New Water New Energy

A Conference Linking Desalination and Renewable Energy

56th Annual New Mexico Water Conference Proceedings

NM WRRI Report No. 360

December 13-14, 2011, Alamogordo, New Mexico

New Mexico Water Resources Research Institute

RECLAMATION

56th Annual New Mexico Water Conference Highlights

Most participants of the annual WRRI water conference attended tours of the Brackish Groundwater National Desalination Research Facility in Alamogordo.

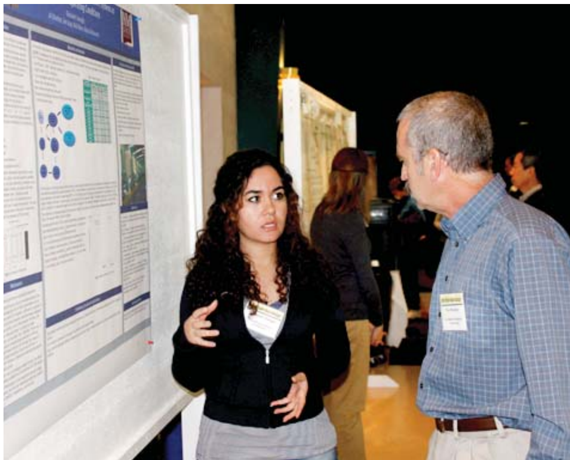
Over 40 participants took part in breakout groups charged with developing project descriptions for research projects that couple renewable energy to brackish desalination systems for small communities. Reclamation's Kevin Price (standing) gave instructions to experts.

Breakout groups of five or six members met for a morning to develop project descriptions that were later presented to the afternoon plenary session.

Mike Hamman of the Bureau of Reclamation's Albuquerque office presented New Mexico State University President Barbara Couture with a plaque commemorating the 2010 signing of the cooperative agreement between Reclamation and NMSU to conduct advanced water treatment research at the Brackish Groundwater National Desalination Research Facility.

Nearly 150 participants attended the day-and-a-half conference including desalination experts from Australia, Europe, the Middle East, North Africa, Canada, and Singapore.

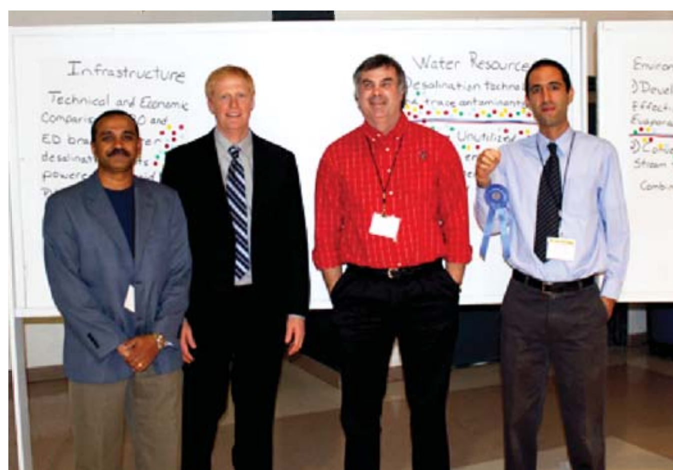
New Water New Energy:
A Conference Linking Desalination and Renewable Energy



The second day of the conference included fourteen poster presentations on various water-related topics. The posters and oral presentations were sponsored by Sandia National Laboratories.

After breakout group spokespersons presented their top projects, conferees weighed in on which projects they deemed most critical. The top project from this process proposed an integrated photovoltaic and solar thermal system to treat brackish water in remote areas. Breakout members from left are Michael Landis, Guillermo Zaragoza, Ardeth Barnhart, Hill Kemp, Mitch Haws, and Kevin Black.

Fifteen oral presentations were given in response to the Call for Abstracts. Topics included algae production, sources and treatment of alternative water supplies, treatment, use, and disposal of desalination by-products, and the interaction of soils and surface water.



The project conferees deemed second-most critical is an effort to better understand the role of trace contaminants in various desalination technologies. The proposal was advanced by the group including (from the left) Ali Sharbat, Sam Fernald, Ken Rainwater, and Jaya Tharamapalan.

photos by Will Keener

The project described in this publication was supported by Grant/Cooperative Agreement Number G12AC20006 from the United States Geological Survey. Its contents are solely the responsibility of the authors and do not necessarily represent the official views of the USGS.

Proceedings

56th Annual New Mexico Water Conference
NM WRRI Report No. 360

New Water New Energy: A Conference Linking Desalination and Renewable Energy

presented by

Reclamation
New Mexico Water Resources Research Institute

December 13-14, 2011
Alamogordo, New Mexico

Co-sponsored by

New Mexico State University
Institute for Energy and the Environment, NMSU
Sandia National Laboratories

New Mexico
Water Resources Research Institute

RECLAMATION

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2011 Water Conference Planning Committee

Angela Adams, Reclamation, Yuma Area Office, AZ

Sam Fernald, New Mexico Water Resources Research Institute

Catherine T. Ortega Klett, New Mexico Water Resources Research Institute

James Loya, Institute for Energy and the Environment, New Mexico State University

M. Kevin Price, Reclamation, Denver, CO

Lara Riele, Reclamation, BGNDRF, Alamogordo, NM

Randy C. Shaw, BGNDRF, Alamogordo, NM

56th Annual New Mexico Water Conference Program

New Water New Energy: A Conference Linking Desalination and Renewable Energy

Tuesday, December 13

9:30 - 11:30 am	Brackish Groundwater National Desalination Research Facility (BGNDRF) Tours (optional, 30-minute tours)
1:00 pm	Plenary Session Introductions • Sam Fernald, WRRI Director • Ron Griggs, Alamogordo City Mayor • Jim Loya, Institute for Energy and the Environment, NMSU • Mike Hamman, Manager, Albuquerque Area Office Bureau of Reclamation
1:30	Guillermo Zaragoza, Project Researcher Promotion of Renewable Energy for Water Production through Desalination (ProDes) Training Session and Review of the European Program
3:30	Break
3:45	Bekele Debele, Middle East and North Africa Region, World Bank
4:05	David Furukawa, Chief Scientific Officer, National Center of Excellence in Desalination, Australia
4:30	Joseph Jacangelo, WateReuse Research Foundation
5:00	Break
5:15	Kevin Black and Mitch Haws, Phoenix Office, Bureau of Reclamation Projects
5:40	Ali Al-Qaraghuli, National Renewable Energy Laboratory
6:30 - 8:30 pm	Working Dinner for Expert Groups

Wednesday, December 14

8:00 am	Track 1 - Expert Groups Continue to Work on Project Recommendations (at BGNDRF) Track 2 - Posters and Oral Presentations (at Civic Center)
12:00 noon	Luncheon for Plenary Group (at Civic Center) Welcome by Barbara Couture, New Mexico State University President David Townsend, Local Historian, Professor Emeritus, NMSU/Alamogordo
2:00 pm	Expert Group Presentations of Proposed Projects to plenary Group
3:15	Proposed Projects Review Participants Vote on Top Two Proposed Projects Kevin Price, Bureau of Reclamation Provides Initial Summary
5:30 - 6:00 pm	Adjourn (followed by optional tours of BGNDRF)

Introduction

The U.S. Bureau of Reclamation (Reclamation) and the New Mexico Water Resources Research Institute (NM WRRI) sponsored a day-and-a-half conference to identify U.S. research needs concerning inland, small-scale, low-cost rural brackish desalination water projects using renewable energy such as solar, wind, geothermal, and waste heat sources. The conference brought together about 150 participants to gain a better understanding of the topic and to propose projects relevant to rural communities. The NM WRRI coordinated the conference with the assistance of Reclamation and the Brackish Groundwater National Desalination Research Facility (BGNDRF).

The conference took place in Alamogordo, New Mexico, the home of the BGNDRF, on December 13-14, 2011. Tours of the desalination research facility were held before and after the conference and most conference participants attended a tour. The BGNDRF is a focal point for developing technologies for the desalination of brackish and impaired groundwater found in U.S. inland states. The facility brings together researchers from federal government agencies, universities, the private sector, research organizations, and state and local agencies to work collaboratively and in partnership. The facility's mission is to pursue research into supply-enhancing technologies using brackish groundwater sources including solutions to concentrate management, renewable energy/desalination hybrids, desalination technologies for produced water, and small-scale desalination systems. Water desalination apparatuses being developed by entities such as New Mexico State University, University of Texas at El Paso, General Electric, Veolia, Reclamation, and others were highlighted during the tours.

The conference convened experts from several continents, bringing attention to the important linkages between renewable energy sources and desalination of brackish groundwater. International experts representing Europe, Australia, the Middle East, Northern Africa, Canada, and Singapore described state-of-the-art projects and their applicability to inland states such as New Mexico.

Objectives

The conference objectives were to:

1. identify U.S. research needs concerning new approaches and techniques applicable to inland, small-scale, low-cost rural brackish desalination water projects using renewable energy sources;
2. identify research priorities for projects that can be conducted at the BGNDRF or elsewhere;
3. identify potential collaborations for proposed projects; and
4. distribute the results of the conference broadly.

To meet the first objective, a conference planning committee comprising staff from Reclamation, the NM WRRI, and BGNDRF held regular conference calls for several months prior to the event. Planning committee members identified and invited participants with an interest in the topic including researchers and users of the technology; invited speakers to give presentations to conference participants informing attendees on current regional, national, and international projects focused on desalination using renewable energy; and identified and invited experts to serve in working groups whose charge would be to identify relevant projects.

The conference's second objective was to identify research priorities for projects that could be conducted at facilities such as the BGNDRF. The invited members of the working groups were assigned to one of eight break-out groups: wind, solar, geothermal, action, infrastructure, water resources, environmental impacts, and institutional considerations (see break-out group participants below). A week prior to the conference, members of the working groups were provided with a sample Project Description Sheet and Participant Instructions. At dinner on the first evening of the conference, a table was assigned to each break-out group and members of the group met each other and agreed on a group facilitator. Reclamation staff member, Kevin Price, provided an overview of the Project Description Sheet, Participant Instructions, Facilitator Instructions, and the proposed protocol for the next day. Each group was asked to meet the next morning, complete Project Description Sheets, and present their agreed upon top projects to the plenary group during the afternoon session. After projects were presented in a plenary conference session, each conference participant voted on their favorite proposed projects.

The third objective was to identify potential research and dissemination collaborators. The Project Description Sheet included a request to identify Proposed Partners for each project.

The final conference objective was to prepare a final report that would be posted on Reclamation's and NM WRRI's websites. This report provides a conference proceedings including PowerPoint presentations from plenary speakers, two top-ranked project descriptions, other break-out group project descriptions, and links to relevant papers as provided by plenary speakers.

Break-out group participants

Action
Mike Hightower, Sandia National Laboratories
Larry Jessup, Veolia Water
Randy Shaw, Reclamation, Brackish Groundwater National Desalination Research Facility, Alamogordo
Wendel Ela, University of Arizona
Tommy Fuller, Holloman Air Force Base, Alamogordo

Environmental Impacts
Anthony Tarquin, University of Texas at El Paso
Kevin Price, Reclamation, Denver
Jill Shaunfield, U.S. Department of State
Shahid Chaudhry, California Energy Commission
Jalal Rastegary, Institute for Energy and the Environment, New Mexico State University

Geothermal
Jorge Arroyo, Texas Water Development Board
Tom Davis, Center for Inland Desalination Systems, University of Texas, El Paso
Jim Witcher, Witcher and Associates
Jim Loya, Institute for Energy and the Environment, New Mexico State University
Amy Halloran, Sandia National Laboratories

Infrastructure
Ali Al-Qaraghuli, National Renewable Energy Laboratory
Katie Guerra, Reclamation, Denver
Neil Moe, General Electric

Institutional Considerations
Andrea Achilli, University of Nevada, Reno
Ian Watson, American Membrane Technology Association
Mike Hamman, Reclamation, Albuquerque
John Hawley, Hawley Geomatters, Inc.
Miguel Rocha, Reclamation, Denver

Solar
Kevin Black, Reclamation, Phoenix
Michael Landis, Reclamation, El Paso
Guillermo Zaragoza, Plataforma Solar de Almeria
Hill Kemp, Kll, Inc. Suns River
Ardeth Barnhart, University of Arizona
Mitch Haws, Reclamation, Arizona, Phoenix

Water Resources
Alexander Fernald, New Mexico Water Resources Research Institute
Jaya Tharamapalan, University of Central Florida
Bekele Debele Negewo, World Bank
Ken Rainwater, Texas Tech University
Ali Sharbat, Institute for Energy and the Environment, New Mexico State University

Wind
James Stalker, Precision Wind
Linda Reekie, Water Research Foundation
Peter Fox, Arizona State University
Dave Furukawa, National Centre of Excellence in Desalination, Australia
Joe Jacangelo, WateReuse Research Foundation
Angela Adams, Reclamation, Yuma, AZ

Promotion of Renewable Energies for Water Production through Desalination

Guillermo Zaragoza, Plataforma Solar de Almeria

Dr. Guillermo Zaragoza is a senior scientist at the Plataforma Solar de Almería (PSA), which is the largest center for research, development, and testing of concentrating solar technologies in Europe and a reference in solar energy for the last 30 years. PSA is a division of the Center for Energy, Environment and Technological Research (CIEMAT), part of the Ministry of Science and Innovation that acts as a public research agency for excellence in the areas of energy, environment, and technology.

Dr. Zaragoza has a degree in astrophysics and a PhD in applied physics. He has worked at the Instituto de Astrofisica de Andalucía of the Spanish Research Council and the Atmospheric Physics department of the University of Oxford but with the new millennium moved to sunnier climates to work on solar energy. He has participated in several European R&D projects on solar thermal energy and desalination. His lecturing activities include a master course on solar energy at the University of Almería and an international course on desalination with solar energy organized by the European Desalination Society.

One of the projects he has been involved with is ProDes (Promotion of Renewable Energy for Water production through Desalination), which brought together fourteen leading European organizations to support the market development of renewable energy desalination in Southern Europe. The project started on October 1, 2008, and continued for two years, facilitating collaboration between RE-desalination technology providers and SMEs on the local level. It also supported communication between technology providers and investors. It developed courses and a road-map on RE-desalination, and provided recommendations for improving the legislative and institutional conditions in each country. It also provided training for students and professionals. Dr. Zaragoza is a founding member of the RE-desalination working group, which aims to carry on the torch of ProDes project.

Relevant Paper: Roadmap for the Development of Desalination Powered by Renewable Energy *(http://wrri.nmsu.edu/conf/conf11/prodes_roadmap_online.pdf)*

PowerPoint Presentation **http://wrri.nmsu.edu/publish/watcon/proc56/Zaragoza.pdf**

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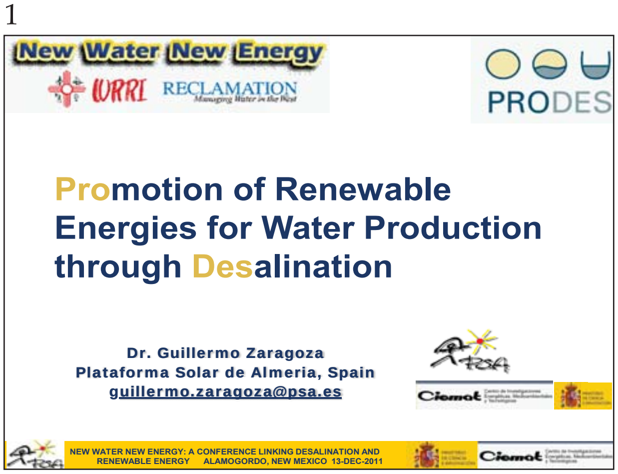

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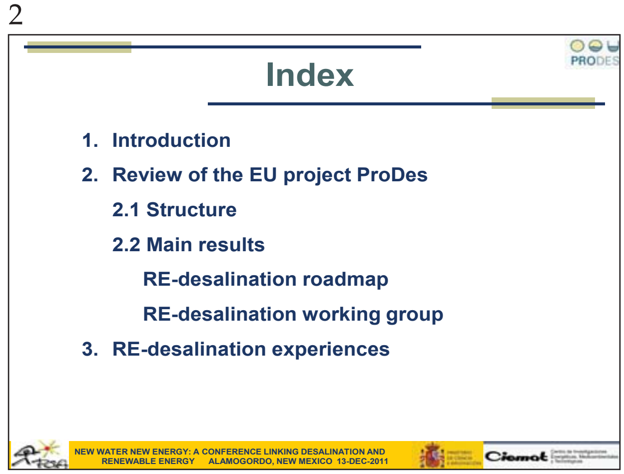

