), Aefioria (Italy), Cítricos del Andarax S. A. (Spain), The Cyprus Phassouri Co. LTD (Cyprus), Sanifrutta (Italy), Spyros Nikolitsas S.A. (Greece), Talos (Cyprus), Agricultural Research Institute (Cyprus), el Benaki Phytopathological Institute (Greece) and University of Thrace (Greece).
2. Acciones de Dinamización "Redes de Excelencia" from MINECO. New materials and reactors photocatalysts for the removal of micropollutants and pathogens, FOTOCAT (CTM2015-71054-REDT) Universidad Rovira i Virgili, U. Extremadura, U. Ramon Llull, U. Rey Juan Carlos, U. Politécnica de Valencia, U. Almería, PSA-CIEMAT e ICRA.
3. Call for International Partnerships Projects - Fund for International Collaboration Engineering Institute of the National Autonomous University of Mexico, UNAM-2015. Treatment type reactors raceway water contaminated with emerging organic compounds by photo-Fenton process using metallurgical slag and iron oxide nanoparticles supported on titania as catalys. Main researchers Rosa María Ramírez Zamora (UNAM) and José Antonio Sánchez Pérez.
4. Call for LIFE + project of the European Union. Challenges of drinking water in the XXI Century: demonstration of technologies for the removal and on-line monitorization of natural radioactivity in groundwater, Aura XXI. Lead by centro tecnológico CARTIF, Participants: CIESOL, Diputación Provincial de Almería, the company LABAQUA, the Water Technology Centre (CETAQUA) and the University of Tartu (Estonia).

2.4 ACTIVITIES OF MODELING AND AUTOMATIC CONTROL

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 20 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 agriculture.
- 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.

2.4.3 Main researchers

Manuel Berenguel Soria (Scopus Author 6701834872)

He received the industrial engineering and Ph.D. (extraordinary doctorate award) degrees from the University of Seville, Seville, Spain. He is Full Professor of automatic control and systems engineering with the University of Almería, 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" (<http://arm.ual.es>) from 2000. He has participated in more than 60 R&D projects and 30 contracts with companies. He is co-author of the books Advanced Control of Solar Plants (Springer, 1997), Control of Solar Energy Systems (Springer, 2012), Control Automático con Herramientas Interactivas (Pearson Education, 2012), Comfort Control in Buildings (Springer, 2014) and Modeling and Control of Greenhouse Crop Growth (Springer, 2014). He has been director of 14 PhD Thesis in these lines. He is co-author of 110 international journal papers, more than 150 papers in international conferences and 4 patents. H-index: 33 (Google Scholar), 25 (Scopus), 18 (Web of Science). He has participated in the International Program Committee of 8 international conferences (in one as IPC Chair) and 3 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 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. He was the organizer of the XXVII Jornadas de Automática (the annual meeting of the Spanish Automatic Control Committee) in 2006. He has been representative of the University of Almería in the Advanced Renewable Energy Technological Centre (CTAER), acting as Vice-President (2010-2015).

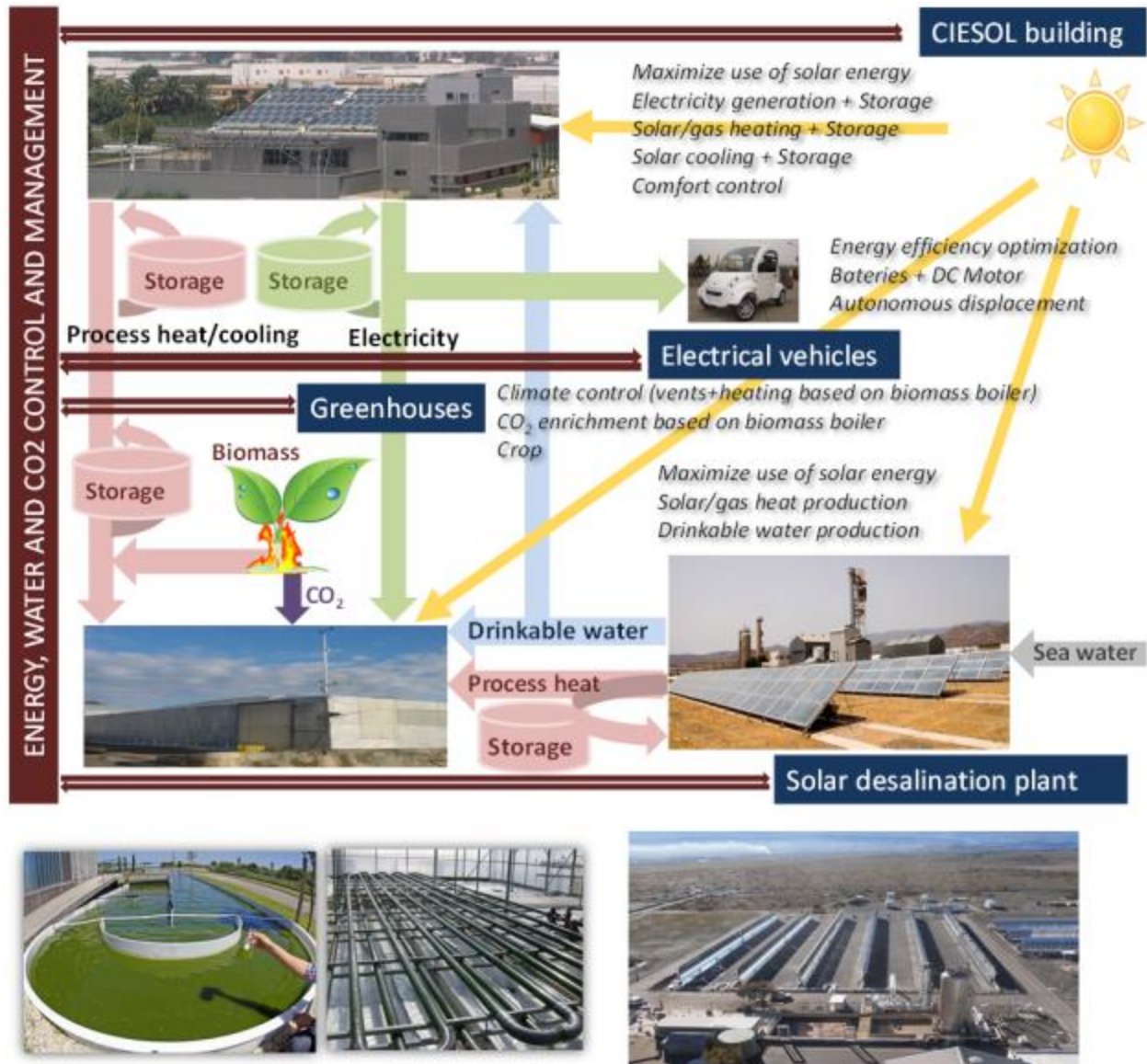
Luis José Yebra Muñoz (Scopus Author 15926309900)

He belongs to the MINECO Research Scientists body. He began his research activity in CIEMAT, in the Plataforma Solar de Almería center (PSA-CIEMAT) in 1999, developing a thesis on modeling and control of solar thermal plants, with specialization in object-oriented modeling activities of thermosolar plants with two-phase flow parabolic troughs. He has participated in research activities summarized in 35 research projects with public funding, 2 contracts with companies, creation of a spin-off, codirection of 4 PhD Theses, 26 journal publications in JCR, 68 contributions to conferences and 4 books. During some periods he has combined the research activity with the coordination of groups of technical services in PSA, as the Computing Service or the Industrial Informatics group, leading the Automatic Control group of PSA-CIEMAT from 2011 composed by 4 researchers. This activity was also combined with educational ones at the University of Almería within the Systems Engineering and Automatic Control area. He is also editor and reviewer of scientific journals in this area.

2.4.4 Summary of activities carried out during 2015

- Control and energy management strategies in production environments with support of renewable energy.
- Modeling and control of fotobioreactors and fotoreactors. Control and optimization for the biomass production from microalgae as renewable energy source.
- Modeling and control of solar desalination plants.
- Set up and technical and energetic evaluation of a novel hybrid loop for thermal generation (solar and biomass) for climate control of semi-closed greenhouses.
- Development of fertigation models and controllers, 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.

- Preparation and coordination of activities for future projects in TCP-100 PSA field.
- 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.



2.4.5 New staff: pre and post-doctoral fellowships, contracts, scholarships

- Gary Omar Ampuño Avilés. Lecturer at Universidad Pontificia Salesiana (Ecuador) and PhD student of the group (supervisors: Lidia Roca Sobrino, Manuel Berenguel Soria).
- María Mónica Miranda Ramos. Lecturer at Universidad Pontificia Salesiana (Ecuador) and PhD student of the group (supervisors: Francisco Rodríguez Díaz, Sixto Malato Rodríguez).
- Gabriel Castro Ronquillo. Lecturer at Universidad Pontificia Salesiana (Ecuador) and PhD student of the group (supervisors: José Luis Guzmán Sánchez, José Luis García Sánchez).
- Yaser Alamin. Granted by EU Project Phoenix-Marhaba (supervisors: José Domingo Álvarez Hervás, Antonio Ruano)
- César Hernández Hernández. FPI contract of the Ministry of Economy and Competitiveness - project DPI2010-21589-C05-04 (supervisors: Francisco Rodríguez Díaz, José Carlos Moreno Úbeda).
- José Antonio Carballo López. Predoctoral contract, PSA-UAL agreement (supervisors: Javier Bonilla Cruz, Manuel Berenguel Soria).

