Centro de Investigación en Energía Solar

Centro Mixto UAL-PSA-CIEMAT

SOLAR ENERGY RESEARCH CENTER

JOINT CENTER UAL-PSA CIEMAT

CIESOL

INFORME ANUAL CIESOL 2016

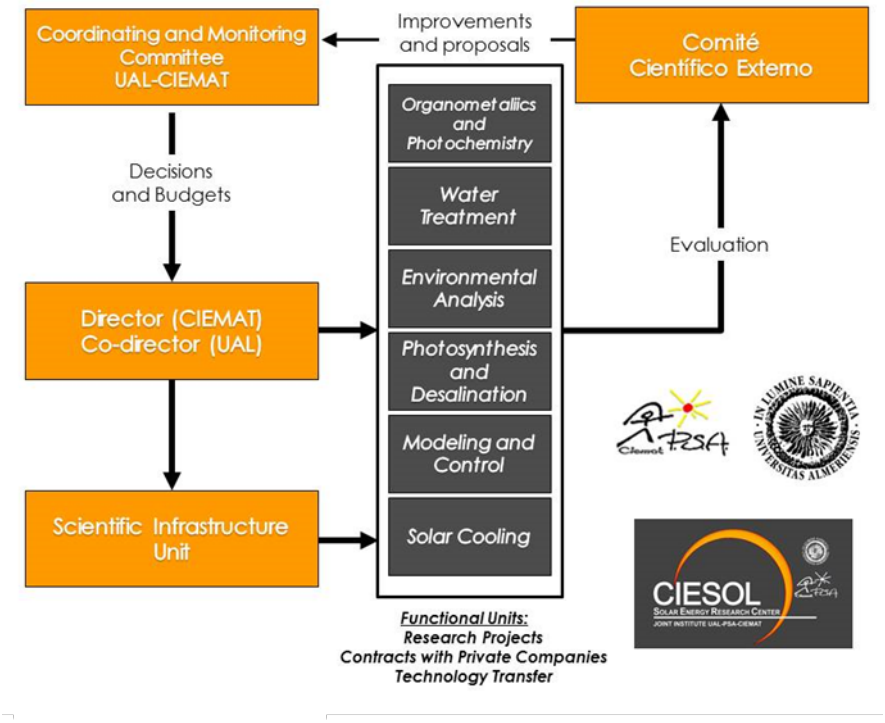
CIESOL ANNUAL REPORT 2016

ÍNDICE

0. INTRODUCTION

CIESOL brings together the experience of more than 20 years of collaboration between research groups from the University of Almería and the Plataforma Solar de Almería. This UAL-PSA relationship formally commenced in April 2005 with the signing of an agreement between the University of Almería and CIEMAT-PSA for the creation of a joint research center. The operations of the center are governed by this UAL-CIEMAT agreement, which was recently extended by 10 years.

The operating structure of CIESOL is formed by a Coordination and Monitoring Committee, a highest decision making body, a Management Team and a set of 6 Operating Units uniting researchers from both institutions in different specific subject areas. It should be noted that CIESOL has an External Evaluation Committee, including four nationally and internationally renowned members , which annually assesses and supervises the scientific production of its different operating units as well as the management of the center. There is also a scientific facilities and management unit , made up of technical specialists, which is in responsible for the maintenance and operation of the center's equipment.



Functional Organisation

The Coordination and Monitoring Committee is made up of two researchers from the UAL, one of whom must be the Vice-Rector of Research, Development and Innovation of the university and two researchers from the PSA, one of whom must be the Director of the Plataforma Solar de Almería. Currently, the Coordination and Monitoring Committee comprises Antonio Posadas Chinchilla (Vice-Rector for Research) and Manuel Berenguel Soria for the UAL as well as Sixto Malato Rodríguez (Director of the Plataforma Solar de Almería) and Eduardo Zarza Moya for the PSA. The Management Team consists of a director and a deputy director, belonging to UAL and PSA (and vice versa) for three year periods. At present the director

is José Antonio Sánchez Pérez from the UAL, whileSixto Malato Rodríguez from the PSA is deputy director. Regarding the External Evaluation Committee, its members are Rafael van Grieken, former director of ANECA and current Counsellor of Education, Youth and Sport for the Community of Madrid, María Luisa Castaño, Managing Director of Innovation and Competitiveness (MINECO, Government of Spain), David Serrano, Director of IMDEA ENERGÍA from Madrid and Sebastián Dormido, Full Professor of Computer Science and Automation from the UNED (Doctor Honoris Causa from the UAL).

The six operating units are briefly described below.

Organometallics and photochemistry.

The initial scope of this Operating l Unit, the synthesis of metallic catalysts for the mediation of photochemical reactions in water, has now been extended to other areas such as photo-generation of hydrogen or the transformation of small molecules by solar radiation. Its primary researchers are Antonio Manuel Romerosa Nievas (UAL) and Christoph Richter (DLR-PSA), the strategic lines of action being :

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

Water treatment.

This Operating Unit focuses its activity on the study of solar photocatalysis for the elimination of toxic substances and the disinfection of water, as well as its combination with advanced biological methods. There is close collaboration with the "Analytical evaluation of water treatment and environmental analysis",unit, complementing and strengthening the main current lines of work. Its primary researchers are José Antonio Sánchez Pérez (UAL) and Manuel Ignacio Maldonado Rubio (PSA), the strategic lines of action being:

- Application of photo-Fenton solar to the decontamination of toxic waters and to the elimination of microcontaminants and disinfection of purified water (regeneration).
- Optimization of the operation and development of new technology for photo-Fenton. Water Economics.

Analytical evaluation of water treatment and environmental analysis.

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 be regenerated and thus enable their possible reuse. Its primary researchers are Ana Agüera López (UAL) and Isabel Oller Alberola (PSA), the strategic lines of action being :

- Development of advanced analytical methods for characterizing complex effluents and their application to monitoring of organic micropollutants during wastewater treatment to ensure their elimination.
- Identifying transformation products generated during wastewater treatment and establishing routes of degradation.

- Study of the influence of treatments on the quality of reclaimed water and evaluating the impact of its reuse in agriculture.

Photosynthesis and desalination.

The group carries out two parallel lines of work dealing with solar energy application in desalination, using membrane systems and microalgal cultivation. This is geared particularly towards recycling by solar energy-driven synthesis of commodities such as biofertilizers or biodiesel and high-value products such as carotenoids and essential fatty acids. Seawater is the main raw material used, although the research deals with other types of sources, freshwater, brines, brackish waters or wastewaters being considered. Its primary researchers are José M. Fernández Sevilla (UAL) y Guillermo Zaragoza del Águila (PSA) and the core research lines are:

- Development of membrane-based solar desalination and effluent treatment systems.
- Application of solar energy to the treatment of hypersaline media.
- Recovery of high-value compounds from brines and hypersaline effluents.
- Design of photobioreactors for the cultivation of microalgae.
- Applications of microalgae for the purification of wastewaters and industrial effluents
- Production of valuable compounds using microalgae.

Modeling and automatic control.

The group counts among its areas of interest: intensive agriculture, solar energy, biotechnology and bioengineering, as well as modeling, mechanization and robotics in general. Collaborative activities between the group and the PSA have been carried out continuously over the past 20 years, with the noteworthy participation of UAL researchers in developing some of the SCADA (Supervisory Control And Data Acquisition) systems as part of the test facilities located in the PSA. Following the experience gained in the ARFRISOL project, the group also has a research line linked to the applications of control systems to achieve thermal, visual and air quality comfort and energy efficiency in buildings.

Its primary researchers are Manuel Berenguel Soria (UAL) and Luis José Yebra Muñoz (PSA), the strategic lines of action being :

- Modelling and control of thermosolar plants, photo-bioreactors and robotics in agriculture.
- Energy efficiency and comfort control in buildings.
- Engineering Education.
- Electric vehicles.
- Energy smart grids.
- Predictive, hierarchical and robust control.
- Supervisory systems and industrial communications.

Solar resource assessment and solar cooling.

The 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. Its primary researcher is Francisco Javier Batlles Garrido (UAL) and the main research lines are:

- Modelling and control of thermosolar plants.
- Evaluation and forecast of solar resources.
- Teledetection and sky cameras.
- Design and optimization of solar thermal cooling and heating systems and trigeneration systems.
- Thermal energy storage through phase change materials

Objectives, areas of research and scope

As part of the CIESOL agreement UAL-CIEMAT, the following objectives are considered:

- Development of solar energy research and its environmental applications.
- Development of different lines of research in a common space, located in the UAL, sharing facilities to carry out work on joint projects.
- Support and intensify research activity connected with the UAL higher education and the CIEMAT-PSA research groups, which are part of CIESOL.
- Provide young graduates with access to the research field, as well as the training and promotion of the CIESOL staff.
- Improve relations with other national and international centers to promote a better connection in related areas.
- To promote and boost international scientific relations in the solar energy research field in order to encourage the exchange of experiences with scientists from other countries.

CIESOL focus its activities on the following fields (using UNESCO nomenclature):

- Automatic control [3311-0 1, 3311-02, 3311-05, 3311-15]
- Bioclimatic architecture [3305-01, 3305-14, 3305-22, 3305-90]
- Environmental chemistry [2391]
- Pollution control and physicol-chemical water treatment [3308-8, 3308-06, 3308-10, 2508-11, 3302-90]
- Desalation using distillation [3328-07]
- Photochemical and organometallic synthesis [221 0-22, 2303-21]
- Solar radiation measurement [21 06-01, 2202-06]
- Materials technology [3312]

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 and demonstration projects.
b) Foster collaboration with companies related to energy and the environment.
c) Develop technological innovation patents that facilitate the 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.

1. EXECUTIVE SUMMARY

As a result of of its activity, CIESOL stands out as a thriving and dynamic center, the fruitof the efforts of its researchers being its ever increasing number of publications and projects.

During 2016, 71 researchers participated in projects and contracts assigned to CIESOL, 22 of them working on a permanent basis in its laboratories and offices. The activities of these researchers formed part of 19 official competitive calls for projects (National Research Plan and Incentive Programme for the Andalusian Agency of Knowledge), 6 contracts with companies and institutions, 8 European projects and 6 patents. In 2016 10 new projects were applied for .

As for scientific production, a total of 96 publications indexed in the Journal Citation Report was reached. All units participated in Congress as well as national and international scientific meetings (10) (46) throughout 2016.

Also worth mentioning is the funding obtained by the above projects, which totalled around 2,102,910 euros in 2016, being substantially higher than the €955,833 in 2015 and the €1,180,461 in 2014. None of this would have been possible without the convergence of objectives that UAL and CIEMAT share.

It should not be overlooked that one of the most important fruits of the UAL-PSA collaboration during 2016 was the reading by 5 students of their UAL Doctoral Theses co-directed by researchers from the UAL and the 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 information detailed in the following chapters by the operating and technical units, the following milestones from 2016 stand out in this initial summary of activities:

Network participation

- Workgroup “WG5: Wastewater reuse” (NORMAN W604002510)
- European COST Action: 'NEW AND EMERGING CHALLENGES AND OPPORTUNITIES IN WASTEWATER REUSE (NEREUS)' (RED COST Action ES1403).
- CONSOLIDER TRAGUA NETWORK (CTM2014-53485-REDC)
- European Network on Smart Inorganic Polymers (RED COST Action COST CM1302)
- New materials and photocatalytic reactors for the removal of micropollutants and pathogens, FOTOCAT (CTM2015-71054-REDT).
- European Robotics Research Network EURON
- Thematic Network of Control Engineering. National Plan Special Action. DPI2014-51731-REDT

Awards received in 2016:

- Agustín de Betancourt” Medal from the Royal Spanish Academy of Engineering to CIESOL researcher José Luis Guzmán Sánchez for its 7th award ceremony .

- Best Engineering work in SNIH16 II Symposium: "Predictive control to satisfy water demand in greenhouses using solar desalination". L. Roca. J.A. Sánchez, F. Rodríguez, J. Bonilla, A. de la Calle and M. Berenguel

Dissemination and research transfer:

As part of the interest in dissemination and transfer of research, CIESOL actively participated in activities during 2016, related to the field of solar energy, namely

- Various seminars of technology transfer and numerous invitations to conferences.
- Organization of the Conference: "Comfort and Sustainable Building, a response from the Automatic and Micro-Energy Networks", 20th October 2016.
- Participation in the European Robotics Week, 25th November 2016.
- Creation and activities associated with the UAL Robotics Club: Participation in Science Week , talks in secondary schools, 2016.
- Participation in the European project: Researcher's Square (RESSQUA) for the organization of the European Night of Researchers, 26th September 2016.
- Participation in 2016 Automation Days (Madrid) and organization of the Control Engineering Thematic Group, 7-9 September 2016.
- Research stay in the month of July at the University of Antofagasta (Chile) where various seminars and conferences were presented.

Regarding the management of the center, during 2016 an Internal Regime Regulation was created in compliance with the Regulation of Research Centers of the University of Almeria, approved by its Governing Council on September 28th, 2016. As part of ofHSE (Health, Safety & Environment) , the infrastructure of the center was reviewed and adapted, and a specific course for staff was run . CIESOL also played a significant role in the proposal and development of the official Master's Degree in Solar Energy of the University of Almería beginning with the 2017/2018 course.

Additionally, the center welcomed numerous researchers, including two from Mexico (2 months each), two from Italy (1 month), two from the Czech Republic (1 month), two from Tunisia (3 months), etc. Further details are provided in the sections for each unit.

2. ACTIVITIES OF CIESOL

2.1 ACTIVITIES OF "ORGANOMETALLICS AND PHOTOCHEMISTRY"

2.1.1 Functional unit description

In 2016 the unit was constituted by 10 members (three university professors, five researchers, one predoctoral contract and one postdoctoral cntract) most of then pertaining to the research team FQM-317 entitled "Coordination/Organometallic Chemistry and Photochemistry " that is constituted by researchers from U. Almeria, La Laguna and Cádiz and a researcher at the German Aerospace Centre - Plataforma Solar de Almeria (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 (> 200 articles in international journals chemical impact). The initial interest of the team, the synthesis of metal catalysts for photochemical reactions in water, has been extended to other areas such as photo-hydrogen-generation, conversion of small molecules by solar radiation and production of electricity by solar light.

2.1.2 Main research lines

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

2.1.3 Main researchers

Antonio Manuel Romerosa Nievas (ORCID ID = 0000-0002-6285-9262; Scopus Author ID 6603792206)
Antonio Romerosa was born in Granada (Spain) in 1964. He graduated in 1987 (University of Granada) and received his PhD (Universitat Autonoma 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 Almeria (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 131 international refereed papers, 14 Spanish and international patents and made more than 225 presentations at national and international meetings. He has been responsible for more than 20 national research regional and European projects, was supervisor of 17 PhD and is supervising 2 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 functional unit's activities carried out in CIESOL during 2016

Along the 2016 the group has been restructured including a postdoctoral researcher and several students of degree and master. It is important to point out that 4 PhD theses were completed and were published articles in the best journals in the area of chemistry, inorganic chemistry and materials (one of them referred to by the journal Nature as one of the most relevant contributions of the University of Almería). Two patent were also well evaluated. Recently, an AACI project has been obtained for the development of Latin American countries, which together with industry contracts, provide support for continuing its research activity in the coming years.

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

The group incorporated in 2016 a postdoctoral researcher, one predoctoral (stable with a grant), four students of degree and one of masters. Unfortunately for the group, a predoctoral student left the group to get a project scholarship in another group of CIESOL-PSA, which was obviously very positive for the student. Finally, the team hosted two Tunisian students for 6 months as well as an Ecuadorian student for 2 months.

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

Papers

- Evaluation of catalytic activity of [RuClCp(dmoPTA)(PPh3)](OSO2CF3) in the isomerization of allylic alcohols in water (dmoPTA = 3,7-dimethyl-1,3,7-triaza-5-phosphabicyclo[3.3.1]nonane). Journal of Molecular Catalysis A: Chemical, 2016, 411, pp 27-33.
- Ruthenium complexes containing 2,2'-bipyridine and PTA (PTA = 1,3,5-triaza-7-phosphaadamantane). European Journal of Inorganic Chemistry, 2016, pp1528–1540.
- Amorphization of a Ru-Ru-Cd-Coordination-Polymer at Low Pressure. ChemistrySelect 2016, 5, pp 901–905 .
- One-pot three-component Biginelli-type reaction to synthesize 3,4-dihydropyrimidine-2-(1H)-ones catalyzed by Co phthalocyanines: Synthesis, characterization, aggregation behavior and antibacterial activity. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 2016, 167, pp 165–174.
- Synthesis and antiproliferative activity of [RuCp(PPh3)2(HdmoPTA)](OSO2CF3)2 (HdmoPTA = 3,7-H-3,7-dimethyl-1,3,7-triaza-5-phosphabicyclo[3.3.1]nonane). Inorganic Chemistry, 2016, 55(16), pp 7820-7822.
- Convenient synthesis of novel unmetalled and metallophthalocyanines bearing coumarin derivatives: synthesis, characterization, aggregation behaviors and antimicrobial activity. Journal of Inclusion Phenomena and Macrocyclic Chemistry (Journal of Inclusion Phenomena and Macrocyclic Chemistry), 2016, 86, pp 201-210
- Synthesis, characterization and theoretical study of the complexes [RuCp(8MTT-κS)LL'] (8MTT = 8-methylthio-theophyllinate; L,L' = PTA, mPTA; L = mPTA, L' = PPh3; PTA = 1,3,5-triaza-7-

phosphaadamantane, mPTA = N-methyl-1,3,5-triaza-7-phosphaadamantane). Inorganica Chimica Acta, 2017, 455, pp 557-567.