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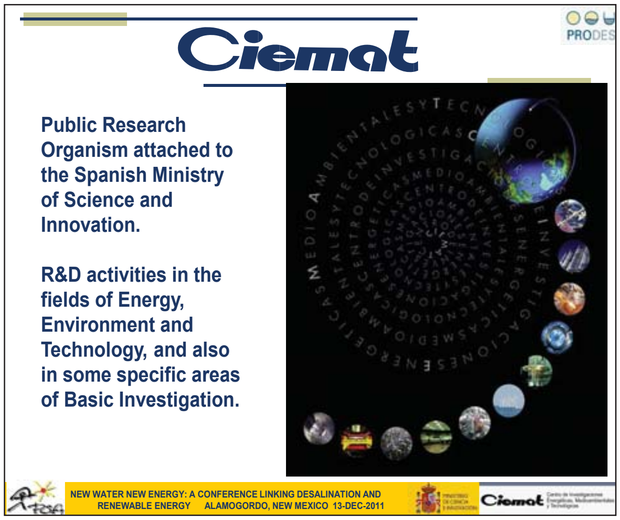
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PRODES
Public Research Organism attached to the Spanish Ministry of Science and Innovation.
R&D activities in the fields of Energy, Environment and Technology, and also in some specific areas of Basic Investigation.
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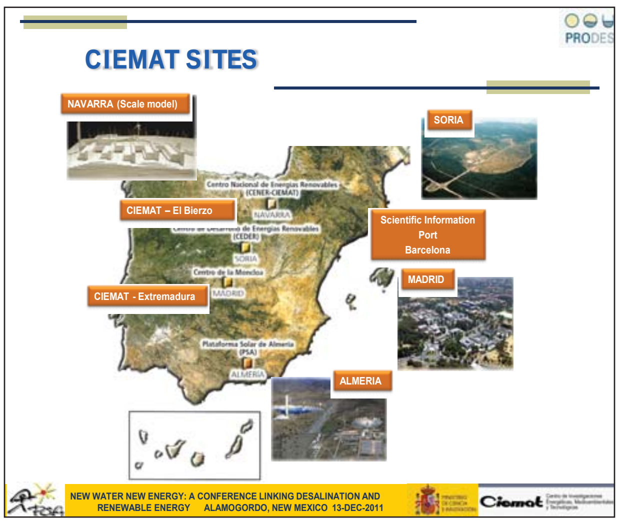
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CIEMAT SITES
NAVARRA (Scale model)
SORIA
CIEMAT – El Bierzo
Scientific Information Port Barcelona
MADRID
CIEMAT - Extremadura
ALMERIA
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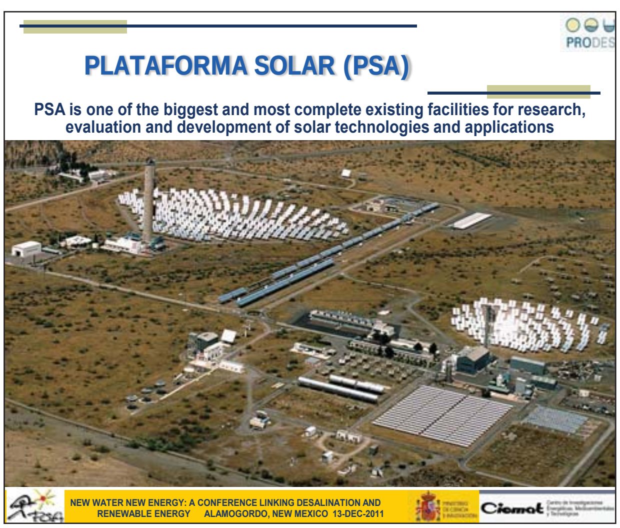
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PLATAFORMA SOLAR (PSA)
PSA is one of the biggest and most complete existing facilities for research, evaluation and development of solar technologies and applications
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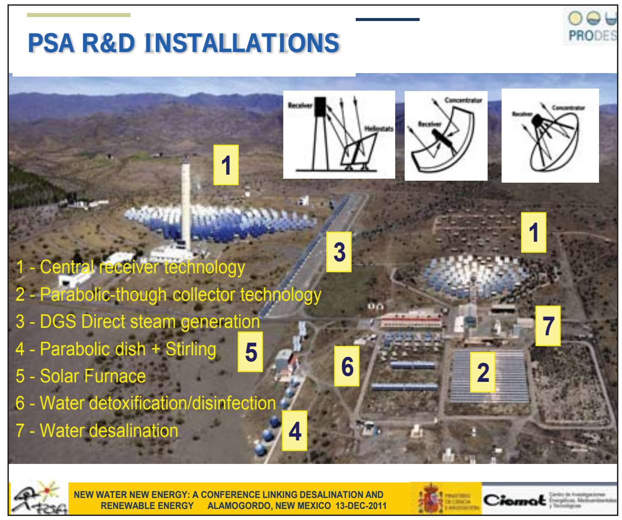
PRODES
PSA R&D INSTALLATIONS
1 - Central receiver technology
2 - Parabolic-though collector technology
3 - DGS Direct steam generation
4 - Parabolic dish + Stirling
5 - Solar Furnace
6 - Water detoxification/disinfection
7 - Water desalination
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ENVIRONMENTAL APLICATIONS OF SOLAR ENERGY
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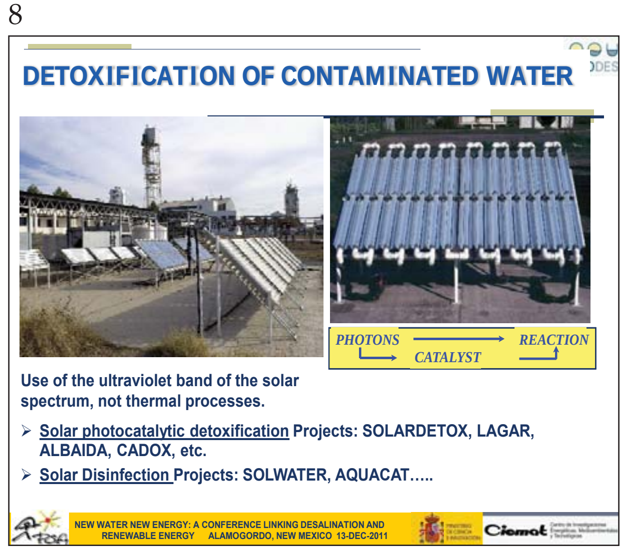
DETOXIFICATION OF CONTAMINATED WATER
PHOTONS
REACTION
CATALYST
Use of the ultraviolet band of the solar spectrum, not thermal processes.
Solar photocatalytic detoxification Projects: SOLARDETOX, LAGAR, ALBAIDA, CADOX, etc.
Solar Disinfection Projects: SOLWATER, AQUACAT.....
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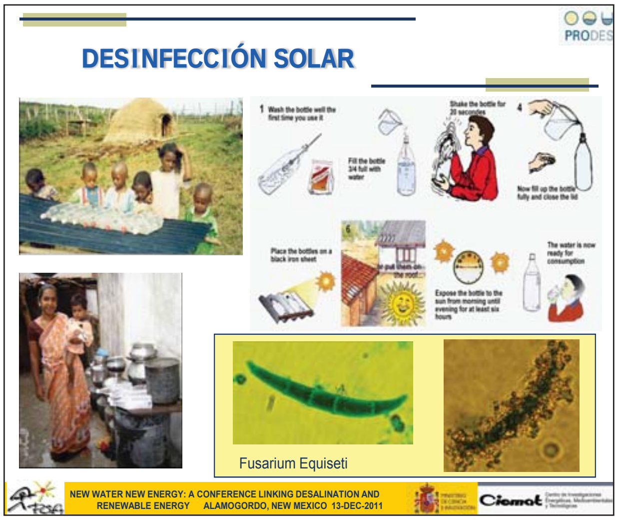

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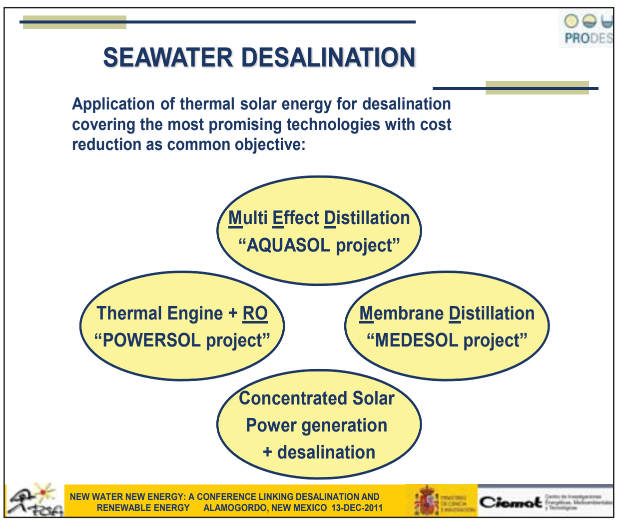

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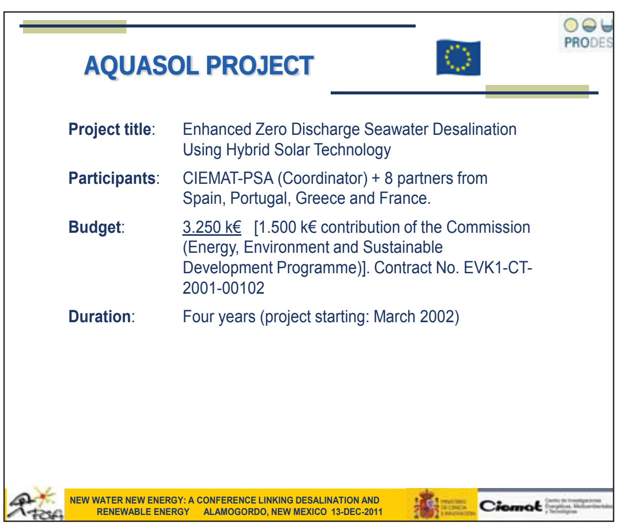

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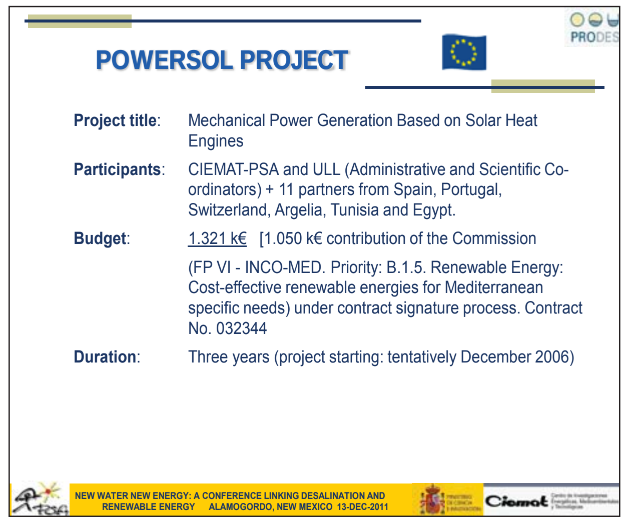

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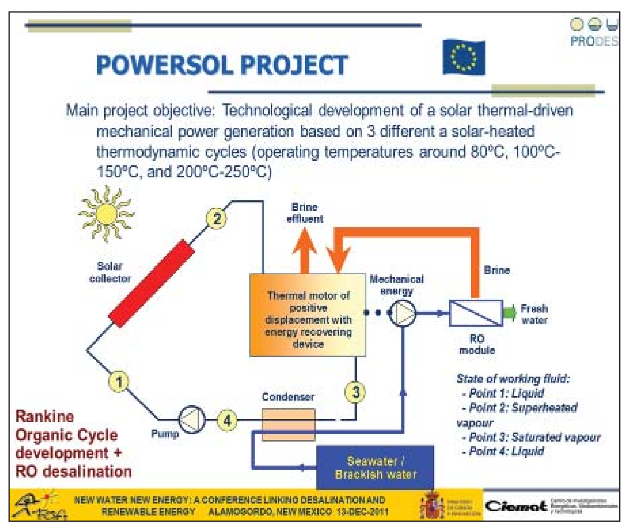

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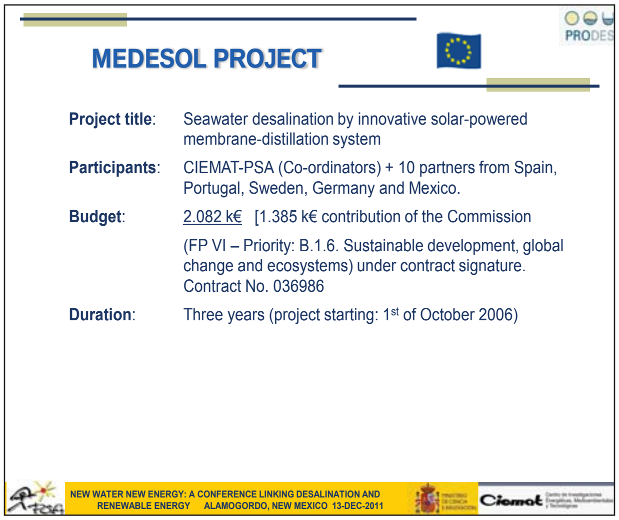

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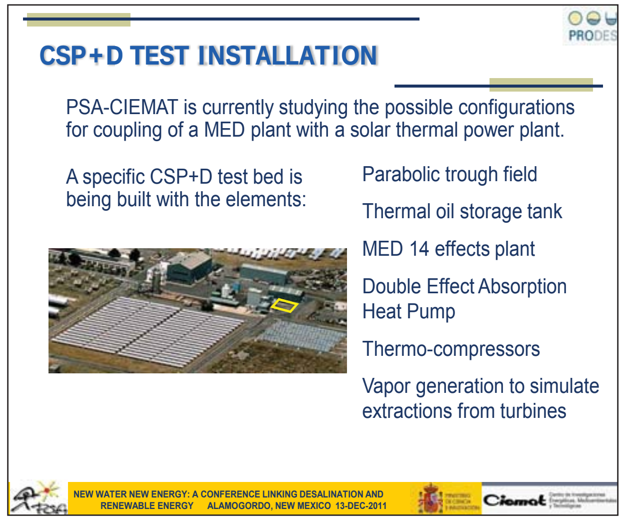

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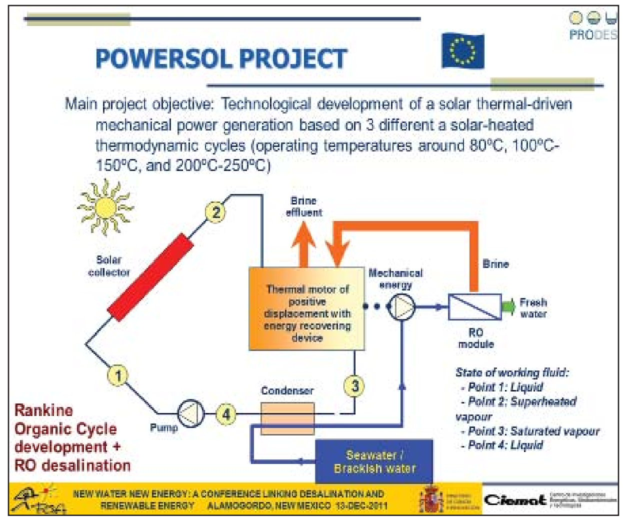

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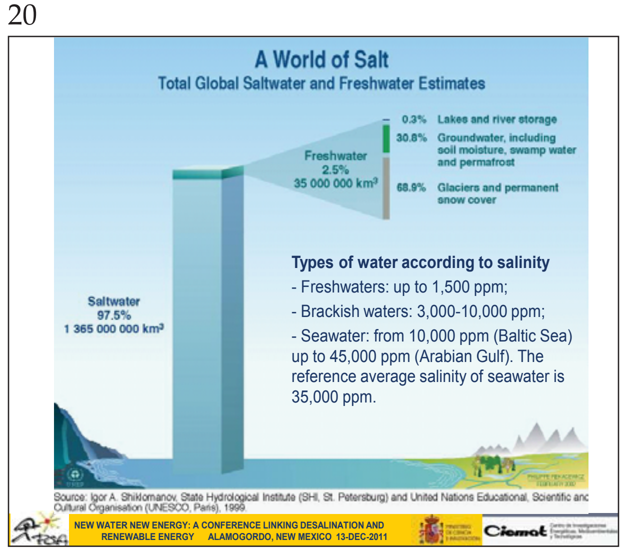

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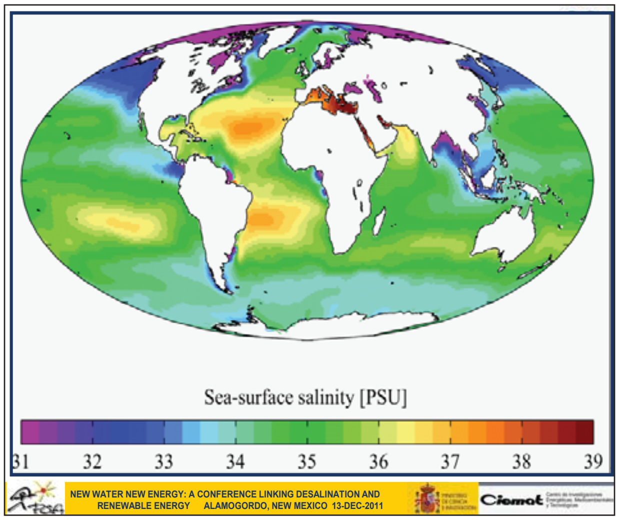