2.4.6 Publications (Journal articles, doctoral theses, conference communications, book chapters etc.)

Papers

- Nonlinear controllers for solar thermal plants: a comparative study. *Control Engineering Practice* 2015, 43, pp 12-20.
- Sliding mode control of distributed parameter processes: Application to a solar power plant. *Journal of Control, Automation and Electrical Systems* 2015, 25, pp 291-302.
- On reduction of control effort in feedback linearization GPC strategy applied to a solar furnace. *Optimal Control Applications & Methods* 2015.
- A low-cost modular platform for heterogeneous data acquisition with accurate interchannel synchronization 2015. *Sensors*, vol. 15, no. 10, pp 27374-27392.
- TP-Space RRT: Kinematic path planning of non-holonomic any-shape vehicles. *Journal of Advanced Robotic Systems* 2015, vol. 12, no. 55.
- Multibody dynamic systems as Bayesian Networks: applications to robust state estimation of mechanisms. *Multibody System Dynamics* 2015, vol. 34, no. 2, pp 103-128.
- Object-oriented modeling of a multi-pass Shell-and-tube heat exchanger and its application to performance evaluation. *IFAC-PapersOnLine* 2015, 48(11), pp 97-102.
- Switching moving boundary models for two-phase flow evaporators and condensers. *Communications in Nonlinear Science and Numerical Simulation* 2015, 20(3), pp 743-768.
- Dynamic modeling and simulation of a solar-assisted multi-effect distillation plant. *Desalination* 2015, 357, pp 65-76.
- Editorial optimal control of solar energy systems. *Optimal Control Applications and Methods* 2015.
- Hierarchical non-linear control of a tubular photobioreactor. *IFAC-PapersOnLine* 2015, 48(23), pp 224-229.
- A parabolic-trough collector for cleaner industrial process heat. *Journal of Cleaner Production* 2015, 89, pp 272-285.
- Comparison case between Modelica and specialized tools for building modelling. *IFAC-PapersOnLine* 2015, 48(1), pp 874-879.
- Robots Móviles con Orugas: Historia, Modelado, Localización y Control. *Revista Iberoamericana de Automática e Informática industrial* 2015, 12, pp 3-12.
- Performance indices for feedforward control. *Journal of Process Control* 2015, 26, February 2015, pp 26-34.

- Modeling of energy demand of a high-tech greenhouse in warm climate based on bayesian networks. *Mathematical Problems in Engineering* 2015, Article ID 201646.
- Teaching control engineering concepts using open source tools on a Raspberry Pi board. *IFAC-PapersOnLine* 2015, 48(29), 99-104.
- Efficient Reactive Navigation with Exact Collision Determination for 3D Robot Shapes: *International Journal of Advanced Robotic Systems* 2015, vol. 12, no. 63.
- Design and analysis of a flexible linkage for robot safe operation in collaborative scenarios. *Mechanism and Machine Theory* 2015, vol. 92, pp. 1-16.
- Selective pH and dissolved oxygen control strategy for a raceway reactor within an event-based approach. *Control Engineering Practice* 2015, 44, pp 209-218.
- Approximating the Pareto-front of a planar bi-objective competitive facility location and design problem. *Computers & Operations Research* 2015, 62, pp 337-349.
- Architecture to develop Semi-virtual industrial laboratories for the interactive learning of process automation. *Computer Applications in Engineering Education*, 2015.
- Semi-virtual Plant for the Modelling, Control and Supervision of batch-processes. An example of a greenhouse irrigation system. *IFAC-PapersOnLine* 2015, 48(29), pp 123-128.
- Understanding closed-loop identification with ITCLI (Interactive Tool for Closed-Loop Identification). *IFAC-PapersOnLine* 2015, 48(28), pp 739-744.
- Bayesian networks for greenhouse temperatura control. *Journal of Applied Logic* 2015.
- Modelling of a non-commercial UAV for control and robotics laboratory. *IFAC-PapersOnLine* 2015, 48(29), pp 65-69.
- Support system for decision making in the management of the greenhouse environmental based on growth model for sweet pepper. *Agricultural Systems* 2015, 139, pp 144-152.
- Water content virtual sensor for tomatoes in coconut coir substrate for irrigation control design. *Agricultural Water Management* 2015, 151, pp 114-125.
- Distributed MPC for resource constrained control systems. *Optimal Control Applications and Methods* 2015, 36(3), pp 272-291.
- A 3D printed power-split device for testing energy management strategies applied to hybrid vehicles. *IFAC-PapersOnLine* 2015, 48(29), pp 164-169.
- Energy recovery using salinity differences in a multi-effect distillation system. *Desalination and Water Treatment*, 2015, 55(11), pp 3048-3055.

Books

- *Modeling and Control of Greenhouse Crop Growth*. F. Rodríguez, M. Berenguel, J.L. Guzmán, A. Ramírez-Arias. Springer 2015. ISBN: 978-3-319-11133-9.
- *Modelado y Simulación Dinámica de Procesos Termoquímicos en Instalaciones Termosolares*. A. de la Calle, L. Roca, J. Bonilla, S. Dormido. Colección Documentos CIEMAT 2015. ISBN: 978-84-7834-743-8.

Book Chapters

- *Book: Event-Based Control and Signal Processing*. Chapter: Event-Based Generalized Predictive Control. A. Pawlowski, J.L. Guzmán, M. Berenguel, S. Dormido. Marek Miskowicz, CRC Press – Taylor & Francis 2015. ISBN: 9781482256550.
- *Book: Domótica para Ingenieros*. Chapter: Un ejemplo práctico de arquitectura bioclimática: el edificio CDdl-CIESOL-ARFRISOL. M. Castilla, J.D. Álvarez, F. Rodríguez, M. Berenguel. Parainfo 2015. ISBN: 9788497329767.

Congress

- 1st Conference on Modelling, Identification and Control of Nonlinear Systems (MICNON), 2015 San Petersburgo, Rusia.
- 11th International Modelica Conference, 2015, Versailles, France.
- 5th IFAC Conference on Nonlinear Model Predictive Control NMPC 2015, Seville, Spain.
- 23th Mediterranean Conference on Control and Automation MED 2015, Málaga, Spain.
- IEEE 20th Conference on Emerging Technologies & Factory Automation (ETFA) 2015, Luxemburgo.
- 1st International Conference on Event-Based Control, Communication, and Signal Processing 2015, Krakow, Poland.
- 17th IFAC Symposium on System Identification SISYD 2015, Beijing, China.
- 21st SolarPACES Conference 2015, Ciudad del Cabo, Sudafrica.
- Join International Conference on Intelligent Agriculture 2015, Beijing, China.
- 3rd IFAC Workshop on Internet Based Control Education 2015, Brescia, Italy.
- International Symposium on new technologies and management for greenhouse Greensys2015, 19-23 July 2015, Evora, Portugal.
- ECCOMAS Thematic Conference on Multibody Dynamics, 29 June – 2 July 2015 Barcelona.
- 14th World Congress in Mechanism and Machine Science, IFToMM, 25-30 October 2015 Taipei, Taiwan.
- IX Jornadas sobre Innovación Docente de la Universidad de Almería, 17 de September de 2015. Almería.
- VIII Congreso Ibérico de Agroingeniería, Orihuela, Spain, 2015.
- 5th IFAC Conference on Nonlinear Model Predictive Control, NMPC 2015, Seville, Spain, 2015.
- XXXVI Jornadas de Automática, Bilbao, 2015. Premio al mejor trabajo del grupo temático en Ingeniería de Control.
- XIV Congreso Nacional de Ciencias Hortícolas, Orihuela, Spain, 2015.

Doctoral Theses

- Contributions to the modelling and simulation of intensive growing systems, Jorge Antonio Sánchez Molina, directors Francisco Rodríguez Díaz and José Luis Guzmán Sánchez. Universidad de Almería. June 2015
- Contribuciones al modelado dinámico de procesos termoquímicos en instalaciones termosolares, Alberto de la Calle Alonso, directors Sebastián Dormido Bencomo, Lidia Roca Sobrino and Javier Bonilla García. UNED June 2015.

2.4.7 Staff

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2.4.8 Ongoing projects in 2015

2.4.8.1 ENERPRO – Control and energy management strategies in production environments with support of renewable energy

Participants:

Research group "Automatic Control, Robotics & Mechatronics". University of Almería (TEP 197)
PSA-CIEMAT

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Source of funding:

Ministerio de Economía y Competitividad. Plan Nacional 2014 (DPI2014-56364-C2-1-R)

Duration:

January 2015 – December 2017

Status:

In progress

Abstract:

This project deals with the analysis, design and application of modeling, control and optimization techniques (in the framework of hierarchical and model-based predictive control, MPC) to achieve an efficient energy (electricity and process heat/water), water and CO₂ management in production environments with support of renewable energy and storage systems.

A key element of the project is that a real production system will be use as test-bed plant (including a bioclimatic building, a greenhouse, an electric vehicle and a solar desalination plant), on which the developed modeling and control techniques will be validated.

Objectives:

- Development of methodologies for obtaining models of processes that contain renewable energy sources to produce/consume process heat, electricity, water and CO₂. Development of estimators and predictors of generation and demand stages.
- Development of hierarchical, hybrid and, in general, MPC control and management strategies to optimize production from the economic, security and energy and water use points of view in heterogeneous systems, using a coordinated and comprehensive approach.
- Implementation and validation of the strategies in the production environment selected as test-bed plant. This will facilitate the development of the different tasks of the project over realistic conditions. Possible extensions to more complex environments like campus or industrial clusters will be demonstrated.

2.4.8.2 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:

January 2015 – December 2017

Status:

In progress

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 CO₂, 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:

- 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.
- 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.
- 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.

