Sustainable Water Integrated Management (SWIM) – Support Mechanism
Project funded by the European Union

European Desalination Society

EDS-SWIM Intensive Course on Desalination with Solar Energy

COURSE SUMMARY REPORT

October 1–3, 2014
Almeria, Spain

INDEX

1. INTRODUCTION

The course covered the topic of solar desalination and included a visit to one of the world's main solar facilities Plataforma Solar Almeria where a demonstration MED desalination plant plus other remarkable experimental facilities has been operating for a number of years. It was delivered by three foremost experts in the field and sponsored by the European Union. Some of the earliest work on solar desalination was done by Prof. Anthony Delyannis of Athens Technical University, founder of the Working Party, which is the forerunner of the European Desalination Society.

Participants hailed from government departments of water, energy and environment in six Maghreb and Middle East countries. One participant was specifically involved in solar desalination. There was significant interest by all who knew that renewable energy for production of water might still be expensive and demands terrain, but that we should be prepared for decreasing oil resources and further research and experience which would lead to the preferable use of the great resource of solar energy and considerable reduction of costs especially abundant in the countries of the participants. The excellent interpreters eased understanding and participation of the French-speaking participants.

There was an intensive program where lectures continued till the evening and discussions continued at lunches and into the night at friendly dinners together between participants and lecturers.

2. COURSE DEVELOPMENT

2.1. Day 1 (01.10.2014). Introduction to Solar Energy and Desalination

Topic / lecturer	Brief technical content description
Prof. Miriam Balaban / Dr. Julian Blanco	Course opening and introduction. Welcome to the participants from M. Balaban and J. Blanco outlining main course objectives and scheduled program. Delivery of badges and course documentation to the attendants, as well as providing to them practical and logistic information
Fundamentals of solar energy Dr. Diego-César Alarcón	This lecture starts with a description of the basic concepts related with the Sun. Sun-Earth relationships like subtended angle by the solar disk, Earth-Sun distance, air mass and solar constant equations are reviewed in order to study its variation along the day or year and see what is the effect over the performance of solar collector systems. A special emphasis is given in the review of the algorithms to determine the position of the Sun in the sky for any instant of time of the year. It is important to distinguish between simple algorithms for simulation purposes and complex algorithms for implementation in the tracking mechanisms of solar collectors. From the determination of the solar vector, it is explained how to get the solar incidence angle, a parameter that is present in all the collection efficiency equations of the different solar collection technologies. Solar irradiance components (direct, diffuse, reflected) are explained in order to show their definition and to understand that some solar

Topic / lecturer	Brief technical content description
	collector technologies can only take advantage of one component. Next it is explained the different sensors that are required in order to register solar radiation (and its different components) and meteorological data that are required in order to assess the performance of any solar collector field. The concept of Typical Meteorological Year (TMY) is also explained and how it is used in order to get yearly performance values of a solar powered system. The lecture ends with the two alternatives to get a TMY when it is not possible to get real data from a on-site meteorological station: solar radiometric databases (commercial and freely available) as well as the fundamentals of solar irradiance prediction based on satellite images.
Water desalination: Fundamentals, conventional technologies and research trends Dr. Diego-César Alarcón	The lecture starts with a review of basic topics about water and desalination that affects the design and performance of the different desalination technologies available: - Water classification based on salinity - Seawater chemistry - Seawater temperature After this the basic equations of desalination process are reviewed as well as the different parameters (concentration factor, recovery factor, capacity, GOR, performance ratio, etc.) that characterize the different desalination processes. After presenting a classification of the different desalination processes available (at commercial and laboratory level) the lecture focuses in the description of the ones that has been successfully implemented at commercial level. Within thermal desalination technologies, multi-stage flash evaporation (once-through and brine recirculation), multi-effect distillation (LT-MED and TVC-MED) and mechanical vapor compression are reviewed. A special emphasis is given in order to identify the energy efficiency and the typical operating temperatures of each process in order to be able to select the most appropriated solar technology to power such kind of desalination processes. Within membrane technologies reverse osmosis and electrodialysis are described and their current performance are reviewed. The lecture ends with a review of the current trends in desalination technology as well as the current world outlook, where the most important statistic data about desalination are reviewed: - Worldwide capacity - Worldwide capacity distribution - Distribution by process - Final use of desalted water - Feedwater trends
Coffee break	
Low temperature solar collector fundamentals Dr. Diego-César	In this lecture, static solar thermal collector technology is reviewed in order to study its application for low temperature (<150 ºC) applications. The following technologies are reviewed: - Flat plate collectors (unglazed and glazed, FP)

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<tr><th>Topic / lecturer</th><th>Brief technical content description</th></tr>
<tr><td>Alarcón</td><td>
- Compound Parabolic Concentrators (CPC)
- Evacuated tube solar collectors (Heat pipe and direct-flow, ETC)
Within the lecture, the different parameters that are required in order to assess the thermal performance of a static solar collector are reviewed. The concept of efficiency curve is explained and the attendants are able to identify that for a specific application (with a certain temperature level required) the best solar collector (in terms of performance) is not always the best option because there is a balance between thermal efficiency and investment cost.
The standard EN12976 for solar collector efficiency is explained and The Solar Keymark database is explained in order to see how to access to efficiency parameters of different commercially available products.
Despite static solar collectors are mainly devoted for low temperature applications, the novel technology of ultra-vacuum flat plate collectors has been introduced in order to see how this technology can challenge solar concentrating technologies for temperatures up to 250 ºC.
The lecture ends with a practical exercise to determine the outlet temperature and the instantaneous efficiency of a commercially available static solar collector for a specific location and date.
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<tr><td>Concentrating solar technologies and thermal storage

Dr. Julian Blanco</td><td>
In this lecture the main characteristics of medium temperature CSP linear-focusing solar thermal technologies (parabolic trough and linear Fresnel collectors) were initially reviewed and discussed:
- Concentration ratio from 30 to 100
- Nominal working temperature: 350 to 400 ºC
- Glass tubes situated on the optical focal line of mirror surface
- Metallic pipe with high absorptivity surface inside the glass tube
- Working fluid: thermal oil / steam
- Modules organized in parallel and connected by heat exchangers to a conventional power block and turbine
- Typically installed in large fields to power production of 30 to 200 MW
The analysis of the specific technological components of these systems followed:
- Mirror reflector
- Absorber tube
- Metallic structure
- Sun tracking system
- Drive system
- Foundations
- Piping collector connections
- Heat transfer fluid
A comparison of performance of parabolic trough and linear Fresnel collectors was also addressed.
The analysis of technological status of high temperature CSP central receiver technologies followed. Main characteristics here are:
- High solar concentration ratios permit the achievement of high global efficiencies in the power production
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- The solar concentrator is the heliostat field, which represent about the 50 percent of total investment of the plant
- The receiver, located at the top of the tower, is the key component and require specific technological solutions to guaranty high efficiencies, easy operation, reliability and durability.
- Power dispatchability can be higher than other solar thermal technologies if proper thermal storage is added (15 hours of continuous operation demonstrated)
- Two axis sun tracking imply specific features if compared with PTC, such as:
  o Higher land requirements; occupied land can be around 20% of total (mirror surface / total land surface required)
  o Lower civil works requirements; up to 3-4 % of land inclination permitted
  o Better use of solar resource; concentrated solar radiation in the receiver can be 10-15% higher than in one axis tracking devices (PTC technology)
  o Higher current investment costs (mainly due to tracking mechanisms) but, due to its modularity, a high cost reduction potential exits
  o Higher Operation & Maintenance costs, due to the higher distribution of the solar field
Main receiver technology types were reviewed: a) water/steam, b) molten salts; c) volumetric air receivers (both atmospheric and pressurized).
Finally, thermal storage technological status was presented, as the main feature that is providing a key difference with regard to all other renewable energy technologies.
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<tr><td colspan="2">Lunch break</td></tr>
<tr><td>Concentrating solar power plants

Dr. Julian Blanco</td><td>
This lecture reviewed the current status of Concentrated Solar Power Plants around the world. Starting with the first commercial CSP plants (Solar Energy Generating Systems, SEGS) built in California during the 80’s, and later following a chronological evolution by individual technologies:
- Parabolic trough
- Linear Fresnel
- Tower systems
In parallel, it was made a review of the status and prospect of CSP development at key countries/regions, such as:
- Spain (currently the leading country considering both installed power and large companies behind)
- United States
- MENA (Middle East and North Africa) countries
- South Africa
- India
Specific and major differences of current State of the Art large plants were also briefly outlined. A technology status comparison was presented, including the comparative power production cost. Finally,
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Topic / lecturer	Brief technical content description
	current CSP technology context was summarised as follows: - Highly dynamic current situation, with all possible technologies speeding up its development. - Dominance of big companies with large technical and financial capacity. - Widespread of thermal storage systems will increase power production capacity and dispatchability. - Intense research efforts all over the world, typically under a national governmental support and structure, involving research institutions and leading national companies. - Possibilities of technical improvement in the short term with associated efficiency increase and cost reductions also expected in the short term. - Intense development of Parabolic Trough, Linear Fresnel and Central Receiver technologies, with strong commercial competition. Uncertainty in the cost reduction possibilities, but with high potential in all cases.
Coffee break	

PV fundamentals
 	
Dr. Julian Blanco
	Review of performance and current status of different PV technologies:
	- Wafer-based crystalline Silicon. With more than 50 years of manufacturing history, commercially, have the highest total area module efficiency (between 15 and 20%), main reason of his clear market dominance. Main research objective is the cost reduction.
	- Thin-film technologies. Common characteristic to all of them is their standardization and high-throughput production equipment, achieving lower production costs, but with lower efficiencies than crystalline silicon. Market share is around 15% and main research objective here is the efficiency enhancement. Here, there are three main differentiated families:
	    o Thin film silicon (amorphous) with efficiencies between 6 and 9%
	    o Cadmium telluride (CdTe), with commercial efficiencies between 9 and 11%
	    o Copper-indium/gallium-selenide/sulphide (CIGSS), with many variations and commercial efficiencies between 10 and 12%.
	- Multi-junction cells. Have a high efficiency (25 – 40%) using optical systems to concentrate the light (CPV, 300 to 1000 suns). Only direct sunlight and solar tracking devices can be used by this technology, requiring locations with high DNI values. There is still a lack of long-term experience but this technology is very promising in the medium-term. Cost is still high
	- Novel and emerging PV technologies, including a wide variety of new conversion principles and device concepts (advanced thin-films, organic solar cells, dye solar cells, etc.). Still a long way to go to commercial applications. Research activities here are aimed to the achievement of very high efficiencies (full spectrum utilization) and very low cost manufacturing