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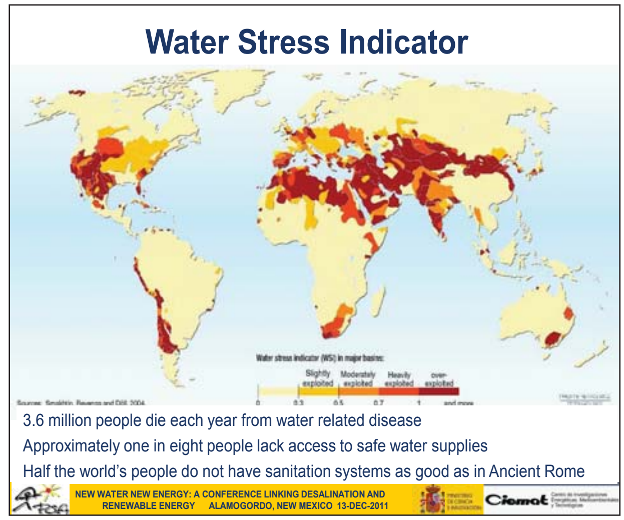

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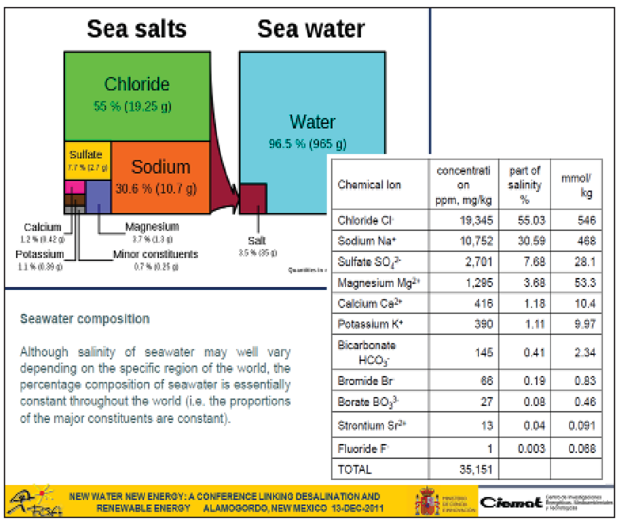

Chemical Ion	concentration ppm, mg/kg	part of salinity %	mmol/ kg
Chloride Cl^-	19,345	55.03	546
Sodium Na^+	10,752	30.59	468
Sulfate SO_4^{2-}	2,701	7.68	28.1
Magnesium Mg^{2+}	1,295	3.68	53.3
Calcium Ca^{2+}	416	1.18	10.4
Potassium K^+	390	1.11	9.97
Bicarbonate HCO_3^-	145	0.41	2.34
Bromide Br^-	66	0.19	0.83
Borate BO_3^{3-}	27	0.08	0.46
Strontium Sr^{2+}	13	0.04	0.091
Fluoride F^-	1	0.003	0.068
TOTAL	35,151		

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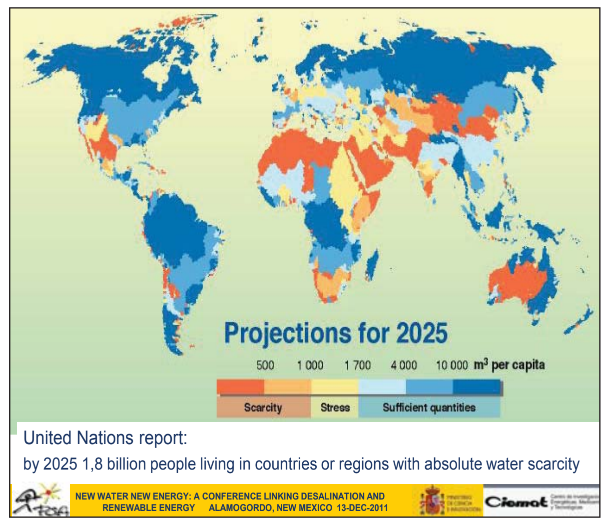

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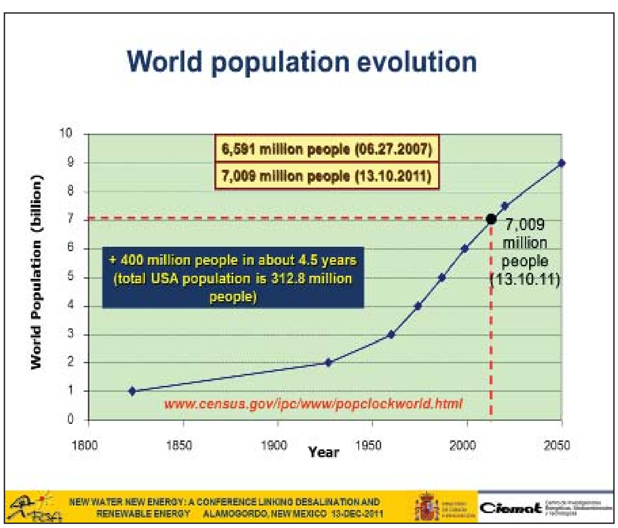

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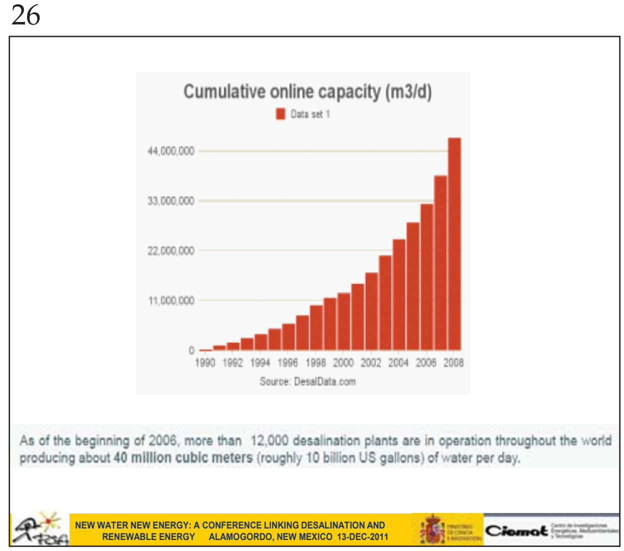

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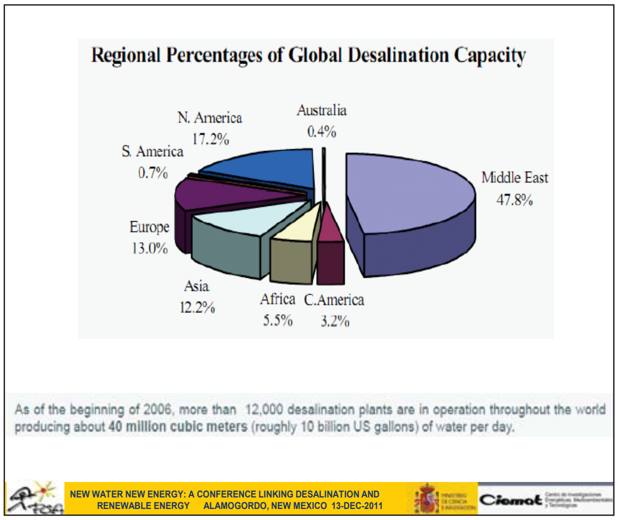

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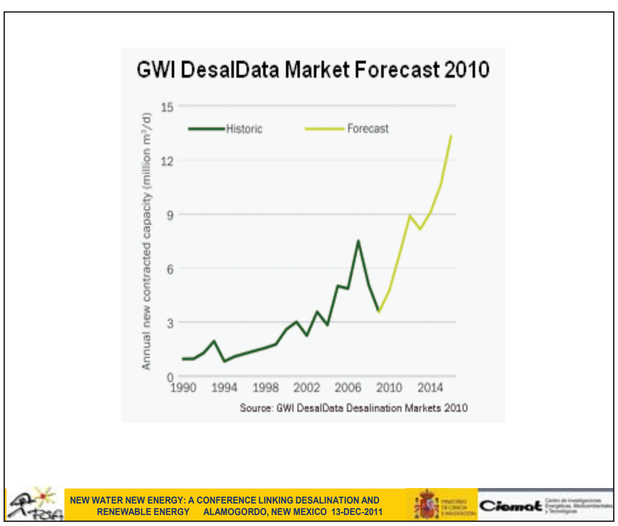

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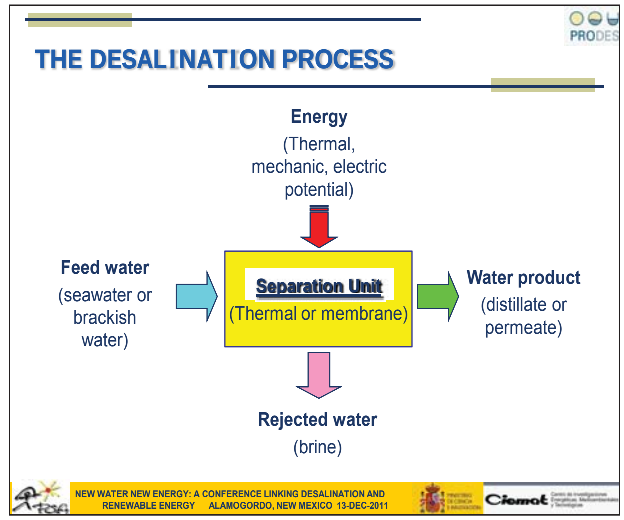

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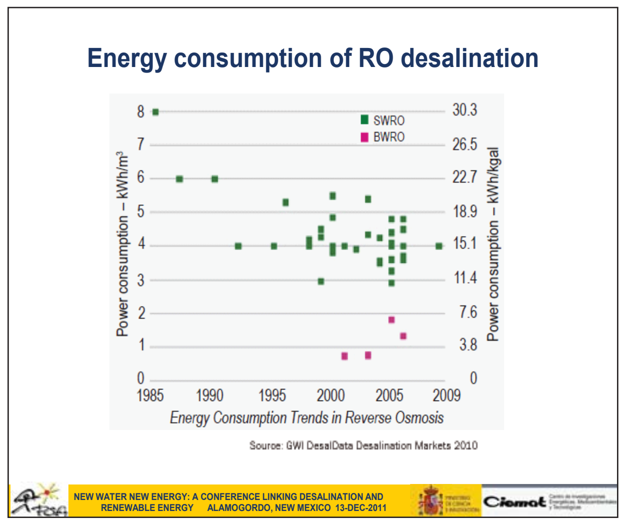

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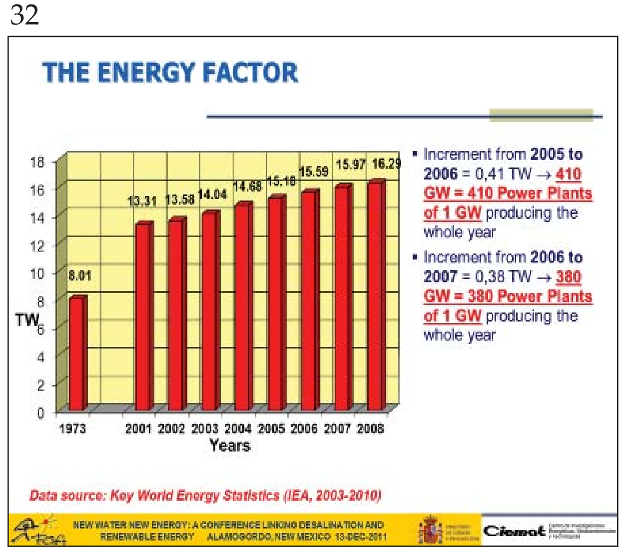

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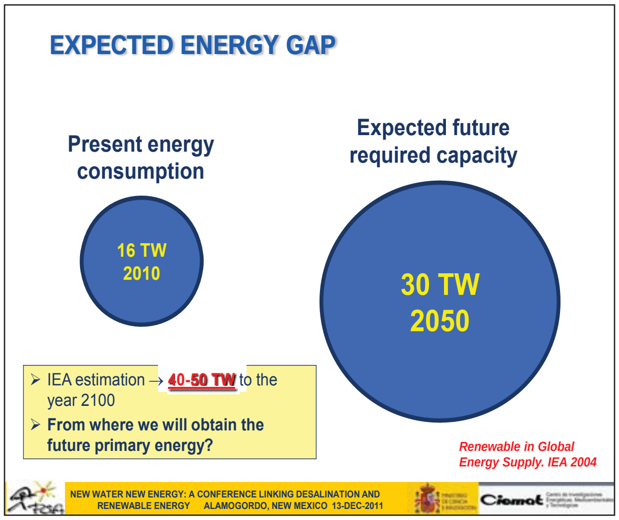

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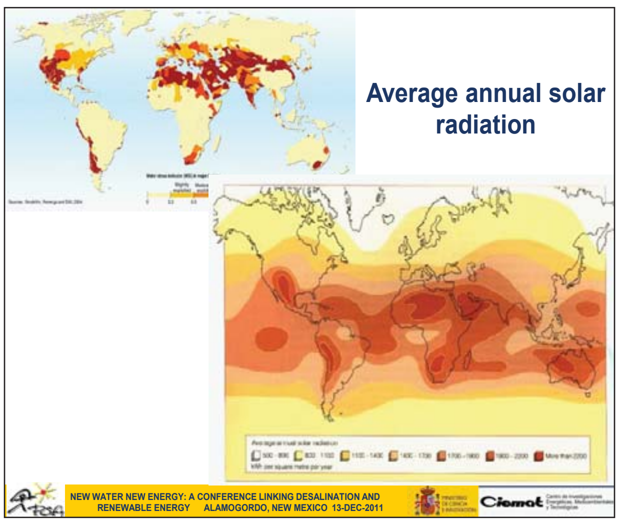

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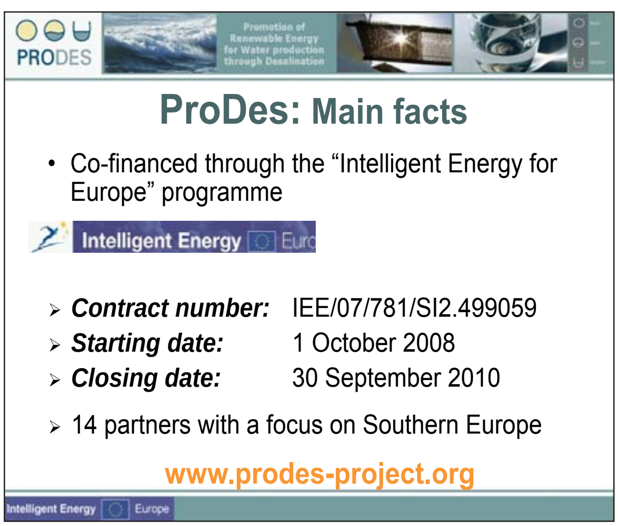

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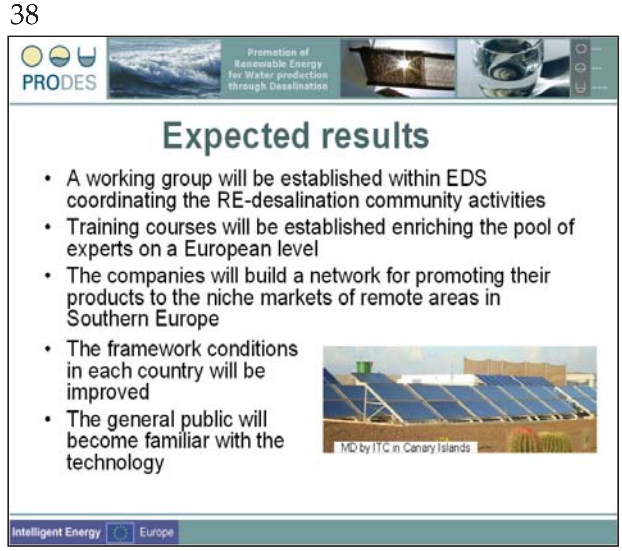

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Specific objectives of PRODES

- Develop & communicate a road-map on RE-desalination
- Develop courses and provide training for students and professionals
- Facilitate collaboration between RE-desalination technology providers & SMEs on the local level
- Support communication and understanding between technology providers & investors
- Provide recommendations for the improvement of the legislative & institutional conditions

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Workpackages of PRODES

- Transfer of research results to the market
- Introducing RE-desalination to higher education
- Creating the link with the market
- Mobilizing investment
- Legislative and Institutional Issues

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PRODES
Transfer of research results to the market

Identify the research needs of the industry for developing competitive products ready for the market.

Find know-how pools within the academic community or other research performing entities.

A large number of relevant stakeholders consulted during that process

RE Desalination Roadmap

presented and discussed in a dedicated event within a conference organised by the European Desalination Society (Baden Baden 2009).

RE Desalination Working Group which will operate independently from the project to be established and integrated in the structures of the European Desalination Society.

The main task of this group is to update the road-map and follow-up its implementation after the completion of ProDes.

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PRODES
Introducing RE-desal to higher education

RE-desalination introduced in the **higher education** system of relevant countries in order to fill the knowledge gap and help produce the missing specialists that will work with entrepreneurs active in this fast emerging market.

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THEORY CONTENT (themes are presented with their relative contribution to the total)

1. Introduction. Basics and principles of salt water chemistry. Definition and fundamentals of desalination. Historical overview . [5%]

2. Conventional desalination processes and technologies. State of the art of desalination industry. Current technologies, their evolution and perspectives. [15%]

3. Renewable energies in relation to desalination. State of the art of renewable energy generation technologies and their application to desalination processes. [7.5%]

4. Technologies for desalination powered by renewable energy. Description of the basics of the technology and the development of the engineering of several desalination processes powered by solar energy.