2.4.8.3 Simulation and control of thermosolar plants with parabolic troughs in industrial and refrigeration applications

Participants:

Research group "Automatic Control, Robotics & Mechatronics". University of Almería (TEP 197)
PSA-CIEMAT – "Solar concentration" unit

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Source of funding:

Junta de Andalucía. Proyecto de Excelencia 2010. (P10-RNM-5927)

Duration:

March 2011 – March 2015

Status:

Finalized

Abstract:

Recent developments by manufacturers and research organizations of low aperture parabolic trough concentrators, with and without transparent cover, are allowing us to have solar conversion devices ideal for applications involving industrial process heat and absorption refrigeration dual effect, characterized by temperature range between 100 and 250 °C. However, the multiple generator-demand coupling existing schemes derived from the diversity of industrial processes and the purely non-stationary nature of the processes require a research and development effort to enable a) to establish a framework simulation to provide a correct dimensioning of the facilities and b) the development of control algorithms that optimize the routine operation thereof. Parallel to the development of these tools, the project addresses an analysis of market potential based on the assessment of regional industrial heat demand and the technical-economic optimization of specific case studies.

Objectives:

- Development of guidelines of heat demand in industrial and refrigeration units aimed at feeding dynamic simulation of integration projects of parabolic trough collectors.
- Development of a database of elements (solar collectors, storage systems, controllers, pumps, ...) and coupling schemes of sub-systems.
- Development and validation of mathematical models of mass and energy exchange processes and integration in a specific computing platform.
- Conducting studies of optimization of facilities and processes from the exploitation of the developed computational platform.
- Integration of project results in a guide providing engineers and designers access to simplified options for integrating the solar field with the process.
- Design of informative resources for dissemination among potential users, including environmental and techno-economic aspects.

2.4.8.4 CONTROLCROP: Control of greenhouse crop growth optimizing sustainability, energy and economic criteria

Participants:

Research group "Automatic Control, Robotics & Mechatronics". University of Almería (TEP 197)

Research group "Information Systems". University of Almería (TIC 194)

Research group "Management system of federated databases and data warehouses". University of Granada (TIC 172)

Research group "Data Analysis". University of Almería (FQM 244)

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Source of funding:

Consejería de Economía, Innovación, Ciencia y Empleo de la Junta de Andalucía (P10-TEP-6174).

Duration:

March 2011 – March 2016.

Status:

Finalized

Abstract

The objective of this project is to devise a strategy for controlling the growth of greenhouse crops optimizing sustainability, economic, energy efficiency and quality criteria. The project is based on the development of a hierarchical control system that integrates economic criteria (the difference between the gross income from the sale of the crop and production costs is maximized), energy saving, water use efficiency and horticultural product quality improvement. Thus, the producer of the responsible technician can reconfigure the operation of the farm based on what is desired in each scenario imposed by the variable agricultural market.

Objectives:

- The development of a control framework with multiple objectives for greenhouse crop production using hierarchical optimal control, approaching the problem as a whole, analyzing the interactions between estimation and hierarchical control levels to get the temperature, CO₂ and water quantity and quality setpoints.
- The development of control strategies including new climate variables as CO₂ combined with temperatura regulation using renewable energy sources, as an additional degree of freedom to control crop growth.
- The development of fertigation control strategies with an efficient use of water while reducing deposition of pollutant salts.

Stability, robustness and convergence will be analyzed under unmodelled dynamics and disturbances acting on any level of the control hierarchy.

2.4.8.5 BIOGREEN: Advanced model of greenhouse crop production

Participants:

UAL	FUNDACIÓN CAJAMAR
PRIMARAM	CIAT
IFAPA	GOGARSA

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Source of funding:

Corporación Tecnológica de Andalucía, PRIMARAM

Duration:

January 2014 – June 2015

Status:

Finalized

Abstract

This is a project that develops the technology required to establish a new system of production of greenhouse vegetables in arid climate and semiarid climate, through reliable and highly efficient use of natural resources, managing the microclimate by heat and cold supply, preferably from renewable sources to improve the productive potential and keeping continuously high CO₂ concentrations. Semi-closed greenhouses reduce pest damage while maintain high levels of CO₂ by carbon enrichment. However, given the lower air exchange, equipment is required to maintain the levels of temperature and humidity conditions suitable for crops, for which heat exchangers have to be used. In closed greenhouses, the demands on cooling energy requirements are so high that productive activity in the warmer months is not affordable. This circumstance, as in the case of heating demands, can be avoided or minimized through semi-closed greenhouse concept proposed in this project based on the capabilities of reduction and control of loads. While there are experiences in using cooling methods such as ventilation in greenhouses, both natural and mechanical, mobile screens shading and evaporative cooling, it is evident that the heat extraction capacity thereof is not comparable to that offered by conventional refrigerant cycles through heat exchangers

Objectives

The main objective of BIOGREEN Project is to develop the required technology to stablish a new, secure, reliable and innovative vegetables production system within greenhouse for arid and semi-arid climates, searching for high efficiency in the use of natural resources (with energy obtained from renewables, soil, water, CO₂, ...) It should be able to work in open regime (with maximum efficiency in natural ventilation) and adaptable to work in semi-closed regime (by managing the microclimate through heating/cooling based in renewable sources) to improve the productive potential while maintaining high CO₂ concentrations.

2.4.8.6 Set up and technical and energetic evaluation of a novel hybrid loop for thermal generation (solar and biomass) for climate control of semi-closed greenhouses

Participants:

Research group "Automatic Control, Robotics & Mechatronics". University of Almería (TEP 197)
Physiology and Technology Unit of Protected Crops. IFAPA Center "La Mojonera"

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Source of funding:

Instituto de Investigación y Formación Agraria y Pesquera. Junta de Andalucía.

Duration:

September 2014 – June 2015

Status:

Finalized

Abstract:

This activity is a supplementary contract to the BIOGREEN one to design a thermal generation loop based on renewables (solar and biomass) whose function is the supply of primary energy to heating and cooling processes of the greenhouse prototype.

2.4.8.7 Development of a Decision Support System tool for climate, production and cost management applied to a polygon of greenhouses

Participants:

Hispatec Group

Research group "Automatic Control, Robotics & Mechatronics". University of Almería (TEP 197)

Fundación Cajamar – Estación Experimental Las Palmerillas

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Source of funding:

Corporación Tecnológica de Andalucía.

Duration:

September 2015 – December 2016

Status:

In progress

Abstract:

The overall objective of the Project is the technological development of an agricultural predictive simulation model and a support system for decision making (DSS). This model will be supported by an ICT platform that implements it and can make recommendations on greenhouse management to maximize production.

The agronomic predictive simulation model supported by the ICT platform will allow estimating tomato production during the crop cycle for different crop management scenarios and use of technologies that are not covered in classical models developed for cold climates and that constitute a common practice in areas of warm weather. The developed agronomic model will provide a decision making tool allowing the grower to maximize quality, size and production.

2.4.8.8 OPTICONES: Multi-objective optimization of air conditioning and lighting systems for comfort achievement in sustainable buildings

Participants:

Research group "Automatic Control, Robotics & Mechatronics". University of Almería (TEP 197)
Iberdrola Foundation

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Source of funding:

Fundación Iberdrola Spain.

Duration:

September 2015 – September 2016

Status:

In progress

Abstract:

The project deals with the analysis, design and implementation of control architectures and advanced optimization techniques able to increase user comfort, and thereby productivity, inside buildings and achieve efficient energy management by using air conditioning systems supported by renewable energy and storage systems.

El cumplimiento de los Objectives del proyecto va a permitir, en función de los resultados obtenidos, el desarrollo de una guía de orientación para conseguir entornos confortables bajo una gestión eficiente de la energía consumida permitiendo, de esta forma, mejorar la calificación energética de los edificios.

Objectives

- Study the influence of the main structural elements of a building in the comfort of the users and the energy needs without using control strategies.
- Multi-objective evaluation of thermal comfort, visual comfort and energy efficiency trying to find tradeoff optimal solutions.
- Comparison of different comfort control architectures using climate and illumination (blinds and artificial light) with renewable energy supply.
- Analysis of the results of the implementation and validation of the developed control and optimization strategies within the framework of CIESOL building.

The achievement of these objectives will, depending on the results, allow us the development of a guide for getting comfortable environments under enabling efficient management of energy consumed, thus improving the energy rating of buildings.

2.4.8.9 Advice in the development of a methodology for inside greenhouse climate modeling using exogenous environmental conditions

Participants:

Research group "Automatic Control, Robotics & Mechatronics". University of Almería (TEP 197)
TECNOVA Foundation

Contacts:

Francisco Rodríguez Díaz (frodridg@ual.es)
Jorge Antonio Sánchez Molina (jorgesanchez@ual.es)

Source of funding:

Fundación TECNOVA.

Duration:

February 2015 – June 2016

Status:

In progress

Abstract:

The main objective of the Project is advising on the design and implementation of a first-order principles model to estimate climatic variables inside a greenhouse.

Objectives

- Estimation of inside temperature variables from outside ones, actuators positions, soil temperature and crop state.
- Predicting the ideal conditions to get the maximum rate of photosynthesis.

2.4.8.10 3DCOAST: Spatial monitoring of vulnerable coastal areas through remotely controlled aerial platforms

Participants:

Research group "Automatic Control, Robotics & Mechatronics". University of Almería (TEP 197)

Research group "Integrated Land Management & Spatial Information Technology". University of Almería (RNM 368).

Contact:

José Carlos Moreno (jcmoreno@ual.es)

Source of funding:

Corporación Tecnológica de Andalucía.

Duration:

September 2015 – February 2016

Status:

Finalized

Abstract:

The main objective of this technical feasibility study is assessing the potential of new technologies to obtain spatial information, such as the use of airborne sensors embarked on unmanned aerial systems (drones or UAVs) in coastal areas. This study aims planning preliminary activities necessary for the articulation of a future research project that delve deeply into the aspects required to develop a methodology that allows the efficient acquisition of spatial information to develop a wide range of applications.