- Easy synthesis and water solubility of ruthenium complexes containing PPh3, mTPPMS, PTA and mPTA, (mTPPMS = meta-triphenyphosphine monosulfonate, PTA = 1,3,5-triaza-7-phosphaadamantane, mPTA = N-methyl-1,3,5-triaza-7-phosphaadamantane). Inorganica Chimica Acta, 2017, 455, pp 528-534.

Book chapter

- Libro: Non-covalent Interactions in the Synthesis and Design of New Compounds. Capítulo: Non-covalent interactions of water with metal complexes in solution. John Wiley & Sons, Inc. 2016, pp 85-99. ISBN: 978-1-119-10989-1.

Congress

- XII Congreso de Estudiantes de la Sección de Química. 11-13 de April de 2016, La Laguna, Tenerife, España.
- 17ª Reunion científica plenaria de química inorgánica 11ª Reunión científica plenaria de química del estado sólido, 19-22 June 2016, Torremolinos, Málaga, España.
- XXXIV GEQP Congress Organometallic Cheimstry Group, 7-9 September 2016, Girona, España
- 13th European Workshop on Phosphorus Chemistry. 7-9 March 2016, Berlin, Germany.
- 42nd International Conference on Coordination Chemistry (ICCC 2016). 3-8 July 2016, Brest, France.
- 3rd European Conference on Smart Inorganic Polymers (3rd EUSIPs). 12-14 September 2016, Porto, Portugal.
- II Congreso Internacional de Ciencia y Tecnología. Universidad Técnica de Machala, 23-25 November de 2016, Machala, Ecuador

Patents

TÍTULO: Aditivación de resinas epoxi mediante complejos poliméricos Homo y Heterometálicos con 1,3,5-triaza-7-fosfaadamantanofosfina y sus derivados.
NÚMERO DE PATENTE: P201600099 (P2016-91000000060) (26/01/2016)
SOLICITANTE: Universidad de Almería/Universidad de La Laguna

2.1.7 Staff members

Antonio Manuel Romerosa Nievas

Main Researcher
Professor UAL
romerosa@ual.es
(+34) 950 015 305
http://cvirtual.ual.es/webual/jsp/investigacion/nuevo/plnicio.jsp?id_grupo=FQM317

Christoph Richter

Main Researcher
DLR-PSA CIEMAT
christoph.richter@dlr.de
+(34) 950 271486
http://www.dlr.de/sf/en/desktopdefault.aspx/tabid-7176/11942_read-28189/

Pablo Antonio Lorenzo Luis

Full Professor
Univ. La Laguna
plorenzo@ull.es

Isaac de los Rios Hierro

Full Professor
Univ. Cádiz
isaac.delosrios@uca.es

Gaspar Francisco Segovia

Researcher
UAL Tecnova
gfst75@gmail.com

Franco Scalambra

PhD Researcher
UAL
fs649@inlumine.ual.es

Cristóbal Saraiba Bello

PhD Researcher
UAL
saraiba@ual.es

Sonia Mañas Carpio

PhD Researcher
UAL
smcarpio@ual.es

Zenaida Mendoza

PhD Student
Univ. La Laguna-UAL
zeni_reni7@hotmail.com

Lourdes Sánchez

PhD Researcher
UAL-CTAP
mlourdes6@hotmail.com

2.1.8 Ongoing projects in 2016

2.1.8.1 Water soluble fluorescent heterometallic polymers.

Participants:
Grupo de Inv. "Química de Coordinación, Organometálica y Fotoquímica". Universidad de Almería (FQM-317)
Contacts:
A. Romerosa Nievas (romerosa@ual.es)
Funds:
Ministerio de Economía y Competitividad. FEDER 2013 (CTQ2015-67384-R)
Time Period:
January 2016 - December 2018
Current situation:
In progress.

Summary

The project is targeted to the design of new heterometallic polymers with gel and fluorescent properties in water, which can be confined in a matrix that increase their respond to environment variations. The ultimate goal is to obtain sensors that are able to tune their optical response against common explosives both in dissolution and vapours.

2.1.8.2 Water purification using activated charcoal from rice husk.

Participants:
Grupo de Inv. "Química de Coordinación, Organometálica y Fotoquímica". Universidad de Almería (FQM-317)
Contacts:
A. Romerosa Nievas (romerosa@ual.es)
Funds:
H. Consejo Universitario de Ecuador Nº 396/2016
Time Period:
October 2016 - October 2017
Current Situation:
In progress.

Summary

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

2.1.9 Activities and Courses, technical capacity

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2.1.10 Project's applications in 2016

Convocatoria 2016 de la Agencia Andaluza de Cooperación Internacional para el Desarrollo. Carbón activo proveniente de la cáscara de arroz y su uso en la purificación de agua. Investigador principal Antonio Manuel Romerosa Nievas, colaborador, Prof. Freddy Pereira Guanuche en al U. de Machala.

2.1.11 Others

El artículo "Synthesis and Antiproliferative Activity of[RuCp(PPh3)2(HdmoPTA)](OSO2CF3)2(HdmoPTA =3,7-H-3,7-Dimethyl-1,3,7-triaza-5-phosphabicyclo[3.3.1]nonane/article/10.1021/acs.inorgchem.6b01207), Inorganic Chemistry (2016-07-27)" fué seleccionado como un TOP ARTICLE por el indice de calidad NATURE PUBLICATION INDEX, dependiente de al revista Nature.

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

2.2.1 Functional unit description

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

2.2.2 Main research lines

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

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

2.2.3 Main researchers

Ana Agüera López (Scopus Author 6701415534)

Full professor at the University of Almeria. Degree in Chemistry (1987). PhD in Chemistry (1995). She has more than 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 21 national and international competitive R&D Projects. She is co-author of 2 patents and 120 scientific publications in indexed international journals (h-index = 48, January 2017). 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 10 International Editorial books chapters. Furthermore, she is co-author of 87 publications in indexed scientific international journals and 270 contributions to different International Congresses and Symposiums (until January 2017). She has also participated as teacher in some national and international curses and masters related with Advanced Treatment of Wastewater. H-index (March 2017): 30.

2.2.4 Summary of the functional unit's activities carried out in CIESOL during 2016

One of the activities that have been developed in the functional unit during the year 2017 and that fits within the framework of the project of the Junta de Andalucía (P12-RNM-1739) corresponds to the characterization of the active sludge of a WWTP through PCR and its comparison with the bacterial population that develops in a fluidized bed reactor when the active sludge is acclimatized to a partially treated complex water by an advanced oxidation process. The procedure followed for conducting PCR analysis of the active sludge by PCR is summarized in Figure 1.

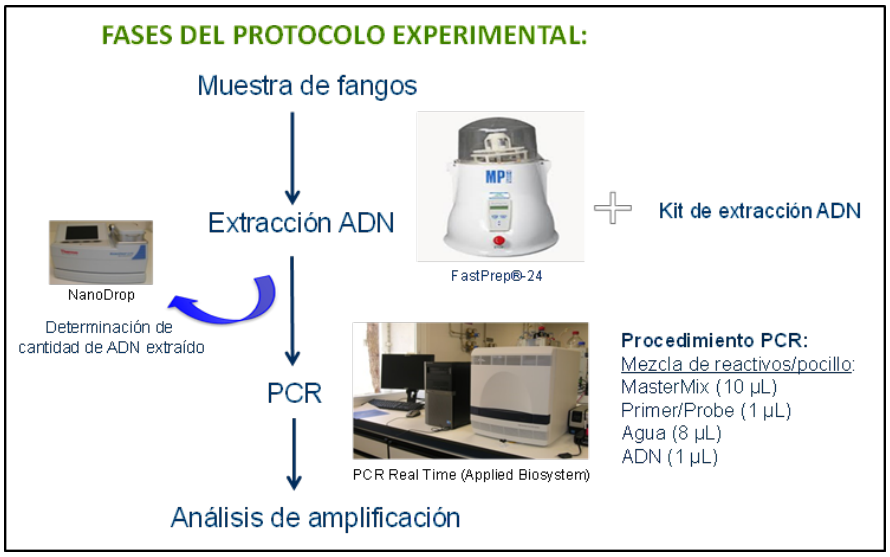

Figura 1. Phases of the experimental protocol for DNA analysis by PCR.

In this study, the biomass fixed on the supports of a fluidized bed biological reactor was acclimatized to the treatment of a partially oxidized landfill leachate by solar photo-Fenton. The evaluation of the bacterial population in the fluidized bed reactor was also carried out by PCR, analyzing not only the samples of the supernatant (in which it is verified that the concentration of bacteria is minimal) but also the biomass adhered to the supports following the extraction procedure detailed in figure 2. From the results obtained it can be concluded that the concentration of nitrifying bacteria is maintained in the supports with respect to those that were suspended in the municipal sewage sludge, while the amount of general bacteria is reduced a log. To see in more detail the microbial species present in the biomass adhered to the supports will be necessary to resort to the mass sequencing technique. Once the majority microbial species are known, specific biological treatment systems can be designed for certain types of complex waters with the consequent reduction of costs with respect to the application of other more expensive oxidation technologies.

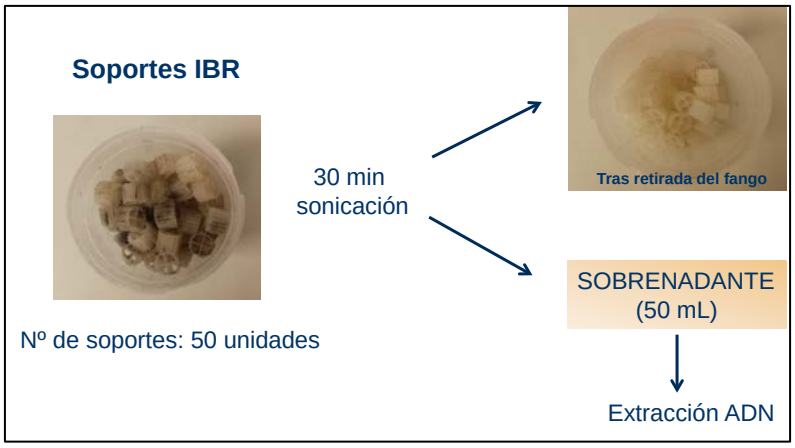

Figura 2. Phases of the experimental protocol for the extraction of the DNA from the bio-film that is attached to the supports of the fluidized biological reactor.

Work has continued on the characterization of the waters from the cork stew. Given the difficulty in identifying the pollutants present in these complex waters, the use of omic techniques has been applied. For this purpose, an integrated strategy has been proposed, including sample preparation (SPE fractionation), different LC separation conditions (HILIC and C18 columns), statistical analysis of data obtained by high resolution mass spectrometry (principal component analysis using MarkerViewer®) and using databases (Chemspider) to identify possible markers for a specific treatment.

Finally, we have continued to work on the development and validation of new methods of analysis (pesticides, antibiotics) that allow us to expand the scope of our laboratory.

Also, following the line of research on the impact of contaminants present in regenerated waters destined for reuse practices, trials have been carried out in order to increase knowledge about the behavior of carbamazepine (a drug frequently found in EDAR effluents) and their potential transformation products in the soil-plant system, so that it is possible to establish the effect of the treatments and the risk associated with the transformation products generated. Part of this work was carried out during the research stay of Ms. Ana Belén Martínez Piernas at the Water Research Institute of Italian National Research Council (CNR-IRSA) in Bari, Italy.

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

In 2016 Ana Isabel Lorenzo Flores, as contracted personnel within the framework of the REAQUA project, has joined the unit. She undertook her predoctoral training at CIESOL under the direction of Dr. Ana Agüera and Dr. José Antonio Sánchez.

Dr. Leonidas Armando Pérez Estrada, hired Ramón y Cajal in the PSA has also been incorporated. Dr. Pérez Estrada comes from the University of Alberta (Canada) and has extensive analytical experience.

During this annuity, the application for a post-doctoral contract HIPATIA 2016 and a predoctoral fellowship in the UAL Research Plan have also been supported.

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

Papers

- Pilot-plant evaluation of TiO2 and TiO2-based hybrid photocatalysts for solar treatment of polluted water. Journal of Hazardous Materials, 2016, 320, pp. 469-478.
- Enhancement of the Fenton and photo-Fenton processes by components found in wastewater from the industrial processing of natural products: The possibilities of cork boiling wastewater reuse. Chemical Engineering Journal, 2016, 304, pp. 890-896.
- Cork boiling wastewater treatment and reuse through combination of advanced oxidation technologies. Environmental Science and Pollution Research,2016, pp. 1-12. Article in Press.
- Strategies for reducing cost by using solar photo-Fenton treatment combined with nanofiltration to remove microcontaminants in real municipal effluents: Toxicity and economic assessment. Chemical Engineering Journal. 2016 Article in Press.
- Ecotoxicity evaluation of a WWTP effluent treated by solar photo-Fenton at neutral pH in a raceway pond reactor. Environmental Science and Pollution Research, 2016, pp. 1-12. Article in Press.
- Ozonation, photocatalysis and photocatalytic ozonation of diuron: Intermediates identification. Chemical Engineering Journal, 2016, 292, pp. 72-81.
- Elimination of organic micro-contaminants in municipal wastewater by a combined immobilized biomass reactor and solar photo-Fenton tertiary treatment. Journal of Advanced Oxidation Technologies. 2016, In press
- Is the combination of nanofiltration membranes and AOPs for removing microcontaminants cost effective in real municipal wastewater effluents? Journal Environmental Science: Water Research & Technology, 2016, 2, pp. 511-520.

Book chapter

- New challenges for the analytical evaluation of reclaimed water and reuse applications, 2016 Handbook of Environmental Chemistry, 44, pp. 7-47.

Congress

- Non-target screening of organic chemicals for a comprehensive environmental risk assessment (Non-Target 2016) 29 May-3 June, 2016, Ascona, Suiza .
- META-2016. 20-22 June, 2016, Madrid, España
- 44th International Symposium on High Performance Liquid Phase Separation and Related Techniques. 19-24 June, 2016, San Francisco, California, USA
- 9th European Meeting on Solar Chemistry and Photocatalysis: Environmental Applications (SPEA9). 13-17 June, 2016, Strasbourgo, Alemania

2.2.7 Staff members

Ana Agüera López

Main Researcher
Professor UAL
aaguera@ual.es
(+34) 950 215 531
www.ciesol.com

Isabel Oller Alberola

Main Researcher
Contratado doctor OPI
CIEMAT-PSA
isabel.oller@psa.es
(+34) 950 387 993
www.psa.es

Sixto Malato Rodríguez

Senior Researcher OPI. Director PSA (CIEMAT)
CIEMAT-PSA
sixto.malato@psa.es
(+34) 950387940
www.psa.es

Inmaculada Polo

Senior Researcher OPI
CIEMAT-PSA
inmaculada.polo@psa.es
(+34) 950387990
www.psa.es

Ana Ruiz Delgado

PhD Student
PSA
ana.ruiz@psa.es
(+34) 950387990
www.psa.es

Ricardo Sánchez

Senior Researcher OPI
CIEMAT-PSA
ricardo.sanchez@psa.es
(+34) 950387990
www.psa.es

Maria Castro Alférez

PhD Student
PSA
maria.castro@psa.es
(+34) 950387990
www.psa.es

Laura Ponce Robles

PhD Student
CIEMAT-PSA
laura.ponce@psa.es
(+34) 950387990
www.psa.es

Ana Martínez

PhD Student
UAL-CIEMAT
aaguera@ual.es
(+34) 950 214136
www.ciesol.com

Marina Celia Campos Mañas

PhD Student
UAL
mcm029@inlumine.ual.es
(+34) 950214136
www.ciesol.com

Ana Lorenzo Flores

PhD Student
UAL
lorenzofloresana@gmail.com
(+34) 950 214136
www.ciesol.com

Leónidas Pérez Estrada

Senior Researcher Ramón y Cajal
CIEMAT
lperez@psa.es
(+34) 950 387 800 ext.826
www.ciesol.com

2.2.8 Ongoing projects in 2016

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

Participants:

Functional Unit of "Environmental Analysis"

Contacts:

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

Funds:

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

Time Period:

January 2014 - January 2019. Extended

Current Situation:

In progress

Summary:

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

Objectives:

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

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

Participants:

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

Contacts:

J. A. Sánchez (jsanchez@ual.es)
A. Agüera (aaguera@ual.es)

Funds:

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

Time Period:

January 2014 – December 2016. Extended to December 2017.