4.1. Solar thermal energy and desalination.

4.1.1. Solar stills. Simple distillation systems based on the passive evaporation of saline water in greenhouse-type devices. [5%]

4.1.2. High capacity solar thermal distillation. Advanced systems of thermal distillation using active solar heating, as multi-effect distillation (MED) and multi-stage flash distillation (MSF). [5%]

4.1.3. Solar thermal membrane distillation. Thermally-driven systems based on hydrophobic micro-porous membranes to separate vapour from a salt water stream through the establishment of a vapour-liquid interface between both sides of the membrane. [7.5%]

4.1.4. Solar thermal humidification/dehumidification. Technologies that replicate the natural cycle of water, with evaporation of saline water and condensation at atmospheric pressure. [5%]

4.1.5. Solar ponds. Thermal desalination processes coupled with salinity-gradient solar ponds as a source of thermal energy. [5%]

4.2. Solar photovoltaic and desalination. Combination of electricity produced by solar photovoltaic energy and desalination using techniques of reverse osmosis and electrodialysis reversal. [10%]

4.3. Wind energy and desalination. Combination of electricity produced by wind energy and desalination using techniques of reverse osmosis and electrodialysis reversal. [10%]

4.4. Other renewable energy sources and desalination. Other processes which associate wave, tidal or geothermal energy generation with desalination. [5%]

5. Design and operation of desalination plants powered by renewable energy. Operation and management of industrial plants. Control and remote monitoring systems. Handling of detrimental effects as scaling, corrosion and fouling. Necessary pre-treatments and post-treatments to guarantee successful plant operation. Optimization of energy consumption and water cost. [10%]

6. Environmental issues on desalination powered by renewable energy. Environmental implications of desalination technologies and their association with renewable energies. [5%]

7. Economic and sustainability issues of desalination powered by renewable energy. Basic economics of the described technologies, costs of operation and maintenance, desalinated water tariff, etc. Sustainability also entails other aspects of society, as the policies of desalination and the involvement of the local community. [5%]

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PRODES
Introducing RE-desal to higher education

PRACTICAL CONTENT (themes are presented with their relative contribution to the total)

1. Practical assessment of solar energy resource. Basics of solar radiation measurement equipment and procedures. Available meteorological data suitable for solar radiation assessment. Characterization of solar radiation resources from in-situ measurements or meteorological data series. [15%]

2. Practical assessment of wind energy resource. Basics of wind energy resource measurement equipment and procedures. Available meteorological data suitable for wind energy assessment. Characterization of wind power resources from in-situ measurements or meteorological data series. [15%]

3. Mass and energy balances in thermal desalination processes, with basic concepts of design. Addressing the physics and chemistry basics of the desalination processes, and how they reflect on the design of the processes and technologies. [10%]

4. Design of low temperature (T < 80ºC) solar thermal fields to be coupled to a membrane distillation / humidification-dehumidification desalination system. Optical and thermal characterization of stationary solar collectors. Technical description of solar plant components and configuration. Solar plant dimensioning for prescribed thermal load and solar resources. [10%]

5. Design of intermediate (80ºC < T < 200ºC) solar thermal fields to be coupled to a multi-effect distillation (MED) plant. Optical and thermal characterization of tracking solar collectors. Technical description of solar plant components and configuration. Solar plant dimensioning for prescribed thermal load and solar resources. [10%]

6. Process design of a conventional membrane desalination process. Major components, process steps and configuration of membrane desalination plants. Optimization of power consumption and water cost. [10%]

7. Design of a solar photovoltaic field to be coupled to a reverse osmosis desalination plant. Photovoltaic panel characterization parameters. Technical description of solar photovoltaic plant components and configuration. Dimensioning for prescribed energy requirements. [10%]

8. Design of a wind energy field to be coupled to a reverse osmosis desalination plant. Wind energy turbine characterization parameters. Technical description of wind energy plant components and configuration. Dimensioning for prescribed energy requirements. [10%]

9. Overview of demonstration installations. Assessment and discussion of real plants, with thorough examination of experiences gained regarding performance, technical issues of operation, main problems encountered and cost analysis. [10%]

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Introducing RE-desal to higher education

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Separate **courses for professionals** to deliver faster results by training the people that are already active in the market.

The course adapted and offered as an **e-learning course**, which will reach a much wider audience than the specific courses.

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PRODES
Introducing RE-desal to higher education

The course (http://agora.cognosfera.org/) is developed into **10** chapters (9 theoretical + 1 practical case) with several intermediate questionnaires for the evaluation.

e-learning course

prodeslearning.com

1. Basic concepts on Desalination and Renewable Energies.
2. Desalination I. Membrane Processes (EDR, RO).
3. Desalination II. Distillation Processes (MED, MSF, H/D, MD).
4. Solar thermal energy and MED.
5. Solar thermal energy coupled with H/D or MD.
6. Solar photovoltaic energy powered RO systems.
7. Wind energy powered RO systems.
8. Other technologies.
9. Non-technical aspects.
10. Practical case (four different cases but only one is mandatory):
    - Case 1. PV - RO system
    - Case 2. Solar - MEH system
    - Case 3. Solar – MD system
    - Case 4. WIND – RO system

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PRODES
Introducing RE-desal to higher education

E-LEARNING COURSE ON INTRODUCTION TO DESALINATION BY RENEWABLE ENERGIES

HOME VideoTutorials Course About Contact Testimonials Press Statistics

E-LEARNING COURSE ON
INTRODUCTION TO DESALINATION BY RENEWABLE ENERGIES

This training action is the first online course focused on the topic "desalination by renewable energies".

The course summarizes the main relevant aspects of desalination (membrane and distillation processes) and the application of renewable energy technologies for autonomous operation.

This e-learning course is based on an interactive and friendly use philosophy and is developed into ten chapters with several intermediate questionnaires for the evaluation. Glossaries, videos, games, and other elements complete the training process. The student will know his/her progress in any moment.

The purpose is that the on-line student is the main leader of his/her own training process in a flexible way: the students with high time restrictions will be able to complete it with a minimum dedication of ten hours; on the other hand, the course will offer several complementary training options for the students with more time or specific interest.

The **E-LEARNING COURSE ON INTRODUCTION TO DESALINATION BY RENEWABLE ENERGIES** is organized byThe Canary Islands Institute of Technology (ITC), with a long history (since 1996) in testing autonomous desalination units driven by renewable energies. This training activity is developed under the framework of the PRODES project, an EU co-financed project within the Intelligent Energy for Europe Program

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Introducing RE-desal to higher education

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Separate **courses for professionals** to deliver faster results by training the people that are already active in the market.

The course adapted and offered as an **e-learning course**, which will reach a much wider audience than the specific courses.

A course on **desalination with solar energy** is offered yearly by EDS (in collaboration with scientists from Plataforma Solar de Almería).

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PRODES
Introducing RE-desal to higher education

European Desalination Society

Other EDS Courses

Desalination with Solar Energy

A 3-day intensive course

Lecturers: Julián Blanco, Diego-César Alarcón Padilla Guillermo Zaragoza

April 18-20, 2012, Almeria, Spain

REGISTER NOW

Special Offer: Both Barcelona Conference 2012 and Course

	Till March 20	After March 20
EDS Members Course only	€ 2150	
Non-members Course only	€ 2350	
Special Offer - EDS	€ 2400	€ 2700
Special Offer- Non-members	€ 2700	€ 3000

The fee includes 4 nights accommodation, lunches, coffee, dinners, course Workbook and CD.

The general purpose of this 3-day intensive course is to provide experts, professionals and postgraduate students from all around the world with the latest knowledge of the different existing technologies involving the use of solar energy to drive desalination techniques. More specifically, the course will instruct scientists and technicians on the basic principles of desalination using solar energy, the state of the art of the most promising technologies and the experiences acquired so far. Theory lessons will be complemented with visits to the test facilities of Plataforma Solar de Almeria operating on solar power production and desalination, which are the most advanced in the Mediterranean area.

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PRODES
Creating the link with the market

Facilitate collaboration between technology providers and key actors in local markets (municipalities, utilities or small enterprises supplying water treatment or renewable energy equipment and services).

- Municipalities or local utilities gain access to the new technology enabling them to solve their water supply problems.
- Local entrepreneurs generate new business
- Technology providers find markets for their products
- Local companies develop partnerships with technology providers promoting the products in the regions they are active, offering installation, operation and maintenance services.

Networking events organized in each country to facilitate contacts between local enterprises and international technology providers.

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PRODES
Mobilizing investment

Crucial for RE-desalination technology developers to improve their products and compete equally with conventional water supply solutions in isolated, water-scarce areas.

Support technology providers in plans to investors for raising capital by:

- conducting a **survey** among technology developers to analyze the nature and size of resources required and the methods they use to raise funds
- approaching potential investors to collect their **feedback** on the fund raising methods followed by the companies and Research Institutes
- developing **guidelines** for technology developers with recommendations on fund-raising strategies and instructions for developing a business plan
- identifying the most promising **niche markets** and concrete **project opportunities** in the involved countries
- identifying opportunities for European companies to **export** innovative desalination systems powered by renewable energies

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PRODES
Legislative and Institutional Issues

Collaborate with key-decision makers to improve framework conditions for promotion of water production by RE-desalination and ensure adequate legal protection of the consumers and the environment.

An assessment on how the **framework conditions** in the target countries can affect the implementation of RE-desalination.

Concrete **recommendations** for improvements developed and communicated **to key decision-makers** like public authorities and policy makers through an event in each country.

Realistic **targets** defined for the future regarding the share of water produced by RE-desalination on the overall desalinated water produced.

Concrete **suggestions** made for **local, regional or national schemes** to promote the more efficient use of current public spending to support sustainable solutions in line with the social and environmental policies.

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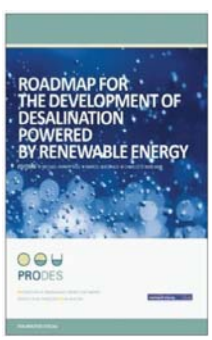
RE Desalination Roadmap

The Roadmap for RE-desalination is one of the main project results.

Developed with input from all target groups and extensive review of existing work, carried out by the ProDes consortium.

Final document widely distributed and a working group established which will lead the implementation of the strategy outlined in the Roadmap.

www.prodes-project.org



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RE Desalination Roadmap

Objective:

Outline the vision, barriers and strategies to accelerate the development of RE desalination so that it can become a significant part of the unconventional water supply market

Structure:

- **Current status** of the technology
- **Perspectives** of RE desalination
- **Barriers** that hinder the development of the technology
- Outline of the **strategy** to overcome the barriers
- Resources needed for the **implementation** of the technology

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Current status of the RE-desalination technology

Technology combination of the 131 RE-desalination plants reviewed in 2009

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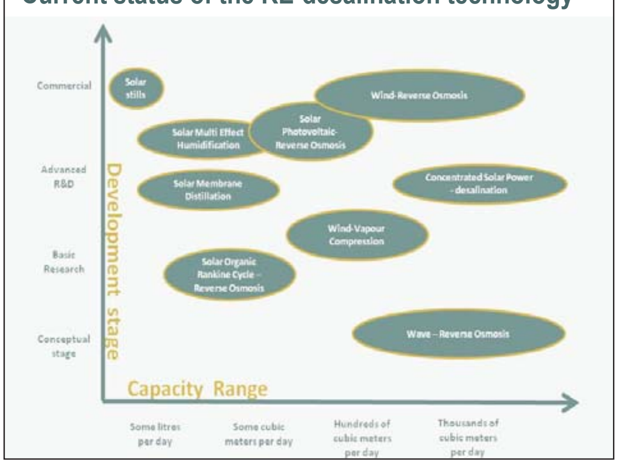
Current status of the RE-desalination technology



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	TYPICAL CAPACITY	ENERGY DEMAND	WATER GENERATION COST	TECHNICAL DEVELOPMENT STAGE
SOLAR STILL	< 0.1 m³/d	solar passive	1–5 €/m³	applications
SOLAR MEH	1–100 m³/d	thermal: 100 kWh/m³ electrical: 1.5 kWh/m³	2–5 €/m³	applications/ advanced R&D
SOLAR MD	0.15–10 m³/d	thermal: 150–200 kWh/m³	8–15 €/m³	advanced R&D
SOLAR/CSP MED	> 5,000 m³/d	thermal: 60–70 kWh/m³ electrical: 1.5–2 kWh/m³	1.8–2.2 €/m³ (prospective cost)	advanced R&D
PV-RO	< 100 m³/d	electrical: BW: 0.5–1.5 kWh/m³ SW: 4–5 kWh/m³	BW: 5–7 €/m³ SW: 9–12 €/m³	applications/ advanced R&D
PV-EDR	< 100 m³/d	electrical: only BW: 3–4 kWh/m³	BW: 8–9 €/m³	advanced R&D
WIND-RO	50–2,000 m³/d	electrical: BW: 0.5–1.5 kWh/m³ SW: 4–5 kWh/m³	units under 100 m³/d BW: 3–5 €/m³ SW: 5–7 €/m³ about 1,000 m³/d 1.5–4 €/m³	applications/ advanced R&D
WIND-MVC	< 100 m³/d	electrical: only SW: 11–14 kWh/m³	4–6 €/m³	basic research
WAVE-RO	1,000–3,000 m³/d	pressurised water: 1.8–2.4 kWh/m³ electrical: 2.2–2.8 kWh/m³	0.5–1.0 €/m³ (prospective cost)	basic research

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COMBINATION	COST (€/m³)	ASSUMPTIONS
Off-grid wind powered-seawater RO systems	1.07	• Nominal capacity: 1,000 m³/d • Number of annual operation hours: 5,200 • Specific energy consumption: 3.3 kWh/m³
Seawater PV-OR	11.81	• Nominal capacity: 100 m³/d • Number of annual operation hours: 3,000 • Specific energy consumption: 6 kWh/m³
Brakish water PV-RO	8.29	• Nominal capacity: 100 m³/d • Number of annual operation hours: 3,000 • Specific energy consumption: 1.6 kWh/m³
Brakish water PV-EDR	8.47	• Nominal capacity: 100 m³/d • Number of annual operation hours: 3,000 • Energy consumption: 3.31–3.65 kWh/m³ (depending)
MED + solar pond	1.44	• Nominal capacity: 6,000 m³/d • Number of annual operation hours: 8,320* • Electric consumption: 2.25 kWh/m³
CP solar collectors + biomass-MED	4.84	• Nominal capacity: 6,000 m³/d • Number of annual operation hours: 8,320* • Electric consumption: 2.25 kWh/m³

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Main barriers of the RE-desalination technology

Barrier	Effect	Strategy
Technological		
Most RE-D[1] are not developed as a single system but are combinations of components developed independently	→ Poor reliability → Increased water cost	

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Main barriers of the RE-desalination technology

Barrier	Effect	Strategy
Technological		
Desalination development focuses on ever larger systems	→ Lack of components appropriate for small scale desalination plants, typical of many RE-D combinations	

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Main barriers of the RE-desalination technology

Barrier	Effect	Strategy
Economical		
Lack of comprehensive market analysis as to the size, locations and segments of the market	→ It is difficult to assess the risk and investors are reluctant to invest	

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Main barriers of the RE-desalination technology

Barrier	Effect	Strategy
Economical		
The pricing structures and the subsidies of water supply create unfair competition	→ Investment in RE-D remains unprofitable even where it offers better value than the current solutions	

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Main barriers of the RE-desalination technology

Barrier	Effect	Strategy
Institutional and Social		
Negative perception of desalination by the population	→ Opposition of local communities to installation	

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Main barriers of the RE-desalination technology

Barrier	Effect	Strategy
Institutional and Social		
Bureaucratic structures not tailored for independent water production; separation of energy and water policies	→ The cost and effort required to deal with the bureaucracy does not favor small companies	• Promote simpler and straightforward processes to obtain a license for independent water production • Lobby for greater cooperation between the power and water branches in governmental and non-governmental institutions
Lack of training and infrastructure	→ Reduced plant availability → Lack of personnel for operation and maintenance	• Support education and training at all levels
Cultural gap between project developers and the end-users	→ Projects fail for non-technological reasons like conflict about control	• Encourage adequate consideration of socio-cultural factors and establishment of communication channels with the end-users

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Targets for the RE-desalination technology

New desalination plants to be constructed up to 2016 are expected to be worth, in total, over $64 billion.

RE -desalination community is targeting a **3–5% share of that market**, worth $2–3 billion over the next 7 years.

This is a market large enough to attract the interest of major players who will catalyse fast developments.

- Plants with capacities below 1,000 m^3/day: 15 to 20% of the market share aimed by RE -desalination, using existing technologies like wind-RO, wind-MVC, solar MD, solar MEH and PV-RO.
- Larger plants: just below 2% of the market could be reached when in addition to the very large wind powered RO systems, CSP-MED and wave-RO plants start being implemented.