Topic / lecturer	Brief technical content description

	Main technological characteristics (solar radiation and temperature influence) were presented, including some basic equations governing the technology.
	The status of PV worldwide development and current largest PV plants on grid and under erection were reviewed.
	Performance comparison and comparative capacity factor of PV and CSP plants were also presented and discussed.
	Final summary of PV plants main technical characteristics:
	- Technological maturity of components:
	    o Modules - Reliable, commercially established technology; significant potential for cost and efficiency improvement.
	    o Inverters - Durability issues, require replacement or rebuild at ~10 yr intervals. Efficiency ~ 90%.
	- Flat plate technology operates on global (indirect & direct) radiation
	- Trackers significantly increase captured energy (~130%), though at greater cost.
	- Diurnally intermittent and seasonally variable output
	    o No storage
	    o Extreme ramps (clouds) may preclude large arrays at single locations
	- Regulation and load-following reserves required for system integration (issue not yet technically solved)
	- Very limited peaking capacity value
	- Poor seasonal & diurnal load-resource coincidence for winter-peaking utilities; good load-resource coincidence for summer-peaking utilities.
	Additionally, a procedure to PV panel selection was presented followed by several practical examples.

Photovoltaic and reverse osmosis **Dr. Guillermo Zaragoza**	This lecture focuses on the combination of reverse osmosis and photovoltaic energy First, RO technology is revised in terms of its energy requirements, including: - Pre-treatments - Pumping - Energy recovery systems The role of PV to power RO is discussed in the context of renewable energy desalination technologies. Two configurations are possible: PV-RO for stand-alone systems (usually low-scale), and PV-RO for large-scale grid connected systems (usually large-scale). In the former, the main barrier is the necessity to adapt the RO process to variable energy source. The rest of the lecture is devoted to the analysis of small-scale PV-RO for stand-alone operation. The energy performance of RO systems is discussed with the aim of approaching the operation with variable energy supply. The limitations of energy recovery in small-scale systems are highlighted and the different alternatives presented.

Topic / lecturer	Brief technical content description
	Finally, real experiences of PV-RO are presented and discussed. Existing systems for seawater desalination are available for capacities in the order of several m^3/h. The installations are described and their performance assessed based on the real operation and results. The main sources of inefficiency in small-scale PV-RO are: (i) the batteries (fast charge/discharge cycles decrease their performance); (ii) the motors (small size are less efficient); (iii) energy recovery systems which are not available. Results from real plants in north Africa and the Mediterranean sea are presented. Finally, costs are discussed and conclusions taken, together with design recommendations: - Design and build larger systems - Use clark pumps and APM for energy recovery in small-scale - Minimize the energy going to the batteries - Use positive displacement pumps

Fig. 1. Views of lecturing and class room (at hotel)

2.2. Day 2 (02.10.2014). Solar Desalination Technological Status

Topic / lecturer	Brief technical content description
Low capacity solar thermal distillation systems I Dr. Guillermo Zaragoza	This lecture focuses on low capacity solar thermal distillation, starting from the most basic system which is the passive solar still, describing the different options, and progressing towards more advanced systems based on the principles of humidification-dehumidification with higher efficiency. Finally, the commercial technologies developed based on this concept are presented and discussed. A review of solar stills is presented, describing: - Mechanisms of the solar still and classification - Materials used - Energy balance - Performance, productivity and parameters it depends on - Different designs to improve the performance: (i) optimizing light transmission; (ii) enhancing evaporation; (iii) enhancing

Topic / lecturer	Brief technical content description
	condensation; and (iv) reusing the latent heat of condensation in several stages. - Available products The conclusion is that solar stills have an intrinsic low efficiency due to the loss of the latent heat of condensation and the fact that evaporation and condensation take place in a single component. Improvement in the design is not economically justified and the separation of evaporation and condensation leads to humidification-dehumidification (HDH) systems. The transition from solar stills to HDH is shown based on several prototypes. A review of Humidification – dehumidification (HDH) systems is presented, describing: - HDH process - Materials used in HDH system (in the evaporator and in the condenser) - Cycles of HDH where water is heated: (i) closed air, open water circuit, including a discussion of the multi-effect option where temperature stratification minimizes the heat losses; (ii) closed water, open air circuit, including a comparison with the previous cycle - Cycles of HDH where air is heated: (i) closed air, open water; (ii) closed air, open water using a multi-stage concept to minimize heat losses; Pilot plants and commercial products: - Multi-effect humidification systems, principles and results - Dewvaporation systems, principles and results Enhanced HDH systems, including the coupling with vapor compression and dessicant absorption. Finally, a global assessment is performed of the application of HDH to decentralized small-scale desalination.
Low capacity solar thermal distillation systems II: membrane distillation Dr. Guillermo Zaragoza	This lecture is based on membrane distillation. Membrane distillation is an evaporative process in which water vapour, driven by a difference in vapour pressure, permeates through a hydrophobic membrane, thus separating from the salt water phase. First, the fundamentals of the technology are presented and analyzed. The different configurations of membrane distillation are shown, discussing the differences between direct-contact, air-gap, permeate-gap, sweep-gas and vacuum membrane distillation configurations. The role of membranes is discussed, as well as the pernicious effect of membrane wetting. Next, the focus is on membrane distillation modules, comprising: - configuration: plate and frame with flat-sheet membranes vs tube and shell with hollow fibre membranes - energy transport phenomena and temperature polarization - heat recovery: the role of spiral-wound modules vs the novel concept of vacuum multi-effect membrane distillation - coupling with solar energy A second part of the lecture is focused on the evaluation of different

Topic / lecturer	Brief technical content description
	commercial systems of membrane distillation in PSA pilot plants: - Scarab modules using flat-sheet membranes in plate-and frame arrangements with air-gap configuration - Keppel Seghers modules using flat-sheet membranes in plate-and frame arrangements with permeate-gap configuration, comparing a compact module with a concept of modules connected in series for recovering of the latent heat of condensation. - Solar Spring modules using flat-sheet membranes in spiral-wound arrangement with permeate-gap configuration. - Aquaver modules using flat-sheet membranes in spiral-wound arrangement with air-gap configuration. - Memsys modules using flat-sheet membranes in vacuum multi-effect configuration. The evaluation of the different modules is based on the quality of the distillate (conductivity), the quantity (distillate flux and recovery ratio) and the heat consumption (energy efficiency expressed as the gain output ratio). Based on the results of the evaluation of the modules, further detailed analysis are made of: - The enhanced heat recovery of spiral-wound modules compared to plate and frame modules - The trade-off between productivity and energy efficiency in membrane distillation, comparing spiral-wound modules with permeate-gap and air-gap configuration - The difference between using different membranes and configurations in SolarSpring and Aquastill modules - The difference between recovering sensible heat in spiral-wound modules and latent heat in vacuum multi-effect modules
Coffee break	
Desalination concentrate management Dr. Guillermo Zaragoza	This lecture begins analyzing the environmental problems associated to desalination, in order to contextualize related to brine disposal and the limitations of it. Brine disposal to the sea and its impacts are thoroughly discussed, comparing the brine from thermal desalination systems (lighter and warmer, it floats) and reverse osmosis (heavier and cooler, it sinks). Mechanisms for dilution are also presented. Brine disposal inland comprises: - deep aquifer injection; - discharge to wastewater plants; - discharge to sewage systems; - discharge to open land; - reuse in agriculture; - solar evaporation ponds Solar evaporation ponds are studied in more detailed, especially several aspects related to them: construction, valorization of salt production, synergies with other activities and salinity gradient solar ponds. The next topic of the lecture is brine minimization, starting with different technologies for that and ending with the concept of zero

Topic / lecturer	Brief technical content description
	liquid discharge. An analysis of the different products that can be extracted from brine is presented, including valuable salts and concentrated bittern solutions. Real cases of combination of desalination systems and brine treatment are presented. Technologies for zero liquid discharge are discussed and examples of applications shown. Recovery of energy from brine is introduced with two different systems: pressure retarded osmosis and reverse electrodialysis. Finally, salinity gradient solar ponds are discussed in more depth, covering several aspects: - principles and concept - structure and operation - thermal efficiency - role of solar ponds as solar collectors - coupling of solar ponds with desalination systems - real examples of desalination powered by salinity gradient ponds
High capacity solar thermal distillation systems. The PSA experience Dr. Diego-César Alarcón	Review of worldwide experiences in indirect solar thermal desalination This lecture is focused in the use of solar thermal systems for high capacity solar desalination. For that reason only desalination technologies with high-energy efficiency are considered in order to reduce as much as possible the size of the required solar field. Two options are presented for high capacity solar desalination: standalone solar thermal desalination plants (where a MSF or MED plant is directly coupled to a solar field) and dual-purpose cogeneration plants (where a MED or MSF unit is coupled to a solar power plant in order to be powered with the steam exhausted or extracted from power block). This lecture focuses on the first option. A review of the worldwide experiences reveals that only small plants at pilot scale have been implemented to date. Between the R&D projects developed in this field, the ones at the Plataforma Solar de Almería (PSA) are of special relevance. Next, an extensive review of the main PSA R&D solar thermal desalination projects involving multi-effect distillation technology is carried out. An special emphasis was performed in the following technical aspects: - Low temperature multi-effect distillation (LT-MED) powered by parabolic trough solar collectors using thermal oil as working fluid and thermal storage media. - Multi-effect distillation with thermocompression using steam ejectors (TVC-MED) powered by parabolic trough solar collectors - Multi-effect distillation coupled with Double Effect LiBr-H_2O Absorption Heat Pumps (DEAHP) powered by small aperture parabolic trough solar collectors - Low temperature multi-effect distillation (LT-MED) powered by CPC solar static collectors using water as working fluid and thermal storage media.