Current Situation:

In progress

Summary:

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, as kinetic behavior is different with respect to that observed with high concentration of pollutants, where chemical oxygen demand and dissolved organic carbon are monitored.

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. This concept was barely studied in the development of the first experimental plants, as the ability to concentrate solar energy was prioritized.

In addition to the technical development, an economic assessment has become essential to turn the photo-Fenton process into a commercial treatment. In this project, we propose the use of open reactors, "raceway" type, due to their low cost (amortization and operation) and the fact that they allow changing the optical path (volume depth) as a function of incident solar radiation. We expect to minimize total costs, maximizing reclaimed water volume per surface area. To this effect special attention will be given to the operating variables, reactant dosage and operating mode, batch and continuous (during the day).

Analytical assessment is especially important to monitor micro-contaminants and detect their transformation products during the treatment. This will permit to evaluate the reactor efficiency and the optimization of the operating parameters. 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

Participation in the **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. Work is under way on the evaluation of the data collected in the sampling campaigns and a new work plan for 2017 has recently been approved.

Participation in the **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 March 2016, it took place the "**4th Management Committee and Working Groups Meeting**" in Malta, As a result of the meeting, it has been sent to publish an opinion article titled: "Two important limitations relating to the spiking of environmental samples with emerging contaminants: How close to the actual analyte are the reported recovered values?" and a review article on "Antibiotic-related microcontaminants in current agricultural fields and realistic experimental conditions as a result of wastewater reuse: Fate and implications for plant uptake" is in preparation. In addition, a study has also been started to detect antibiotic-resistant bacteria at European level in order to gain general knowledge about the dispersion of antibiotic-resistant bacteria through EDAR effluents. The unit participates actively in all the mentioned activities.

Participation in the **CONSOLIDER TRAGUA NETWORK (CTM2014-53485-RED)**, MINECO. The Ministry has authorized the extension of the execution period of TRAGUANET for another year, so it will continue its activity until November 30, 2017.

2.2.10 Project's applications in 2016

- Program Interreg MED, 2014-2020. "Closing the Urban Water Cycle in the Mediterranean area through sustainable utilization of urban wastewater". RE-WATER-MED Led by Technical University of Crete, School of Environmental Engineering (TUC). Partners: 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, Crete, 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. In recent years, the aquatic environment suffers from the discharge of various anthropogenic micro-

pollutants, such as pharmaceutical and personal care products. Among the various micro-pollutants, special emphasis has been given to antimicrobial compounds (AMCs). Urban wastewater treatment plants are among the main sources of AMCs release into the environment. Their occurrence may promote the selection of antibiotic resistance genes and antibiotic resistant bacteria, which shade health risks to humans and animals. Wastewater reuse can act as an important driver towards closing the urban water cycle if implemented sustainably and in such a manner that both human and environmental health is protected. The aims of the present project are:

- To analyse wastewater samples per country in order to identify the main antimicrobial compounds and antibiotic resistant bacteria present.
- To study the technical feasibility and sustainability of various advanced wastewater treatment technologies, such as adsorption onto powdered and granular activated carbon, membrane filtration, UV/H2O2, O3, O3-H2O2, UV/O3-H2O2, Fenton and photo-Fenton oxidation, ferrate oxidation, in pilot units. Advanced oxidation processes will be also compared with conventional disinfection systems (e.g., chlorination and UV radiation). Several antimicrobial compounds will be monitored at different stages of the treatment train. In addition, various ecotoxicological tests will be performed to evaluate effluent toxicity.
- Perform cost – benefit analysis of the best technologies or combination of technologies identified
- Based on the results of the pilot studies and economic data, to recommend to the regional and national authorities of the Mediterranean countries the upgrading of the WWTPs as an effective strategy to reduce the release of antimicrobial compounds into the aquatic environment
- To test the reuse of the effluents treated with the above mentioned advanced methods for the irrigation of various cultivations, such as tomatoes, lettuce, orange and olive trees.
- To build up a strong Mediterranean network in wastewater treatment and reuse
- To establish a communication / dissemination plan for the spread of relevant information towards the wider public and for building capacity among the relevant stakeholders and policy makers

This project was submitted in 2005, but was excluded due to administrative deficiencies. In October 2016 the call was reopened and the information not included in the regular call was completed. The project was, however, dismissed in December 2016.

- Call for R + D + I projects 2016, corresponding to the state program of research, development and innovation oriented to the challenges of society, DISINFECTION OF WWTP SECONDARY EFFLUENTS BY SOLAR PHOTO-FENTON PROCESS IN RACEWAY POND REACTORS. EFFECT ON ANTIBIOTIC RESISTANCE TRANSFER.". CTQ2016-78255-R The general objectives of this project can be summarized as follows: i) the study of the operating variables of raceway pond reactors for water disinfection, dosing of reagents and liquid depth, at pilot plant scale; ii) the analytical monitoring of micropollutants and their transformation products, improving and validating new analytical

methods; iii) evaluating the effect of treatments on the transfer of AR, through the inactivation of ARB and ARG; and iv) the economic optimization of the proposed process at pilot plant scale to facilitate decision-making for implementation on a larger scale and pre-commercialization of the developed technology. This project has been approved having started the execution period in January 2017

2.2.11 Others

Ana Belén Martínez Piernas has made a research stay at the Water Research Institute of the National Research Council (CNR-IRSA) in Bari (Italy) from September to December 2016 (3 months) to carry out the research work of title "Behavior Of Carbamazepine and its transformation products in soil and lettuce grown under controlled conditions ", funded by the NEREUS Short-Term Scientific Mission (STSM) Program.

2.3 ACTIVITIES OF "WATER TREATMENT" FUNCTIONAL UNIT

2.3.1 Functional 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 micropolluant 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 leaded 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 14 PhD theses in different fields such as biotechnology of microalgae, filamentous fungi fermentation and water treatment, co-authored more than 120 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 96 paper-reviewed international publications (h index 35), co-author of 6 books as well as 20 chapters in others, 120 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 functional unit's activities carried out in CIESOL during 2016

The development of the solar photo-Fenton process in raceway pond reactors has led the work of the group during 2016, without losing dedication to the study of the application of LEDs powered by photovoltaic energy as a source of radiation.

A new line of work has been the study of the heterogeneous photo-Fenton process at neutral pH. To this end, a collaboration has been initiated with the Institute of Engineering of the UNAM, Mexico, for the use of iron slags as a source of iron. The results obtained are very promising. In the field of photo-Fenton process at neutral pH, a collaboration with the University of Palermo, Italy, has been initiated in the study of the photocatalytic activity of iron hydroxide precipitates and iron oxides, and with the University of Clermont-Ferrand, France, In the mechanisms of action of the Fe^{3+}/EDDS complex.

With regard to the operation of raceway pond reactors, the application at neutral pH using the Fe^{3+}/EDDS complex has been carried out with a study of the effect of liquid depth and its comparison with CPC tubular reactors. The "raceway" showed a greater efficiency of use of the radiation being 15 cm the best depth. This research with the complexed iron has been carried out in collaboration with the functional unit "Analytical evaluation of water treatment and environmental analysis" of CIESOL. A pioneering work developed in this year 2016 has been the continuous operation of the solar photo-Fenton process, both at acid pH and at neutral pH, for the elimination of microcontaminants in WWTP secondary effluents. Effective eliminations are achieved with residence times of 20 minutes, significantly increasing the productivity of the solar photo-Fenton process and bringing this technology to the commercial field.

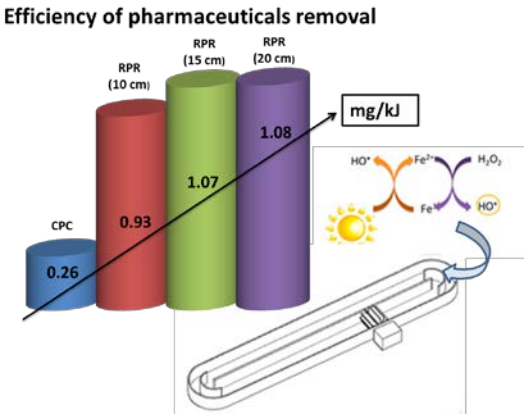

Figure. Comparison of solar radiation efficiency in a 5 cm diameter CPC tubular reactor and in raceway pond reactors of different depths for pharmaceutical removal in secondary effluents by the solar photo-Fenton process.

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. The analysis of energy efficiency in the photo-Fenton process has been carried out both for the elimination of contaminants at micrograms per lite r scale and for the mineralization of contaminants at the milligrams per liter scale. In both cases, the energy evaluation has been performed based on the energy consumed

per order of reaction, with the optimum wavelength being around 380 nm. All of this study was carried out at acidic pH and tests are currently being carried out at neutral pH.

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

During 2016, the chemical engineer Irene de la Obra Jiménez with an FPI predoctoral contract and the biologist Ana Belén Esteban García with a post-doctoral contract both corresponding to the SULAYR project (P12-RNM-1437) joined the group.

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

Papers

- Wastewater disinfection by neutral pH photo-Fenton: the role of solar radiation. Applied Catalysis B: Environmental. 2016, 181 pp1-6.
- Solar disinfection is an augmentable, in situ-generated photo-Fenton reaction-Part 1: A review of the mechanisms and the fundamental aspects of the process. Applied Catalysis B: Environmental. 2016, 199, pp 199-223.
- Solar disinfection is an augmentable, in situ-generated photo-Fenton reaction-Part 2: A review of the applications for drinking water and wastewater disinfection. Applied Catalysis B: Environmental. 2016, 198, pp 431-446.
- Ecotoxicity evaluation of a WWTP effluent treated by solar photo-Fenton at neutral pH in a raceway pond reactor. Environmental Science and Pollution Research 2016 Jun 22. Epub 2016 Jun 22.
- Performance of different advanced oxidation processes for tertiary wastewater treatment to remove the pesticide acetamiprid. Journal of Chemical Technology and Biotechnology 2016, Volume 91, Issue 1, pp 72–81.
- Is the combination of nanofiltration membranes and AOPs for removing microcontaminants cost effective in real municipal wastewater effluents? Journal Environmental Science: Water Research & Technology, 2016, 2, pp. 511-520.
- Strategies for reducing cost by using solar photo-Fenton treatment combined with nanofiltration to remove microcontaminants in real municipal effluents: toxicity and economic assessment. Chemical Engineering Journal 2016.
- Low cost UVA-LED as a radiation source for the photo-Fenton process: A new approach for micropollutant removal from urban wastewater. Photochem. Photobiol. Sci., 2017, 16, pp. 72-78.
- Microcontaminant removal in secondary effluents by solar photo-Fenton at circumneutral pH in raceway pond reactors. Catalysis Today. 2016
- Cost estimation of COD and color removal from landfill leachate using combined coffee-waste based activated carbon with advanced oxidation processes. 2017, volume 5, Issue 1, pp 114–121.
- Intracellular mechanisms of solar water disinfection. Nature Scientific Reports. 2016.
- Effect of temperature and photon absorption on the kinetics of micropollutant removal by solar photo-Fenton in raceway pond reactors. Chemical Engineering Journal. 2016.
- Combination of nanofiltration and ozonation for the remediation of real municipal wastewater effluents: Acute and chronic toxicity assessment. Journal of Hazardous Materials. 2017 Feb 5, 323 (Pt A): pp 442-451.
- Photocatalytic inactivation of the waterborne protozoan parasite Cryptosporidium parvum using TiO2/H2O2 under simulated and natural solar conditions. Catalysis Today. 2017, volume 280, Part 1, pp. 132-138.
- Assessment of solar photocatalysis using Ag/BiVO4at pilot solarCompound Parabolic Collector for inactivation of pathogens in wellwater and secondary effluents. Catalysis Today. 2017 volume 281, Part 1, pp. 124–134.

- Legionella jordanis inactivation in water by solar driven processes: EMA-qPCR versus culture-based analyses for new mechanistic insights. Catalysis Today. 2017
- Mechanistic model of the Escherichia coli inactivation by solar disinfection based on the photo-generation of internal ROS and the photo-inactivation of enzymes: CAT and SOD. Chemical Engineering Journal. 2016

Book Chapter

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Congress

- 251st AMERICAN CHEMICAL SOCIETY NATIONAL MEETING & EXPOSITION. 13-17 March 2016, San Diego, California, USA.
- XXXVII Encuentro Nacional de la Academia Mejicana de Investigación y Docencia en Ingeniería Química A.C. 3-6 May 2016, Puerto Vallarta (Jalisco), Méjico.
- XVIII Reunión de Economía Mundial 1-2 June 2016, Alcalá de Henares (Madrid), España.
- 9th European meeting on solar chemistry and photocatalysis: environmental applications (SPEA9) 13-17 June 2016, Estrasburgo, Francia.
- XII Reunión de la Mesa Española de Tratamientos de Aguas (META 2016) 20-22 June 2016, Madrid, España.
- 44th International Symposium on High Performance Liquid Phase Separations and Related Techniques. 19-24 June 2016, San Francisco, USA.
- XXX Congreso Internacional de Economía Aplicada Asepelt 2016, 1-2 July 2016, Valencia, España.
- IV Encuentro de Especialización para la Investigación en Economía, Empresa y Derecho, November 2016 Almería, España;

PhD Thesis

- Assessment of Solar Photo-Fenton in Raceway Pond Reactors for Micropollutant Removal in Secondary Effluents from Agro-food Industry and Municipal WWTPs, Gracia Rivas Ibáñez, directors J.A. Sánchez Pérez, José Luis Casas López Almería, 14 july 2016.

2.3.7 Staff members

José Antonio Sánchez Pérez

Full Professor
UAL
jsanchez@ual.es
(+34) 950 215 314 www.ciesol.com

Manuel Ignacio Maldonado

Researcher OPI
CIEMAT-PSA
mignacio.maldonado@psa.es
(+34) 950 215 314 www.psa.es

Antonia Pilar Fernández

Researcher OPI
CIEMAT-PSA
pfernandez@psa.es
(+34) 950 387 900 www.psa.es

José Luis Casas López

Professor
UAL
jlcasas@ual.es
(+34) 950 215 832 www.ciesol.com

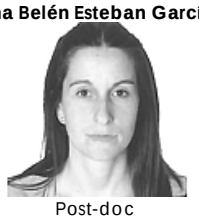
José Luis García Sánchez

Professor
UAL
jlgarcia@ual.es
(+34) 950 015 900 www.ciesol.com

Isabel María Román Sánchez

Professor
UAL
iroman@ual.es
(+34) 950 015 180 www.ciesol.com

Ana Belén Esteban García



Post-doc
UAL
abgarcia@ual.es
(+34) 950 214 431 www.ciesol.com

Gracia Rivas Ibáñez

PhD Student
UAL
gracia.rivas@ual.es
(+34) 950 215 049 www.ciesol.com

Paula Soriano Molina

PhD Student
UAL
paula.soriano@ual.es
(+34) 950 215 049 www.ciesol.com

Sandra Arzate Salgado

PhD Student
UAL
sandra.arzate@ual.es
(+34) 950 215 049 www.ciesol.com

Irene de la Obra Jiménez

PhD Student
UAL
Irene.delaobra@ual.es
(+34) 950 214 148 www.ciesol.com

2.3.8 Ongoing projects in 2016

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**)**

Funds:

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

Time Period:

July 2011 – October 2016

Current Situation:

Finished

Summary:

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:

J. A. Sánchez (jsanchez@ual.es)

P. Fernández (pfernandez@psa.es)

Funds:

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

Time Period:

January 2014 – January 2019

Current Situation:

In progress

Summary:

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 (REAQUA)

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)

Funds:

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

Time Period:

January 2014 – December 2017

Current Situation:

In progress

Summary:

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, as kinetic behavior is different with respect to that observed with high concentration of pollutants, where basically chemical oxygen demand and dissolved organic carbon are monitored.

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. This concept was barely studied in the development of the first experimental plants, as the ability to concentrate solar energy was prioritized.

In addition to the technical development, an economic assessment has become essential to turn the photo-Fenton process into a commercial treatment. In this project, we propose the use of open reactors, "raceway" type, due to their low cost (amortization and operation) and the fact that they allow changing the optical path (volume depth) as a function of incident solar radiation. We expect to minimize total costs, maximizing reclaimed water volume per surface area. To this effect special attention will be given to the operating variables, reactant dosage and operating mode, batch and continuous (during the day).