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R&D priorities for the RE-desalination technology

- Components suitable for specific RE-D

→ Adaptation of pumps and energy recovery systems for efficient operation in small-scale plants

→ Development of seawater-resistant materials (e.g. pumps)

→ Automated and environmental friendly pre- and post- treatment technologies

→ Control systems that optimize performance and minimize maintenance

→ Obtain certification for food proofed systems for materials that are in contact with the water

- Components suitable for the smooth and efficient coupling of the existing desalination with renewable energy technologies

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R&D priorities for the RE-desalination technology

- Development of elements that will make RE -desalination robust for long **stand-alone operation** in harsh environments
- Development of components and control systems that allow desalination technologies to deal better with **variable energy input**

→ Hybrid systems

→ Energy storage

→ Salinity gradient systems

- Development of **co-generation** systems that produce water and power

The fact that RE-Desalination belongs to both water and energy sectors, has been a barrier for securing R&D funding since neither sector felt totally responsible for this area

→ reverse this situation and use it as an opportunity to include RE-D priorities in both.

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Legislative and institutional issues

Greece:

Development of a specific framework for the desalination of brackish and seawater

Priority should be given to implementation of small autonomous RE Desalination units in remote areas (small islands).

→ new RES Law 3851/2010, already provides priority on the licenses authorization for the implementation of RE desalination projects.

Public or private projects and activities categorized according to their impacts on the environment. Desalination units >100 m^3/day: serious risks for the environment, <100 m^3/day: subject to general specifications, terms and restrictions for reasons of environmental protection.

→ proposed: <50 m^3/day to belong at Category C (insignificant risk or nuisance or degradation to the environment).

<10 m^3/day for Municipal Use, exempted from the licenses procedures

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Legislative and institutional issues

Spain:

RE is a key and powerful industrial sector in Spain with a very significant contribution to electricity generation: 24,7 % of electricity in 2009 and very promising role for the next decade (42.3% in 2020).

The subsidy strategy (Feed-in tariffs) has allowed this high development of the RE sector.

Initiatives on subsidies, as the one, focused on desalination in the Canary Islands, addressed to reduce water prices in the region, which are higher than the average price in the country.

→ proposed: specific subsidy to desalinated water produced by RE resources.

Desalination included in the new Plan for Renewable Energy in Spain (2011-2020).

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RE-desalination Working Group

Working group on Renewable Energy Desalination to promote the use of desalination powered by renewable energy as an environmentally friendly and decentralized solution for sustainable water supply.

Work of the group guided from the Road Map.

Participation open to stakeholders → register in **www.prodes-project.org**

There are already more than 100 registered members that will be meeting annually in events coordinated with the conferences organized by the European Desalination Society.

Next meeting to take place parallel to the "*Desalination for the Environment, Clean Water and Energy*" conference in 23-26 April 2012 in Barcelona (Spain).

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Activities of the RE-desalination Working Group

- **Define the R&D priorities** that will benefit the entire sector and **coordinate activities** in this direction

→ R&D worth more than 100 M€ in the period 2014 to 2020

- Support the wider establishment of RE-desalination **education and training** activities

→ 2,000 students and 500 professionals yearly within Europe by 2015

- Supervise and coordinate a comprehensive **market analysis**
- Develop and promote appropriate **legal structures and policies**

→ both on a country by country basis

- **Raise awareness** about the technology and **demonstrate its market potential**

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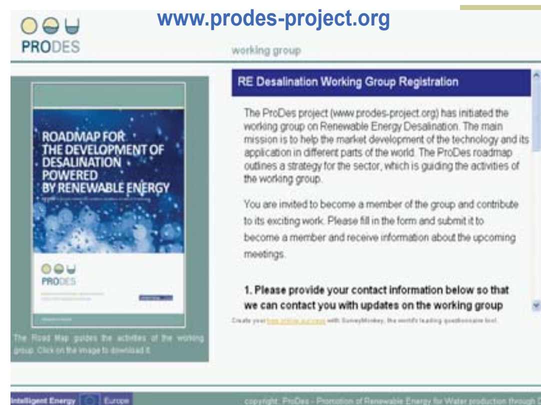
RE-desalination Working Group



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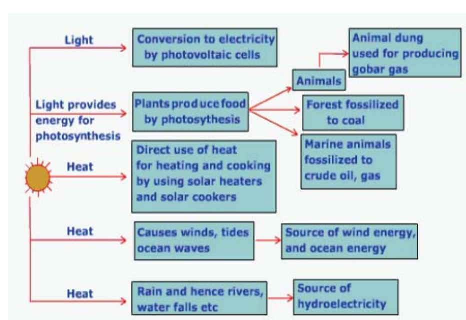
Renewable Energy

Renewable energy resource: illimitably available and not generate pollution



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Renewable Energy

Limitations:

- Intermittent, difficult to predict and fluctuant
- Occupy large areas
- Adverse impact on the environment:
  - visual impact
  - noise
  - influence marine and aerial life
- Size of RE power plants is limited (few MW)
- → despite being one of the most used, hydropower is not considered because it is associated to high availability of water (desalination not necessary)

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Renewable Energy for Desalination

A number of different technologies allow the exploitation of renewable energy resources, providing energy as heat, power or even a combination of both energy forms

heat production RE technologies

Solar thermal

Biomass

Geothermal

Solar Thermal electricity

Wind Power

Wave Power

Solar Photovoltaic

power production RE technologies

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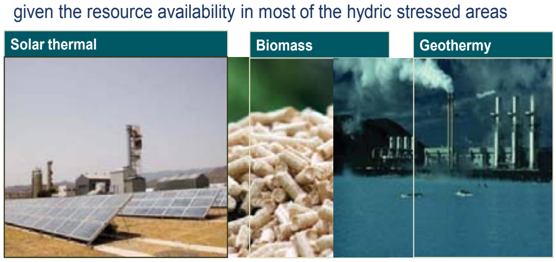
Renewable Energy

Heat oriented RE technologies are based on three major resources:

1. Solar radiation;
2. Biomass / Biogas;
3. Geothermal heat.

Solar based solutions are particularly suitable for desalination purposes, given the resource availability in most of the hydric stressed areas



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Renewable Energy

Power oriented RE technologies are based on three major resources:

1. Solar radiation;
2. Wind;
3. Waves.

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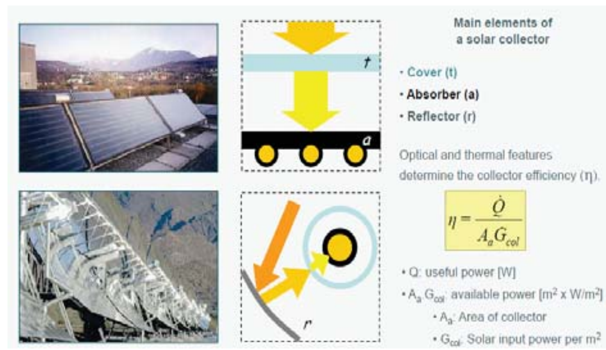
Solar thermal energy



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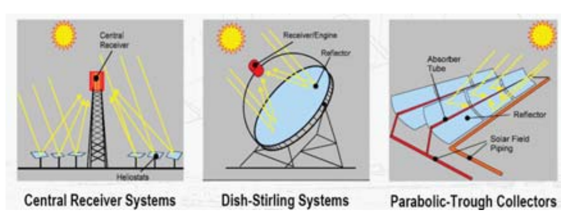
Solar thermal electricity

Solar thermal collectors concentrate solar radiation into heat energy to produce steam, which then turns a turbine to produce electricity.



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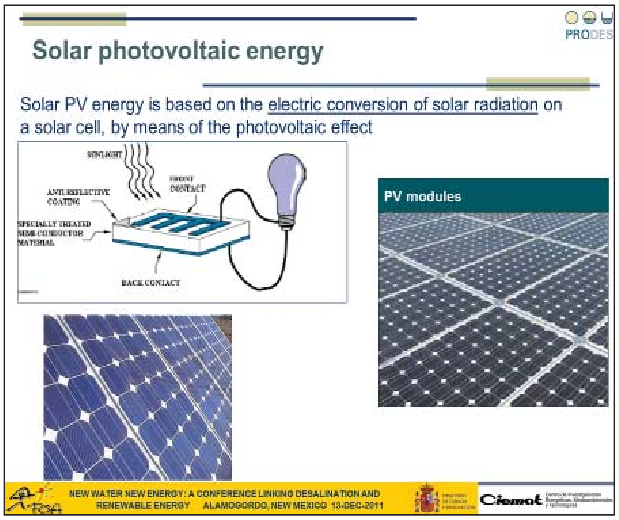

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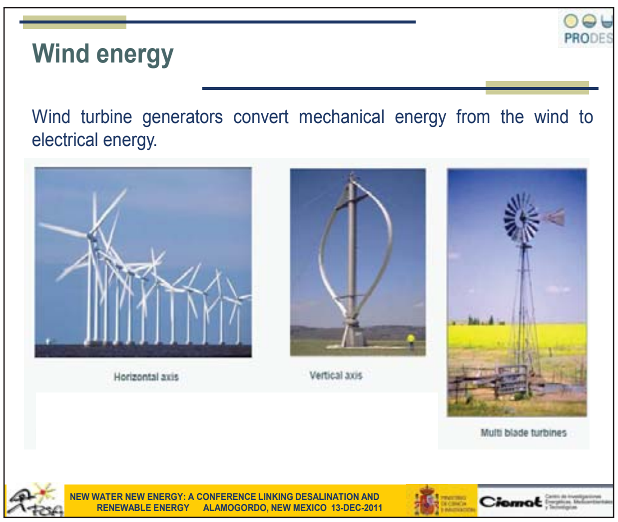

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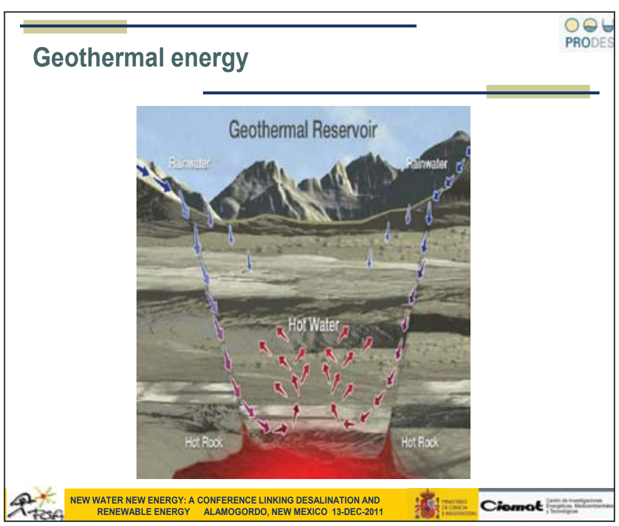

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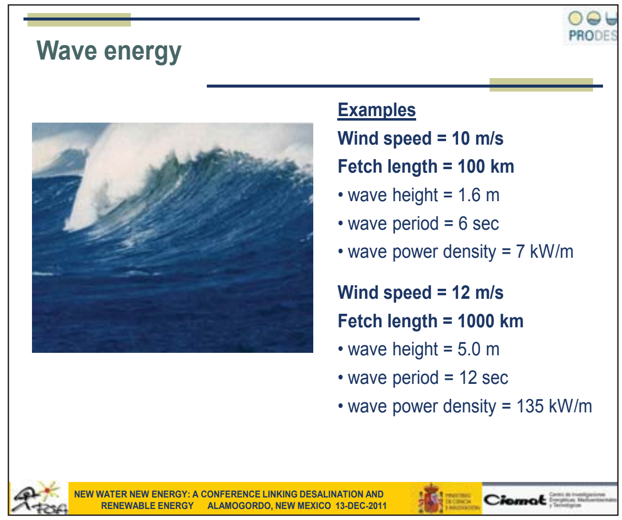

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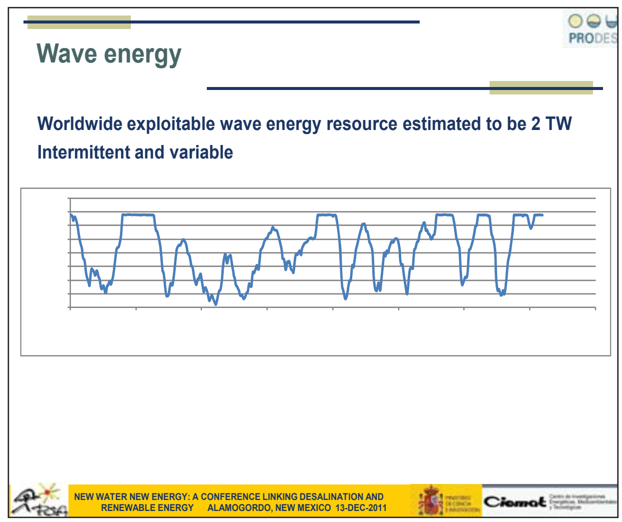

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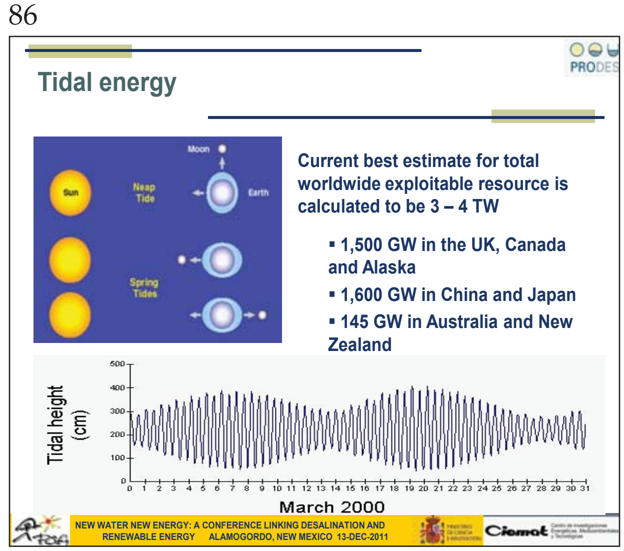

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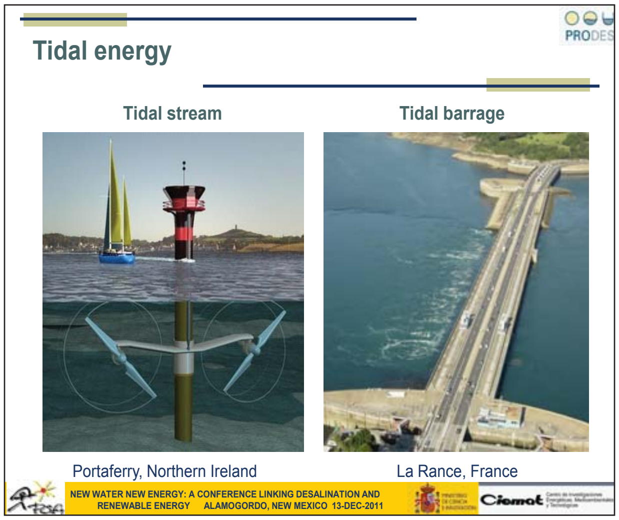

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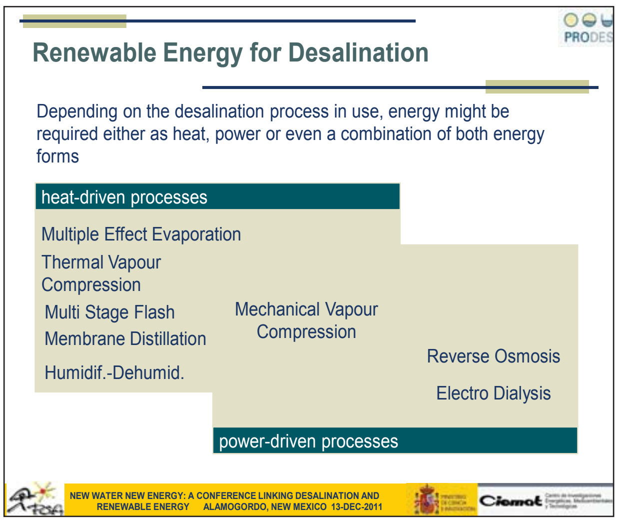

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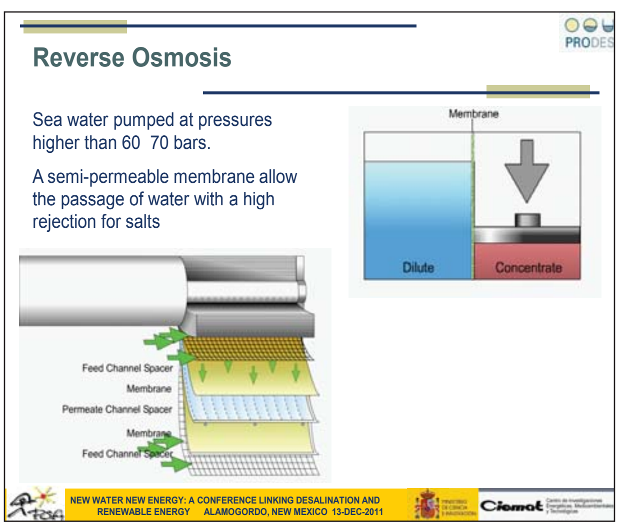