Topic / lecturer	Brief technical content description
Lunch break	
Practical exercises Dr. Diego-César Alarcón	During this lecture, a practical exercise about the design of a solar field to power a multi-effect distillation plant with thermo-compression (TVC-MED) is performed. The steam ejectors of the TVC-MED plant are powered by live steam at 330ºC and 4.56 bar. For that temperature level, parabolic trough solar collectors (PTC) of big aperture are proposed as the best available solar technology to drive such thermal desalination process. Design of the solar field consists in determining the number of PTC in series required to get the temperature difference between inlet and outlet of the solar field, as well as determining the number of parallel rows of solar collector needed to achieve the required thermal power by the desalination process. During the practical exercise, all the input parameters required for the sizing process are explained as well as the consequences of the different options the solar designer has to choose during such work. Selection of the design day, thermal fluid, solar field orientation are performed and the equations required to determine the solar field configuration are explained in detail.
Coffee break	
Concentrating solar power and desalination Dr. Julian Blanco	This lecture deals with the benefits and drawbacks of Desalination integration into CSP power plants (CSP+D). Combining CSP and Desalination facilities could be a very attractive solution due to: - At many locations with high solar potential, projects can be more attractive to local stakeholders than just power production ones. - Technological synergies can be identified to potentially reduce the cost of combined power and water production against the independent production of the same products. - Financial schemes could also benefit, as water and power cost can be better adapted to the specific local conditions of the facility. However, the concept has also some drawbacks: - CSP+D concept needs, obviously, facilities to be located near the sea, where land cost and availability could be a significant problem. - DNI (Direct Normal Irradiation) is normally lower at the areas close to the sea. - Some / many technological aspects are not yet fully solved. Conventional power plants + MSF/MED desalination facilities combination: - Thermal desalination plant with gas turbine and heat recovery boiler - Thermal desalination plant with high pressure boiler and steam turbine - Thermal desalination plant with gas turbine, heat recovery boiler and steam turbine - Hybrid RO and thermal desalination plant with gas turbine, heat recovery boiler and steam turbine

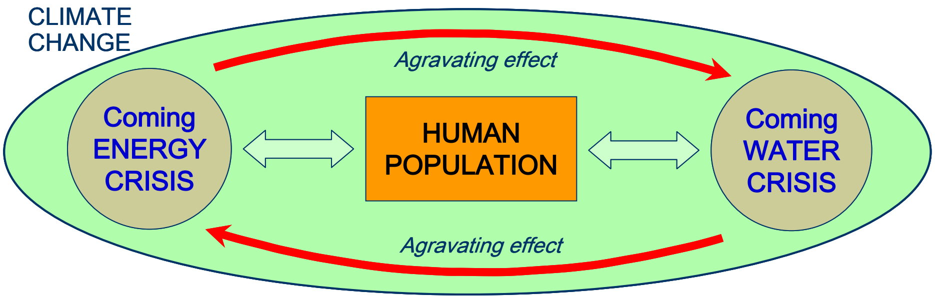
Topic / lecturer	Brief technical content description
	The thermodynamical analysis of all previous configuration, including water and power production ratios, was made and results discussed, followed by the description and analysis of suitable CSP+D configurations. Finally, the case study of pre-feasibility study of CSP+D facility in Port Safaga (Egypt) was presented (project recently executed). Initial selected configurations (first project phase) were reduced to four into the second phase to deeper study the impact of different cooling options into the overall plant performance. In all cases considered net turbine power production and thermal storage capacity were, respectively, 50 MW and 6,5 hours. Also, considered net water production was the same in all cases - CSP plant + LT-MED using condensing turbine steam to drive the desalination process - CSP plant + RO, using seawater once through as cooling option - CSP plant + RO, using evaporative cooling - CSP plant + RO, using dry cooling Final conclusion of the lecture were: - Once-Through cooling option shows the higher combined CSP+D efficiency, followed by MED - Once-though imply the lowest steam condensing temperature and MED the highest - The gross power generation in the different cases varies up to around 10 MW (due to the different internal power consumption of the system components) - The power consumption of the MED is roughly 1/3 of the consumption of the RO. Therefore in all RO cases a larger gross capacity is required in order to achieve the 50 MW net power production. - Lower thermal efficiency (MED, dry cooling) → higher thermal requirements for the turbine → but not the largest solar field - Dry cooling presents the lowest system efficiency and the highest internal power consumption for the cooling
Economic aspects of desalination using solar energy Dr. Julian Blanco	Specific cost calculation methodology was presented and used to calculate power and water costs: $C_W = \frac{\Sigma CAPEX \times crf}{W_C \times T_{eq}} + \frac{FO\&M}{W_C \times T_{eq}} + \lambda Y_P + VO\&M$ - Σ CAPEX: total capital needed to be invested into the production facility. This value amounts to the current value of all expenses during the planning, procurement, construction, etc. - crf: capital recovery factor (%), given by: $crf = \frac{z(1+z)^n}{(1+z)^n - 1} + k_i$ - z: discount rate (%/year) - n: amortization period in years

Topic / lecturer	Brief technical content description
	- ki: yearly insurance rate (1%) - Wc: rated water output (m3) - ζeq: equivalent utilization time at rate output (hours/year) - λ: specific power (electricity) consumption of the facility (kWh/m3) - FO&M: fixed cost of operation, maintenance and administration ($/year) - VO&M: variable cost of operation, maintenance and repair ($/m3) - Yp: price of power ($/kWh) With this methodology, the following case studies were analysed and described: - Water cost from seawater reverse osmosis - Water cost from seawater multi-effect distillation - Power generation cost by parabolic trough plant - Power generation by photovoltaic plant. - CSP+D cost estimation (previous configurations from CSP+D Port Safaga project) Finally all current and different renewable energies cost were presented and compared each other.

2.3. Day 3 (03.10.2014). Final course lecture

Topic / lecturer	Brief technical content description
Closing Lecture and Discussion Why solar desalination? Dr. Julian Blanco	The 20th century brought unprecedented development in the history of mankind with extraordinary advances in every discipline of science and technology. However, we are now realizing that the associated evolution of human society has not always been the best, and the overall price "paid" may be considered excessive from certain points of view. The main factor behind this unsustainable path is undoubtedly global population growth, which is also the main factor behind all the major problems mankind will face in the 21st century. There were already 6 billion people in 1999, reaching the 7 billion in 2011. This dramatic population increase in the 20th century has many current serious implications and consequences, as the pressure on natural resources, negligible in previous centuries, is now on the verge of reaching the limit of the planet's sustainability. This pressure is the main reason for the most serious problems we now face, which are, in order of their relevance to mankind: 1) Water; 2) Energy, 3) Climate change. We must realize that all these problems are closely related and, therefore, the simultaneous existence of all 3 problems, a fact that today seems nearly impossible to avoid, poses a challenge without precedence in human history. Of all challenges mankind will have to confront in the coming decades, water is without doubt the most serious problem. Even though access to water is essential to life and a fundamental human right, today more than 1 billion people are denied clean water and 2.6 billion people lack access to adequate sanitation, and these figures capture only one dimension of the problem. The United Nations has therefore posted an

Topic / lecturer	Brief technical content description
	alert for an unprecedented crisis in the coming years as the consequence of the growing scarcity of fresh water per inhabitant, especially in developing countries. By 2025 the per capita water availability in developed countries is expected to have been reduced to less than 60 percent of the 1950 level. Where developing countries are humid, this figure will be reduced to about 25 percent and, in the worse case, to about 15 percent in arid or semiarid developing countries. In the next twenty years, the average world water supply per inhabitant will drop a third. The main reasons for this severe problem are the growth of the world population, environmental pollution, inappropriate management policies and, very probably, climate change. The forecast for the second half of this century is even more worrisome. Around the globe, nearly all running surface water is already being used and, as many water stress indicators point out, groundwater aquifers are heavily overexploited in many regions of the world. Global water extraction has significantly increased since 1970 to irrigate also increasing areas for food production. Consequently, two out of three people on Earth will live in water-stressed areas by 2025 as competition for water will intensify in the decades ahead. Energy is another serious challenge. The world is now recognising that the oil era is nearing its end, and we now urgently need to adapt the overall economic system to alternative sources of energy. The depletion of conventional oil and gas sources will force, within the next few decades, to change our global energy scheme, with the important associated economic consequence of higher (or much higher) energy costs. In this scenario of future energy crisis, water problems are expected to substantially worsen. And vice versa, as due to the close relationship between water and energy, water shortages are expected to contribute to increased energy problems and aggravate their consequences. Furthermore, environmental considerations such as global warming will surely add significant pressure. Closely associated with the energy issue and a direct consequence of the continuous burning of carbon-based fuels, global warming has gained very significant momentum and importance in recent years. Due to the previously mentioned end-of-oil horizon, many countries are looking for alternative primary energy resources suitable for maintaining the economy with the minimum possible disturbance. Coal, second in the current primary energy ranking, the most abundant fossil energy resource on Earth, has very large reserves. However, its massive use involves very high CO_2 emissions with a serious negative impact on climate change issues, as the relationship between average air temperature and carbon dioxide concentration in the atmosphere has been clearly demonstrated and is widely assumed by the entire scientific community. Greenhouse gas concentration in the atmosphere increases, and in addition to its implications for climate change, it is also expected to negatively affect water availability in many already water-stressed regions of the globe, demonstrating that all these problems are closely related to each other and pointing out that effects and interactions which

Topic / lecturer	Brief technical content description
	may be marginal to one could be very severe and significant to another and, therefore, global approaches will always be needed for the proper assessment of any potential solution. It can thus be concluded that none of the present conventional energy technologies are sustainable, as they are all inefficient and none of them meet the basic criteria of not burdening future generations. In this context, what would the role of renewable energies and its contribution to the definitive solution of these problems be?  Previous figure represents the current status quite fairly and how all these problems interact, making the overall situation much more complex and of deeper concern. Exponential population growth is at the root of both energy and water problems, but with the special characteristic that each of these problems significantly reinforces the others. The water problem can be significantly reduced in a context of cheap and abundant energy and something similar could also happen with energy and water. However, the opposite situation has the contrary effect. Water problems will be significantly worsened in a context of scarce and costly energy, and energy will be more difficult and costly to be produced in a context of water shortage. In addition, this entire situation will take place in a context of climate change and global warming with all indicators pointing to all possible scenarios worsening. Finding a suitable and affordable solution to this complex interlocking puzzle will not be an easy task due to the many issues involved (of which financing is just one). But is it very clear that no adequate and sustainable solution will be found without the strong participation of the following three components: - Reduction in the per capita consumption of energy and water (increased efficiency) - Substantial introduction of renewable energies into the energy mix - Continuous scientific and technological research and development In addition, no solution could be envisaged to the water problem without a significant global increment in desalination applications and, in the case of the energy, without the significant use of renewable energy sources. Therefore the development of suitable and economically renewable energy seawater desalination technologies seems to be a major necessity. And due to the clear synergy between solar energy availability and water problems, among all the renewables, solar energy is clearly the best option to desalination.