Analytical analysis is especially important to monitor micropollutants and detect their transformation products during the treatment. This will permit to evaluate the reactor efficiency and the optimization of the operating parameters. 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 economical 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 micropollutants and their transformation products during treatment, to obtain effluent suitable for reuse in different applications.

2.3.8.4 Treatment in raceway pond reactors of water contaminated with emerging organic compounds by the photo-Fenton process using metallurgical slags and titanium-supported iron oxide nanoparticles as catalysts

Participants:
Grupo de Inv. "Ingeniería de Bioprocesos y Tecnologías del Agua". Universidad de Almería (BIO-263)
Contacts:
J. A. Sánchez (jsanchez@ual.es)
Funds:
Fondo de Colaboración Internacional del Instituto de Ingeniería de la UNAM, Méjico
Time Period:
January 2016– December 2017
Current Situation:
In progress

Summary:

The economic problem that is proposed to solve is the reduction of the cost of water treatment by the photo-Fenton process, because when it is carried out in homogeneous phase the catalyst is lost. In order to alleviate this problem, catalysts have been developed using (economic) iron-based industrial wastes and byproducts, which have the limitation of acceptable performance but can be improved by more efficient agitation to reduce mass transfer problems, but which at the same time is economical. The use of raceway pond reactors for the photo-Fenton process also allows a better use of solar energy, which is a source of irradiation at no cost, to activate catalysts and which can significantly increase the efficiency of water treatment. Slags have the great advantage that they are also good adsorbents of toxic metals such as arsenic. All these improvements of the proposed system for the photo-Fenton reaction make it possible, as a whole, to be applied as a tertiary treatment to the effluent from a WWTP for the reuse of those waters in agricultural irrigation.

Objetive:

It is proposed to use raceway pond reactors to reduce costs and make more efficient the use of metallurgical slags (iron, copper and titanium oxides) as alternative catalysts, to degrade organic compounds and disinfect water contaminated with pathogens in a photo-Fenton system that operates at pH neutral.

2.3.8.5 New photocatalytic materials and reactors for removal of micropollutants and pathogens, FOTOCAT (CTM2015-71054-REDT)

Participants:
Grupo de Inv. "Ingeniería de Bioprocesos y Tecnologías del Agua". Universidad de Almería (BIO-263)
Contacts:
J. A. Sánchez (jsanchez@ual.es)
Funds:
Ministerio de Economía y Competitividad
Time Period:
January 2016– December 2017
Current Situation:
In progress

Summary:

To achieve a sustainable use of water resources, it is necessary to increase the volume of reclaimed water. To obtain an effluent of suitable quality for the different uses permitted for reclaimed water it is necessary to reduce the content of pathogens and persistent organic pollutants. This could be achieved through the proper development of photocatalytic processes. The aim of the FOTOCAT network is to achieve a significant progress in the development of materials and photocatalytic reaction systems for the treatment and reuse of wastewater. The research groups that comprise the FOTOCAT network (Rovira i Virgili University, U. Extremadura, U. Ramon Llull, U. Rey Juan Carlos, U. Politécnica de Valencia., U. Almería, PSA-CIEMAT and ICRA) have altogether a wide experience in the synthesis of new catalytic materials, photocatalytic reactor design and implementation of these processes for the treatment and reuse of wastewater, allowing them to face the challenges identified for their industrial application.

Scientific advances arising from the activities of the FOTOCAT network will contribute to R+D+I plans, both European (H2020-Social Challenge 5, Water JPI), state (Spanish Strategy for Science, Technology and Innovation-Research facing Society Challenges) and regional (particularly RIS3 strategies).

Objetives:

- To contribute to the training of new researchers in the application of photocatalytic processes for water treatment.
- To promote the implementation of photocatalysis for water treatment on an industrial scale and increasing the impact and international projection of the Spanish groups in this field, both at European and Iberoamerican level.

2.3.9 Activities and Courses, technical capacity

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2.3.10 Project's applications in 2016

- The project entitled "DISINFECTION OF WWTP SECONDARY EFFLUENTS BY SOLAR PHOTO-FENTON PROCESS IN RACEWAY POND REACTORS. EFFECT ON ANTIBIOTIC RESISTANCE TRANSFER" has been submitted to the Ministry for Economy and Competitiveness call for research projects at national level. Disinfection of secondary effluents using solar photo-Fenton has been reported; mainly at lab scale and only a few papers deal with pilot plant scale in tubular reactors equipped with Compound Parabolic collectors (CPC). Despite the interest in that water reclamation for irrigation in Spain, no experiences at large scale and cost evaluation are known, mainly due to the recent nature of these investigations. For any of the different uses for which the reuse of treated wastewater is allowed (RD 1620/2007), it is necessary to reduce the content of pathogenic microorganisms in reclaimed water. In this regard, the applicant team has investigated the use of raceway pond reactors for the removal of organic micropollutants with promising results that have aroused the interest of the scientific community. However, to the best of our knowledge, this kind of reactor has never been used for water disinfection. Another aspect that has not been evaluated is its ability to reduce the risk of spreading antibiotic resistance (AR). The antibiotic

resistance is today one of the most pressing problems worldwide for public health. Spain is recognized as a country with a high prevalence of resistance, especially in species that cause infections mainly: Pneumococcus, meningococcus, Haemophilus influenzae, Campylobacter, Salmonella sp or E. coli. Spain is also one of the countries with the highest consumption of antibiotics per capita. There is evidence that conventional disinfection processes of wastewater are not effective in controlling the spread of AR. In this context, the generation of disinfection by-products has also been investigated and the need for sophisticated analytical monitoring using advanced techniques has been reported. Finally, the economic assessment and cost minimization are key to bringing this technology to the commercial scale, ultimate goal of the proposed research. The hypothesis of this project is that raceway pond reactors can be used to disinfect water by the solar photo-Fenton process without generating toxic by-products, improving control of the spread of antibiotic resistance and reducing costs substantially. The general objectives of this project can be summarized as follows: i) the study of the operating variables of raceway pond reactors for water disinfection, dosing of reagents and liquid depth, at pilot plant scale; ii) the analytical monitoring of micropollutants and their transformation products, improving and validating new analytical methods; iii) evaluating the effect of treatments on the transfer of AR, through the inactivation of ARB and ARG; and iv) the economic optimization of the proposed process at pilot plant scale to facilitate decision-making for implementation on a larger scale and pre-commercialization of the developed technology. In September 2016 the project entitled "Toward a smart & integral treatment of natural radioactivity in water provision services. LIFE ALCHEMIA". was presented for evaluation in the call for LIFE+ project of the European Union. The project application was led by the CARTIF technology center, and as partners, in addition to CIESOL, participated the Diputación Provincial de Almería, the University of Tartu (Estonia), the Technical University of Tallin (Estonia) and the company Viimsi Vesi Ltd. LIFE ALCHEMIA addresses one of the current challenges of water for human consumption such as the presence of natural radioactivity. There is a considerable lack of knowledge by the actors involved and it can be stated that, despite the current legislation (Directive 2013/51/Euratom), radioactivity is not systematically monitored at European level. In this regard, it is noteworthy that this project has the support of 43 of these actors, including the maximum national authorities of the 2 countries integrating the consortium: Estonian Ministry of Environment and the Spanish Nuclear Safety Council. Indeed, this is an environmental problem that cannot be solved at source, as it is generated by the groundwater dilution of minerals rich in radioactive isotopes, mainly from uranium (U), radium (Ra) and thorium (Th) series. Therefore, new systems able to provide sustainable removal of radioactivity from a cost-effectiveness point of view are needed. Reverse osmosis (RO) is the most commonly treatment used for this application; however, carbon footprint of this process is very high and generates large volumes of water rejection with radioactivity that needs further treatment. LIFE ALCHEMIA offers a breakthrough in this problem from two angles. First, with the use of removal systems based on bed filters, which will reduce up to five times the cost of the water purification. Moreover, the whole life cycle of the radioactivity will be considered, including the management of the waste generated. Main objectives of LIFE ALCHEMIA project are:

- To demonstrate the technical and economic feasibility of bed filters that will be optimized to remove radioactivity from water and to minimize the generation of Naturally Occurring Radioactive Materials (NORM) exceeding the exemption level. 4 pilot plants in Spain and Estonia will be operated with different strategies to prevent NORM generation.
- To replicate LIFE ALCHEMIA solutions in facilities of other 5 European countries (Italy, Poland and Finland, among others)
- To promote the transferability to other facilities and EU members.
- To encourage the active involvement of interested parties in the implementation of the Directive2013/51/Euratom for minimising the environmental impact of radionuclides treatment in water provision services.

2.3.11 Others

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2.4 ACTIVITIES OF "MODELING AND AUTOMATIC CONTROL" FUNCTIONAL UNIT

2.4.1 Functional unit description

This functional unit is composed by researchers of the group "Automatic Control, Robotics and Mechatronics (TEP197, arm.ual.es) of the University of Almería (UAL) and the Automatic Control Unit of the Plataforma Solar de Almería (PSA). The group has among its areas of interest: intensive agriculture, solar energy, biotechnology and bioengineering, in addition to control education, mechanization and robotics in general. Collaborative activities between the group and the PSA have been developing continuously over the past 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 and co-director of 14 PhD Thesis in these lines. He is co-author of 120 international journal papers, more than 150 papers in international conferences and 4 patents. H-index: 36 (Google Scholar), 27 (Scopus), 22 (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 adjoin-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.

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, 72 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 the functional unit's activities carried out in CIESOL during 2016

- 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).
- 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).
- Jerónimo Ramos Teodoro. FPI contract of the Ministry of Economy and Competitiveness - project ENERPRO DPI2014-56364-C2-1-R (supervisors: Francisco Rodríguez Díaz, Manuel Berenguel).
- Juan Diego Gil Vergel. Contract the Ministry of Economy and Competitiveness - project ENERPRO DPI2014-56364-C2-1-R (supervisors: Manuel Berenguel Soria, Lidia Roca Sobrino).
- Wang Hui. Researcher from NERCITA (China). PhD student of ARM group (supervisors: Jorge Antonio Sánchez Molina, Fernando Bienvenido Bárcena).

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

Articles

- Optimization of biomass production in outdoor tubular photobioreactors. 2016, Journal of Process Control, 37, pp 58-69.
- Distributed sliding mode control of pH in tubular photobioreactors. Transactions on Control Systems Technology. 2016, 24(4), pp 1160-1173.
- On reduction of control effort in feedback linearization GPC strategy applied to a solar furnace. 2016, Optimal Control Applications & Methods, 37, pp 521-536.
- Dynamic modeling and simulation of a double-effect absorption heat pump. 2016 International Journal of Refrigeration, 72, pp 171-191.
- Editorial optimal control of solar energy systems. 2016, Optimal Control Applications & Methods, 37, pp 463-465.
- A room simulation tool for thermal comfort control in a bioclimatic building: A real example of use with an optimal controller. 2016, Optimal Control Applications & Methods, 37, pp 479-495.
- A parallel Teaching-Learning-Based optimization procedure for automatic heliostat aiming. 2016, Journal of Supercomputing. 2017, 73, pp 591-606.
- High performance computing for the heliostat field layout evaluation. 2016, Journal of Supercomputing. 2017, 73, pp 259-276.
- Dynamic model of an industrial raceway reactor for microalgae production. 2016, Algal Research, 17, pp 67-78.
- Hierarchical control for microalgae biomass production in photobioreactors. 2016, Control Engineering Practice, 54, pp 246-255.
- An efficient modeling for temperature control of residential buildings. 2016, Building and Environment 103, pp 86-98.
- A comparison of energy consumption prediction models based on neural networks of a bioclimatic building. 2016, Energies 9(1), p 57.
- Time-variant gas distribution mapping with obstacle information. 2016, Autonomous Robots, 40(1), pp 1-16.
- A hybrid-controlled approach for maintaining nocturnal greenhouse temperature: Simulation study. 2016, Computers and Electronics in Agriculture 123, pp 116-124.
- A constant-time SLAM back-end in the continuum between global mapping and submapping: application to visual stereo SLAM. 2016, International Journal of Robotics Research, 35, pp1036-1056.
- Application of SSOD-PI and PI-SSOD event-based controllers to greenhouse climatic control. 2016, ISA Transactions, 65, pp 525-536.
- Measurable disturbances compensation: Analysis and tuning of feedforward techniques for dead-time processes. 2016, Processes, 4, pp 12.
- Vehicle parameter estimation using a model-based estimator. 2017, Mechanical Systems and Signal Processing 87, part B, pp 227-241.
- Predictive control applied to a solar desalination plant connected to a greenhouse with daily variation of irrigation water demand. 2016, Energies 9(3), pp 194.
- Procedures for testing valves and pressure transducers with molten salt. 2016, Applied Thermal Engineering, 101, pp 139-146.
- Robust design methodology for simultaneous feedforward and feedback tuning. 2016, IET Control Theory and Applications, 10(1), pp 84-94.
- On the filtered Smith predictor with feedforward compensation. 2016, Journal of Process Control, 41, pp 35-46.

- Bayesian networks for greenhouse temperature control. 2016, Journal of Applied Logic, 17, pp. 25-35.
- Odor recognition in robotics applications by discriminative time-series modeling. 2016, Pattern Analysis and Applications, 19(1), pp. 207-220.
- Online kinematic and dynamic-state estimation for constrained multibody systems base don IMUs. 2016, Sensors, 16(3), pp. 333.
- Modelo dinámico de un recuperador de gases-sales fundidas para una planta termosolar híbrida de energías renovables. 2017, Revista Iberoamericana de Automática e Informática Industrial, 14(1), pp 70-81.
- Optimal operating conditions analysis of a multi-effect distillation plant. 2017, Desalination and Water Treatment.
- Review of software for optical analyzing and optimizing heliostat fields. 2017, Renewable & Sustainable Energy Reviews.
- Event-based GPC for multivariable processes: A practical approach with sensor deadband. 2017, IEEE Transactions on Control Systems Technology.
- Evaluation of event-based irrigation system control scheme for tomato crops in greenhouses. 2017, Agricultural Water Management.
- cFertigUAL: A fertigation management app for greenhouse vegetable crops. 2017, Agricultural Water Management.
- Leaf area index estimation for a greenhouse transpiration model using external climate conditions based on genetic algorithms, back-propagation neural networks and nonlinear autorregressive exogenous models. 2017, Agricultural Water Management.

Book Chapters

- Libro: Prospects and Challenges in Algal Biotechnology. Capítulo: Event-based control systems for microalgae culture in industrial reactors. A. Pawlowski, J.L. Guzmán, M. Berenguel, F.G. Acién, S. Dormido. Bhumi Nath Tripathi and Dhananjay Kumar. Springer 2016-2017. ISBN 978-981-10-1950-0.
- Libro: Prospects and Challenges in Algal Biotechnology. Capítulo: Dynamic modelling of microalgal production in photobioreactors. I. Fernández, J.L. Guzmán, M. Berenguel, F.G. Acién. Bhumi Nath Tripathi and Dhananjay Kumar. Springer. 2016-2017. ISBN 978-981-10-1950-0.

Congress

- 1st Conference on Modelling, Identification and Control of Nonlinear Systems (MICNON), 2015 San Petersburgo, Rusia.
- International Workshop on Hybridisation of CSP with other Energy Sources, 2016.
- 11th IFAC Symposium on Dynamics and Control of Process Systems, including Biosystems DYCOPS-CAB 2016, Trondheim, Norway, 2016.
- 11th IFAC Symposium on Advances in Control Education – ACE 2016, Bratislava, Slovakia, 2016.
- 24th Mediterranean Conference on Control and Automation MED 2016, Athens, Greece 2016.
- 21st IEEE International Conference on Emerging Technologies and Factory Automation ETFA 2016, Berlin, Germany, 2016.
- 2nd International Conference on Event-Based Control, Communication, and Signal Processing EBCCSP 2016, Krakow, Poland, 2016.
- International Joint Conference on Mechanics, Design Engineering & Advanced Manufacturing, Catania, Italy, 2016.
- ISPRS Congress, Praga Czech Republic, 2016.
- EUROSUN 2016 – 11th ISES Eurosun Conference, International Conference on Solar Energy for Buildings and Industry, Palma de Mallorca, Spain, 2016.