2.4.9 Activities and Courses, technical capacity

Agreement with University of Brescia and participation in Sfera 2 project

The agreement includes joint supervision of theses, Erasmus Exchange, double degree students in Mechatronics for industrial automation, ... Result of the agreement has been the co-direction of the PhD thesis of Manuel Beschi (A. Visioli and M. Berenguel) in co-tutela, some research stays in the framework of Sfera 2 project (Domenico Gorni y Antonio Visioli) and joint publications in the framework of Building models.

UAL-CIEMAT Agreement

Participants: Research group "Automatic Control, Robotics & Mechatronics". University of Almería (TEP 197) and Automatic control group of PSA

Contacts: Manuel Berenguel (beren@ual.es) and Lidia Roca (lidia.roca@psa.es)

Objectives:

The overall objective is to contribute to the development and application of activities related to research in modeling and control of thermosolar plants, using the PSA installations. The specific objectives are:

- Study of processes and subsystems involved in hybrid solar plants at PSA.
- Development of dynamic models of hybrid solar plants and validation.
- Development of control strategies for hybrid solar plants.

Colaboración con la Unidad de Eficiencia Energética en la Edificación UIE3 del CIEMAT

Participants: Research group "Automatic Control, Robotics & Mechatronics". University of Almería (TEP 197) and Energy Efficiency in Buildings Unit UIE3 (CIEMAT)

Contacts: Francisco Rodríguez Díaz (frrodri@ual.es) and María José Jiménez (mjose.jimenez@psa.es)

Objectives:

- Colaboration in organizing training activities.
- Support of PhD thesis.
- Colaboration in the application to national and/or UE Research Calls.

Additional activities in the Automatic control and Industrial Informatics Lab

Design of different setups for modeling and control of synchronous electrical motors and DC motors.

2.4.10 Project's applications in 2015

1. UE Project. AGRINSOL-SUDOE – SOE1/P1/E0259. Specialized network in intensive agricultura and solar energy in SouthEast Europe. Interreg-SUDOE. Participants: CIESOL-UAL (coord.), Universidad de Evora (PT), INRA Institut National de la Recherche Agronomique (FR), Universidad de Lleida (ES), IFAPA (ES), Fundación CAJAMAR (ES), SUNTI (FR), SUN'R (FR), COEXPHAL (ES), Assemblée des Régions Européennes Fruitières Légumières et Horticoles (FR)
2. MARIE SKŁODOWSKA-CURIE ACTIONS. Innovative Training Networks (ITN). Call: H2020-MSCA-ITN-2015. HortSim: A toolbox for model-based greenhouse horticultural support software. Participants: AgroTech (DK), Aarhus University (DK), IFAPA (ES), Wageningen University (NL), University of Évora (PT), University of Southern Denmark (DK), University of Thessaly (EL), Hortimax (NL), Copenhagen Business School (DK), Hispatec (ES), Coexphal (ES), Flextechnic A/S (DK), HortAdvice Scandinavia (DK), Knud Jepsen A/S (DK), Agritex (EL), Technical University of Denmark (DK), University of Almería (ES).
3. MARIE SKŁODOWSKA-CURIE ACTIONS. Innovative Training Networks (ITN) "Interactive technologies as support to the industrial transfer of control engineering research". Participants: Lund University (Sweden), UNED (Spain), UPC (Spain), University of Bohemia (Czech Republic), EPFL (Switzerland), UAL (Almería), Calerga Sarl (Switzerland), Yokogawa Europe (The Netherlands).
4. EU Project SOLYERO. SOLYERO: New highly energy performing house with concentrating solar collector and year-round high temperature storage system. Call: H2020-EE-2015-1-PPP Energy Efficiency - PPP EeB and SPIRE topics. Topic: EE-02-2015 Buildings design for new highly energy performing buildings. Participants: Wroclaw University of Technology, Faculty of Mechanical and Power Engineering (PL), Plataforma Solar de Almería-CIEMAT Unidad de Sistemas Solares de Concentración (ES), VŠB – Technical University of Ostrava, Centre ENET – Energy Units for Utilization of Non-traditional Energy Sources (CZ), Synergia Krzysztof Cebrat (PL).
5. MARIE SKŁODOWSKA-CURIE ACTIONS. Innovative Training Networks (ITN) "Training next-generation researchers to develop FUTURe DESALination systems with minimal carbon footprint, FUTURDESAL". Participants: Aston University (UK), Queen Mary University of London (UK), Agricultural University of Athens (Greece), Demokritos National Centre for Scientific Research (Greece), University of Porto (Portugal), Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas CIEMAT-PSA (Spain), Nanolnova Technologies (Spain), LiqTech International (Denmark).

2.4.11 Others

Otros proyectos:

- Thematic Network in Control Engineering. Special Action of R&D Plan. DPI2014-51731-REDT. IP. Ramon Vilanova, 01/2015-01/2017.
- Research Lab on perception and 3D digital reconstruction (3DLAB). Technical Infrastructure Project 2012-2013. Ministry of Economy and Competitiveness and ERDF Funds. UNAM13-1E-1991. IPs. Manuel Berenguel, Fernando Aguilar, 01/2013-12/2015.
- Spanish Technological Platform HISPAROB (<http://www.hisparob.es>)
- European Robotics Research Network EURON (<http://www.euron.org/>)
- Spanish Committee on Automatic Control (www.ceautomatica.es)

Other contracts:

- Verde Smart Co, S.L: Advice to the development of a crop production in greenhouses modeling methodology (01/09/2014-31/03/2015).
- Fundación Cajamar: Analysis of the behaviour of tomato crop under diferente climate conditions (01/09/2014-31/03/2015).
- FIC: Advice on the development of a decision making system for climate control in greenhouses based on external weather predictions (01/09/2014-31/03/2015).

Student practices:

- Blas Salvador Criado. Modeling electrical power consumption in CIESOL.
- Juan Diego Gil Vergel. Modeling and control of solar desalination plants.
- José Ángel Martínez Navarro. Modeling and control of asynchronous motors.
- Carlos García Pérez. Modeling and control of Photobioreactors.
- Alberto Flores Martínez. Simulation of Central Receiver Thermosolar Plants with Tonatiuh.
- José Añenza Piedra. Design of a control laboratory with DC motors.
- José Manuel Fernández. Modeling and control of asynchronous motors.

Stays abroad:

- Jorge Antonio Sánchez Molina: Chinese Academy of Agriculture + NERCITA China (08/01/2015-09/04/2015, 25/09/2015-08/10/2015).
- Manuel Berenguel Soria: Tianjin Climate Center + NERCITA China (25/09/2015-08/10/2015).
- José Luis Guzmán Sánchez: Universidad Politécnic de Catalunya (01/06/2015-08/06/2015).
- José Domingo Álvarez Hervás: Universidad Politécnic de Catalunya (09/11/2015-15/11/2015).

Stays in CIESOL of researchers coming from abroad:

- July Elías Normey Rico, Universidad Federal de Santa Catarina, Florianópolis, Brasil (29/03/2015-03/04/2015).
- Antonio Visioli, Universidad de Brescia, Italy (12/07/2015-18/07/2015).
- Antonio Ruano y Hamid Reza Khosravani, Universidad del Algarve, Portugal (01/07/2015-15/07/2015).
- Daniel Rivera, Universidad de Arizona (EEUU) (24/04/2015-30/04/2015).
- Tore Hägglund, Universidad de Lund, Suecia (11/07/2015-15/07/2015).

- Gary Omar Ampuño Avilés, Universidad Politécnica Salesiana de Ecuador (08/03/2015-12/05/2015, 01/10/2015-08/11/2015).
- María Mónica Miranda Ramos y Gabriel Castro Ronquillo, Universidad Politécnica Salesiana de Ecuador (08/03/2015-12/05/2015).

Congress Organization

- Manuel Berenguel Soria (IPC Chair). 3rd IFAC Internet Based Control Education, Brescia, Italy 04-06/11/2015.

Awards

- Award to the best work in Control Engineering in XXXVI Jornadas de Automática, Spanish Committee on Automatic Control, 2015.
- Award to the best work in Energy in VIII Congreso Ibérico de Agroingeniería 2015
- UNED Extraordinary Doctorate Award to Alberto de la Calle Alonso.

Another scientific activities:

- Organization of Training Network course "Robotics in Agriculture" ceiA3 2015
- Participation in European Robotics Week
- Creation and activities associated with the Robotics Club UAL: Participation in the Science Week, talks Institutes, ...
- Participation in the European project Researcher's Square (RESQUA) for the organization of the European Researchers' Night
- Participation in Master on Automation and Remote Management for Water Resources and Energy
- Participation in the XIII Symposium CEA on Control Engineering. University of the Basque Country, San Sebastián.
- Participation in the Fourth Conference of University - Control Engineering Industry Connection, Cordoba, Spain

2.5 ACTIVITIES OF SOLAR RESOURCE ASSESSMENT AND SOLAR COOLING

2.5.1 Functional unit description

Solar Resource Assessment and Solar Cooling unit has extensive experience in the design/optimization of thermal systems, ground-coupled heat exchangers, and shallow geothermal systems along with the integration of solar thermal and photovoltaic energy within the construction sector. This experience is supported by the publication of more than 60 articles in journals and about 150 conference papers. Over the last five years, all group members have participated in various national, international and industry-funded research projects.

2.5.2 Main research lines

- Modeling and control of thermosolar plants
- Evaluation and forecast of solar resource
- Teledetection
- Sky camera
- Optimization of the 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

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. He is the head of the research group Solar Resource Assessment and Climatology at the University of Almería. His research interests include evaluation and forecast of the solar resource, design and optimization of the solar thermal cooling and heating systems. He has authored and coauthored over 60 articles in international journals, about 150 conference papers, both national and international and 7 doctoral theses directed. Prof. Batlles has been the Principal 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.