Topic / lecturer	Brief technical content description
Trip to Plataforma Solar de Almería	

2.4. Day 3 (03.10.2014). Practical Work at Plataforma Solar de Almería

CIEMAT (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas) is a Spanish Public Research Institution owned by the Ministry of Economy and Competitiveness (MINECO) (www.ciemat.es). Since its founding in 1951, it has developed and led R+D projects in the fields of Energy, Environment and Technology, placing the institution at the forefront of science and technology. CIEMAT has a wide presence in both national and international scientific and technical forums. In addition to the head offices and laboratories located in Madrid, CIEMAT owns several research centers located in other Spanish provinces. The Plataforma Solar de Almería, PSA (www.psa.es), which is one of these outlying centers of the CIEMAT, is formally considered by the European Commission as an *European Large Scientific Installation* and it is also the largest and most complete R+D center in the World devoted to solar thermal concentrating systems. PSA is also a *Singular Science and Technology Infrastructures (ICTS)* of Spain. The good solar conditions, its diverse solar facilities and the highly-skilled PSA staff, provide a unique infrastructure for R+D, evaluation, demonstration and technology transfer regarding solar energy applications. PSA is located in southeastern Spain, in the Tabernas Desert and counts with over 35 years of experience in the operation, maintenance and evaluation of solar thermal concentrating systems, their components and different types of commercial applications.

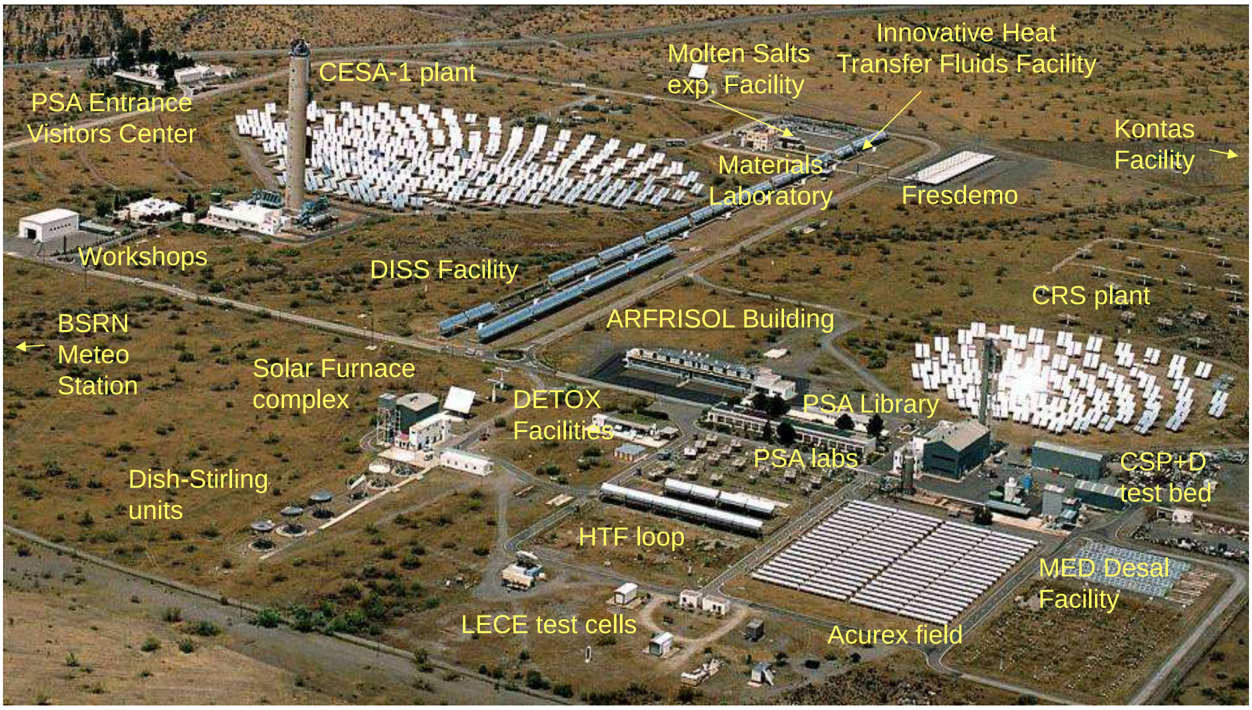


Fig. 2. Location of the main PSA test facilities for solar thermal concentrating systems

Part One. Quick visit to some of most important PSA facilities

a) Central Receiver Facilities: 5 MWt CESA-1 Plant

The CESA-1 plant is a very flexible facility operated for testing subsystems and components such as heliostats, solar receivers, thermal storage, solarized gas turbines, control systems and concentrated high flux solar radiation measurement instrumentation. It is also used for other applications that require high photon concentrations on relatively large surfaces, such as in chemical or high-temperature processes, surface treatment of materials or astrophysics experiments. Direct solar radiation is collected by a 330 x 250-m south-facing heliostat field composed of 300 39.6-m2 heliostats distributed in 16 rows. The CESA-1 facility has the most extensive experience in glass-metal heliostats in the world. Maximum thermal power delivered by the field onto the receiver aperture is 7 MW at a typical design irradiance of 950 W/m2, achieving a peak flux of 3.3 MW/m^2. 99% of the power is focused on a 4-m-diameter circle and 90% in a 2.8-m circle. The 80-m-high concrete tower, which has a 100-ton load capacity, has four test levels

Fig. 3. The CESA-I facility seen from the East with heliostat rows focusing on the medium-height test level (60 m.)

b) Central Receiver Facilities: SSPS-CRS 2,5 MWt facility

The SSPS-CRS plant is currently devoted to testing small solar central receivers in the 200 to 500-kWth capacity range. The heliostat field is composed of 91 39.3-m2 first generation units manufactured by Martin-Marietta. A second field north of it has 20 52-m2 and 65-m2 second-generation heliostats manufactured by MBB and Asinel. The CRS heliostat field was improved several years ago with the conversion of all of its heliostats into completely autonomous units powered by photovoltaic energy, with centralized control communicated by radio by a concept developed and patented by PSA researchers. The 43-m-high metal tower has two test platforms. The first is a two-level open area at 32 and 26 m prepared for testing new receivers for thermochemical applications. The second test platform is at the top of the tower at 43 m, and houses an enclosed room with crane and calorimetric test bed for the evaluation of small atmospheric-pressure volumetric receivers, and solar reactors for hydrogen production.

Fig. 4. Aerial view of the experimental SSPS-CRS facility

c) Linear Focusing Facilities: The HTF Test Loop

The HTF test loop is a facility for evaluating parabolic-trough collector components under real solar energy operating conditions. The facility is suitable for qualifying and monitoring of the following components: i) Parabolic-Trough collector mirrors; ii) Parabolic-trough collector absorber tubes; iii) New designs of parabolic-trough collectors (up to 75 m long); iv) Solar tracking systems. The facility consists of a closed thermal-oil circuit connected to several solar collectors of 75-m long connected in parallel, being able to operate only one at a time. The east-west rotating axis of the solar collectors increases the number of hours per year in which the angle of incidence of the solar radiation is less than 5º. The thermal oil used in this facility (Syltherm 800) has a maximum working temperature of 420ºC and a freezing point of -40ºC.

Fig. 5. PSA "HTF test Loop"

d) Linear Focusing Facilities: The DISS experimental plant

This test facility was implemented at PSA for experimenting with direct generation of high-pressure high-temperature (100 bar/400ºC) steam in parabolic-trough collector absorber tubes. It was the first facility built in the world where two-phase-flow water/steam processes in parabolic-trough collectors could be studied under real solar conditions. The facility consists of two subsystems, the solar field of parabolic-trough collectors and the balance of plant (BOP). In the solar field, feed water is preheated, evaporated and converted into superheated steam at a maximum pressure of 100 bar and maximum temperature of 400ºC as it circulates through the absorber tubes of a 700-m-long row of parabolic-trough collectors with a total solar collecting surface of 3,838 m2. The system can produce a nominal superheated steam flow rate of 1 kg/s. In the balance of plant, this superheated steam is condensed, processed and reused as feed water for the solar field (closed loop operation). Three additional parabolic-trough collectors were installed in the solar field in 2012 and all the absorber tubes were replaced by new ones, to increase up to 500ºC the temperature of the superheated steam produced, enabling to generate direct steam at 100bar and 500ºC. Facility operation is highly flexible and can work from very low pressures up to 100 bars.