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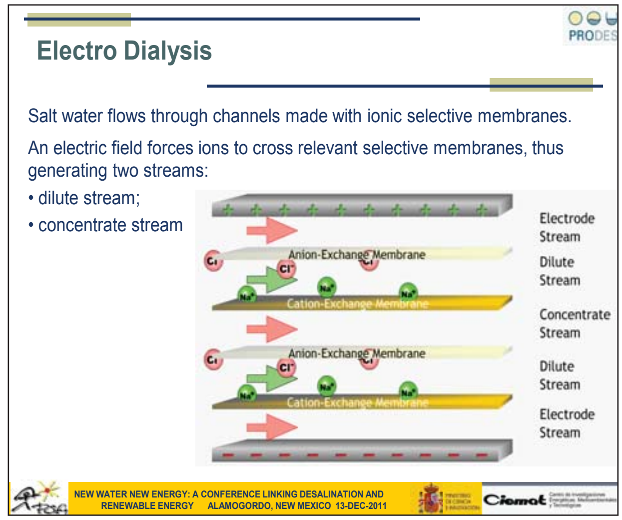

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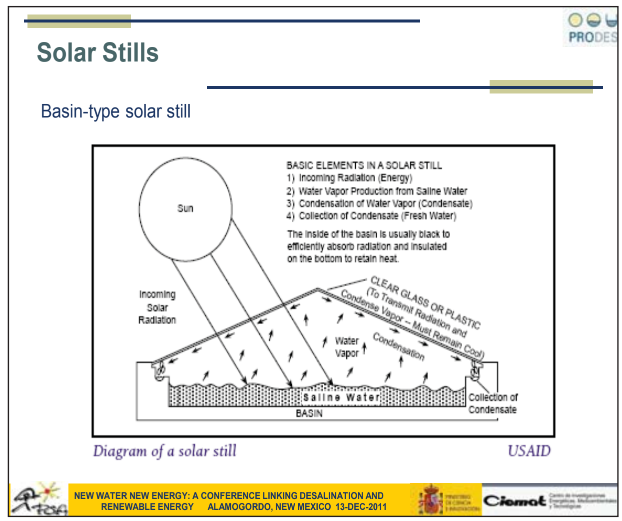

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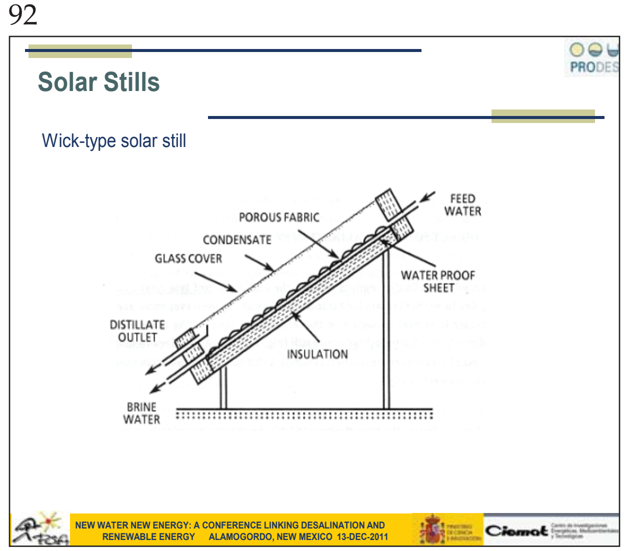

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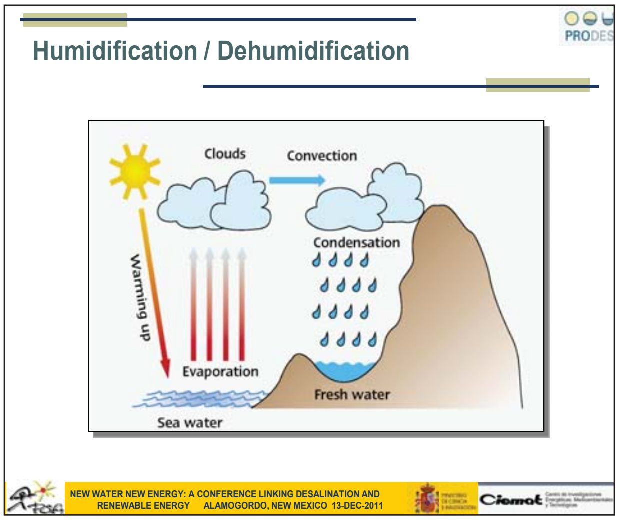

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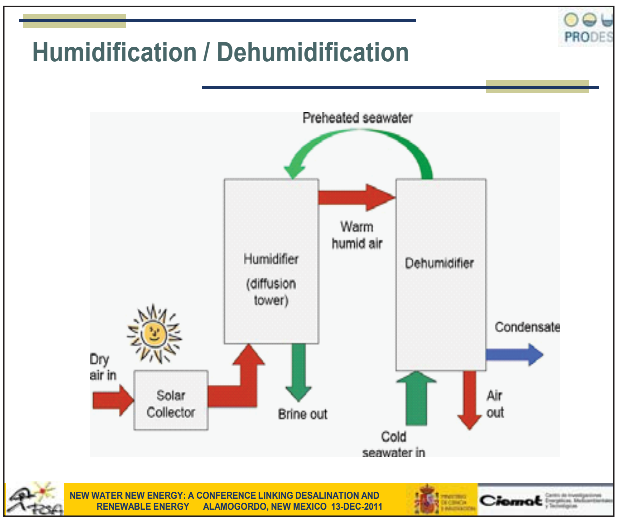

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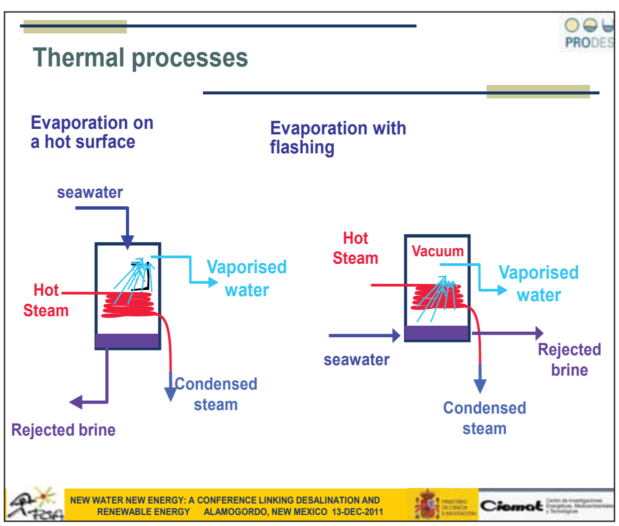

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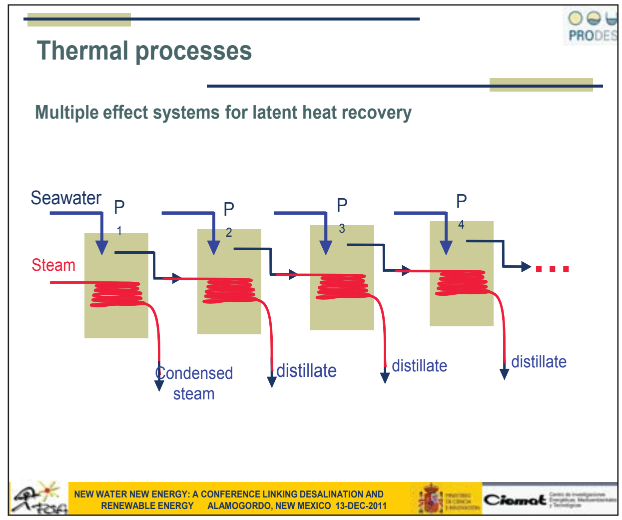

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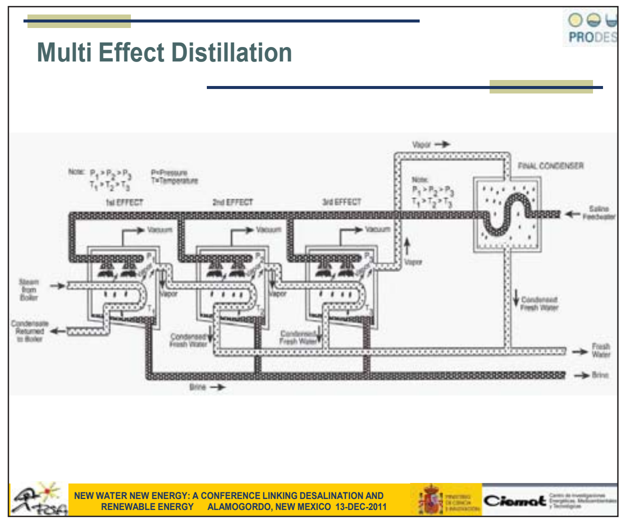

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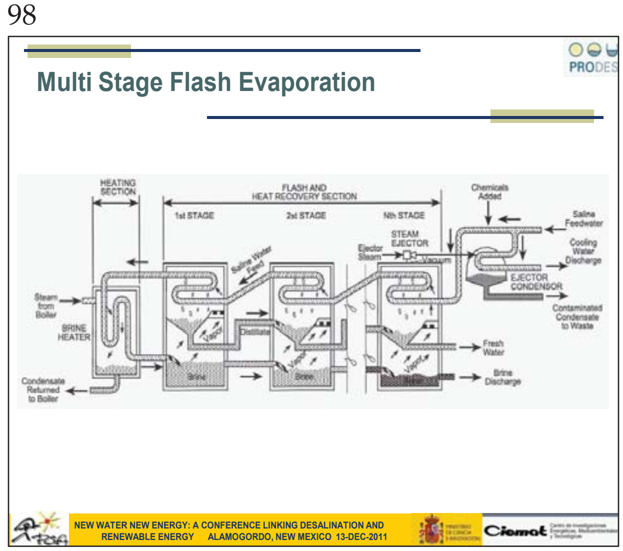

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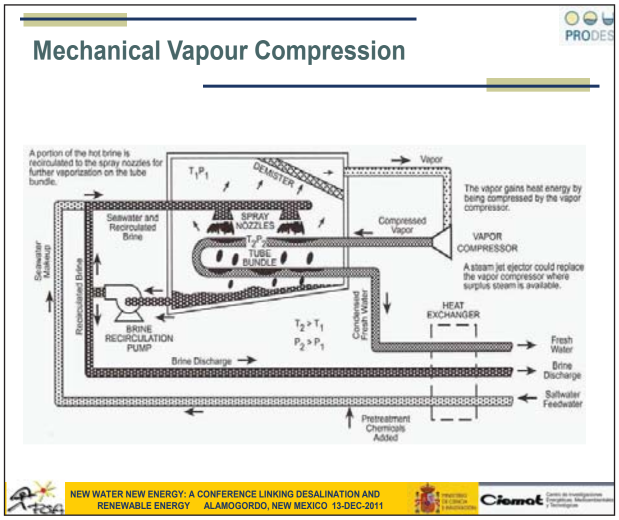

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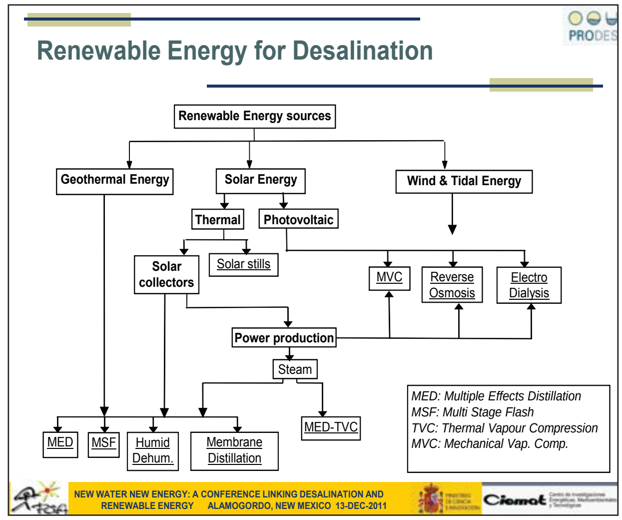

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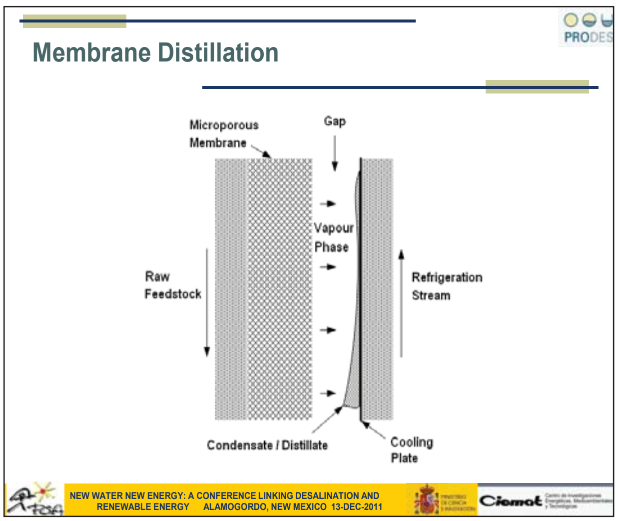

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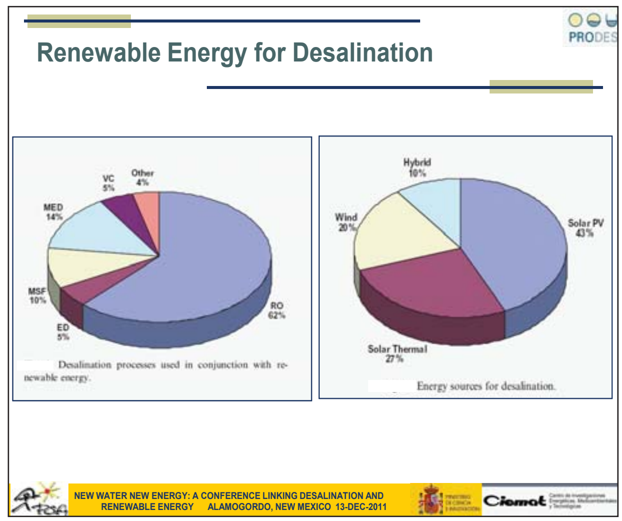

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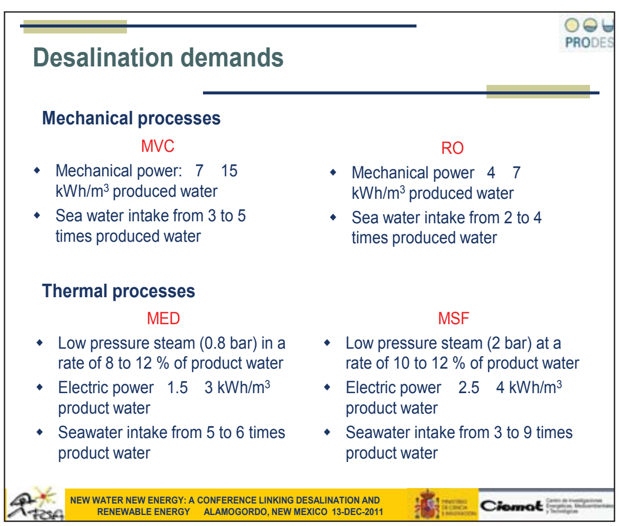

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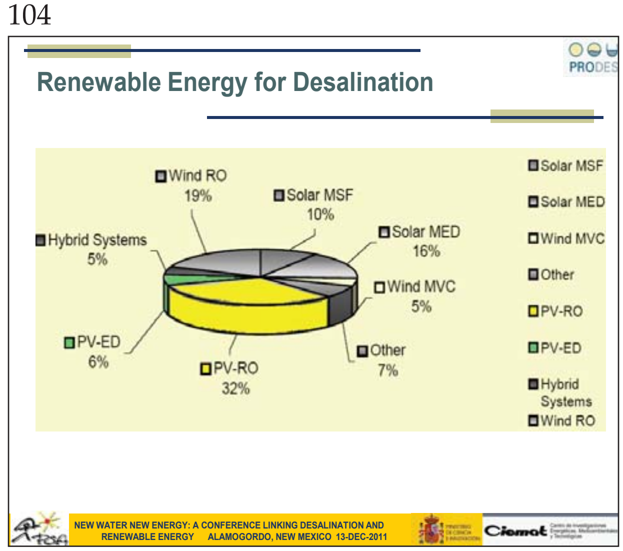

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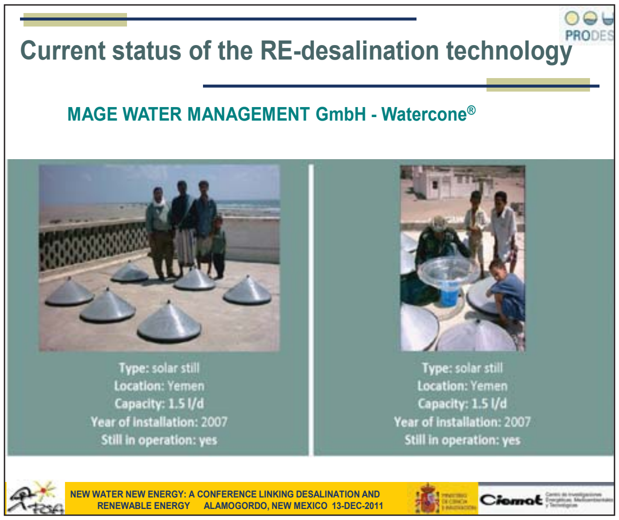