- Desalination for the Environment: Clean Water and Energy, Rome (Italy), 2016.
- 12th SOLLAB Doctoral Colloquium, Almería, Spain, 2016.
- 16th International Conference on Computational and Mathematical Methods in Science and Engineering, CMMSE 2016, Salamanca, Spain, 2016.
- EUROSIM 2016 – The 9th Eurosim Congress on Modelling and Simulation, Oulu, Finland, 2016.
- Conference on Renewable Energies and Power Quality (ICREPQ'16), 2016.
- X Jornadas sobre Innovación Docente de la Universidad de Almería, España 2016.
- XXXVII Jornadas de Automática, Madrid, España, 2016.
- XXVII Jornadas de Paralelismo, JP 2016, Salamanca, España, 2016.
- II Simposio Nacional de Ingeniería Hortícola – Automatización y TICs en Agricultura, Almería, 10-12 de February, Almería, España 2016.
- XXI Congresso Brasileiro de Automática CBA-2016, Vitória, Brazil, 2016.

Disclosure Articles

- Guzmán, J.L., R. Costa-Castelló, S. Dormido, M. Berenguel. An interactivity-based methodology as support to control education. 2016, *IEEE Control Systems Magazine*, 36(1), pp 63-76.
- Pérez, M. Energía solar para la agroindustria. Una aproximación desde la innovación en sistemas y redes energéticas. 2016, Agricultura 2000, pp 20-21.
- Pérez, M., F.J. Cabrera, J. Sánchez-Molina, F. Rodríguez. Aprovechamiento de la energía solar en invernaderos. 2016, Era Solar, 6-15, edición 192, May/June 2016, año XXXIV.
- Pérez, M., F.J. Cabrera, J. Sánchez-Molina, F. Rodríguez. Energía solar para invernaderos, un nuevo enfoque basado en la innovación en sistemas y redes energéticas. 2016, Horticultura, pp 26-33.
- Rodríguez, F., J.L. Guzmán, M. Castilla, J.A. Sánchez-Molina, M. Berenguel. "A proposal for teaching SCADA systems using Virtual Industrial Plants in Engineering Education". En: 11th IFAC Symposium on Advances in Control Education, Bratislava (Slovak Republic), 2016.
- Rodríguez, C., J.L. Guzmán, M. Berenguel, S. Dormido. Teaching real-time programming using mobile robots. Preprints of the 11th IFAC Symposium on Advances in Control Education – ACE 2016, Bratislava, Slovakia, 2016.
- Rodríguez, C., J.L. Guzmán, M. Berenguel, J.C. Moreno, F. Rodríguez, S. Dormido. Robótica móvil para el aprendizaje de conceptos de programación en tiempo real. XXXVII Jornadas de Automática, Madrid, España, 2016.
- Sánchez-Molina, J.A., F.G. Acién, F. Rodríguez, J.V. Reinoso, J.C. López. Desarrollo de un sistema de recuperación de gases de combustión de biomasa para enriquecimiento carbónico en invernaderos Revista agropecuaria Agricultura, July, 2016, Nº 997. http://www.editorialagricola.com/v_portal/apartados/apartado.asp?te=72
- Las algas como combustible del futuro, resultado de una investigación de la UAL (http://news.ual.es/las-algas-como-combustible-del-futuro-resultado-de-una-investigacion-de-la-ual/, http://almeria360.com/sociedad/20042016_140839_140839.html).
- Las Microalgas Automatizadas, NovaCiencia (http://novaciencia.es/web/las-microalgas-automatizadas/)

PhD Thesis

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Patents

TÍTULO: Concentrador Solar Multi-Modo (MULTISOL)
NÚMERO DE PATENTE: P201400974, iet 201400974 (18/11/2014)
SOLICITANTE: R. Silva, M. Pérez, M. Berenguel, A. Fernández, L. Valenzuela, E. Zarza

2.4.7 Staff members

Dr. Manuel Berenguel Soria

Prof. of Systems
Engineering and Automatic Control
UAL
beren@ual.es
(+34) 950 015 683
arm.ual.es, www.ciesol.es

Dr. Luis José Yebra Muñoz

Researcher OPI
CIEMAT-PSA
luis.yebra@psa.es
(+34) 950 387 923
www.psa.es, www.ciesol.es

Dr. Manuel Pérez García

Associate Prof. of Applied Physics
UAL
mperez@ual.es
(+34) 950 015 295
http://www.ual.es/~mperez/

Dra. Lidia Roca Sobrino

Researcher
CIEMAT-PSA
lidia.roca@psa.es
(+34) 950 387 964
www.psa.es, www.ciesol.es

Dr. Francisco Rodríguez Díaz

Associate Prof. of Systems
Engineering and Automatic Control
UAL
frrodrig@ual.es
(+34) 950 015 681
http://www.ual.es/~frrodrig/

Dr. Javier Bonilla Cruz

Researcher
CIEMAT-PSA
javier.bonilla@psa.es
(+34) 950 387 908
www.psa.es, www.ciesol.es

Dr. José Luis Guzmán Sánchez

Associate Prof. of Systems
Engineering and Automatic Control
UAL
joseluis.guzman@ual.es
(+34) 950 214 133
http://www.ual.es/~joguzman/

Dr. Antonio Giménez Fernández

Associate Prof. of
Mechanical Engineering
UAL
agimfer@ual.es
(+34) 950 214 234
arm.ual.es, www.ciesol.es

Dr. José Carlos Moreno Úbeda

Associate Prof. of Systems Engineering and Automatic Control
UAL
jcmoreno@ual.es
(+34) 950 015 677
arm.ual.es, www.ciesol.es

Dr. Julián García Donaire

Associate Prof. of Computer Technology and Architecture
UAL
jugarcia@ual.es
(+34) 950 015 653
arm.ual.es, www.ciesol.es

Dr. José Domingo Álvarez Hervás

Researcher Ramón y Cajal
UAL
jhervas@ual.es
(+34) 950 214 274
arm.ual.es, www.ciesol.es

Dr. José Luis Blanco Claraco

Lecturer of Mechanical Engineering
UAL
jlblanco@ual.es
(+34) 950 214 233
http://www.ual.es/~jlblanco/

Dr. José Luis Torres Moreno

Researcher of Mechanical Engineering
UAL
jltmoreno@ual.es
(+34) 950 214 232
arm.ual.es, www.ciesol.es

Dra. María del Mar Castilla Nieto

Researcher of Systems Engineering and Automatic Control
UAL
mcastilla@ual.es
(+34) 950 214 155
arm.ual.es, www.ciesol.es

Dr. Jorge Antonio Sánchez Molina

Researcher of Systems Engineering and Automatic Control
UAL
jorgesanchez@ual.es
(+34) 950 214 536
arm.ual.es, www.ciesol.es

Dr. Fco. Javier Cabrera Corral

Researcher of Applied Physics
UAL
fjcabrera@ual.es
(+34) 950 015 295
arm.ual.es, www.ciesol.es

Dr. Ricardo Silva Parreira

Researcher
UAL
ricardosilva@ual.es
(+34) 950 015 295
arm.ual.es, www.ciesol.es

Dr. Alberto de la Calle Alonso

Researcher
CSIRO Energy Technology, Australia
alberto.calle@psa.es

Jerónimo Ramos Teodoro

Researcher UAL
jeronimo.rt@ual.es
(+34) 950214539
arm.ual.es, www.ciesol.es

José Antonio Carballo López (UAL-PSA)

Researcher UAL-PSA agreement
UAL-PSA
jcarballo@psa.es
(+34) 950 387 908
www.psa.es, www.ciesol.es

Juan Diego Gil Vergel

Researcher UAL
juandiego.gil@ual.es
(+34) 950214539
arm.ual.es, www.ciesol.es

2.4.8 Ongoing projects in 2016

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

Contacts:

M. Berenguel (beren@ual.es)
M. Pérez (mperez@ual.es)
D. Alarcón (diego.alarcon@psa.es)

Funds:

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

Time Period:

January 2015 – December 2017

Current Situation:

In progress

Summary:

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. Through optimal management of these resources and by adapting generation to demand, it should be demonstrated how automatic control allows to achieve cost savings and reduce the environmental impact on the operation of complex processes.

Around this theme, concepts like micro-grids (MG), related to the efficient use of electricity, renewable heat and cooling (RHC), in the area of primary energy supply from renewable sources and water efficiency (WE), around adequate use of water have arisen. The paradigm treated in this project goes beyond, since it treats comprehensive and coordinated management of those heterogeneous resources focusing on efficiency and economics. The problem is composed by different control and decision levels about the final use of the available energy based on different objectives (minimizing the use of conventional fossil energy sources, economic, environmental and quality aspects, etc.) This gives rise to a hierarchical control problem that requires coordination and cooperation between systems and that will be addressed using hierarchical and hybrid predictive control techniques, both in centralized and distributed versions. It will be also necessary to develop models, estimators and predictors of the energy generation and demand stages.

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:

The three basic objectives of the coordinated project are:

- 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.

The fulfilment of the preceding goals represents a significant contribution with real impact in this class of processes as evidenced by the interest shown by firms like Fundación Cajamar, Unica Group SCA, Wagner Solar, Solar Jiennense, naming only a few. The proposal is also a natural continuation follow-up of previous work carried out the research groups integrating the project. The team has a remarkable experience in control systems backed by many papers published in some of the most cited scientific journals and relationships with international research teams.

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

Contacts:

J.L. Guzmán (joseluis.guzman@ual.es)
José Sánchez (jsanchez@dia.uned.es)

Funds:

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

Time Period:

January 2015 – December 2017

Current Situation:

In progress

Summary

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:

The main objectives of the coordinated project are:

- 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.

This proposal constitutes the continuation of a new research line on biomass prodcution from micralgae in photobiorreactors, that was opened for the applicant control engineering groups in a previous reseach project focused on tubular photobiorreactors. The applicant groups have had a strong collaboration during the last years through research projects and joint publications. The team has a remarkable experience in control systems backed by many papers published in some of the most cited scientific journals. On the other hand, the multidisciplinarity of the group is complemented with researchers with strong background in microalgal biomass production by photobiorreactors. Moreover, the international collaboration is fostered in the project because three relevant researchers from two European universities (Swedish and Italian) and one researcher from Arizona State University (USA) belonging to the control engineering field take part in the proposal. On the other hand, the project topic belongs to the strategic research lines of the European Union and the National Research Plan, within the challenge on Secure, Efficient and Clean Enegy and thus being a hot research topic. Hence, the fulfilment of the proposed objectives would be a significant contribution in this emerging renewable energy field and it would have a real impact in the energy market competitivity of this type of processes. Consequently this proposal has risen the interest of different companies and research centers such as Acciona, AlgaEnery or CIESOL.

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

Contacts:

M. Pérez (mperez@ual.es)
L. Valenzuela (loreto.valenzuela@psa.es).

Funds:

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

Time Period:

March 2011 – March 2016

Current Situation:

Finished

Summary:

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)

Contacts:

F. Rodríguez (frrodrig@ual.es), http://aer.ual.es/controlcrop/

Funds:

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

Time Period:

March 2011 – March 2016.

Current Situation:

Finished

Summary

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 analized under unmodelled dynamics and disturbances acting on any level of the control hierarchy.

2.4.8.5 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

Contacts:

Francisco Rodríguez (mperez@ual.es)
Rafael Ferrer (rferrer@hispatec.es)
Juan Carlos López (juancarloslopez@fundacioncajamar.com)

Funds:

Corporación Tecnológica de Andalucía.

Time Period:

September 2015 – December 2016

Current Situation:

In progress

Summary:

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.

2.4.8.6 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

Contacts:

María del Mar Castilla (mcastilla@ual.es)
Manuel Berenguel (beren@ual.es)

Funds:

Iberdrola Foundation (Spain)

Time Period:

September 2015 – October 2016

Current Situation:

In progress

Summary:

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.

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.

2.4.9 Activities and Courses, technical capacity

Agreement with University of Brescia and participation in Sfera 2 project

The agreement includes joint supervisión 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)
- Automatic control group of PSA

Contacts:

- Manuel Berenguel (beren@ual.es)
- 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.

Cooperation with Energy Efficiency in Buildings Unit UiE3 (CIEMAT.

Participants:

- Research group "Automatic Control, Robotics & Mechatronics". University of Almería (TEP 197)
- Energy Efficiency in Buildings Unit UiE3 (CIEMAT)

Contacts:

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

Objectives:

- Colaboration in organizing training activities.
- Supoort 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 2016

- Horizon 2020 Framework Programme. Call for proposals: H2020-IOT-2016-2017 (H2020-IOT-2016). Proposal: 731884 — IoF2020. IoT-01-2016 — Large Scale Pilots. Innovation action. IP UAL. Manuel Berenguel 01/01/2017-31/12/20 (560.000 €). Started.
- COST Action. In-Situ BEPA-MAS – OC-2016-2-21388. Building Energy Performance Assessment based on in-situ Measurement, Analysis and Simulation. Participants: CIEMAT (coord.), CIESOL-UAL (ES), University of Innsbruck (AT), University of Leuven (BE), INIVE EEIG (BE), Belgian Building Research Institute (BE), ES-SO vzw European Solar-Shading Organization (BE), University of Praga (CR), Technical University of Denmark (DK), Scientific-Technological Center Bâtiment (FR), University of Mont-Blanc (FR), Cerema, (FR), University of Bolonia (IT), Grupo Permasteelisa (IT), Technological University of Kaunas (LT), Saxion Hogeschool (NL), Wroclaw University of Technology (PL), University of Porto (PT), University of Pais Vasco (ES), ACCIONA (ES), greenTEG AC (SW), Instituto de Ingeniería Termo-física de NASU (Ukraine), University of Strathclyde (UK), University College London (UK), Leeds Beckett University (UK), University of Salford (UK).
- HortShare (Training in modelling for open-source software design in protected crop cultivation). Marie Sklodoswka-Curie Actions. Consorptium leaded by Agrotech (Denmark). H2020-MSCA-ITN-2016.

2.4.11 Others

Other projects or contracts:

- 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 Infraestructure 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)

Collaborators of the group in CIESOL:

- Sebastián Dormido Bencomo (UNED)
- Carlos Rodríguez Contreras (UNED)
- Andrzej Pawlowski (UNED)
- Pilar Martínez Ortigosa (UAL)
- Juana López Redondo (UAL)
- Nicolás Calvo Cruz (UAL)
- Fernando Bienvenido Bárcena (UAL)
- Juan Carlos López (CAJAMAR)
- José María Cámara (UMH).
- Ramón Costa Castelló (UPC)
- Carlos Bordóns (US)
- Eduardo F. Camacho (US)
- Manuel G. Ortega (US)
- Manuel R. Arahal (US)

Students Practices:

- Aparicio, A.; Development of Heatrec tool in Labview, Grade in Industrial Electronics Engineering.
- Claudiu Suciu. Modeling of water consumption in energy-efficient environments. Grade in Industrial Electronics Engineering.
- Mario Alberto López Alonso. Modeling and control of fan-coil units. Grade in Industrial Electronics Engineering.
- Castillo, D.; Illuminance control system optimizing sustainability and energy efficiency criteria. Grade in Industrial Electronics Engineering.
- Gustavo José Martín de Dios. Development of a training tool of hybrid solar plant operators in Labview. Grade in Industrial Electronics Engineering.
- Rocío García Hernández. Analysis of the electrical and electronics installation of a high tech greenhouse. Grade in Industrial Electronics Engineering.

Grade and Master Theses

- Bretones Castillo, Laura. Grade Thesis: Greenhouse temperatura control using natural ventilation – disturbance compensation by feedforward action.
- Gil Vergel, J.D. Master Thesis: Reference governor for a membrane distillation plant powered by solar energy.

- Guerrero, J.; 2016; Grade Thesis: Analysis and implementation of a photovoltaic system on UAL-eCARM electric vehicle.
- Lozano López, María del Mar. Master Thesis: Implementation of the simulation core of a decision support system for greenhouse climate, production and economical cost applied to a polygon of greenhouses.
- Martínez, J.; 2016; Master Thesis: Development of an irrigation automatic control system base don transpiration models and substrate humidity content.
- Rivera Hernández, Leonardo. Master Thesis: Tecno-economic analysis of the use of robots inside greenhouses within the Almería model.
- Tomillero Urrutia, M.A. Grade Thesis: Setup and analysis of performance of a dehumidification plant for greenhouses.
- Zanini, Paolo. Master Thesis_ *Rule-based fuzzy logic control of visual comfort*.

International collaborations:

- Antonio Visioli y Domenico Gorni (University of Brescia, Italy)
- Tore Hägglund (Lund University, Sweden)
- Antonio Ruano y Hamid Khosravani (Universidad del Algarve, Portugal)
- Julio Normey, Daniel Pagano, Gustavo Andrade (Universidad Federal de Santa Catarina, Brasil)

Stays abroad:

- J.L. Torres. National Engineering Research Center for IT in Agrigulture (NERCITA). Beijing, China. 12/08/2016- 14/09/2016.