Fig. 6. Solar collector field of the PSA DISS loop

e) Linear Focusing: Innovative Fluids Test Loop + molten salt facility

The purpose of this experimental facility is to study pressurized gases as working fluids in parabolic-trough collectors, which has not been done to date, evaluating their behavior under a diversity of real operating conditions. The facility can achieve temperatures of up to 515ºC and it is connected to a two-tank molten-salt thermal storage system to test their joint capacity for collecting and storing solar thermal energy with a view to making use of them in dispatchable high-performance thermal cycles. The molten-salt thermal storage system basically consists of: i) Two 39-ton salt tanks, hot and cold, able to provide about six hours of thermal storage; ii) A 344-kW air cooler to cool the salt with ambient air; iii) A 344-kW gas/salt exchanger providing the salt circuit with the solar energy collected in the innovate fluids test loop. The thermal storage system is also connected to a small 344-kWt thermal oil loop, with VP-1 oil, allowing the thermal storage system to be charged and discharged by using this thermal oil system, with a salt/oil heat exchanger.

Fig. 7. View of the pressurized gas test loop connected to a molten-salt thermal energy storage

f) Linear Focusing Facilities: The FRESDEMO Loop

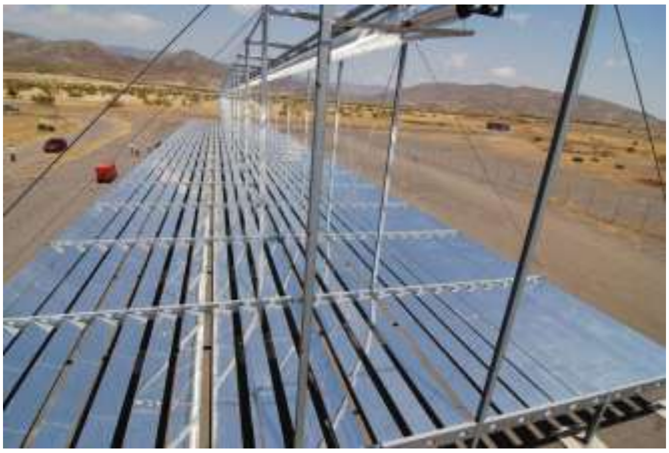


Fig. 8. Photo of the linear Fresnel concentrator erected at the PSA

The FRESDEMO loop is a "Fresnel linear concentrator" technology pilot demonstration plant. This 100m-long, 21-m-wide module has a primary mirror surface of 1,433 m^2, distributed among 1,200 facets mounted in 25 parallel rows spanning the length of the loop. This collector loop is designed for direct steam generation at a maximum pressure of 100 bar and maximum temperature of 450º. This pilot facility is supplied with solar steam at different pressures and temp. for testing the three working modes: preheating, evaporation and superheating.

g) Parabolic DISH Systems: Accelerated ageing test bed and materials durability

Fig. 9. Parabolic-dish DISTAL-I used for accelerated materials ageing

This installation consists of 4 parabolic dish units, 3 DISTAL-II type with 50 kW total thermal power and two-axis sun tracking system, and 1 DISTAL-I type with 40 kW total thermal power and one-axis polar solar tracking system. In the 4 dishes, the initial Stirling motors have been replaced by different test platforms to put the materials or prototypes at small scale of high concentration receivers and perform accelerated temperature cycling. With fast focusing and defocusing cycles, the probes placed in the concentrator focus stand a large number of thermal cycles in a short time interval, allowing an accelerated ageing of the material.

h) Parabolic DISH Systems: EuroDISH

Under the Spanish-German EUROdish project, two new dish-Stirling prototypes were designed, constructed and erected at PSA, discarding the stretched-membrane technology and applying a new molded composite-material system. Technical characteristics are quite similar to DISTAL-1 units: 50 kWth maximum power and 16.000 suns maximum concentration at the focus. Tracking system is also azimuth-elevation.

Fig. 13. Front view of PSA EURODISH

i) Solar Furnaces: SF-60 Solar Furnace

Fig. 14. Exterior view of the PSA SF-60 in operation

In this furnace, the heliostat collects solar radiation and redirects it to the concentrator. The heliostat's reflective surface is made up of flat, non-concentrating facets, which reflect the sun's rays horizontally and parallel to the optical axis of the parabolic-dish concentrator, continuously tracking the sun. The only heliostat associated with the SF-60 consists of 28 flat facets with a total surface of 120 m2 and 92% reflectivity. Its focal distance is 7.45 m. The characteristics of the focus with 100% aperture and solar radiation of 1000 W/m^2 are: peak flux, 300 W/cm^2, total power, 69 kW and focal diameter, 26 cm.

j) Solar Furnaces: SF-40 Solar Furnace

The new SF-40 furnace, so called because of its 40-kW power, consists mainly of an 8.5-m-diameter parabolic-dish, with a focal distance of 4.5 m. The concentrator surface consists of 12 curved fiberglass petals or sectors covered with 0.8-mm adhesive mirrors on the front. The parabola thus formed is held at the back by a ring spatial structure to give it rigidity and keep it vertical. Finally, the flat heliostat with a 100-m2 reflective surface, which is still under construction, completes the installation.

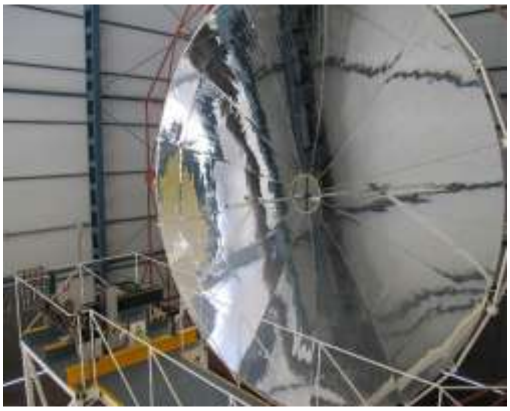


Fig. 15. Interior view of the SF-40 solar furnace, showing the parabolic concentrator

k) SF-5 Solar Furnace

Fig. 16. Exterior view of the SF-5 vertical solar furnace

The vertical axis Furnace, the SF-50, has been recently designed and erected at the PSA. It has been designed to test high radiant flux, high gradients and high temperatures. This new solar furnace consists basically of a concentrator, located in inverted position (reflecting surface floor-oriented) onto an 18-m high metal tower; in the center of the base of the tower is a flat heliostat, which rotating center is aligned with the concentrator optical axis. The test table is in the upper part of the tower of the SF-5 furnace, inside the test room and 2 m below the concentrator vertex. Finally, and as the test room "floor", is the shutter in horizontal position, which is located between the heliostat and the concentrator, completes the main components of the vertical axis solar furnace. This solar furnace started operation in 2012

Part Two. Detailed working visit to PSA Solar Desalination facilities

a) Solar Multi-Effect Distillation Facility

This facility is composed of the following subsystems: i) A 14-stage multi-effect distillation (MED) plant; ii) A field of stationary CPC (compound parabolic concentrator) solar collectors; iii) A water solar thermal storage system; iv) A double effect (LiBr-H_2O) absorption heat pump; and v) A fire-tube gas boiler. The multi-effect distillation unit is made up of 14 stages or effects, arranged vertically with direct seawater supply to the first effect (forward feed configuration). At a nominal 8 m^3/h feedwater flow rate, the distillate production is 3 m^3/h, and the thermal consumption of the plant is 190 kW_t, with a performance factor over 9. The saline concentration of the distillate is around 5 ppm. The nominal temperature gradient between the first cell and the last is 40 ºC with a maximum operating temperature of 70 ºC in the first cell. The system heat transfer fluid is water, which is heated as it flows through the solar collectors to the storage system. The hot water from this storage system provides the MED plant with the thermal energy required for its operation. The solar field is composed of 252 stationary solar collectors with a total surface area of 500 m^2 arranged in four rows of 63 collectors. The maximum working temperature of the solar field is 100 ºC since the collectors are connected to atmospheric pressure storage tanks in an open loop. The thermal storage system consists of two water tanks connected to each other for a total storage capacity of 24 m^3. This volume allows the operation sufficient autonomy for the fossil backup system to reach nominal operating conditions in the desalination plant. The double effect (LiBr-H_2O) absorption heat pump is connected to the last effect of the MED plant, cutting in half the thermal energy consumption required by a conventional multi-effect distillation process. The fossil backup system is a propane water-tube boiler that ensures the heat pump operating conditions (saturated steam at 180 ºC, 10 bar abs), as well as operating the MED plant in the absence of solar radiation.

Fig. 17. PSA SOL-14 MED Plant (left), double-effect LiBr-H2O absorption heat pump (upper right) and 500-m2 CPC solar collector field (bottom right)

b) CSP+D Test Bed: Integration of MED thermal desalination solar thermal power plants

This facility is devoted to the research of the coupling of a concentrating solar thermal power plant (CSP) and a water desalination plant (CSP+D), which makes use of the steam turbine (extracted or exhausted) to drive the thermal desalination process. The basic purpose is to simulate and analyze the various possible configurations for integrating a thermal desalination plant in a solar thermal power plant. The test bench enables the operating conditions of different types of commercial turbines and interconnection configurations to the PSA multi-effect (MED) desalination plant to be simulated. The system power supply is thermal energy coming from an existing parabolic-trough collector field able to deliver thermal oil with temperatures up to 400 ºC and an auxiliary electrical power system that raises the temperature when necessary.