2.5.4 Summary of the activities carried out during 2015

During 2015 the Solar Resource Assessment and Solar Cooling group's activities were related with the ongoing project, titled "Multipurpose pilot module for assessment, optimization and improvement of agrifood cold storage systems based on renewable energies, UNAM13-1E-2532". The Pilot Module consisting of three complementary main modules was built, along with the supervision and control room, where a data acquisition system was installed to monitor and control all variables. Aforementioned cold rooms were installed in the workspace of CIESOL with the purpose to supply one of them with chilled water provided by solar-assisted air-conditioning system, already tested and proven to be technically and economically viable. The main objective of this project is to compare the energy efficiency of those three cold rooms, where the second one is driven by a conventional cooling system, and the first is fully off-grid based on the use of Phase Change Materials (PCM) and renewable energies cooling system.

A new research line focused on thermal characterization of PCMs has been started. The Solar Resource Assessment and Solar Cooling group has been actively collaborating with Professor Svetlana Ushak University of Antofagasta (Chile), Professor Antonio Manuel Puertas Lopez, member of the Chemistry and Applied Physics Department (University of Almería) as well with Phase Change Technologies S.L. in research tasks related with development of a new methodology for the thermal characterization of new highly energy performing materials used in the manufacture of PCMs.

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 University of Chile. Different models of solar irradiance with extreme daily temperature measurements in desert areas and studies of atmospheric attenuation in the Atacama Desert (Chile) have been developed. Additionally, measurements of atmospheric aerosols in the Atacama Desert have been carried out as well characterization and influence of dust in the production of photovoltaic panels was studied.

2.5.5 New staff: pre and post-doctoral fellowships, contracts, scholarships

N/A

2.5.6 Publications (Journal articles, doctoral theses, conference communications, book chapters etc.)

Papers

- Beam, diffuse and global solar irradiance estimation with satellite imagery. Energy conversion and management 2015, 105, pp 1205-1212.
- Solar irradiance forecasting at one-minute intervals for different sky conditions using sky camera images. Energy conversion and management 2015, 105, pp 1166-1177.
- The use of a sky camera for solar radiation estimation based on digital image processing. Energy 2015, 90(1), pp 377-386.
- Solar radiation forecasting in the short- and medium-term under all sky conditions. Energy 2015, 83, pp 387-393.

2.5.7 Staff

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2.5.8 Ongoing projects in 2015

2.5.8.1. Multipurpose pilot module for assessment, optimization and improvement of agri-food cold storage systems based on renewable energies

Participants:

"Solar Energy Resources Assessment and Climatology". University of Almería (TEP-165)

Contacts:

F.J. Batlles (fbatlles@ual.es).

Source of funding:

N.A.

Duration:

September 2014 – December 2015

Status:

Finalized

Abstract:

The main objective of this project is to analyze from the energetic point of view three agri-food storage and conservation systems driven by the PCM-based tanks coupled with fully off-grid reverse heat pump system, vapour compression and absorption chiller, respectively. During this project four main research lines will be carried out, namely, PCM-based storage's energy performance, modeling of ice-based storage system coupled with the renewable energy sources, characterization and modeling of agri-food storage and conservation systems.

Objectives:

The feasibility study will be assessed in terms of its energy savings, initial cost, operating costs and environmental performance. Particular emphasis will be paid to a) applying artificial neural network techniques to predict the performance of the three proposed systems and b) an exergy analysis to determine whether it is well suited to efficiently manage energy resources, helping to find the irreversibilities of the novel cooling systems' components this allows the prediction of its exergetic performance from the very beginning of the design process. Additionally, we will analyze different operating modes for the studied system along with a new control algorithm strategy. An environmental study will be performed in order to assess the potential environmental costs and benefits of the developed technology. The cooling system coupled with PCM-based tanks will be analyzed in detail from a mass and energy balance perspective. Affected activities upstream and downstream from the plant will also be considered to evaluate the full life cycle. Two scenarios will be compared, namely the current situation and a scenario where the storage energy system is applied. Environmental impacts will be compared for the two scenarios, allowing us to quantify the potential benefits, or otherwise, of this new technology. Lastly, the economic feasibility study will be presented in addition to an analysis of the optimal operating strategies for maximum cost and environmental pollution reduction for three studied systems.

2.5.8.2. Improvement of the agri-food storage and conservation systems from energetic and economic point of view.

Participants:

"Solar Energy Resources Assessment and Climatology". University of Almería (TEP-165)

Contacts:

F.J. Batlles (fbatlles@ual.es).

Source of funding:

Savia Biotech

Duration:

November 2014 – December 2016

Status:

In progress

Abstract:

This project focuses on the development, implementation and diffusion of technologies to improve energy efficiency in agri-food storage and conservation systems applicable Europe-wide but centred on the Mediterranean region with an example of Almería high efficiency horticulture regional market. The integration of physical infrastructure such as a highly efficient PCM-based storages coupled to a fully off-grid reversible water-source HP or the use of the solar-assisted air-conditioning system, already installed in CIESOL, creates new value through reuse and repurposing for Almeria food processing industry. Almeria could become a pioneer when it comes to working in harmony with the biological cycle, looking on combustible its agri-food storage and conservation systems with different renewable energy resources, especially with solar thermal energy.

Objectives:

- Study of the efficiency and energy savings potential of the agri-food storage and conservation systems.
- Comparative study of the proposed hybrid system with the vapour compression reference system.
- Analysis of PCM-based storage systems for the Almeria case.
- Evaluation and optimization of the ice-based storage system coupled with renewable energy sources.
- Exploitation and communication activities.
- Market knowledge and economic advantages/return of investment.

2.5.8.3. Forecast of solar radiation at the receiver of a solar power tower.

Participants:

"Solar Energy Resources Assessment and Climatology". University of Almería (TEP-165)

Contacts:

F.J. Batlles (fbatlles@ual.es).

Source of funding:

Ministerio de Economía y Competitividad.

Duration:

January 2015 – December 2017

Status:

In progress

Abstract:

It is crucial to have an accurate forecast of the DNI levels reaching the SPT receiver, which affects not only the plant operation but the energy price market.

The project goal is to produce a short-term forecast of the DNI reaching the SPT receiver. To this end, we propose to forecast the DNI arriving to the heliostat field and develop techniques to determine and forecast the reflected solar radiation attenuation on its path to the receiver.

Objectives:

- Ground direct solar radiation estimation using satellite images.
- Ground direct solar radiation estimation using sky camera images.
- Design, implementation and execution of a real-time system, for synchronous data collection from ceilometer, visibilimeter and radiation.
- Installation, orientation and starting of CCD cameras. Design and implementation of algorithms for image collection and processing.
- Development of an atmospheric modeling system in the nearest layers to surface, using techniques based on the extinction coefficient obtained with data from ceilometer, visibilimeter and CCD cameras. Comparison of results of both methodologies.
- Design, implementation and development of a system for predicting direct radiation one hour-ahead, combining estimation and prediction studies of radiation with developments concerning to atmospheric attenuation.
- Evaluation of solar radiation prediction with measured data from radiometric station.
- Design of a user interface with a corresponding implementation of control algorithms and data processing, where radiation forecasting is presented in real-time in the central tower solar thermal plants.

2.5.9 Activities and Courses, technical capacity

Numerous brain storming meetings with the Hedera Helix Ingeniería y Biotecnología S.L. and Phase Change Technologies S.L. companies with the main goal to submit a joint proposal.

Fellowship at the University of Antofagasta (Chile) (July-August 2015) with the main purpose to demonstrate the solar-assisted air-conditioning system installed in CIESOL building as well the sky images and satellite observation-based system to forecast solar incident radiation. Measurements at the Atacama Desert.

Conference “Solar resources modeling using artificial neural network”. Event location: Centro de Desarrollo Energético de Antofagasta, Antofagasta (Chile). July of 2015.

Conference: “Solar resources evaluation and forecast using satélite imagery”. Event location: Escuela Politécnica Superior de Ingeniería de la Universidad de Antofagasta, Chile.

Conference: “Solar resources evaluation and forecast using sky camera”. Event location: Escuela Politécnica Superior de Ingeniería de la Universidad de Santiago, Santiago de Chile (Chile).

2.5.10 Project's applications in 2015

1. WaterWorks 2014 ERA-NET Cofunded Call, European Union "THERBIOR: thermal energy recovery from a novel sequencing batch biofilter granular reactor". Lead by Universidad de Almería, participants: CIESOL 2.-0 LCA Consultants (Denmark), Hedera Helix Ingenieria Y Biotecnologia S.L. (Spain), and The National Research Council (Italy).
2. European Union H2020-EE-2015-1-PPP Call SOLYERO: newly highly energy performing house with concentrating solar collector and year-round high-temperature storage system. Lead by Wroclaw University of Technology (Poland), participants: CIESOL, PSA, Technical University of Ostrava (Czech Republic) and Synergia Krzysztof Cebrat (Poland).
3. ERANETMED_ENERG-11-163, JC-ENERGY-2014- renewable energy and energy efficiency for smart and rural communities call. Collaborative research project: GEHMME: geothermal and hybrid-geothermal systems to improve Mediterranean agronomic sector. Lead by The National Research Council (Italy), participants CIESOL, UHBC University (Alegría) and The Abdelmalek Essaadi University (Morocco).
4. European Union H2020-SC5-2015 Call. COOLCITY: Innovation in solar-assisted pavement COOLing to boost air quality and shrink carbon emissions in the CITY. Lead by Universidad de Almería, participants: CIESOL, Huygen Installatie Adviseurs (Holand), Institute for Renewable Energy (Italy), University of Nottingham (England), National y Kapodistrian University of Athens (Greece) and The Cyprus Institute (Cipre).
5. 2015 call "programa estatal de investigación, desarrollo e innovación orientada a los retos de la sociedad, modalidad 3: proyectos de I+D+I para jóvenes investigadores sin vinculación o con vinculación temporal". Design of an instalation for food processing refrigeration based on the thermal energy storage system with phase change materials and renewable energy.