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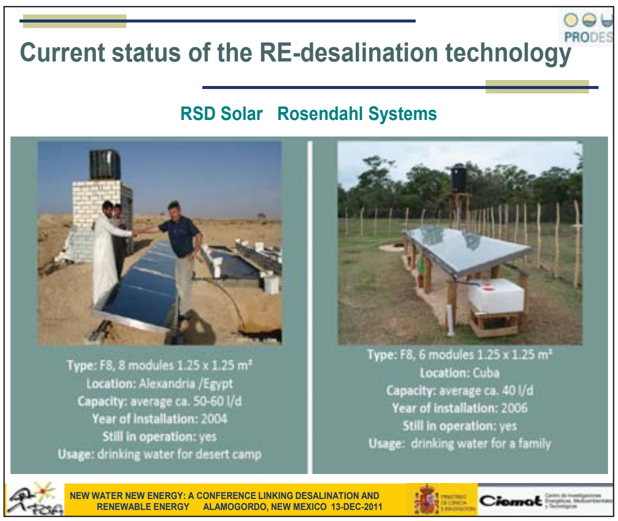

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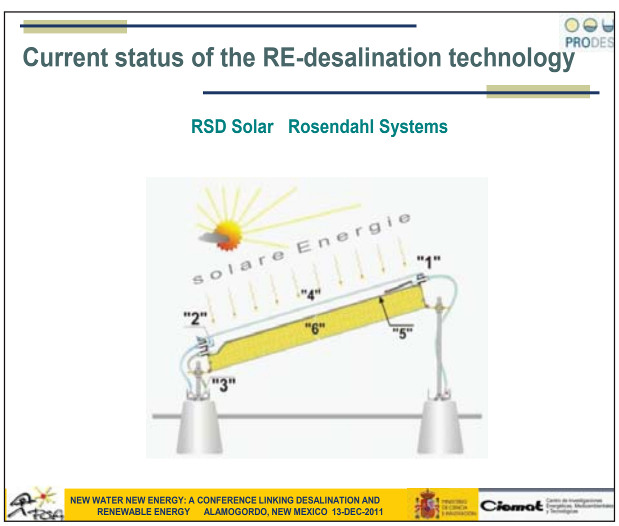

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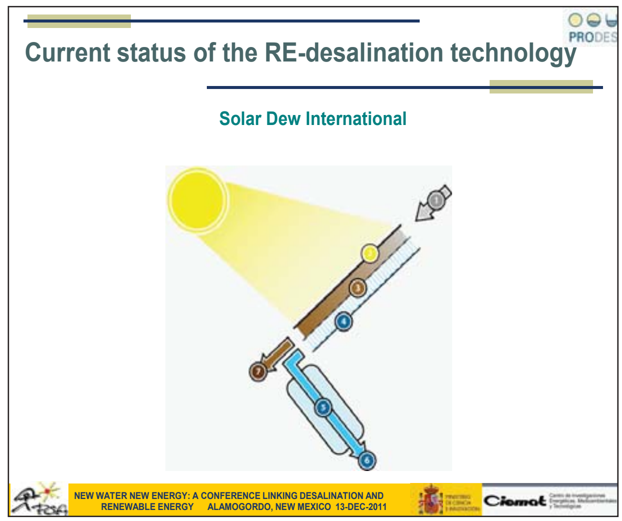

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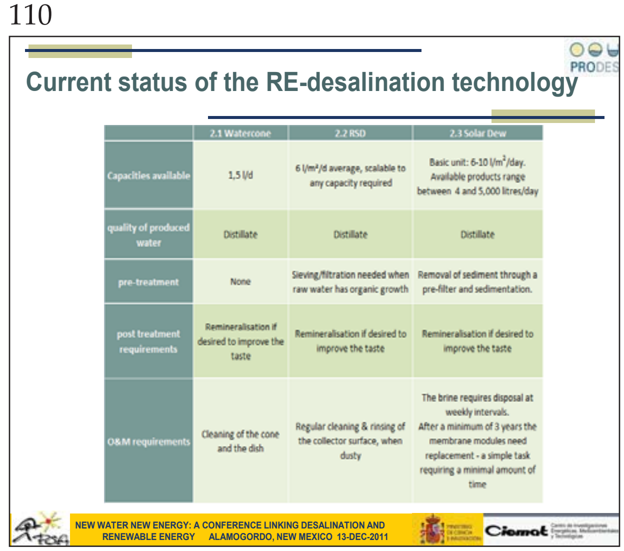

	2.1 Watercone	2.2 RSD	2.3 Solar Dew
Capacities available	1,5 l/d	6 l/m²/d average, scalable to any capacity required	Basic unit: 6-10 l/m²/day. Available products range between 4 and 5,000 litres/day
quality of produced water	Distillate	Distillate	Distillate
pre-treatment	None	Sieving/filtration needed when raw water has organic growth	Removal of sediment through a pre-filter and sedimentation.
post treatment requirements	Remineralisation if desired to improve the taste	Remineralisation if desired to improve the taste	Remineralisation if desired to improve the taste
O&M requirements	Cleaning of the cone and the dish	Regular cleaning & rinsing of the collector surface, when dusty	The brine requires disposal at weekly intervals. After a minimum of 3 years the membrane modules need replacement - a simple task requiring a minimal amount of time

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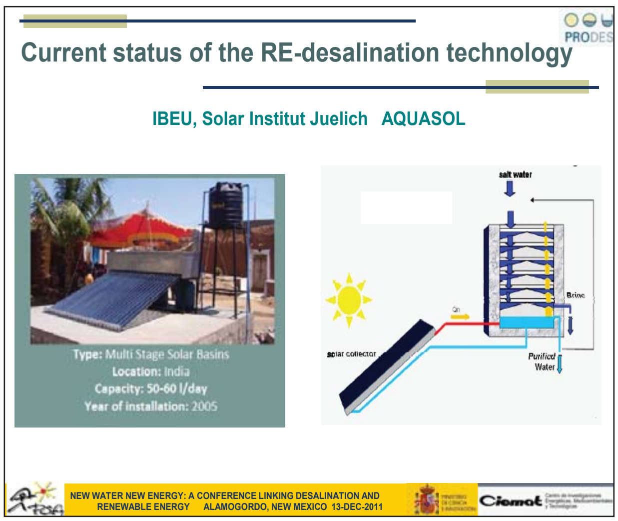

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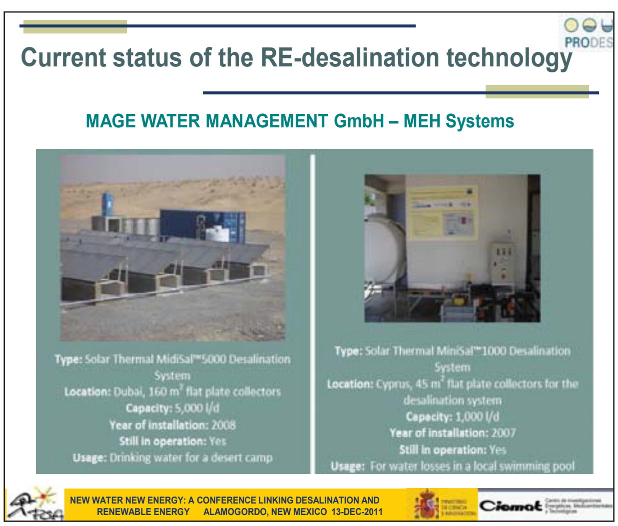

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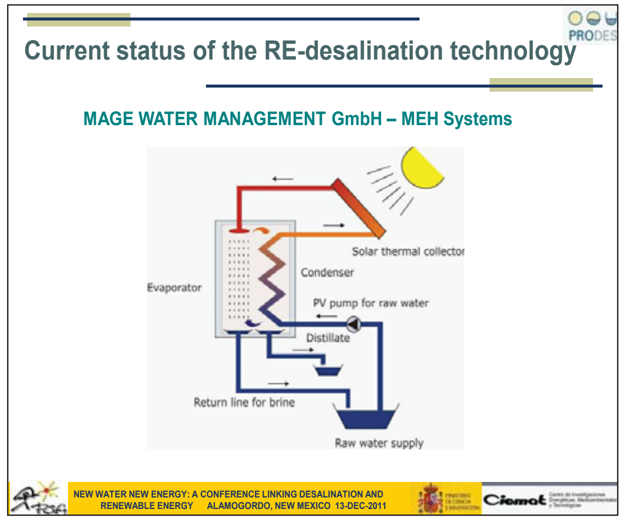

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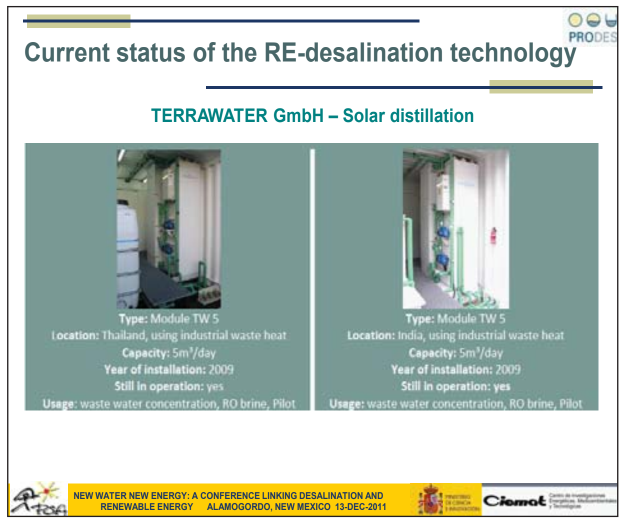

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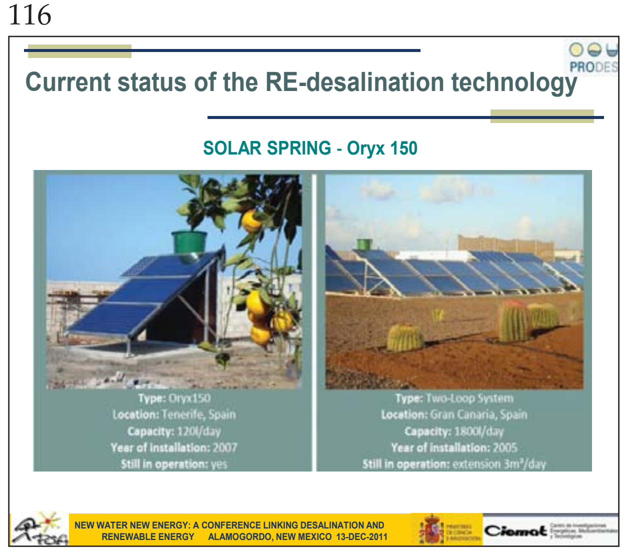

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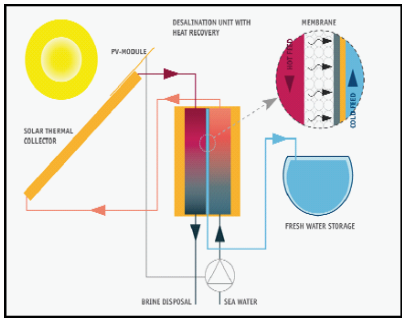
Current status of the RE-desalination technology

PRODES

SOLAR SPRING - Oryx 150



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Current status of the RE-desalination technology

PRODES

	3.1 AQUASOL	3.2 MEH-System	3.3 Terrawater	3.4 Solar Spring
Capacities available	30-70 l/d 100- 250 l/d hybrid system Modular up to 5m³	MiniSal™ 1000 l/d MidiSal™ 5000 l/d MegaSal™ 10000 l/d MaxiSal™ 50000 l/d	TW 5 Modules up to 6000 l/d combining TWS modules up to 500 m³/day	Compact System: 150 l/d Two Loop System: > 1,000 l/d
quality of produced water	Distillate	Distillate	Distillate	Distillate
pre-treatment	Use of a sand filter if necessary - depends on the feedwater	50 µm backwash Filter or sand filter	in some cases coarse filter < 1mm	Standard pre-filtration at 80-150 micron filter element depending on raw water quality
post treatment requirements	Remineralisation if desired to improve the taste	Remineralisation if desired to improve the taste	Remineralisation if desired to improve the taste	Remineralisation if desired to improve the taste
O&M requirements	plants can be cleaned by simple demounting of the condenser steel trays	cleaning of solar thermal collectors and PV (monthly) Backwashing of raw water filter if turbid raw water is used (weekly to yearly) Exchange of evaporation sheets (easy and cheap, every 1-2 years) Maintenance of circulation pumps (every 5 years)	Visual check every Month (water tightness) Change pumps and ventilator (every 3 years) Change humidifier material (every 5 years) cycles depending on raw water quality	Every 2 years acid and chlorine cleaning (depending on the raw water source) New MD-Module every 5 years, Pump every 10 years

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Current status of the RE-desalination technology

PRODES

Technology: **solar MED**
Energy Source: **Solar thermal (CPC collectors)**
Daily Capacity (nominal): 72m³/d
Year of installation: 2005
Type of installation: R&D
Location: Almeria, Spain
Installed by: Plataforma Solar de Almeria; Aquasol Project

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Current status of the RE-desalination technology

PRODES

Canary Islands Institute of Technology (ITC) – DESSOL®

Type: PV-RO for brackish water
Location: Morocco
Capacity: 1,000 l/h
Year of installation: 2008
Still in operation: yes
Usage: supply to local people

Type: PV-RO for brackish water
Location: Tunisia
Capacity: 2,100 l/h
Year of installation: 2006
Still in operation: yes
Usage: supply to local people

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Current status of the RE-desalination technology

PRODES

ENERCON GmbH – Wind RO

Type: Seawater Desalination System
Location: Greek Island
Capacity: 500m³/day
Year of installation: 1998
Still in operation: no, until 2004
Usage: Public water supply

Type: EDS 1200 SW
Location: Aurich, Germany
Capacity: 1200m³/day
Year of installation: 2004
Still in operation: yes
Usage: Demonstration

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Current status of the RE-desalination technology

PRODES

WME – Wind driven vapour compression

Type: wind-vapour compression
Location: Rügen Island, Germany
Capacity: 15 m³/h
Year of installation: 1995
Still in operation: yes
Usage: drinking water

Type: wind-vapour compression
Location: Symi, Greece
Capacity: 20m³/h
Year of installation: 2009
Still in operation: yes
Usage: drinking water

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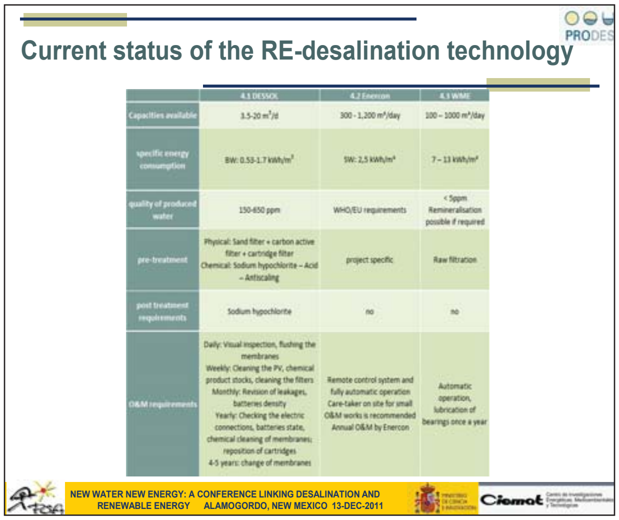

	4.1 DESSOL	4.2 Enercon	4.3 WME
Capacities available	3.5-20 m³/d	300 - 1,200 m³/day	100 – 1000 m³/day
specific energy consumption	BW: 0.53-1.7 kWh/m³	SW: 2,5 kWh/m³	7 – 13 kWh/m³
quality of produced water	150-650 ppm	WHO/EU requirements	< 5ppm Remineralisation possible if required
pre-treatment	Physical: Sand filter + carbon active filter + cartridge filter Chemical: Sodium hypochlorite – Acid – Antiscaling	project specific	Raw filtration
post treatment requirements	Sodium hypochlorite	no	no
O&M requirements	Daily: Visual inspection, flushing the membranes Weekly: Cleaning the PV, chemical product stocks, cleaning the filters Monthly: Revision of leakages, batteries density Yearly: Checking the electric connections, batteries state, chemical cleaning of membranes; reposition of cartridges 4-5 years: change of membranes	Remote control system and fully automatic operation Care-taker on site for small O&M works is recommended Annual O&M by Enercon	Automatic operation, lubrication of bearings once a year

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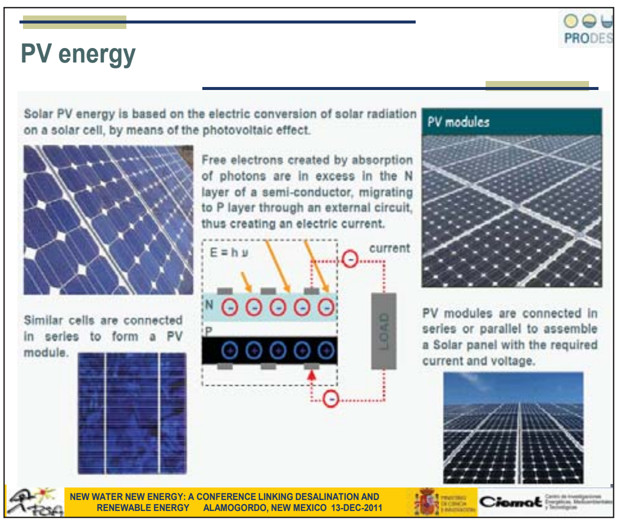