Fig. 18. View of the outside of the CSP+D test bed building with the air coolers (left) and partial view of the interior of the CSP+D test bench (right)

The facility makes it possible to simulate any turbine that could be used for simultaneous production of electricity and water from concentrated solar energy on a scale up to 500 kW. There are a series of steam ejectors for this purpose that can operate with motive and exhaust steam for a variety of Rankine Cycle turbine outlet conditions. Other types of steam from other intermediate extractions can also be reproduced. The test bed is also designed to study the possibility of using a part of the exhaust steam from the turbine outlet by regenerating it with steam from an intermediate extraction to power an MED desalination plant. The main underlying idea is to attempt to use the first MED plant cell as the condenser in the power cycle, reducing Rankine Cycle cooling requirements and making use of that thermal energy to produce desalinated water.

c) Facility for polygeneration applications

Polygeneration is an integral process for the purpose of producing two products from one or several resources. In the case of solar energy, it makes use of the thermal energy from a solar field for several simultaneous applications, such as generating electricity, desalinating water for drinking water supply and the rest for heating sanitary water (ACS). The purpose of this facility is preliminary study of the behavior of a parabolic trough solar field of small concentration ratio, determination of its feasibility as a heat source in polygeneration schemes, in particular in CSP+D requiring temperatures around 200ºC. The collector selected was the Polytrough 1200 prototype by NEP Solar. It has a production of 15.8 kW per module (0.55 kW/m2) under nominal conditions, with a mean collector temperature of 200 ºC, and efficiency over 55% in the range of 120-220 ºC (for 1000 W/m2 of direct normal irradiance). The field is configured in 8 collectors placed in 4 parallel rows, with two collectors in series in each row. This configuration supplies 125 kW of thermal energy. The temperature of the thermal oil can be up to 220 ºC, so different schemes for making use of the thermal energy for polygeneration can be evaluated. Also, the solar field can be used to generate steam for supplying the double-effect absorption heat pump coupled to the PSA MED plant.

Fig. 19. NEP PolyTrough 1200 solar field

d) Low temperature Solar Thermal Desalination applications facility

The installation consists of a test-bed for evaluating solar thermal desalination applications. It comprises a 20 m2 solar field of flat-plate collectors with a thermal heat storage (1500 liters), connected to a distribution system that enables simultaneous connection of several units. The thermal heat storage allows for a stationary heat supply to the applications connected to the test-bed but can also be bypassed for direct supply of solar energy without buffering. The installation is fully automated and monitored (temperatures and flows), and allows for heat flow regulation. The maximum thermal power is 7 kWth, and it supplies hot water with temperature up to about 90ºC. The installation has a separate water circuit that can be used for cooling (about 3.5 kWth) in the desalination units and a device for supplying simulated seawater, with the possibility of working in open loop or closed loop. In the latter case, both the distillate and brine fluxes are collected and mixed together, to be fed again into the desalination units after a heat dissipation system. The installation currently operates with membrane distillation modules but allows for testing other thermal desalination applications. Two membrane distillation units have been evaluated: the Oryx 150 supplied by the German company Solar Spring GmbH, which is a spiral-wound permeate gap distillation module, and the WTS-40A unit from Dutch company Aquaver, which is based on multi-stage vacuum membrane distillation technology using modules fabricated by Memsys.

Fig. 20. Internal (left) and external (right) views of the Membrane Distillation experimental test bed within the PSA low-temperature solar thermal desalination facility

Fig. 21. Different photos taken during the group visit to PSA

Lunch break
Return to hotel in Almeria

3. LECTURERS AND CONVENER

The course was given by researchers and scientists from Plataforma Solar de Almeria (CIEMAT-PSA) and convened by the European Desalination Society.

3.1. Dr. Ing. Julián Blanco Plataforma Solar de Almeria

<u>Academic Education</u>

- 1985 Industrial Engineer (Seville University, Spain);
- 1994 Master in Environmental in Sciences by the Instituto de Investigaciones Ecologicas / The Open International University (Malaga, Spain)
- 2003 Ph.D. by the University of Almeria. Dept. of Applied Physic (Almeria, Spain)

Current professional status

Employer:	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT)
Department:	Department of Energy
Unit:	Plataforma Solar de Almería (PSA). Large European Scientific Installation. Most important and complete world facility for Concentrated Solar Power and solar thermal energy applications research.
Position:	Associate Director
Contract:	Senior Researcher of the Spanish Ministry of Economy and Competitiveness / Civil Servant of Spanish Public Research Institutions
Address:	Carretera de Senés s/n. P.O. Box 22. 04200 Tabernas (Almería)
Phone:	(+34) 950 387939
Fax:	(+34) 950 365300
Email:	**julian.blanco@psa.es**
Position from:	01.01.2014

Professional experience

- 1985-1988 Head of production department (COEMTER, Gerona, Spain)
- 1988-1990 Product Engineer (AMP Incorporated, Barcelona, Spain)
- 1990-1991 Engineer (ADESA, Almeria, Spain)
- 1991-2002 Head of Solar Chemistry Group (PSA, Almeria, Spain).
- 2002-2013 Head of Environmental Applications of Solar Energy Unit (CIEMAT-PSA, Almeria, Spain).
- 2014-to date Associate Director (CIEMAT-PSA, Almeria, Spain)

Professional Appointments

- 1995-2007 Spanish National Representative in the Task II (Annex Solar Chemistry) of *International Energy Agency – SolarPACES* (Solar Power and Chemical Energy Systems).
- 2008-2013 Operating Agent of the *International Energy Agency SolarPACES* Program – Task VI (Solar Energy & Water Processes and Applications).
- 2008-to date Spanish alternate member of Executive Committee of the *International Energy Agency SolarPACES* Program.
- 2011-to date Visiting Professor at King Saud University (Riyadh, Saudi Arabia). Dept. of Electrical Engineering.
- 2011-2013 Coordinator of EERA (European Energy Research Alliance) of CSP+D Subprogramme. Leading Researcher
- 2012-to date Coordinator of EERA JP-CSP (Joint Programme on Concentrating Solar Power). Leading Researcher

Scientific Publications

- Peer-reviewed publications in Science Citation Index Journals: 94
- Full books: 10
- Chapter in books: 24
- Honorary/guess editor of Books/Journals/Conference Proceedings: 5

Scientific Citations:

- 4173 citations (self-citations excluded) since 01.01.1998, according to Scopus (October 2014)
- Hirsch index: 35 (Scopus, October 2014)

Scientific and Technological Research Projects

- 1993- to date National Spanish funded projects from public calls: 15 (coordinator in 6 of them)
- 1990- to date European Commission funded projects (public calls): 20 (coordinator in 8 of them)
- 1998- to date Other internationally funded projects (public calls): 3 (coordinator in 2)
- 1990- to date Specific research projects under contracts with Spanish companies: 12
- 2000- to date Specific research projects under contracts with international companies: 4

Commercial Projects (consultancy)

- 2011- to date Specific research projects under contracts with Spanish companies: 4
- 2011- to date Specific research projects under contracts with overseas international companies: 5

Others Scientific and professional activities:

- Patents: 5
- Conference papers: 190
- Magazine articles: 58
- Invited Talks: 40 (15 keynotes)
- Lectures in international courses: 55
- Supervisor of Ph.D. Theses: 2
- Supervisor of M.Sc. Theses: 1
- Supervisor of students training at PSA: 47
- Countries of professional experience (projects and activities developed): Spain, Germany, Italy, Portugal, Belgium, Nederland, France, Sweden, Switzerland, Greece, UK, Morocco, Tunisia, Egypt, Saudi Arabia, Qatar, Oman, Emirates, Argentina, Chile, Peru, Venezuela, Brazil, Mexico, USA, Canada, Uzbekistan, Philippines, Thailand, South Korea, Australia and South Africa.

Scientific Advisory and Publications Boards

- 2006-2007 International Committee to the Scientific Audit Panel of the Mexican program "Sea and brackish water desalination with renewable energies".
- 2007-2009 Member of the Board of AEDES – *Asociación Española de Energía Solar*. Spanish branch of ISES
- 1998-to date Member of Scientific Committees of 15 International Conferences
- 2006-2009 Associate Editor of International Journal of Photoenergy
- 2010-to date Academic Committee of the "Instituto de Investigación e Ingeniería Ambiental" (3iA); Univ. Nacional de San Martín (UNSAM). San Martin, Argentina
- Referee: Normal referee of Desalination, Desalination and Water Treatment, Solar Energy, ASME- Journal of Solar Energy Engineering, Water, Waste and Environmental Research, Environmental Science and Technology, International Water Association (IWA), Industrial & Engineering Chemistry Research, Journal of Advanced Oxidation Technologies, Catalysis Today.

Awards & Honors

- 1993	Honorary member of the UNESCO Club of Pechina, Spain.
- 2004	"Grand European Prix for Innovation Awards" jointly with his colleague Dr. Sixto Malato ("Prix of Jury" modality, www.european-grandprix.com). Monaco, 11 December, 2004

3.2. Dr. Diego-César Alarcón-Padilla. Plataforma Solar de Almeria

Academic Education

- 1993	Degree in Physics, speciality in Electronics (Granada University, Spain);
- 1997	Master in Environmental Audits and Business Planning of the Environment, by the Ecological Research Institute and Technical Architects' Association of Málaga, Spain
- 1997	University Specialist in Industrial Quality by the National Open University, Spain
- 2008	PhD by the University of La Laguna, Spain – Department of Fundamental and Experimental Physics, Electronics and Systems

Current professional status

Employer:	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT)
Department:	Department of Energy
Unit:	Plataforma Solar de Almería (PSA). Large European Scientific Installation. Most important and complete world facility for Concentrated Solar Power and solar thermal energy applications research.
Position:	Head of Solar Desalination Unit
Contract:	Senior Researcher of the Spanish Ministry of Economy and Competitiveness / Civil Servant of Spanish Public Research Institutions
Address:	Carretera de Senés s/n. P.O. Box 22. 04200 Tabernas (Almería)
Phone:	(+34) 950 387900 Ext. 960
Fax:	(+34) 950 365300
Email:	**diego.alarcon@psa.es**
Position from:	01.01.2014

Professional experience

- 1994-1999	Plataforma Solar de Almería (Researcher in the Solar Systems Concentration Unit)
- 1999-2000	University of Almería (Full time lecturer in the Department of Languages and Computation, teaching at Computer Engineering School)
- 2000-2014	CIEMAT-Plataforma Solar de Almería (Senior Researcher in the Environmental Applications of Solar Energy Unit)
- 2003-2012	University of Almería (Part time lecturer in the Department of Languages and Computation, teaching at Computer Engineering School)
- 2014-to date	Head of Solar Desalination Unit (CIEMAT-PSA, Almería, Spain)

Professional Appointments

- 2013-to date Operating Agent of the *International Energy Agency SolarPACES* Program – Task VI (Solar Energy & Water Processes and Applications).
- 2013-to date Coordinator of EERA (European Energy Research Alliance) of CSP+D Subprogramme (Concentrating Solar Power + Desalination) within JP-CSP (Joint Programme on Concentrating Solar Power). Leading Researcher

Scientific Publications

- Peer-reviewed publications in Science Citation Index Journals: 37
- Full books: 3
- Chapter in books: 4

Scientific Citations:

- 654 citations (self-citations excluded) since 01.01.1998, according to Scopus (October 2014)
- Hirsch index: 11 (Scopus, October 2014)

Scientific and Technological Research Projects

- 1993- to date National Spanish funded projects from public calls: 7
- 1990- to date European Commission funded projects (public calls): 12
- 1998- to date Other internationally funded projects (public calls): 2
- 1990- to date Specific research projects under contracts with Spanish companies: 6
- 2000- to date Specific research projects under contracts with international companies: 2

Others Scientific and professional activities:

- Conference papers: 75
- Magazine articles: 10
- Lectures in international courses: 55
- Supervisor of Ph.D. Theses: 1
- Supervisor of M.Sc. Theses: 1
- Supervisor of students training at PSA: 1
- Countries of professional experience (projects and activities developed): Spain, Germany, Italy, Portugal, Belgium, Netherlands, France, Sweden, Switzerland, Greece, UK, Morocco, Tunisia, Egypt, Saudi Arabia, Qatar, Oman, Emirates, Argentina, Chile, Mexico, USA, Uzbekistan, Philippines and South Africa.