Stays in CIESOL of researchers coming from abroad:

- Paolo Zanini, Universita di Brescia, Italia (15/02/2016-30/07/2016).
- Luis Orlando Polanco Vasques (01/01/2016-30/06/2016), Cristian Andrés Carreño Meneses (01/01/2016-30/04/2016), Cristhiam Jesid Gutiérrez Lozano (01/05/2016-31/07/2016). Universidad de Guanajuato (México), Departamento de Ingeniería Eléctrica. CONACYT becas mixtas 2016.

Organization of Conferences:

- Francisco Rodríguez Díaz (IPC Chair). II Simposio de Ingeniería Hortícola. Universidad de Almería. 10-12/02/2016. http://www2.ual.es/SNIH16/
- Manuel Berengue: IPC member of ACE2016, MED2015, MED2016, COGINFOCON2016 and EBCCSP2016.
- Luis Yebra: minisimposium in Eurosim2016 (Finlandia): "S5:Modeling and simulation in solar thermal power plants". Difusión en: "http://www.ciemat.es/cargarAplicacionNoticias.do?idArea=-1&identificador=1036".

PhD Theses in progress by other personnel:

– Francisco José Gómez Navarro (supervisors Luis José Yebra y Antonio Giménez).

– César Hernández Hernández (supervisors Francisco Rodríguez y José Carlos Moreno).

– Ana Paola Montoya (supervisors José Luis Guzmán y José Carlos Moreno).

Awards

- "Agustín de Betancourt" Medal of the Spanish Real Academy of Engineering in the 7th edition to CIESOL researcher José Luis Guzmán Sánchez.
- Best Engineering work in SNIH16 II Symposium: "Predictive control to satisfy water demand in greenhouses using solar desalination". L. Roca. J.A. Sánchez, F. Rodríguez, J. Bonilla, A. de la Calle and M. Berenguel

Assistance to technology transfer meetings

Sector TIC – TTAndalucía sector Smart Cities: 17/06/2016. Sala Gran Forum. Hotel AC Málaga.

Other scientific activities:

- Energy management in agricultural production environments supported by renewable energies: Agro-alimentary Technical Conferences "Application of renewable energies to intensive agriculture" Organized by the Cajamar Foundation, 29th November 2016.
- Organization of the Conference "Comfort and Sustainable Building, a response from the Automatic and Micro-Energy Networks", 20th October 2016.
- News in general press and scientific dissemination about results of the OPTICONES project. Title: Sustainable comfort. This news was published the number 125 of the journal Novaciencia corresponding to November 2016.
- "Control of air conditioning and lighting in sustainable building. Results of the OPTICONES project ". In: Conference "Comfort and Sustainable Building, a response from the Automatic and Micro-Energy Networks". Invited conference. 20th October 2016, Conferencia Invitada.
- Participation in the European Robotics Week, 25th November 2016.
- Creation and activities associated with the Robotics Club of the UAL: Participation in the Week of Science, talks in Institutes, ... 2016.
- Participation in the European project Researcher's Square (RESSQUA) for the organization of the European Night of Researchers, 26th September 2016.
- Participation in the XIV Symposium CEA of Control Engineering. University of La Rioja, 12-11 March 2016.
- Participation in 1st IEEE International Conference on Event-Based Control, Communication, and Signal Processing, 13-15 june 2016, Krakow, Poland.
- Participation in 2016 Automation Days (Madrid) and organization of the Control Engineering Thematic Group, 7-9 September 2016.
- Participation in Eurosun 2016, Mallorca España, 14 October 2016.
- Participation in Eurosim 2016, Oulu, Finland. 12-16 September 2016.
- Participation in Workshop on Past, Present and Perspectives of MPC, Gent, Belgium, 26th August 2016.
- Participation in 24th Mediterranean Conference on Control and Automation MED 2016, Athens, Greece, July 2016.
- Participation in Desalination for the Environment: Clean Water and Energy, Rome, Italy, May 2016.

2.5 ACTIVITIES OF "SOLAR RESOURCE ASSESSMENT AND SOLAR COOLING" FUNCTIONAL UNIT

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 researchers

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 Assesment 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 functional unit's activities carried out in CIESOL during 2016

During 2016 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 install to monitoring 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. The execution of the project ended successfully in December 2016.

During 2016 we have been working on characterization of PCMs. 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

- International stay. Mauricio Trigo González (13/09/2016 – 07/12/2016).
- International stay. Daniel Reyes Guerrero (11/01/2016 – 08/04/2016).

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

Articles

- The application of Bayesian network classifiers for cloud classification in satellite images. 2016, Renewable Energy, 97, pp 155-161.
- Identification of cloud contamination in sun photometric data using ground-based sky imagery. 2016, J Aeronaut Aerospace Eng, 5:2(Suppl).
- Direct normal irradiance forecasting on one hour-ahead under partially-cloudy sky conditions through Meteosat second generation satellite images. 2016, J Aeronaut Aerospace Eng 5:2(Suppl).

- Cloud detection in the sun area of total sky images using a conventional and a low-cost sky camera. 2016, J Aeronaut Aerospace Eng 5:2(Suppl).

Congress

- Water JPI Conference, Rome, 19th of May 2016.
- 11th ISES EuroSun Conference, 11 – 14 October 2016, Palma de Mallorca, España.
- 2nd International Conference and Exhibition on Satellite & Space Missions, 21 – 23 July 2016, Berlin Germany.
- 9ª Asamblea Hispano Portuguesa de Geodesia y Geofísica, 28 – 30 June 2016, Madrid, España.

2.5.7 Staff members

Francisco Javier Batlles Garrido

Professor
UAL
fbatlles@ual.es
(+34) 950 015 914
www.tep165.com

Francisco Javier Barbero Francisco

Associate Professor
UAL
jbarbero@ual.es
(+34) 950 015 307
www.tep165.com

Sabina Rosiek

Senior Researcher
UAL
srosiek@ual.es
(+34) 950 014082

Mercedes Martínez Durbán

Associate Professor
UAL
mdurban@ual.es
(+34) 950 015 676
www.tep165.com

Joaquín Alonso Montesinos

Senior Researcher
UAL
joaquin.alonso@ual.es
(+34) 950 014430
www.tep165.com

2.5.8 Ongoing projects in 2016

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).

Funds:

N.A.

Time Period:

September 2014 – December 2016

Current Situation:

Finished

Summary:

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).

Funds:

Savia Biotech

Time Period:

November 2014 – December 2016

Current Situation:

In progress

Summary:

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. Thermal energy recovery from a novel sequencing batch biofilter granular reactor (THERBIOR)

Participants:

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

Contacts:

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

Funds:

Comissión Europea (ERA-NET Cofund WaterWorks2014 Call, Water JPI), MINECO (Ref. PCIN-2015-258)

Time Period:

April 2016 – April 2018

Current Situation:

In progress

Summary:

THERBIOR focuses on the development, implementation and diffusion of technologies to improve energy efficiency in wastewater treatment plants (WWTPs) using a fully off-grid solar-assisted heat pump (HP) hybrid system, applicable Europe-wide but centred on the Mediterranean region. The THERBIOR project aims to provide solution for the tourism sector, which is characterised by intense seasonal water demand and wastewater discharge. The integration of physical infrastructure such as a highly efficient tubular heat exchanger coupled to a fully off-grid reversible water-source HP with a pioneering, novel Sequencing Batch Biofilter Granular Reactor (SBBGR) already installed in the Water Research Institute (CNR-IRSA, Italy), which creates new value through reuse and repurposing. This technology may help to produce benefits for local populations in the form of wastewater management, giving people access to clean water, and thus contributing to societal well-being through better human health as a result of better water quality. Projections for future climate change point to increasing resource depletion and water scarcity, which will have a serious socio-economic and environmental impact. Current global changes (such as climate change and urban sprawl) demand innovative practices to minimise the risks associated with water distribution and storage facilities in urban areas. Consequently, efforts are needed to strengthen public participation and imbue a sense of social responsibility concerning water and energy use, especially regarding freshwater resources, and adapting to the above-mentioned threats. Innovative technologies are required by the water industry to develop products and services fuelling the European economy. The main goal is to reuse the heat from the existing novel SBBGR reactor at CNR-IRSA into a low-temperature air conditioning system capable of covering the heating/cooling and domestic hot water (DHW) demand of an experimental test laboratory; this will be constructed during the project at the CNR-IRSA site. The system will be backed up by short-term storage based on Phase Change Materials (PCM) to ensure year-round coverage of the experimental lab's heating/cooling and DHW demand. After obtaining satisfactory results from the developed prototype, we will analyse this innovative application's viability for incorporation into Almeria's (Spain) and Bari's (Italy) tourist facility network. Our main goal will be to evaluate how much energy we can gain from a specific urban wastewater network to reduce energy consumption (coming from fossil fuels) for cooling/heating purposes in tourist buildings located in the cities. The project also intends to create new business opportunities, notably by supporting SME involvement in local water and solar-energy supply chains. THERBIOR comprises a consortium of 4 European organisations from Spain, Italy and Denmark, combining a wide range of technical, institutional and business expertise. THERBIOR aims to bring together all the specialists

required to support and promote a novel technological solution to improve urban wastewater treatment process efficiency with an emphasis on model application under the European Water and Energy Directives.

Objectives:

- To evaluate how much energy we can gain from a specific urban wastewater network to reduce energy consumption (coming from fossil fuels) for cooling/heating purposes in tourist buildings located in the cities.

2.5.8.4. 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).
Funds:
Ministerio de Economía y Competitividad.
Time Period:
January 2015 – December 2017
Current Situation:
In progress

Summary:

Direct normal irradiance (DNI) forecast is a research topic of increasing interest in fields such as agriculture or solar power production. Power generation from Solar Power Towers (SPT) -where DNI is a critical input- is experiencing a rapid growth worldwide. SPT technology will be the main contributor to the future mix of renewable energies. The greater challenge posed by these large solar installations is the grid integration. To this end, it is crucial to have an accurate forecast of the DNI levels reaching the receiver, which affects not only the plant operation but the energy price market.

Clouds are the main source of DNI variability in the heliostat field. When solar radiation is not intercepted by clouds, aerosols are the atmospheric component accounting for the largest DNI variability. SPTs are usually located in arid or semi-arid areas, with high percentage of clear skies and a larger frequency of high turbidity episodes. The forecast need is then vital. However, none of the short or mid-term forecast techniques explicitly provide ground DNI. On the other hand, aerosols in the lowest layers of the atmosphere can reduce the solar power reflected by the heliostats up to 40% before reaching the receiver of a SPT. Although the actual attenuation is currently unknown, is it urgently demanded. SPT design software (e.g. HLFCAL or SolTRACE) is unable to reproduce said effects.

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 Ingenieria y Biotecnologia 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).
- Solar Energy: An assured future, Joaquín Alonso-Montesinos. Proyecto Researchers' Square (RESSQUA) – Marie Sklodowska-Curie Actions, European Researcher's Night, 30th September 2016.
- Course in the International School: Fundamentos Teóricos de la Energía Termosolar – FUPSE 2016, 7 al 18th November 2016, University of Antofagasta (Chile).
- Course: Solar radiation forecasting and neural networks, November 2016, University of Antofagasta (Chile).

2.5.10 Project's applications in 2016

- Within ERANET-LAC Joint Call 2015-2016, the project titled "PCMSOL: Thermal Energy Storage with Phase Change Materials for Solar Cooling and Heating Applications: A technology viability analysis" was presented. The PCMSOL consortium consists of 3 European organisations

from Spain and Poland, and 2 Latin America organisations from Chile and Bolivia. The industrial sector is represented through the participation of one SME, namely Phase Change Technologies (Spain). The academic sector was represented by four ALMERIA UNIVERSITY departments (APPLIED PHYSICS AND CHEMISTRY) and Wroclaw University of Science and Technology (Polonia), Catholic University of Bolivia (Bolivia) and the University of Antofagasta (Chile). Total project's cost was 364.668 euros.

- Within **ERC-2017-STG (TOPIC ERC-2017-STG)**, the project titled **"CoolGreenCommunity"** was presented**.** Total project's cost was 1.500.000 euros.

2.6 ACTIVITIES OF "DESALINATION AND PHOTOSYNTHESIS" FUNCTIONAL 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 water desalination with solar energy by using hydrophobic membranes as well as the application of solar energy in biological microalgae-based depuration processes. Both lines present ample opportunities for synergy and for collaboration with other units within CIESOL which raise frequent colaborations.

2.6.2 Main research lines

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

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

2.6.3 Main researchers

Jose M. Fernández Sevilla (Scopus Author 6602856181)

Professor of Chemical Engineering at Universidad de Almeria, currently affiliated with the Engineering Department at Universidad de Almería. He obtaines a Degree in Industrias Chemistry (Químico Industrial) at Universidad de Granada in 1991 and a PhD. In Cheminstry 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 60 papers in peer-reviewed international journals, presented more than 100 papers on international conferences, authored 8 book chapters and co-authored 3 books. 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 WssTP.

2.6.4 Summary of the functional unit's activities carried out in CIESOL during 2016

Regarding the production of microalgae on 2016 two European projects have been finalized: (i) the MANAGER project focused on the treatment of mine waters for the removal of them from heavy metals; and (ii) the CO2ALGAEFIX Focused on the start-up of a microalgae production plant coupled with a natural gas plant in Arcos de la Frontera. Also during this year 2016, other projects related to microalgae previously In progress during 2015 have been continued, such as (i) the national PURALGA project in collaboration with the University of Valladolid and the Instituto Tecnológico Agrario de Castilla y León (ITACyL), (ii) the national EDARSOL project in collaboration with the UPC, (iii) the ERANET-LAC GREENBIOREFINERY project in collaboration with universities and research centers from Portugal, Argentina and Colombia, and (iv) the project BACAGRO in collaboration with the company Biorizon Biotech and the Cajamar Foundation. The first three projects are related to the production of microalgae coupled to the treatment of wastewater, whether animal, as urban or brewing industry. The latter is related to the production of agricultural bacteria for commercial uses. Lastly, during 2016, two new projects related to the upgrading of biogas to biomethane by biological methods have been launched such as the (i) GREENUPGAS project coordinated by Estrella Levante and (ii) the METINGREEN project led by Sacyr and Biorizon Biotech . In addition, (iii) the SETEC contract has been initiated in collaboration with the company SETEC of France focused on the development of a biological process for the production of biopolymers from flue gases using microalgae. At the end of 2016, two new projects have been implemented: (iv) the BIOREFINA project coordinated by AZUD and focused on the recovery of agricultural waste through anaerobic digestion systems and microalgae, and (v) the European project SABANA Led by the University of Almeria and focused on the implementation of a demonstration facility for microalgae production for agricultural and aquaculture applications in Almeria. In all of these projects the implementation of new processes based on microalgae is targeted, especially for large market applications such as biopolymers, biofertilizers and aquaculture feeds, especially integrating with urban and / or livestock wastewater treatment. It is also worth mentioning the opening of a new line of work at the request of some companies interested in it, such as the cleaning of biogas to biomethane, especially by biological methods using microalgae.

Regarding desalination, the RED Heat-to-Power project continued. The objective of the project is to generate electricity from a salinity gradient using a closed-loop reverse electrodialysis process in which thermal energy is used to regenerate the salinity gradient. Our task in the project is to evaluate thermal regeneration systems with different salts. Simulations have been done for multi-effect distillation (MED) and membrane distillation (MD) using different solutions of NaCl, LiCl and KCH_3COO, showing that the specific thermal energy consumption increases with salinity more in MD than in MED, being the effect

of changing the salts not that important, since they have similar water activities. Activities in Zero Carbon Resorts project (ZCR2) continued with the evaluation of audit reports and the participation on a Water conference in Thailand. Also, activities within the national R&D Project EFFERDESAL, subproject of the coordinated project ENERPRO, have continued. This project has, as its main objective, 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 CO_2 management in production environments with support of renewable energy and storage systems.

In 2016, three new EU H2020 projects were started. Project WASCOP is coordinated by the research institute CEA (France) and the main goal is to develop a revolutionary innovation in water management (both for the cooling of the power block and the cleaning of the solar field optical surfaces) of Concentrating Solar Power (CSP) plants. During 2016, partners have been working on the overall model of the CSP plant and on the design of different cooling technologies for the power block that allow the water saving. These devices will be manufactured by the french company Hamon d`Hondt and installed in different research centers (for instance the Plataforma Solar de Almería) for their testing under real conditions. Another new EU H2020 project is REWACEM, coordinated by Fraunhofer Institute and with the objective of reducing water and energy, decreasing wastewater production and recovering valuable metal resources in the metal plating, galvanizing and printed circuit board industry. Our particular task is to implement an integration of diffusion dialysis and membrane distillation in a copper plating process in close collaboration with the Spanish SME Electroniquel, and the German SME SolarSpring. The NESTER Project is coordinated by the Cyprus Institute (Cyl) and the main goal is to firmly embed the solar energy division of the Cyprus Institute as a member of the community of the leading research groups in the field of Solar Thermal Energy, and to establish it as a regional leader in The Eastern Mediterranean and Middle East (EMME region). During 2016 the most remarkable activities have been the establishment of the agenda of winter schools, specific workshops, secondments and mentoring visits during the next three years of the project. From November 7th-17th CIEMAT-PSA participated in the first STE Winter School at Nicosia (Cyprus) where solar desalination was one of the two special topics covered by this course.