2.6 ACTIVITIES OF THE DESALINATION AND PHOTOSYNTHESIS UNIT

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 Almeria and from the Plataforma Solar de Almería who are starting a new independent research group with synergies from two fields. The researchers of this unit also are adscribed to the Plan Andaluz de Investigación research groups "Ingeniería de bioprocesos y tecnologías del agua, BIO263", "Biotecnología de microalgas marinas, BIO173", and to Plataforma Solar de Almería. This unit was started in 2014 and began with the set up and operation of new installations and facilities dedicated to wáter desalination with solar energy by using semipermeable membrans 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 core research lines are:

- Development of membrane-based solar desalination snad effluent treatment systems.
- Application of solar energy to the treatment of hypersaline media.
- Recovery of value compouds from brines an 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 research lines

Jose M. Fernández Sevilla (Scopus Author 6602856181)

Is a Professor of Chemical Engineering at Universidad de Almeria, currently affiliated with the Engineering Department at Universidad de Almería. He obtains a Degree in Industrias Chemistry (Químico Industrial) at Universidad de Granada in 1991 and a PhD. In Cheminsty 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 internationa journals.

Guillermo Zaragoza del Águila (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, 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 55 papers in peer-reviewed international journals, presented more than 100 papers on international conferences, authored 5 book chapters and co-authored 1 book. Teaches in international courses on Solar Desalination organized by the European Desalination Society and is presently 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 WsTP.

2.6.4 Summary of the functional unit's activities carried out during 2015

The RED Heat-to-Power project started in May 2015. During this period a theoretical analysis of the maximum obtainable performance targets of conventional evaporation-based separation technologies such as MED and MD was carried out. MED system operation was considered at temperature above 70°C, since scaling is negligible in a closed loop system where solutions can be selected to avoid irreversible salt precipitations. Also, the option to enhance externally the energetic efficiency through vapour regeneration by adsorption/desorption cycles was considered. Regarding lower temperature options, the use of forward osmosis using switchable polarity solvents was analysed and discarded due to the high energy consumption required for regeneration.

The research project PURALGA has been in progress during 2015 as specified in the project's chronogram. This is a coordinated Project carried out in collaboration with the Universidad de Valladolid and led by the Instituto Tecnológico Agrario de Castilla y León (ITACyL). The main task carried out this year has been optimization of microalgae production in photobioreactors using effluents from the agricultural and cattle industry such as liquid manure, centrates and digestates. This has been done preliminary on a lab scale, to check the concentration intervals tolerated by several species of microalgae, and have then been taken to field experiments in medium and pilot-scale microalgae culturing devices, mainly raceway photobioreactors. Another task partially accomplished has been the fluid-dynamics characterization of the potentially interesting photobioreactors (mainly raceways) by CFD (Computer Fluid Dynamics) para la optimización de las condiciones de cultivo en fotobiorreactores tipo "Raceway" which allows adjusting mixing to maximize mass transfer for proper operation and prevent fouling as well as optimizing light/dark cycle that have a Paramount effect in photosynthetic efficiency. In this task, the collaboration with CIESOL has been instrumental.



Additionally, the Project EDARSOL started during 2015. This is also a coordinated Project carried out in collaboration and led by the Universidad Politécnica de Cataluña (UPC) focused in the microalgae-based treatment of urban wastewaters. Another Project just started in 2015 is the EU GREENBIOREFINERY Project granted within the call ERANET-LAC and will be carried out in collaboration with Universities and Research Centres of Portugal, Argentina y Colombia. This Project deals with the effective treatment of effluents from the beer-brewing by using microalgae, among other technologies. Finally, we have started

another Project for the production of soil bacterias for its application to agriculture. This was funded by RETOS call, and will be carried out with the collaboration and funding of the company Biorizon and the Fundación Cajamar.

2.6.5 New staff: pre and post-doctoral fellowships, contracts, scholarships

Researchers newly incorporated to the "Desalination and Photosynthesis" unit are:

- Azahara Martínez García, internship.
- Jose Peña Martín, EDARSOL project.
- Ismael Martín Cara, GREEN BIOREFINERY project.
- Pablo Fernández del Olmo, PurAlga project.

2.6.6 Publications (Journal articles, doctoral theses, conference communications, book chapters etc.)

Papers

- Techno-economic assessment of a pilot-scale plant for solar desalination based on existing plate and frame MD technology *Desalination* 2015, 374, pp. 70-80.
- Renewable energy desalination: performance analysis and operating data of existing RES desalination plants, *Desalination and Water Treatment* 2015, 55:11, pp. 3120-3140.
- Energy recovery using salinity differences in a multi-effect distillation system, *Desalination and Water Treatment* 2015, 55:11, pp. 3048-3055
- Assessment of the use of solar thermal collectors for desalination, *Desalination and Water Treatment* 2015, 55:10, pp. 2856-2867.
- Assessing the validity of solar membrane distillation for disinfection of contaminated water, *Desalination and Water Treatment* 2015, 55:10, pp. 2792-2799.
- Productivity analysis of two spiral-wound membrane distillation prototypes coupled with solar energy, *Desalination and Water Treatment* 2015, 55:10, pp. 2777-2785.
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- Large-scale solar desalination by combination with CSP: Techno-economic analysis of different options for the Mediterranean Sea and the Arabian Gulf, *Desalination* 2015, 366, pp. 130-138.
- Comparison between CSP+MED and CSP+RO in Mediterranean Area and MENA Region: Techno-economic Analysis, *Energy Procedia* 2015, 69, pp. 1938-1947.
- Characterisation of the coupling of multi-effect distillation plants to concentrating solar power plants, *Energy* 2015, 82, pp. 986-995.
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- Improvement of stability and carotenoids fraction of virgin olive oils by addition of microalgae *Scenedesmus almeriensis* extracts. *Food Chemistry* 2015, 175, pp. 203-211.
- Influence of pH and CO₂ source on the performance of microalgae-based secondary domestic wastewater treatment in outdoors pilot raceways. *Chemical Engineering Journal* 2015, 265 pp. 239-248.
- Outdoor pilot-scale production of *Nannochloropsis gaditana*: influence of culture parameters and lipid production rates in raceway ponds. *Algal Research* 2015, 8, pp. 205-213.
- Direct supercritical methanolysis of wet and dry unwashed marine microalgae (*Nannochloropsis gaditana*) to biodiesel. *Applied Energy* 2015, 148, pp. 210-219.
- A whole biodiesel conversion process combining isolation, cultivation and in situ supercritical methanol transesterification of native microalgae. *Bioresource Technology* 2015, 190, pp. 281-288.
- Energetic, economic and environmental assessment of the pyrolysis and combustion of microalgae and their oils. *Renewable and Sustainable Energy Reviews* 2015, 51, pp. 1752-1770.
- Utilization of secondary treated wastewater for the production of freshwater microalgae. *Applied Microbiology and Biotechnology* 2015, 99, pp. 6931-6944

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- Utilization of centrate from wastewater treatment for the outdoor production of *Nannochloropsis gaditana* biomass at pilot-scale. *Algal Research* 2015, 12, pp. 17–25.
- Outdoor production of *Scenedesmus* sp. in thin-layer and raceway reactors using centrate from anaerobic digestion as the sole nutrient source. *Algal Research* 2015, 12, pp. 99–108.
- Selection of native Tunisian microalgae for simultaneous wastewater treatment and biofuel production. *Bioresource Technology* 2015, 198, pp. 424–430.
- Distributed Sliding Mode Control of pH in Tubular Photobioreactors. *Control Systems Technology, IEEE Transactions on* 99, 2015 pp. 1-4.
- Optimization of biomass production in outdoor tubular photobioreactors. *Journal of Process Control*, 2015, 37, pp. 58-69.

Books

- Concentrating Solar Power and Desalination Plants. Patricia Palenzuela, Diego-César Alarcón-Padilla, Guillermo Zaragoza. Springer 2015. ISBN 978-3-319-20534-2

Book Chapter

- Book: Microalgal Production for Biomass and High-Value Products Chapter: Supply of CO₂ to Closed and Open Photobioreactors. F.G. Ación Fernández, J.M^a Fernández Sevilla and E. Molina Grima. Slocombe/Benemann CRC Press Taylor and Francis Group 2015.

Congress

- 3W Conference, Oral presentation, 28 January 2015 Bangkok, Thailand.
- 23rd Mediterranean Conference on Control and Automation, MED 2015.
- EuroMed 2015. 8 Oral presentation. 10-14 May 2015 Palermo, Italy.
- 2nd International Workshop on Membrane Distillation and Innovating Membrane Operations in Desalination and Water Reuse. 1 oral presentation and 2 posters. 1-4 July 2015 Ravello, Italy.
- Desaltech 2015. International Conference on Emerging Water Desalination Technologies in Municipal and Industrial Applications. 2 oral presentations. 28-29 August 2015 San Diego, USA.
- XXXVI Jornadas de Automática. 2 oral presentations, 2 - 4 September 2015 Bilbao, Spain.
- 2nd International Conference "Investigación, Desarrollo e Innovación en Sostenibilidad Energética", oral presentation 11-13 November 2015 Quito, Ecuador.
- Expoliva 2015. El Aceite de Oliva. Poster. Jaén, Spain.
- IWA Water and Industry oral presentation and 2 posters, 2015 Vasteras, Suecia.
- 7th international symposium on microalgae and seaweed products in plant/soil systems. Mosonmagyaróvár. oral presentation, 2015 Hungary.
- IV SOLABIAA LATIN AMERICAN CONGRESS. Oral presentation and poster, 2015 Florianopolis, Brazil.
- V Congreso Latinoamericano de Biotecnología Algal. Oral presentation and 3 posters, 2015 Viña del Mar, Chile.
- ALGAERUROPE Conference oral presentation, 2015. Lisbon, Portugal.
- International Symposium on New Technologies and Management for Greenhouses Póster 2015. Evora, Portugal.