3.3. Dr. Guillermo Zaragoza del Aguila. Plataforma Solar de Almeria

Academic Education

- 1991 Degree in Astrophysics by University Complutense of Madrid, Spain
- 1996 PhD in Applied Physics by the University of Granada, Spain

Current professional status

Employer: Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT)
Department: Department of Energy
Unit: Plataforma Solar de Almería (PSA). Large European Scientific Installation. Most important and complete world facility for Concentrated Solar Power and solar thermal energy applications research.
Position: Senior Researcher

Address: Carretera de Senés s/n. P.O. Box 22. 04200 Tabernas (Almería)
Phone: (+34) 950 387900 Ext. 941
Fax: (+34) 950 365300
Email: guillermo.zaragoza@psa.es

Professional experience

- 1992-96 PhD student in Instituto de Astrofísica de Andalucía (Spanish Research Council), Granada, Spain
- 1997-98 Post-doc in the Department of Atmospheric, Oceanic and Planetary Physics, University of Oxford, UK
- 1999-2000 Post-doc in Instituto de Astrofísica de Andalucía (Spanish Research Council), Granada, Spain
- 2001-05 Researcher in Estación Experimental of Cajamar, Almería, Spain
- 2006-08 Responsible of research in the Renewable Energy Department of Fundación Cajamar, Almería, Spain
- 2009-now Senior Researcher at the Plataforma Solar de Almería (Environmental Applications of Solar Energy).

Professional Appointments

- 2013-to date Coordinator of the Renewable Energy Desalination Action Group of the European Innovation Partnership on Water (European Commission).

Scientific Publications

- Peer-reviewed publications in Science Citation Index Journals: 48
- Full books: 1
- Chapter in books: 4

Scientific Citations:

- 320 according to Scopus (October 2014)
- Hirsch index: 11 (Scopus, October 2014)

Scientific and Technological Research Projects

- National Spanish funded projects from public calls: 4
- European Commission funded projects (public calls): 12
- Other internationally funded projects (public calls): 2
- Specific research projects under contracts with Spanish companies: 6
- Specific research projects under contracts with international companies: 2

Others Scientific and professional activities:

- Conference papers: 82
- Invited Talks: 6 (3 keynotes)
- Lectures in international courses: 55
- Referee of 10 scientific journals
- Supervisor of Ph.D. Theses: 1
- Supervisor of M.Sc. Theses: 4
- Supervisor of students training at PSA: 5
- Countries of professional experience (projects and activities developed): Spain, Germany, Italy, Portugal, Belgium, Netherlands, France, Sweden, Switzerland, Greece, UK, Morocco,

Tunisia, Algeria, Egypt, Saudi Arabia, Qatar, Oman, Emirates, Argentina, Chile, Mexico, USA, Uzbekistan, Philippines, Thailand and South Africa.

3.4. Prof. Miriam Balaban. EDS, Convener

Prof. Miriam Balaban with headquarters at the Faculty of Engineering, Universita Bio-Medico in Rome, Italy where she programs and organizes courses, conferences and workshops in desalination. She is associated with the desalination program – Center for Clean Water and Energy in the Department of Mechanical Engineering of the Massachusetts Institute of Technology (MIT). She has served as a board member and officer of the International Desalination Association and received the Lifetime Achievement Award from the Association in 2009. She has received the Order of the Star of Italy from the President of Italy, honorary membership in the European Membrane Society and the Sidney Loeb Award from the European Desalination Society.

She is founder of *Desalination*, the international journal for desalting and purification of water and was Editor-in-Chief from 1966 to 2009 where she reviewed and edited over 12,000 papers and reviewed many more. In 2009 she launched the monthly journal *Desalination and Water Treatment* to accommodate the growing flood of papers in the field, now already over 4,000 papers, and editor of the *Desalination Directory*, the international online database which serves to network over 30,000 individuals and 5,000 organizations, a calendar of events and other information. She is a member of the PRODES program and coauthor of the book ABCs of Solar Desalination. Prof. Miriam Balaban is Secretary General of the European Desalination Society.

Fig. 22. Course professors and Miriam Balaban during the visit to PSA

4. INTERPRETERS

4.1. Mr. William Edmund Clarke (Madrid, Spain)

EDUCATION

- Emanuel school London, 1973-1978
- University of Exeter, 1978-1982
- University of Cambridge, 1985-1986

LANGUAJES

- English
- French
- Spanish

QUALIFICATIONS

- Advanced level GCE in English, Spanish, French and Art, 1978 Emanuel School.
- BA Combined Honours Degree in French and Spanish, 1982 University of Exeter.
- Post Graduate Certificate of Education, 1986 University of Cambridge.
- Royal Society of Arts Preparatory Certificate for the teaching of English as a Foreign Language for Adults, 1986 International House London.
- Simultaneous Interpretation Course, 1991 CYMA/Procongreso Madrid.

PROFESSIONAL EXPERIENCE

23 years experience since 1991 simultaneously translating from and into English, French and Spanish.

<u>Examples of interpreting assignments for THE EUROPEAN UNION</u>

- EU COHESIONS FUNDS meetings and conferences (Madrid).
- Training courses for border control officials. SCHENGEN TREATY (Avila).
- EU STRUCTURAL FUNDS meetings and conferences (Madrid).
- EUROPEAN ECONOMIC AND SOCIAL COMMITTEE debates. EU energy policy: new prospects under the Lisbon Treaty (Madrid).
- European Explosives Ordnance Meeting EOD (Madrid).
- SOCIAL AND ECONOMIC COUNCIL seminar. The strategy for growth in a changing Europe as from 2010 (Madrid).
- EDUCATION AND CULTURE DG. The internationalization of higher education. A foresight exercise for 2020 and beyond.
- UNIVERSIDAD COMPLUTENSE (Madrid).
- II EUROPEAN ROMA PEOPLE SUMMIT Spanish presidency of the EU (Cordoba).
- EUROPEAN ECONOMIC AND SOCIAL COMMITTEE. Discussions on socially responsible financial instruments (Madrid).
- Meeting on limits and potential in relations between the European Union and Latin America DEMOCRACY AND COOPERATION
- INTERNATIONAL FORUM (Madrid).

<u>Examples of interpreting assignments for THE UNITED NATIONS ORGANIZATION and other international organizations</u>

- FAO agriculture and fisheries meetings (Madrid, La Corunna, Split).
- UN discussions on the quality of agro-food chain produce (La Manga).
- IUCN Mediterranean forum (Malaga).
- Transnational meetings EQUAL (Murcia).
- OECD Organization for Economic Cooperation and Development.
- IOC Internationl Olympic Committee.
- COUNCIL OF EUROPE.
- ANTARCTIC TREATY discussions.
- WTO World Tourism Organization.

- BRITISH, AUSTRALIAN and INDIAN Embassies.

Examples of interpreting assignments in ENERGY

- FUNDACIÓN IBERDROLA (Madrid).
- GAS NATURAL training courses (Madrid y Barcelona).
- CLUB ESPAÑOL DE LA ENERGÍA regular international conferences and meetings (Madrid).
- EUROPEAN ECONOMIC AND SOCIAL COMMITTEE open debate “EU energy policy: new prospects under the Lisbon Treaty” (Madrid).
- GAMESA financial results (Madrid).
- Climate change: the road to 2050 GAS NATURAL FENOSA (Madrid).
- AREVA yacht race (Valencia).

Other areas with large experience on interpreting assignments:

- Spanish Ministries and Local Government
- Law
- Law Enforcement and Security Services
- Business and Finance
- Agriculture
- Politics
- Medicine, Pharmaceuticals and Health
- Environment
- Education
- Television and radio
- Information Technology and Communications
- Industry, Business and Commerce
- Trade Unions and Employment
- Fine Arts, Music, Fashion and Sport
- Architecture

Also, wide experience in interpreting assignments for VIPs, PERSONALITIES and CELEBRITIES, Conference Organizer and Coordinator, written translator, etc.

4.2. Ms. Violeta Arranz de la Torre (Granada, Spain)

UNIVERSITY DEGREES

- Licenciatura en Traduccion e Interpretacion in the University of Granada, Spain. Specialities: Conference Interpreting and Legal and Economic Translation (with subjects of specialised translation and legal and economic subjects). Final project with the mark of First Class with Distinction. 2001.
- B.A. (Hons) in Applied Languages Europe in Thames Valley University in London, United Kingdom. 2001.
- Maîtrise en Langues Etrangères Appliquées in the Université de Provence in Aix-en-Provence, France. 2001.