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

In the area of microalgae no new personal has been incorporated to the research team, all previously contracted people have been maintained in addition to incorporating frequent stays of researchers from other research centers and universities both national and international..

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

Articles

- Distributed Sliding Mode Control of pH in Tubular Photobioreactors. 2016, IEEE Transactions on Control Systems Technology, vol. 24, issue 4.
- Optimization of biomass production in outdoor tubular photobioreactors. 2015, Journal of Process Control, 37 pp 58–69.

- Integration of microalgae production with anaerobic digestion of dairy cattle manure: an overall mass and energy balance of the process. 2016, Journal of Cleaner Production 112 pp 103–112.
- Modeling of photosynthesis and respiration rate for Isochrysis galbana (T-Iso) and its influence on the production of this strain. 2016, Bioresource Technology 203 pp 71–79.
- Light regime optimization in photobioreactors using a dynamic photosynthesis model. 2016, Algal Research 16 pp 399–408.
- Outdoor production of Tisochrysis lutea Isochrysis galbana (T-iso) in industrialpilot-scale tubular photobioreactors. 2016, Appl Phycol 28: pp 3159.
- Heaven. Optimization of carbon dioxide supply in raceway reactors: influence of carbon dioxide molar fraction and gas flow rate. 2016, Bioresource Technology, vol. 212.
- Hierarchical control for microalgae biomass production in photobioreactors. CONTROL ENGINEERING PRACTICE, 54: 246-255 (2016).
- Outdoor pilot production of nannochloropsis gaditana: influence of culture parameters and lipid production rates in flat-panel photobioreactors. Algal Research, vol. 18 (2016).
- Wastewater treatment using microalgae: how realistic a contribution might it be to significant urban wastewater treatment? 2016, Appl Microbiol Biotechnol. 100(21), pp 9013-9022.
- Dynamic model of an industrial raceway reactor for microalgae production. 2016, Algal Research Vol 17 pp 67–78.
- Mechanistic model for design, analysis, operation and control of microalgae cultures: Calibration and application to tubular photobioreactors. 2017, Algal Research 21, pp 236–246.
- Dynamic modeling and simulation of a double-effect absorption heat pump. 2016, International Journal of Refrigeration 72 pp 171-191
- Experimental parametric analysis of a solar pilot-scale multi-effect distillation plant. 2016, Desalination & Water Treatment 57 pp 23097-23109.
- Quasi-steady state simulations of multi-effect distillation plants coupled to parabolic trough solar thermal power plants. 2016, Desalination and Water Treatment 57 pp 23085-23096.
- Thermoeconomic comparison of integrating seawater desalination processes in concentrating solar power plant of 5 MWe. 2016, Desalination 392, pp. 102-117.
- Two-stage FO-BWRO/NF treatment of saline waters. 2016, Desalination and Water Treatment, 57 (11), pp 4842-4852.
- Dual Stage PRO Process: Impact of the Membrane Materials on the Process Performance. 2016, Desalination and Water Treatment, 57 (14), pp 6172-6183.
- Integration and Optimization of Pressure Retarded Osmosis with Reverse Osmosis for Power Generation and High Efficiency Desalination. 2016, Energy, 103, pp 110-118.
- Solar desalination by air gap membrane distillation: a case study from Algeria. 2016, Desalination and Water Treatment, 57 (48-49), pp 22718-22725.
- Forward Osmosis Process for Supply of Fertilizer Solutions from Seawater Using a Mixture of Draw Solutions. 2016, Desalination and Water Treatment, 57 (58), pp 28025-28041.
- Energy Efficiency of RO and FO-RO system for High Salinity Seawater Treatment. 2016, In Press, Clean Technologies and Environmental Policy.
- Comparative characterization of three commercial spiral-wound membrane distillation modules. 2016, In Press. Desalination and Water Treatment.
- Optimal operating conditions analysis of a multi-effect distillation plant. 2017, In Press, Desalination and Water Treatment.
- Preliminary evaluation of the use of vacuum membrane distillation for the production of drinking water in Arica (Chile). 2017, In Press, Desalination and Water Treatment.

Book Chapters

- Book: Prospects and Challenges in Algal Biotechnology Capítulo Event-based control systems for microalgae culture in industrial reactors. A. Pawlowski, J. L. Guzman, M. Berenguel, F. G. Acien and S. Dormido.
- Book: Water Filtration Systems: Processes, Uses and Importance Desalination Capítulo Forward Osmosis Pretreatment of Seawater for Thermal Desalination. Altaee, A., A. Sharif and G. Zaragoza. Water Resource Planning, Development and Management, NovaScience Publishing, 2016. ISBN: 978-1-63484-039-2.

Congress

- 11th IFAC Symposium on Dynamics and Control of Process Systems. Norway, 2016.
- Clean Water and Energy. Rome, Italy, 2016.
- Congreso Nacional del Color. Orense, España, 2016.
- Congress on the Management of Mining Wastes and Post-mining, GESRIM Marrakech, Marrocco 2016.
- 10th ISEB Conference Barcelona, España 2016.
- 1st EUALGAE workshop of algae bioproducts for early career Valladolid, España 2016.
- 3rd EABA, EC Algae Contractors´Conference & the 10th International Algae Congress. Madrid, España 2016.
- XI International Conference Aedyr, Valencia, Spain, 2016
- 2nd International Conference on Desalination and the Environment, Doha (Qatar), 23-26 January 2016.
- Desalination for the Environment Clean Water and Energy. Rome (Italy), 22-26 May 2016.
- 9th International Desalination Workshop. Abu Dhabi (UAE), 13-15 November 2016.

Patents

Title: Sistema de carbonatacion para cultivo de microalgas en reactores abiertos
PATENT No: P201231485
Date: 26.09.2012.
HIDROTEC TECNOLOGIA DEL AGUA, S.L.
EUROPEAN PATENT: 2712917
Date: 18.11.2015

Title: Method for the valorisation of photosynthetic microorganisms for integral use of biomass
PATENT No: WO2014/122331
Date: 23.07.2014.
ALGAENERGY S.A., Universidad de Almeria

Title: Sistema de eliminación de metales pesados en aguas mediante microalgas.
PATENT No: P201500861
Date: 20.11.2015.
Universidad de Almeria

2.6.7 Staff members

José María Fernández Sevilla

Professor of Chemical Engineering
UAL
jfernand@ual.es
(+34) 950 015 899
www.jfernand.es

Guillermo Zaragoza del Águila

Senior Researcher
CIEMAT – PSA
guillermo.zaragoza@psa.es
(+34) 950 387941

Francisco Gabriel Acién Fernández

Professor of Chemical Engineering
UAL
facien@ual.es
(+34) 950 015 443

Diego César Alarcón Padilla

Senior Researcher
CIEMAT – PSA
diego.alarcon@psa.es
(+34) 950 387800 Ext. (960)

Cintia Gómez Serrano

Associate Researcher
Chemical Engineering – UAL/Las Palmerillas
cinti4201@hotmail.com
(+34) 950 580 488

Alba Ruiz Aguirre

Junior Researcher
CIEMAT – PSA
alba.ruiz@psa.es
(+34) 950 387800 (Ext. 998)

Azahara Martínez García

Junior Researcher
Chemical Engineering - UAL
azahara.mart@gmail.com
(+34) 950 015 899

Juan Antonio Andrés Mañas

Junior Researcher
CIEMAT – PSA
juanantonio.andres@psa.es
(+34) 950 387800 Ext. (812)

Pablo Fernández del Olmo

Associate Researcher
Chemical Engineering - UAL
pfd793@ual.es
(+34) 950 015 914

Patricia Palenzuela

Senior Researcher
CIEMAT – PSA
patricia.palenzuela@psa.es
(+34) 950 387800 Ext. (909)

Jose Peña Martín

Associate Researcher
Chemical Engineering - UAL
josepema.ual@gmail.com
(+34) 950 015 914

Ismael Martín Cara

Associate Researcher
Chemical Engineering - UAL
ismael.martin.cara@gmail.com
(+34) 950 015 914

2.6.8 Ongoing projects in 2016

2.6.8.1 Development of a biological upgrading technology for the production of biometan in agroindustrial environments (GREENUPGAS)

Participants:

ESTRELLA DE LEVANTE, AQUALGAE, ENEVIA, BIONET, AINIA, AIJU, Universidad de Almería, AROSA I+D

Contacts:

Dr. F. Gabriel Acien Fernandez (facien@ual.es)

Funds:

INTERCONNECTA, CDTI EXP - 00083180 / ITC-20151346

Time Period:

January 2016 – December 2017.

Current Situation:

In progress

Summary:

The main objective of the project is to develop the GreenUpGas technology or biological process for the purification of agro-industrial biogas to obtain biomethane suitable for injection in gas networks or use as biofuel in vehicles. GreenUpGas technology consists of three modules: biogas conditioning with microalgae culture, H2 production by electrolysis of water from photovoltaic solar energy, and biocatalytic methanization with hydrogenotrophic methanogenic microorganisms.

Objectives:

The overall objective of GreenUpGas is the development of a new biological upgrading technology for the production of biomethane in agro-industrial environments.

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)

Funds:

Comisión Europea, programa SWITCH-ASIA

Time Period:

May 2014 – April 2018.

Current Situation:

In progress

Summary:

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 (España)
Laboratorio Nacional de Energía y Geologia (LNEG) Portugla
Universidad de Antioquia (Colombia)
Universidad Nacional Tecnológica (Argentina)
Cervecería la Unión (Colombia)
Mahou-San Miguel (España)

Contacts:
F. Gabriel Acién (facien@ual.es)
Funds:
ERANET LAC 2014
Time Period:
October 2015 – September 2018.
Current Situation:
In progress

Summary:

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. Therefore, 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 (liquids and gases) produced will be characterised to be used as feedstock into the microalgae's production by previously selected companies. Several procedures for salvage these wastes will be compared to identify the most suitable to be coupled with microalgae production. After this, several microalgae strains will be evaluated to establish which is the best in accord with both its capacity of growth and its biochemical composition. The characterisation previously cited, will be carried out under laboratory conditions yet simulating real ones, while the selected strain will be tested outdoors too, employing different growth systems and operational modes. Both the production and quality of the biomass produced, as well as the depuration of the brewery wastes used (liquids and gases) will be analysed. From the biomass characterisation proper processes for the complete valorisation of the biomass will be developed. The production of high-value compound as could be pigments and fatty acids, as well as the utilization of the biomass as animal feeding and biofertiliser production will be consider. Finally, the developed technology will be escalated to pilot-scale with 1m^3 photobiorreactors to validate and assess the process as a whole. In this project four organisation with great experience in bioprocess engineering, miocroalgae biotechnology and in vitro cell culture are taking part, with the aim of developing innovative bioprocesses for high-value biomass production from nutrient-rich wastes (C, N, and P) unused currently in brewery industry. 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 Efficient technology for biomethanization of biogas (METINGREEN)

Participants:
Biorizon Biotech, Universidad de Almería
Contacts:
F.G. Acién (facien@ual.es)
Funds:
CDTI
Time Period:
June 2016 – December 2017.
Current Situation:
In progress

Summary:

This project is focused to develop a new product, a series of prototypes (in the METinGREEN will reach the scale of demonstration) that will allow to treat the biogas product of the anaerobic digestion. For this, technology and prototypes will be developed for (1) upgrading and (2) refining. Parallel to the project presented by VALORIZA Agua, called SMART · Met · Value, will seek to optimize the process of valorization of biomethane, adding a new prototype based on blending. The final product obtained will be a biomethane, with similar properties to the Natural Gas at a competitive cost for its commercialization.

Objective:

The objective of the project is to develop a set of prototypes capable of refining and fine-tuning the biogas from Wastewater Treatment Plants (EDARs) and / or Wastewater Treatment Plants (RSU). The overall objective of the project in this case is to test on a sufficient scale (near the demonstration scale) the principle of biogas cleaning under real conditions, and to produce biomethane under conditions of sufficient quality for commercialization (injection into the distribution network or biofuel).

2.6.8.5 Conversion of low grade heat to power through closed loop reverse electro-dialysis (RED-Heat-to-Power)

Participants:
WIP (D)
University of Palermo (IT)
FUJIFILM (NL)
REDSTACK (NL)
UNIVERSITY OF EDINBURGH (UK)
UNIVERSITAT POLITECNICA DE CATALUNYA (ES)
PSA-CIEMAT (ES)
Universidad de Almería (ES)
Contacts:
Dr. Guillermo Zaragoza (guillermo.zaragoza@psa.es
Funds:
European Commission, Horizon 2020 programme
Time Period:
May 2015 – April 2019.
Current Situation:
In progress

Summary:

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 ºC.

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.

2.6.8.6 Sustainable algae biorefinery for agriculture and aquaculture (SABANA)

Participants:

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

Contacts:

F. Gabriel Acién (facien@ual.es)

Funds:

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

Time Period:

December 2016 – November 2020

Current Situation:

In progress

Summary:

SABANA aims at developing a large-scale integrated microalgae-based biorefinery for the production of biostimulants, biopesticides and feed additives, in addition to biofertilizers and aquafeed, using only

marine water and nutrients from wastewaters (sewage, centrate and pig manure). The objective is to achieve a zero-waste process at a demonstration scales up to 5 ha sustainable both environmentally and economically. A Demonstration Centre of this biorefinery will be operated to demonstrate the technology, assess the operating characteristics of the system, evaluate environment impacts and collaborate with potential customers for use.

Objectives:

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

2.6.8.7 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

Funds:

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

Time Period:

January 2015 – December 2017.

Current Situation:

In progress

Coordinated with Modeling and Automatic Control Unit.

Summary:

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:

The main objectives of the EFFERDESAL subproject are:

- Dynamic modeling of solar-gas hybrid desalination plants supplied with novel industrial solar collectors.
- Development of prediction models for environmental variables, disturbances, sources and loads.
- Analysis and modeling of energy storage systems and other auxiliary systems for energy cost reduction
- Development of simplified models for control purposes
- Development of MPC strategies (hierarchical, hybrid and economic) for desalination plants
- Coupling of solar desalination plants as a water and energy supply to greenhouses and buildings.
- Testing of control algorithms both in simulation and in the real installations.

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

Participants:

Coordinated research Project funded by INIA (Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria) with FEDER participation. The Project is being carried out by the Instituto Tecnológico Agrario de Castilla y León (ITACyL) (coordinator) the Universidad de Valladolid and UAL (subproject RTA 2013-00056-C03).

Contacts:

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

Funds:

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

Time Period:

September 2014 – September 2017.

Current Situation:

In progress

Summary:

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. Because microalgae biomass is mainly composed of proteins, carbohydrates and lipids, the bio-products to be obtained are: 1) proteins to be used in animal nutrition through incorporation into feed, 2) alcohols that will be obtained from pre- treatment and fermentation of microalgae biomass, 3) oils from the lipid fraction that can be used to formulate feeds for animal uses, and 4) biogas that will be obtained from the anaerobic digestion of residual algal biomass. 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.

This study will be carried out in coordination with the research groups involved in the project: the Agricultural Technological Institute of Castilla y León (ITACyL) with the University of León, the University of Valladolid and the University of Almería with the Fundación Cajamar.

Objectives:

The objective of this project is the valorization of wastewaters by the complete use of microalgal biomass to obtain bioproducts from 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

The main products the Project aims to obtain are:

- Protein for animal feed to be incorporated in feedstocks;
- Production ob bio-alcohols from the glucidic fraction of the microalgal biomass to be used as fuels by means of hydrolisis/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 biocas though anaerobic digestion.

To enhance the recovery of by products, the Project plans to use the CO_2 generated in the digestion process as te source of inorganic carbon for the microalgae, wich will make these depuration systems act as a sink of atmosferic CO_2 effectively decreasing the emission of greenhouse gases while generating products from the nutrients in wastewater.

2.6.8.9 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

Funds:

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

Time Period:

January 2015– December 2017.

Current Situation:

In progress

Summary:

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 quelity for its reuse. The goal is to develop a portfolio of tools to ease the implementation of these processes in a more efective and safer way.