Patent

Title: A system for the removal of heavy metals in water using microalgae.
No: P201500861
Applicant: University of Almería

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2.6.8 Ongoing projects in 2015

2.6.8.1 Research and Development of New Treatments for the Quality Improvement of Acid Mining Waters (TAAM)

Participants:

SACYR (ES)
SADYT (CIEMAT-PSA as a subcontractor) (ES)
CABAL Geólogos Consultores (ES)
AGQ Mining & Bioenergy (ES)

Contacts:

Dr. Diego-César Alarcón-Padilla (diego.alarcon@psa.es)

Source of funding:

Sociedad Anónima de Depuración y Tratamientos, SADYT. FEDER 2013. (Orden CIN/1729/2011)

Duration:

July 2012 – December 2014. Extended until June 2015.

Status:

Finalized

Abstract:

Tinto and Odiel rivers, in the province of Huelva (Spain), are deeply contaminated as a consequence of the mining activity. During the last years, several research lines have been started aiming to the passive treatment of the acid leachates. However, the high concentration of the contaminants makes necessary the development of new techniques with better economic feasibility than the current ones.

Objectives:

CIEMAT-PSA collaborates within the Research Line 4 of the project, whose main objective is to investigate the effectiveness of treating acid waters with the reverse osmosis process powered by solar thermal energy. More specifically, the objective is to develop a treatment to improve the water quality of the Alcolea dam, in an economic, environmentally-friendly and sustainable way.

2.6.8.2 Zero Carbon Resorts towards Sustainable Development of the Tourism Sector in the Philippines and Thailand (ZCR2)

Participants:

Gruppe Angepaste Technologie GrAT (AT) (Coord.)
Palawan Council for Sustainable Development PCSD (PH)
Green Leaf Foundation GLF (TH)
Health Public Policy Foundation HPPF (TH)
PSA-CIEMAT (ES).

Contacts:

G. Zaragoza (gzaragoza@psa.es)

Source of funding:

European Commission, SWITCH-ASIA programme

Duration:

May 2014 – April 2018.

Status:

In progress

Abstract:

This project builds upon the success and achievements of the ZCR in the Philippines (2009-2014) for replication and upscaling. Regional approach will be implemented through ZCR intervention in Thailand and Green Certification in the Philippines, while increasing the access to green finance and improving policy exchanges on SCP in tourism in both countries.

Objectives>:

The overall objective is to contribute to sustainable development of the tourism sector in the Philippines and Thailand with a focus on reduction of fossil fuel use and CO₂ emissions through improved energy and resource efficiency of SME companies and increased availability of renewable energy. The goal is to enable SME companies in the tourism industry in the Philippines to be a model of sustainable consumption and production for the tourism sector through certified Zero Carbon practices and efficient innovative technologies in a cross-border approach with Thailand, providing incentives and access to finance in both countries.

The specific objectives of the participation of CIESOL are:

- Design an autonomous solar system for supplying water and energy to remote isolated tourist installations.
- Research and characterize the technology of membrane distillation with solar energy.
- Evaluate commercial systems of membrane distillation.
- Research on the application of membrane distillation to treat contaminated waters.
- Dissemination of results and elaboration of scientific reports.

2.6.8.3 Processing of brewery wastes with microalgae for producing valuable compounds (GREENBIOREFINERY)"

Participants:

Departamento de Ingeniería, Universidad de Almería (Spain)
Laboratorio Nacional de Energía y Geología (LNEG) Portugal
Universidad de Antioquia (Colombia)
Universidad Nacional Tecnológica (Argentina)
Cervecería la Unión (Colombia)
Mahou-San Miguel (Spain)

Contacts:

F. Gabriel Acién (facien@ual.es)

Source of funding:

ERANET LAC 2014

Duration:

October 2015 – September 2018.

Status:

In progress

Abstract:

The main objective of GREENBIOREFINERY is to develop new strategies to generate bioproducts with the integration of both the brewery wastes' treatment and the production of microalgal biomass, enhancing this way the economic and environmental sustainability of the process as a whole. This integration will enable the transformation of these wastes of the brewery industry into biomass of interest. This will allow not only the reduction of the environmental impact of beer fabrication processes, but also a recovery of the nutrients (C, N, P) contained in the wastes and their conversion to high-value compounds. To achieve this objective, the wastes produced will be characterised to be used as feedstock into the microalgae's production by previously selected companies. Finally, the developed technology will be escalated to pilot-scale with 1m³ photobioreactors to validate and assess the process as a whole. As a result, we aims to develop flexible and adaptable processes of integral exploitation of the microalgal biomass which could be applicable in different breweries taking into account local necessities and possibilities.

Objectives:

- Characterization of liquid and gaseous wastes derived from brewery industry in terms of its feasibility as raw material for microalgae production Design of a strategy for the treatment and use of brewery wastes using microalgae cultures
- Evaluation of productivity and composition of microalgae grown in brewery wastes at laboratory scale, in addition to its depuration capacity
- Development of biorefinery concept for the integral valorization of produced biomass minimizing the release of wastes.
- Demonstration of the process at pilot scale and evaluation of its economy and feasibility.

2.6.8.4 Conversion of Low Grade Heat to Power through closed loop Reverse Electro-Dialysis (RED-Heat-to-Power)

Participants:

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

Contacts:

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

Source of funding:

European Commission, Horizon 2020 programme

Duration:

May 2015 – April 2019.

Status:

In progress

Abstract:

The concept is based on the generation of electricity from salinity gradient using Reverse Electrodialysis with artificial saline solutions operating in a closed-loop. The original salinity gradient is regenerated by a separation step that uses heat at 40 - 100 °C.

Objectives:

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

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.

2.6.8.5 Management of mine water discharges to mitigate environmental risks for post-mining period (MANAGER)

Participants:

Glówny Instytut Górnictwa, Poland
Hulleras del Norte S.A., Spain
Asociación Para La Investigación Y Desarrollo Industrial de Los Recursos Naturales, Spain
DMT GmbH & CO. KG, Germany
Universidad de Almería, Spain
Centre for Research and Technology Hellas, Greece
Institut National de l'Environnement Industriel et des Risques , France
IXSANE S.A.S, France
The Coal Authority, United Kingdom
TAURON Wydobycie S.A., Poland

Contacts:

F. Gabriel Acién (facien@ual.es)

Source of funding:

European Commission, Research Programme of the Research Fund for Coal and Steel

Duration:

July 2013 – June 2016

Status:

In progress

Abstract:

The objective of the Project MANAGER is to develop and assess different technologies for the treatment of wastewater from the mining industry which are often contaminated with heavy metals. These effluents need to be managed even after decommissioning of mining installations and facilities and in this scenario is where Project MANAGER is focused. This project is participated by several European companies and research centers. The workplan is organized in four stages ranging from basic research in feasible depuration technologies carried out at a lab scale to large field tests done in realistic conditions.

Objectives:

- Evaluation of hazards and environmental impacts due to water contamination in the mining industry after cessation of activities.
- Development of technologies for the treatment of water effluents from the mining industry..
- Application and evaluation of the techniques developed.
- Demonstration at pilot-scale of the best depuration techniques found.
- Coordination and diffusion of the results.

2.6.8.6 Control and energy management strategies in production environments with support of renewable energy (ENERPRO)

Subproject title: Efficient energy control and management of solar thermal desalination systems (EFFERDESAL)

Participants:

Universidad de Almería (ENERPRO)

CIEMAT-PSA (EFFERDESAL)

Contacts:

Dr. Diego-César Alarcón-Padilla, diego.alarcon@psa.es

Source of funding:

Ministerio de Economía y Competitividad, Plan Estatal. I+D+i 2013-2016 orientada a los retos de la sociedad.

Duration:

January 2015 – December 2017.

Status:

In progress

In coordination with Modeling and Automatic Control unit (see 2.4.8.1)

Abstract:

Due to increasing demand -for energy and water, most countries are promoting the efficient use of these resources to reduce costs and increase sustainability. Generally, energy efficiency is not only associated with technological improvements, but also with the improvement of control and energy management. This is the main framework of this research project ENERPRO, which is a natural evolution of a previous project, POWER, where both UAL and CIEMAT-PSA subprojects focused on heat/cooling and water management.

Objectives:

- Dynamic modeling of solar-gas hybrid desalination plants.
- Analysis of energy storage systems and auxiliary systems for energy cost reduction.
- Design of simplified models for control purposes.
- Development of MPC strategies for desalination plants.
- Coupling of solar desalination plants to supply water to greenhouses and buildings.
- Testing of control algorithms both in simulation and in the real installations.

2.6.8.7 Agroindustrial effluents valorization through the use of microalgae to obtain bio-products (PURALGA)

Participants:

Instituto Tecnológico Agrario de Castilla y León (ITACyL)
Universidad de Valladolid
UAL

Contacts:

Jose María Fernandez Sevilla (UAL), jfernand@ual.es

Source of funding:

INIA (Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria) FEDER funds. RTA 2013-00056-C03.

Duration:

September 2014 – September 2017.

Status:

In progress

Abstract:

This project aims at obtaining bioproducts from microalgae biomass, through the recycling of nutrients from agrofood processing wastewater, for a more economical and environmentally sustainable process; integrating the production and valorization under the biorefinery concept, and determining the economic viability by the Life Cycle Analyses (LCA).

Two different strategies about biomass uses are considered in this project. First, the direct utilization of the whole biomass as feed in aquaculture, or in the production of biofertilizers or biogas. Second, the processing of the biomass to obtain different commodities of industrial interest. To close the cycle of biomass production, the CO₂ generated from the anaerobic digestion of residual microalgae will be recycled for algal biomass production step, thus production system will act as a sink for CO₂ reducing the emission of greenhouse gases. Therefore, this holistic approach will allow obtaining bio-products from the recycling of nutrients from agro-industrial wastewater while contributing to mitigate greenhouse gas emissions.