COURSES

- B2 certificate. Krakow, Poland. Lessons of Polish language. Prolog. Krakow, Poland. 2008

- Lessons of Polish language. Prolog. Krakow, Poland. Conversation level. (45 hrs). 2006
- Lessons of Polish language. Prolog. Krakow, Poland. Conversation level. (90 hrs). 2005
- Lessons of Polish language. Prolog. Krakow, Poland. Conversation level. (130 hrs). 2003
- Lessons on Polish language and civilisation (100 hrs). Granada, Spain. 2001-2002.
- Participation in the 1st International Congress on the assessment of quality in conference interpreting. University of Granada. Almuñécar, Spain. 2001.
- Diplôme Approfondi de la Langue Française du Ministère de l'Éducation nationale. 1998
- Certificate of Proficiency in English of Cambrige University. 1995.

WORKING LANGUAGES

- Mother tongue: Spanish.
- Translation and interpret from: French, English, Spanish and Polish.
- Additional interpret into: Spanish, English and French.

PROFESSIONAL EXPERIENCE CONFERENCE INTERPRETING

Since 2001: Simultaneous and consecutive interpreter during various conferences and international meetings (over 80 assignments a year):

- International organizations: FAO's General Fisheries Commission for the Mediterranean, Committee of the Regions, IUCN, INTERPOL.
- High-level politics: personal interpreter for the 3rd Vice-President of the Spanish Government, Mr. Chaves, during the Spanish presidency of the EU.
- European Social Dialogue & Projects: Fisheries, Civil Aviation; EQUAL, INTERREG.
- Nature and the environment: IUCN, MedPan, United Nations' Environmental
- Programme & CBD's Workshop to describe EBSAs, Integrated management of coastal areas, Aquifer management, Natural parks, Climate change, Seagrass.
- Flight training: Airbus EC-145 C-2 helicopter.
- Law: 13th International Conference on International Law on Biodiversity.
- Corporate meetings: Accenture CIO, Abener, Acciona.
- Technical meetings: CIATESA, wastewater treatment, high speed train engineering.
- Medicine: Physical Therapy, Colonoscopy for Colorectal Neoplasia, Paediatrics, Prosthesis Surgery.
- Energy: Training on Thermosolar and Photovoltaic Energy, Solefex project.
- Sports: International Committee of the Mediterranean Olympic Games, Trekking.
- Psychology: European Psychology Congress, Mediation, Autism.

TRANSLATION AS A FREELANCER

- Since 2001: Legal, economic, technical, scientific and sworn translations for different Spanish and international firms (Inboca S.L., Azafatas Alhambra S.L., SWIFT IT S.L., Word Works S.L., Armaris Traduction S.A.R.L., Merril Brink International, RR Donnelley).

SPECIALISATION FIELDS

- Environmental protection and protected areas: MAIA project (working documents, website), seagrass, marine protected areas, natural parks.

- Legal, financial and economic documents, corporate policies, and sworn translations: memorandum and articles of association; files for trials; sentences; contracts; academic documents; certificates; powers of attorney; criminal records; death and birth certificates; corporate policies, financial statements (M&G Investment Funds, Fidelity Investment Funds).
- Medicine: therapeutic information (limphedema, carotid stents); documents of medical instruments (Amsco Century, Radionics); documents on drugs (Viagra); validation studies (Kedrion); interpreting in congresses on physical therapy, cranial surgery and respiratory infections.
- EU-related documents: documents, draft projects, reports, and questionnaires.
- Literary translation: museum catalogues, biographical books

IN-HOUSE TRANSLATION

- Translator-Analyst in Area25 Informática y Telecomunicaciones S.Coop.And. Granada, Spain. (Translating web pages and interfaces), 2002-2003.
- Work placement as junior translator in the firm S.A.R.L. Armaris Traduction. Toulon, (France), 1999.

Fig. 23. Course room with the interpretation cabin for English to French interpretation

5. COURSE PARTICIPANTS

The following 19 persons (from 6 MENA countries) attended and actively participated into the course.

Algeria	
Mr. Abdelaziz Lardjoum Ministére des Ressources en Eau Potable Sous Directeur Tel. +213 771 11 20 79, +213 663 707 797 azizlardjoum@yahoo.fr a_lardjoum@mre.dz	Mr. Nacer Riad Bendaoud Association Ecologique de Boumerdes President Tel. +213 771594353, +213 550888053 rmb_algerie@yahoo.fr
Mr. Nasser Eddine Chekired	Mme Hanane Abu-Rideh

ADE (Algerienne des Eaux) Chef de Département Tel. +213 770893502 nchekired@yahoo.fr	Centre d'Energie Renouvelable Tel. +213 555 725728 h_aburideh@yahoo.fr
Jordan	
Mr. Tal'at Al Dabbas Ministry of Environment Director of Balqaa Tel.+962 655 60113, +962 799 534901 talataldabbas@hotmail.com	Mr. Ibrahim Alshakhanbeh Ministry of Water and Irrigation Project Management Engineer Tel. +962 772477924 ibrahim_alshakhanbeh@MWI.gov.jo alshakhanbeh@hotmail.com
Mr. Mohammed Aldwairi Ministry of Water and Irrigation Project Management Engineer Tel. +962 795228044 mohammad.aldwairi@mwi.gov.jo Mohammad778@gmail.com	Mr. Mehyar Munqeth Eco Peace/foEME President Tel. +962 65866603, +962 7955448477 munqeth@foeme.org
Lebanon	
Mr. Nizar Abou Darwich Ministry of Energy and Water Head of Electric Equipment Service Tel. +961 1565075, +961 3233135 nizaraboudarwich@hotmail.com	Mr. Imad Menhem Ministry of Energy and Water Engineer Tel. +961 1567412 i_menhem@hotmail.com
Ms. Sabine Ghosn Ministry of Environment Environmental Specialist Tel. +961 1976555 (ext 519) s.ghosn@moe.gov.lb	
Morocco	
Mr. Abderraouf Benabou Directorate of Electricity and Renewable Energy, Ministry of Energy, Mines, Water and Environment. Chief, Division of Electric and Rural Tel. +212 537 68 87 69, +212 641 99 38 74 a.benabou@mem.gov.ma	Ms. Siham Laraichi Ministere delegue aupres du Ministre de l'Energie, des Mines, de l'Eau et de l'Environnement, Charge de l'Eau Ingenieur d'etat Tel. +212 537778690, +212 675533495 siham.laraichi@gmail.com laraichi@water.gov.ma
Palestine	
Mr. Rebhy El Sheikh Palestinian Water Authority Deputy Head Tel. +972 82827409,	Mr. Hussein Alnabih Palestinian Energy Authority Director General - Energy & Electricity Tel. +970 22986191,

+972 599 267103 relsheikh@pwa-gpmu.org	+970 599733520 h_alnabih@hotmail.com husseinnabih@gmail.com
Mr. Sadi Ali Palestinian Water Authority Tel. +972 8 282 7409	
Tunisia	
Mr. Abderrahman Ouasli Ministere de L'Agriculture Bureau de Plantification et des Equilibres Tel. +216 71781247, +216 98645508 waslyab@yahoo.fr	Mr. Ferid Skiker Ministére de L'Agriculture Chef de Service de Production Tel. +216 58305173, +216 98317329 skiker.ferid@voila.fr
Ms. Awatef Messai Ministére Change d'Environnement Ingénieur en chef Tel. +216 70728644, +216 91666206 awatef.messai@yahoo.fr	

6. SOCIAL EVENTS

Course fee included all hotel, meals, transport and visit expenditures since the arrival of the participant to the defined hotel to the event (Hotel Tryp Indalo Almeria). The intense course was complemented with a significant number of social side events to foster people interaction (both between them and the professors). With the only exception of arrival and final days (just before departure), the rest two dinners were scheduled outside the hotel. Once of these two dinners took place in a typical Andalusian tapas-tavern, located at walking distance from the hotel and, the second, in a seafood restaurant by the sea (in this case, the transport took place by bus).

Fig. 24. Pictures of the two outside dinners

All lunches were organized at the hotel in order to save time for the lecturing. The only exception was the final day due to the visit to PSA (located in Tabernas, about 35 km from Almeria). After the technical and working visit, a well know nearby restaurant was selected to lunch were the course certificates were distributed to the attendants.

Fig. 25. Delivery of course certificates (final lunch in Tabernas village)

After returning from the visit, the farewell was made by the course professors. The rest of the afternoon was profited to try to get the money transfers to the attendants (unfortunately, not all of them could got it).

Fig. 26. Final participants group picture with Miriam Balaban at hotel lobby

7. CONCLUSION. COURSE OUTCOME

At the end of the course the participants received the following information:

- A complete review of the current technological status (main components and performance features) and worldwide development of all solar energy technologies for power production (photovoltaics and CSP).

- A complete review of the current technological status and worldwide development of solar technologies for thermal energy collection and supply in the whole temperature range:
    - Flat plat collectors (low temperature)
    - Parabolic trough and linear Fresnel (medium temperature)
    - Tower (central receiver) technologies (high temperature)
- A complete review of conventional and innovative desalination technologies, suitable to be coupled with solar energy.
- A full analysis of cost status for both power/energy and water production with both conventional and solar energy technologies.

After the course, it is considered that the attendants could understand:

- How the thermal storage can convert uncontrollable solar energy into full reliable and dispatchable continuous energy/power.
- Why the nominal installed power should never be used to compare different renewable energy facilities.
- Why despite the strong reduction of cost on PV, this technology cannot solve all problems when dealing with solar desalination.
- All reasons and arguments that justify the necessity of developing suitable and cost effective solar desalination technologies.

And, finally, it is also considered that the could learn (or they are in a very good position to learn from the provided material):

- How to design and assess the performance of static solar collector fields to provide low temperature process heat for specific thermal desalination technologies.
- How to calculate and design parabolic trough solar fields to provide process heat to MED or MSF thermal desalination processes.
- How to design and size solar PV fields for SWRO applications.
- How to select among different PV technologies to specific projects.
- How to assess the water cost of different desalination processes when driven by solar energies.