Objectives:

- To characterize and modelize migroalgae-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, incluiding methods such as electrofloculation/coagulation capable of rising the concentration of the harvested biomas up to 100 g/L, and with an improvement on the reclaimed water quality sufficient to mest the specifications od the Directive 91/271/CE.
- Developing valorization processes for the obtained biomass. Among the products proposed are biofertilizers to recover the nitrogen fraction in the effluents and biogas to partially recover thecarbon content of the wastewaters.
- The techno-economic viability of the developed processes will be analized. 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 sostenibility of the whole optimized process will be assessed by a life cycle analysis).

2.6.8.10 Production of bacteria for use in agriculture soil fertility ehnancers 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

Funds:

Proyect RETOS COLABORACIÓN, Ministerio de Economía y Competitividad

Time Period:

October 2015– September 2017.

Current Situation:

In progress

Summary:

The goal of the Project BACAGRO is to develop bioproducts containing bacteria to be applied in agricuture as soil stabilizers and fertility enhancers with a protective function against plant pathogenes. It is an applied research project leaded by the Biorizon Biotech, a company deeply involved in applied biotechnology, with the additional participation of Universidad de Almeria and Fundacion Cajamar as technological partners. Biorizon Biotech is involved in the development and marketing of new and innovative products for agricultural use in order to favour sostenibility and increase rentability mainly in enviroments of intensive agriculture in greenhouse as well as in other types of extensive cultures. For this, the company has been developing, manufacturing and is currently selling different biofertilizers, bio-stimulants and protective agents. Among these, the company is now developing bacteria-based growth promoters containing simbiotic bacteria that improve the radicular function. This kind of bacteria have received intense attention and its beneficial effects have been frequently reported in the literature but, in spite of this, the production of these type of agents is currently very limited. The reason for this is that this bacteria are currently expensive to produce and difficult to stabilize, store and thus distribute. Project BACAGRO aims at solving all these issues by tackling succesively the tasks of characterization and selection of strains, designing mass culture systems and methods of application,

ending with a demonstration in field experiments of the efficacy and enhanceme potential of these bacteria used as additives.

Objectives:

- Selection and identification of beneficial bacteria for soils and plants:
- Development of scalable production processes of the selected bacteria with a price low enough for agricultural aplications.
- Development of technologies for the stabilization, storage, preservation and aplication of the bacteria-based bioproducts.
- Evaluation of the effect in soil and plants of the stabilized bioproducts containing bacteria.

2.6.8.11 Bioplastics production from carbon captured in household waste incineration fumes (SETEC)

Participants:
Universidad de Almería.
SETEC Environnement (France)
Contacts:
F. Gabriel Acién Fernández (UAL), facien@ual.es
Funds:
Contrato privado
Time Period:
May 2016– May 2017.
Current Situation:
In progress

Summary:

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

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

2.6.8.12 Biorefineria a pequeña escala de aplicación in-situ en entornos rurales con actividad mixta agrícola y ganadera (BIOREFINA)

Participants:
Universidad de Almería.
SISTEMA AZUD S.A.
MIGUEL GARCÍA SÁNCHEZ E HIJOS, S.A.
BIORIZON BIOTECH S.L.
J. BOUZADA INGENIEROS S.L.U.
Fundación Cajamar
Contacts:
F. Gabriel Acién Fernández (UAL), facien@ual.es
Funds:
INTERCONNECTA 2016, Ministerio de Economía y Competitividad
Time Period:
November 2016– November 2018.
Current Situation:
In progress

Summary:

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

Objective:

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

2.6.8.13 Water saving for solar concentrated power (WASCOP)

Participants:

CEA
DLR
CIEMAT
Cranfield University
Fundación Tekniker
Moroccan Agency for Solar Energy SA
Rioglass Solar S.A
Archimede Solar Energy S.r.l.
OMT Solutions B.V
Hamon d'Hondt
AMIRES s.r.o.

Contacts:

Dra. Patricia Palenzuela (CIEMAT), patricia.palenzuela@psa.es

Funds:

European Commission, Horizon 2020 programme

Time Period:

January 2016-February 2020

Current Situation:

In progress

Summary:

The main goal of this Project is to develop a revolutionary innovation in water management of CSP plants-flexible integrated solution comprising different innovative technologies and optimized strategies for the cooling of the power block and the cleaning of the solar field optical surfaces. WASCOP main advantage consists in the ability to reflect and adapt to the specific conditions prevailing at individual CSP plants, unlike other competitive approaches proposing a single generic solution applicable only

on some referenced cases. The WASCOP holistic solution provides an effective combination of technologies allowing a significant reduction in water consumption (up to 70%-90%) and a significant improvement in the water management of CSP plants. To demonstrate the benefits (whether economic or environmental), the developed system will be tested and validated in real conditions of four testing sites in France, Spain and Morocco after preliminary demonstration in laboratory environment.

Objectives:

The main objectives of this project are:

- Development and optimization of a heat storage reservoir added to the turbine heat exhaust, and prior to the power block cooling loop, which will lower the dry cooling loss of efficiency down to 5% but give the potential for cooling water saving of 100%.
- Development of a cost effective hybridized dry/wet cooling system and its advanced operating strategy for use at peak ambient temperatures, which will bring an increase in the overall plant efficiency of 5%.
- Development of an unique concept of adiabatic versatile cooler, based on a dry cooling approach with an adjustable amount of water addition, heat exchanger redesign and air handling redesign. This approach will lead to total water saving of 90%.
- Optimization of the traditional cleaning methods to reduce the water consumption.
- Development of a cleaning device based on ultrasound cavitation effect and consuming nearly zero water (98% reduction in comparison with common cleaning methods) to remove adhered particles from reflectors surfaces.
- Development of a cleaning device consuming no additional water but utilizing the condensate dew reflectors.
- Validation of the whole system under real conditions, with each sub-system tested in at least one of the four CSP testing facilities.

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

Participants:

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

Contacts:

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

Funds:

European Commission, Horizon 2020 programme

Time Period:

October 2016-October 2019

Current Situation:

In progress

Summary:

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

Objectives:

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

Further specific objectives of the project are:

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

2.6.8.15 Networking for excellence in solar thermal energy research (NESTER)

Participants:

The Cyprus Institute (CyI)
CIEMAT-PSA
ENEA-UTRINN
CNRS-PROMES
RWTH Aachen

Contacts:

Dr. Diego Alarcón (CIEMAT), diego.alarcon@psa.es

Funds:

European Commission, Horizon 2020 programme

Time Period:

January 2016-December 2018

Current Situation:

In progress

Summary:

The NESTER TWINNING Project aims in upgrading the scientific performance and innovation capacity of the Cyprus Institute (CyI) in the field of Solar-Thermal Energy (STE) and related technologies. The upgrade will be achieved by embedding the Institute's activities in a network of excellence, which will provide access to the latest know-how and facilities, train CyI's scientific and technical personnel, and link it with the European Industry. Within this network the substantial investments already made by CyI in this field, but also the ones planned, will result in a harmonization and optimization of activities in STE with other leading institutions of the field, thus international excellence can be achieved. The proposed network of excellence is defined by four institutions in the field with proven track record in solar thermal research (ENEA-UTRINN, CNRS-PROMES, CIEMAT-PSA and RWTH – Aachen), partners in this project. The NESTER consortium collectively possesses a formidable know-how in the STE area and operates some of the most important experimental facilities, worldwide. The consortium institutions together with their partners and links in research, education and innovation define a network of unparalleled opportunities for CyI to grow in, and allow it to emerge as centre of excellence in its own right.

Objectives:

The overarching objective of the NESTER Project is to firmly embed the solar energy division of the Cyprus Institute (CyI) as a member of the community of the leading research groups in the field of Solar Thermal Energy, and to establish it as a regional leader in The Eastern Mediterranean and Middle East (EMME region).

The specific objectives of this project are:

- Elevate the research output of the Cyprus Institute, in terms of quality and quantity.
- Reinforce and create durable linkages between CyI and the relevant academic partners and networks.
- Increase the prestige and visibility of the Cyprus Institute, in particular in the field of STE.
- Establish CyI as a regional hub for knowledge transfer in the field of STE in the Eastern Mediterranean.
- Improve the success of CyI in competitive grant applications in the field of STE.
- Attract better Doctoral Candidates, Researchers and Faculty.
- Engage with the local, regional and European industry.
- Interact with local and regional policy makers, associations and press.

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

Participants:

Główny 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 Almeria, 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)

Funds:

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

Time Period:

July 2013 – June 2016

Current Situation:

Finished.

Summary:

The objective of the Project MANAGER is to develop and assess different technologies for the trearment of wastewater from the mining industry which are often contaminated with heavy metals. These effluents need to be managed even after decomissioning of mining installations and facilities and in this scenario Is where Project MANAGER is focused. This poject 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 minung industry after cessation of activities.
- Development of technologies for the treatment of wáter effluents from the mining industry..
- Application and evaluation of the techniques developed.
- Demostration at pilot-scale of the best depuration techniques found.
- Coordination and diffussion of the results.

2.6.9 Activities and Courses, technical capacity

- Conferences as invited speaker: F.G. Acien-Fernandez TITLE: Products and processes with microalgae. International Workshop Biotechnology in Energy Production, Madrid, España 2016.
- Conferences as invited speaker: F.G. Acien-Fernandez TITLE: Contribution of microalgae to wastewater treatment processes. IWA Leading edge conference on water and wastewater technologies. Jerez, España 2016.
- Conferences as invited speaker: F.G. Acien-Fernandez. TITLE: Producción de microalgas sobre digerido de plantas de biogás. Jornada Biorefinerias Agroalimentarias (AINIA). Madrid, España 2016.

- Conferences as invited speaker: F.G. Acien-Fernandez. TITLE: Desarrollo de una tecnología de upgrading biológico para la producción de biometano en entornos agroindustriales. Jornada Biorefinerias Agroalimentarias (AINIA). Madrid, España 2016.
- Conferences as invited speaker: F.G. Acien-Fernandez TITLE: Sucess stories: SABANA Project. Infoday and proposal workshop on WP2016-2017 calls 2017 (CDTI). Madrid, España 2016.
- Conferences as invited speaker: G. Zaragoza TITLE: Desalación de agua de mar mediante destilación por membrana. Jornadas "Obtención de agua potable mediante tecnologías de desalación acopladas a energía solar" (Solar Energy Research Center, Chile). Arica, Chile, July 2016.
- Conferences as invited speaker: G. Zaragoza. TITLE: Applications of membrane distillation to water treatment. Desalination for the Environment Clean Water and Energy. Sitges, Barcelona (Spain), September 2016.
- Conferences as invited speaker: G. Zaragoza. TITLE: State of the art of solar desalination. MIT "Low Carbon Desalination" Workshop. Cambridge, Boston (USA), October 2016.
- Conferences as invited speaker: G. Zaragoza. TITLE: Uso de energía solar térmica para refrigeración y riego de invernaderos. Jornadas "Aplicación de energías renovables a la agricultura intensiva". El Ejido, Spain, November 2016.
- Conferences as invited speaker: G. Zaragoza. TITLE: Membrane distillation: a review of commercial modules and their performance. International Membrane Science and Technology Conference. Adelaide (Australia), December 2016.

2.6.10 Project's applications in 2016

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3. CIESOL 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.

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

A study of the electrical installation of the center has been carried out to detect the critical points of the center and to implement the necessary actions. After evaluating this study, a new electric panel has been approved by the Dirección General de Infraestructuras, which will correct the detected deficiencies and will also have sufficient requirements to support future requirements by the units or infrastructures of the center .

- Emergency exits have been installed and the center has been signaled to provide a safe working environment.
- A specific occupational risk prevention course for CIESOL has been carried out.
- Taking advantage of the necessary structure for the installation of the photovoltaic panels of the pilot cold storage houses, a small workshop/warehouse has been installed in the CIESOL yard.
- Pressure boosters have been acquired for the air compressors to increase the pressure of the compressed air lines.
- The RO machine has been replaced.
- A new computer has been acquired to control the air conditioning system of the center.

3.1 SOLAR ENERGY CHEMICAL FACILITIES

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

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

extracts for chromatography analysis (GC/MS, LC/MS, GC, LC), improving laboratory productivity.

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

Spectrophotometers

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

Monochromator-coupled deuterium lamp. It is mainly used to study photochemical reaction mechanisms, identification of reaction intermediates and kinetics.

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

Espectrómetro de masas AB SCIEX QTRAP 5500 LC/MS/MS. The QTRAP is designed to excel at metabolite identification, detection and confirmation of low-level pesticides, It also houses a high sensitive ion trap along with offering ultra-fast scan speeds and full MS3capabilities. Perform multiple reaction monitoring (MRM) scans for quantitation using this high-sensitivity triple quadrupole system. Identify, characterize, and quantitate metabolites more quickly and easily. Enable high-sensitivity, full-scan MS, MS/MS, and MS3with high-selectivity from true triple quadrupole precursor ion (PI) and neutral loss (NL) scans.

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

BRUKER 320MS Mass spectrometer triple quadrupole coupled to BRUKER 450GC gas chromatograph. This chromatographic system complements the previously mentioned ones because it allows analysis of organic compounds of low/medium polarity. It is used especially for the determination of trace levels of contaminants such as synthetic fragrances, and pesticides, among others.

Ion chromatograph (Metrohm 881 Compact IC Pro). This equipment allows the accurate analysis of anions or cations in concentrations from µg/L to g/L, with detection limits of <1 µg/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 (BOD mg O_2/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

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

3.2 SOLAR ENERGY EXPLOITATION FACILITIES.

Durante el año 2016 se ha ido implementado el módulo piloto del en el patio de CIESOL coorespondiente al proyecto de infraestructura científica titulado "Módulo piloto polivalente para evaluación optimización y mejora de los sistemas de frigoconservación agroalimentaria con energías renovables" (UNAM13-1E-2532) en el patio del CIESOL se instaló. Dicha instalación está compuesta por tres módulos principales complementarios entre sí, y de una sala de supervisión y control común en donde se instaló un sistema experto de adquisición de datos, monitorización y control remoto flexible como herramienta de gestión, supervisión y evaluación de los ensayos a realizar dirigidos a caracterizar el modelo sostenible a implantar. La instalación está alimentada por un areogenerador y un sistema fotovoltaico.

During 2016 project entitled "multipurpose pilot assessment optimization and improvement of agrifood systems with renewable energy refrigerated Module" (UNAM13-1E-2532) has been gradually implemented, 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.

The modeling and automatic control unit has the following equipment:

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

4. COMITTEES AND ACTIVITY RESPONSIBLES.

4.1 CIESOL MANAGEMENT

Director — **José Antonio Sánchez Pérez**
Full Professor University of Almería
jsanchez@ual.es

Subdirector — **Sixto Malato Rodríguez**
OPI Researcher - PSA (CIEMAT) CIEMAT-PSA Director
sixto.malato@psa.es

4.2 ACTIVITY RESPONSIBLES

Activity	University of Almería (UAL)	Plataforma Solar de Almería (PSA)
Organometallics and Photochemistry	**Antonio Romerosa** Full Professor UAL romerosa@ual.es	**Christoph Richter** DLR-PSA CIEMAT christoph.richter@dlr.de
Environmental Analysis	**Ana Agüera** Full Professor UAL aaguera@ual.es	**Isabel Oller** OPI PhD-CIEMAT-PSA isabel.oller@psa.es
Water Treatment	**José A. Sánchez** Full Professor UAL jsanchez@ual.es	**Manuel I. Maldonado** OPI PhD-CIEMAT-PSA mignacio.maldonado@psa.es
Modeling and Control	**Manuel Berenguel** Full Professor UAL beren@ual.es	**Luis Yebra** OPI PhD-CIEMAT-PSA luis.yebra@psa.es
Photosynthesis and Desalination	**José M. Fernández** Associate Professor UAL jfernand@ual.es	**Dr. Guillermo Zaragoza** OPI PhD-CIEMAT-PSA guillermo.zaragoza@psa.es
Solar Resource Assessment and Solar Cooling	**Javier Batlles** Associate Professor UAL fbatlles@ual.es	

4.3 COORDINATION AND MONITORING COMMITTEE

University of Almería Vice Chancellor	vinvest@ual.es
Manuel Berenguel (Full Professor UAL)	beren@ual.es
Plataforma Solar de Almería Director, CIEMAT	sixto.malato@psa.es
Eduardo Zarza (CIEMAT Researcher)	eduardo.zarza@psa.es

4.4 SCIENTIFIC COMMITTEE

Sebastián Dormido Full Professor of Computer Science and Control UNED	sdormido@dia.uned.es
María Luisa Castaño Directora General de Innovación y Competitividad. MINECO- Spain Government.	mluisa.castano@micinn.es dgic@mineco.es'
Rafael van Grieken Full Professor of Chemical Engineering at the Rey Juan Carlos University	rafael.vangrieken@urjc.es
David Serrano Full Professor of Chemical Engineering and IMDEA-Energy Director	david.serrano@imdea.org