Objectives:

- Protein for animal feed to be incorporated in feedstocks;
- Production of bio-alcohols from the glucidic fraction of the microalgal biomass to be used as fuels by means of hydrolysis/fermentation treatments;
- Production of oils and fats from the lipidic fraction of the microalgal biomass to be used as animal feed.
- Conversion of the residues in biogas through anaerobic digestion.

2.6.8.8 Valorization of wastewater with microalga-bacteria consortia (EDARSOL)

Participants:

Universidad de Almería.
Universidad politécnica de Cataluña

Contacts:

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

Source of funding:

RETOS INVESTIGACIÓN project, Ministerio de Economía y Competitividad CTQ2014-57293-C3

Duration:

January 2015– December 2017.

Status:

In progress

Abstract:

The objective of the EDARSOL project is to develop sustainable processes for the treatment of wastewater using microalgae and bacteria consortia, thus enabling the transformation of contaminants from wastewater (C, N, P, etc.) into valuable products (fertilizers, biogas), and resulting in regenerated water of sufficient quality for its reuse. The goal is to develop a portfolio of tools to ease the implementation of these processes in a more effective and safer way.

EDARSOL project aims at developing novel technologies for wastewater treatment on the basis of better understanding biological systems, optimizing the design and operation of photobioreactors, as well as biomass recovery and valorisation processes. The objective is to develop integrated processes to enhance the viability and sustainability of wastewater treatment.

Objectives:

- To characterize and modelize microalgae-bacterial consortia those develop during the treatment of wastewaters.
- To develop wastewater treatment processes using low cost reactors either open (raceway and thin layer) or closed (polyethylene tubular reactors).
- To develop industrial methods to enable the separation and concentration of the produced biomass, including methods such as electroflocculation/coagulation capable of rising the concentration of the harvested biomass up to 100 g/L, and with an improvement on the reclaimed water quality sufficient to meet the specifications of the Directive 91/271/CE.
- Developing valorization processes for the obtained biomass.
- The techno-economic viability of the developed processes will be analyzed. Special attention will be given to the critical points of the technologies used and in particular to the costs and the scale-up options. The sustainability of the whole optimized process will be assessed by a life cycle analysis).

2.6.8.9 Production of bacteria for use in agriculture soil fertility enhancers and as anti-pathogen protective agents. (BACAGRO)

Participants:

Universidad de Almería.
Biorizon Biotech S.L.
Fundación Cajamar

Contacts:

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

Source of funding:

Proyecto RETOS COLABORACIÓN, Ministerio de Economía y Competitividad

Duration:

October 2015– September 2017.

Status:

In progress

Abstract:

The goal of the Project BACAGRO is to develop bioproducts containing bacteria to be applied in agriculture as soil stabilizers and fertility enhancers with a protective function against plant pathogens.

Objectives:

- Selection and identification of beneficial bacteria for soils and plants: different strains selected from an already established catalogue will be tested for its bioactivity in intensive cultures in greenhouse. Some bacteria-bearing materials such as compost or manure, will be screened for growth-enhancing activity and as phytoprotective agents that compete with the pathogens of the zone. The application of this bacteria will increase the number of beneficial microorganisms thus allowing to decrease the use of chemical control agents and decreasing the residues of the agricultural activity.
- Development of scalable production processes of the selected bacteria with a price low enough for agricultural applications.
- Development of technologies for the stabilization, storage, preservation and application of the bacteria-based bioproducts. Ensuring safety and application efficiency of these products is a must.
- Evaluation of the effect in soil and plants of the stabilized bioproducts containing bacteria. The objective is to quantify the effect of these products in parameters such as culture, yield, nutrient availability and decrease in pathogens. This will be accomplished by carrying out experiments at field scale in greenhouses under controlled conditions. The objective is to simultaneously measuring net increases in crop productivity while studying the underlying phenomena that may cause these enhancements, thus gaining insight in the mechanism involved that might allow further optimization of the product and application processes.

2.6.9 Activities and Courses, technical capacity

Conferencia: “Production and downstream of microalgae for the production of valuable compounds”. Workshop KOREA-SPAIN, Málaga (Spain).

Conferencia: “Uso de microalgas y/o bacterias en agricultura intensiva”. Seminario Técnico Agronómico, El Ejido (Spain).

Conferencia: “Potential of wastewater treatment using microalgae in the Mediterranean context”. IWA Water and Industry, Vasteras, (Sweden).

Conferencia: “Tratamiento de aguas residuales y efluentes con microalgas”. Jornadas Técnicas sobre biotecnología de microalgas, Instituto Tecnológico de Canarias (Spain).

Conferencias: “Algae biotechnology”, “Environmental applications of microalgae bio-technology” y “Algae bio-technology method: applicability to mine water discharges”. Workshop Innovative treatment technologies for mine water discharges. Universidad de Oviedo (Spain).

Conferencias: “Biofuels from microalgae: When it is possible and when it is feasible to produce” y “Major Factors Limiting the Utilization of Microalgae for Wastewater Treatment”. IV Solabia Latin American Congress. Florianopolis (Brasil).

Conferencia: “Commercial applications of microalgae”. Resultados del Consorcio Desert-Bioenergy. Antofagasta (Chile).

Conferencia: “Integral utilization of microalgae production of biofertilizers”. 3rd Iberoamerican Congress Biorefineries. Concepcion (Chile).

Conferencia: “Use of microalgae for the treatment of urban and agro-industrial wastewaters”. International Workshop Bioprocess Engineering. Temuco (Chile).

2.6.10 Project's applications in 2015

1. Plan Estatal de Investigación Científica y Técnica y de Innovación 2013 - 2016. FEDER INNTERCONECTA programme. Biorefinería a pequeña escala de aplicación insitu en entornos rurales con actividad mixta agrícola y ganadera (bioREFINA).
2. Plan Estatal de Investigación Científica y Técnica y de Innovación 2013 - 2016. FEDER INNTERCONECTA programme. Depuración sostenible de aguas residuales en pequeños entornos (EXPLORA).
3. Marine Biotechnology ERA-NET 2015. Sustainable production of bioactive compounds from marine microalgae (SEA4LIFE).
4. LIFE15 ENV/ES/000285 LIFE GREEN FARMING. Treatment plant for Integral environmental management and bio-valorization of animal manure.

3. SOLAR ENERGY FACILITIES

Since its inception, the center has gradually increased the number as well as capabilities of its scientific and technological facilities. This extensive and advanced equipment, allows it to offer a quality and highly competitive service.

3.1 SOLAR ENERGY CHEMICAL FACILITIES

The EQUIPMENT available at our center is as follows:

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.

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.

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.

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 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 analy (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.

Biochemical oxygen demand analyzer (BOD). Biological oxygen demand ($\text{BOD mg O}_2/\text{L}$) determines the relative oxygen requirements of wastewater effluent and contaminated water for biological degradation. This measure expresses the degree of contamination due to potentially biodegradable organic matter (under aerobic conditions) of wastewater. It is used to control the improvement of biodegradability of toxic effluents treated with photocatalytic processes.

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.

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.

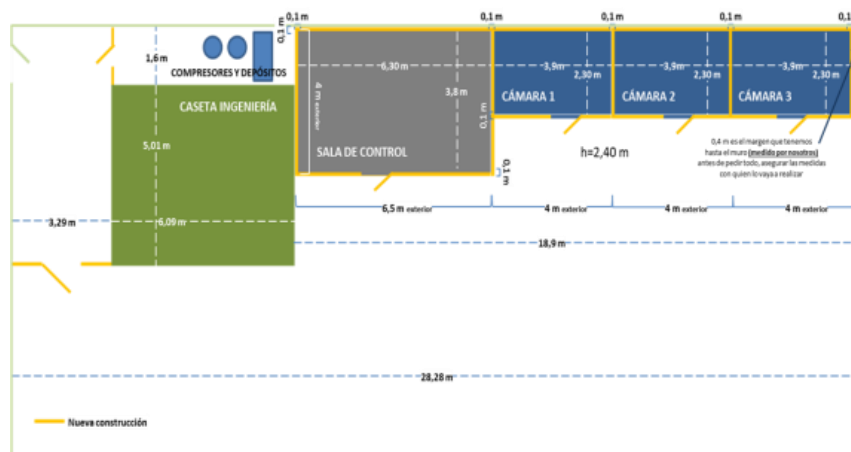
Bioreactors. They are used to simulate different biological water purification processes

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

3.2 FACILITIES AND INFRASTRUCTURE FOR AREA OF SOLAR ENERGY EXPLOITATION

During 2015 and thanks to a scientific infrastructure project entitled "multipurpose pilot assessment optimization and improvement of agrifood systems with renewable energy refrigerated Module" (UNAM13-1E-2532), a pilot module was installed in the CIESOL courtyard. It is composed of three complementary core modules, a common control and supervision room where there is an expert data acquisition system, with monitoring and flexible remote control as a management tool. The aforementioned facilities can be described as follows:

- Refrigerated pilot camera No. 1 with a thermal energy storage phase change system (ice accumulation), hybrid power solar photovoltaic system and wind turbine.
- Refrigerated pilot camera No. 2 for controlling environmental parameters, equipped with expert control system, pattern No. 1 camera, being of the same size and have the same cooling capacity installed.
- Refrigerated pilot camera No. 3 for testing cooling by harnessing water accumulation cycle solar absorption CIESOL building, whose primary objective is to test local cooling through use of cold water absorption cycle of the building CIESOL.



CIESOL Courtyard with the three refrigerated cameras and the control room.



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.

4. COMITTEES AND ACTIVITY RESPONSIBLES.

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