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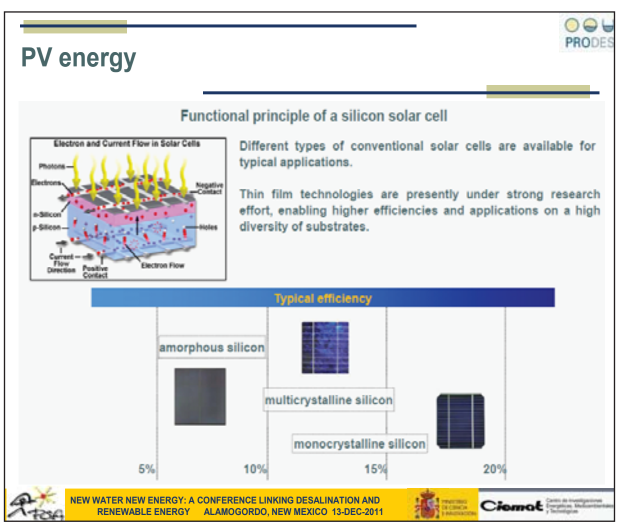

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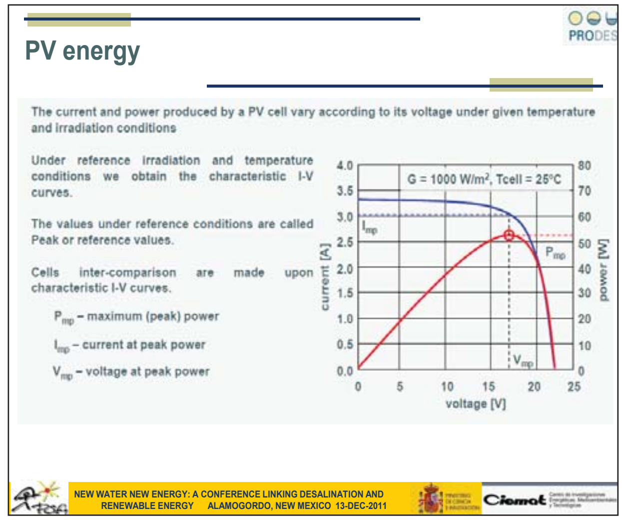

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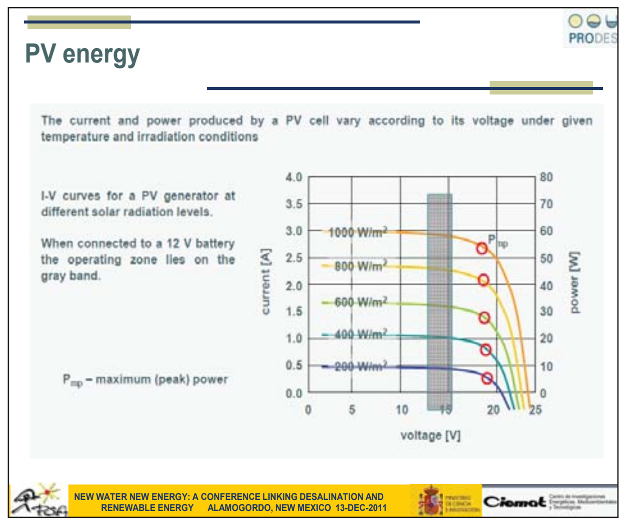

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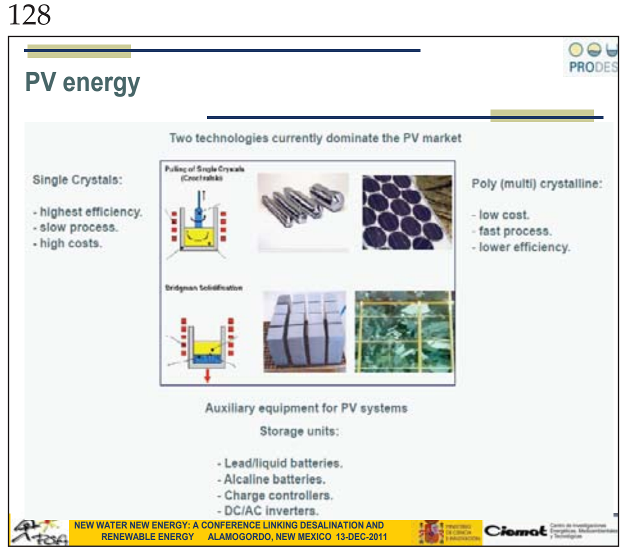

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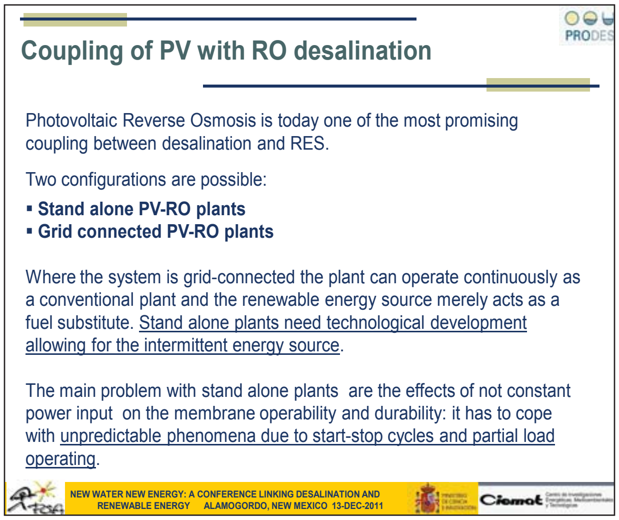

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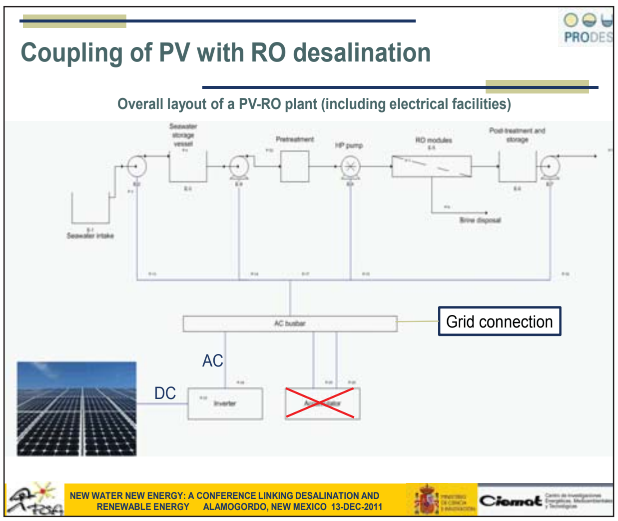

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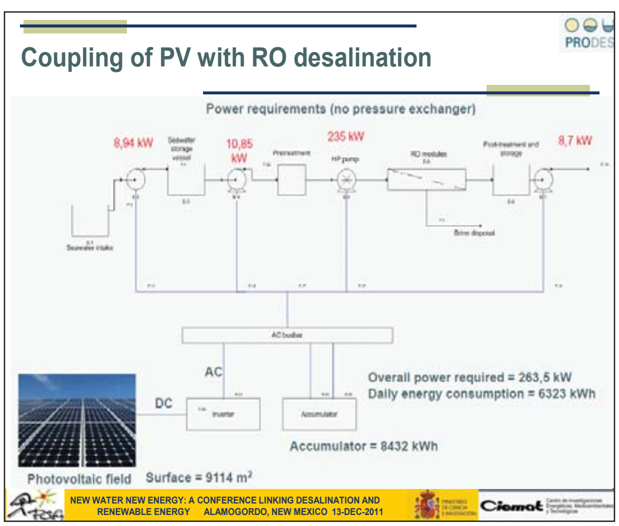

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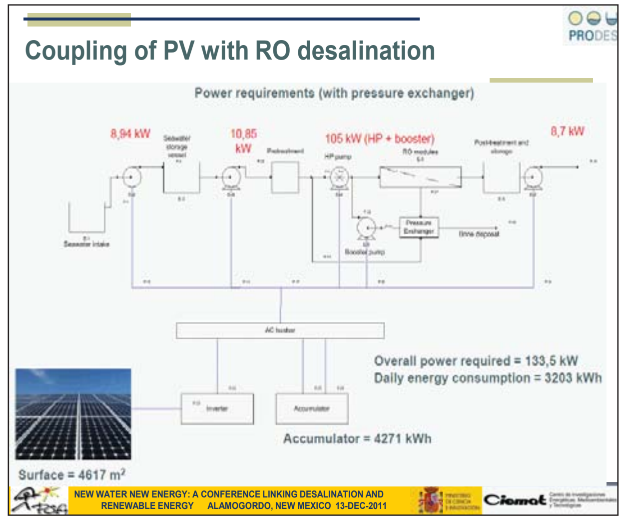

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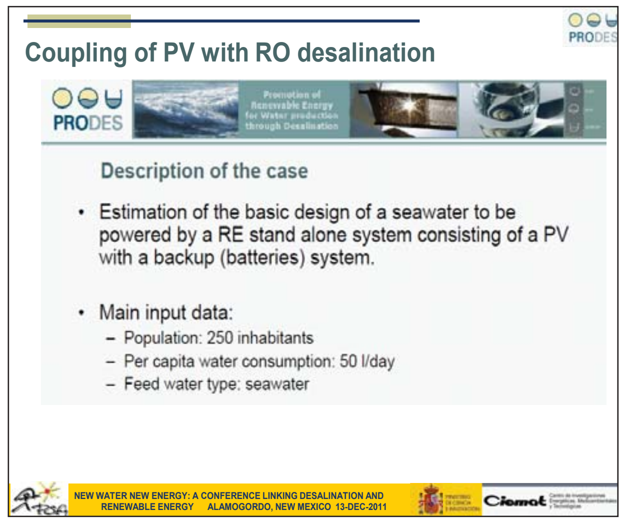

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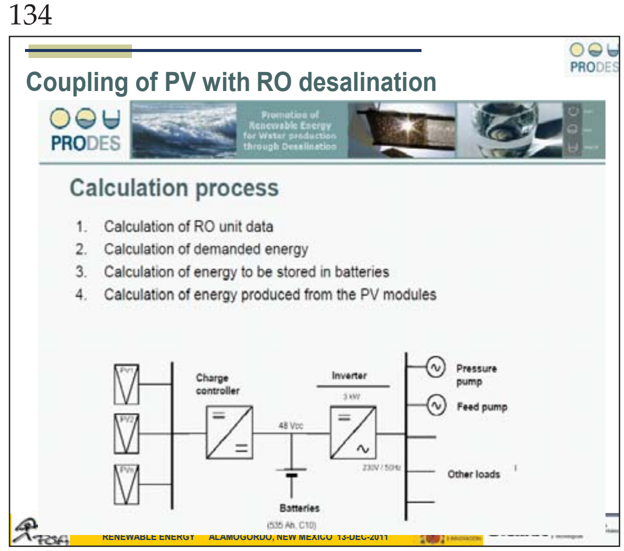

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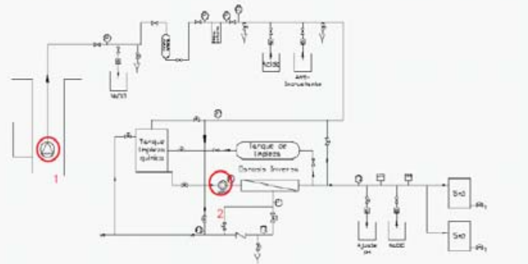
Coupling of PV with RO desalination

RO unit. Basic diagram



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Coupling of PV with RO desalination

RO unit 1. Flows

Data	Value
Recovery ratio	40%
Average daily operation hours	7.5 h

- Water demand: 250 persons x 50 l / p d = 12,500 l / d = 12.5 m^3 / d
- Product water flow [Qp]:
  - 12,5 m^3/d / 7.5 h/d = 1.7 m^3 / h
- Feed water flow [Qa]:
  - Qa = Qp / r = 1.7 / 0.4 = 4.2 m3 / h

$$r = \frac{Q_p}{Q_a} \times 100$$

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Coupling of PV with RO desalination

RO unit 2. Power

Data	Value
Operation pressure of RO pump	60 bar
Operation pressure of feed pump	5 bar
Pumps efficiency of RO pump	80%
Pumps efficiency of feed pump	50%

$$P = \frac{P(Pa) \cdot Q(m^3/s)}{\eta}(W)$$

- Pumps power calculation
  - Feed pump: 4.2 / 3600 (m^3/s) x 5 E5 (Pa) / 0.5 = 1,167 W
  - High pressure pump: 4.2 / 3600 (m^3/s) x 60 E5 (Pa) / 0.8 = 8,750 W
  - Total power: 1,167 W + 8,750 W = 10,211 W

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Coupling of PV with RO desalination

Energy demanded by the system

$$Energy = Power \times Time$$

Element	Operation time (h)	Power (W)	Energy (Wh)
Feed pump	7.5	1,167	8,752
HP pump	7.5	8,750	65,625
TOTAL			74,377

Energy storage calculation

The autonomous electric system has a set of energy losses, which include the inefficiencies of the different components: batteries, inverter and others.

The energy that must be stored has to take into account these losses by a global efficiency factor: **R.** A usual value is **0.7.** Therefore:

Energy from batteries = Energy demanded / R = 106,253 Wh

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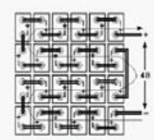
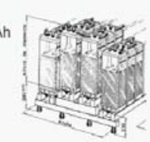
Coupling of PV with RO desalination

Capacity of batteries

Data	Value
Operation voltage (Vo)	48 Vdc
Number of autonomy days (N)	1 day
Discharge depth (Pd)	60%
Unitary voltage of one vessel	2 Vdc



- Useful capacity:
  - C_U = Eb * N / Vo = 106,253 Wh x 1 / 48 V = 2,214 Ah
- Nominal capacity (manufacturer)
  - Cn = C_U / P_d = 2,214 Ah / 0.6 = 3,689 Ah
  - Number of vessels connected in serial: 48 / 2 = 24



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Coupling of PV with RO desalination

PV modules

Data	Value
Efficiency of charge controller	90%
Solar peak hours (SPH)	3.9
Relation between maximum and real efficiency of the modules	0.9
Power of one module (P)	125 W

$$Epanels = \frac{Ebatteries}{0.9}$$

$$Np = \frac{E_p}{0.9P(SPH)}$$

Solar peak hours is a parameter that means the number of solar hours with a radiation of 1,000 W/m² (maximum radiation that produces the maximum power from the PV modules). This value changes each month, thus calculation is made for the most unfavorable month (normally December).

- Energy from the panels: Ep = Eb / 0.9 = 106,253 / 0.9 = 118,059 Wh
- Number of panels: Np = 118,059 / 0.9 x 125 x 3.9 = 269 modules
- Total installed PV power: Wp = 269 modules x 125 W / mod. = 33,635 W

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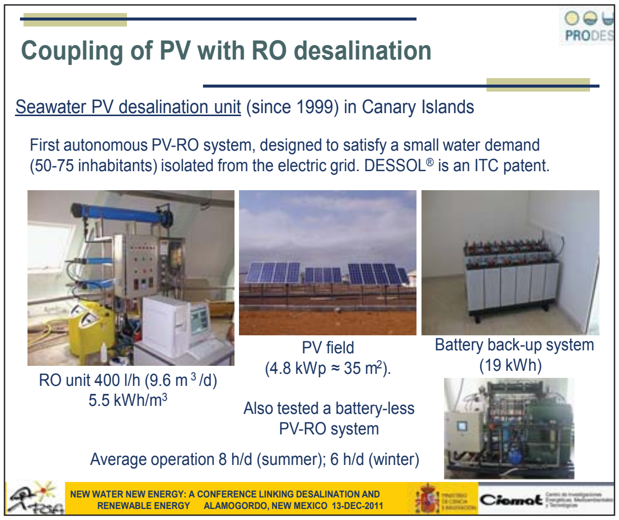

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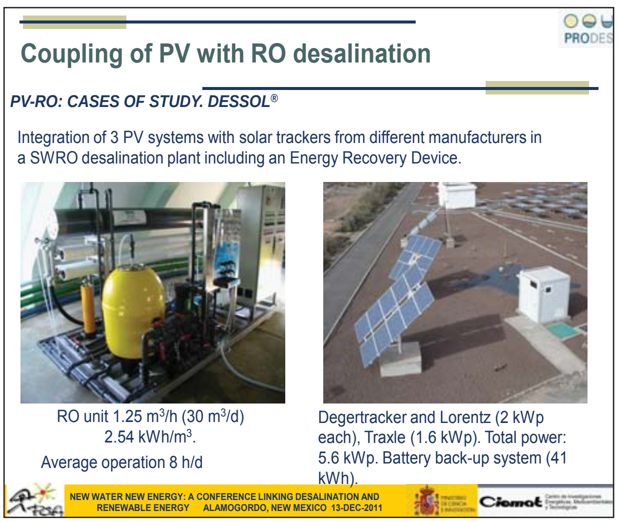

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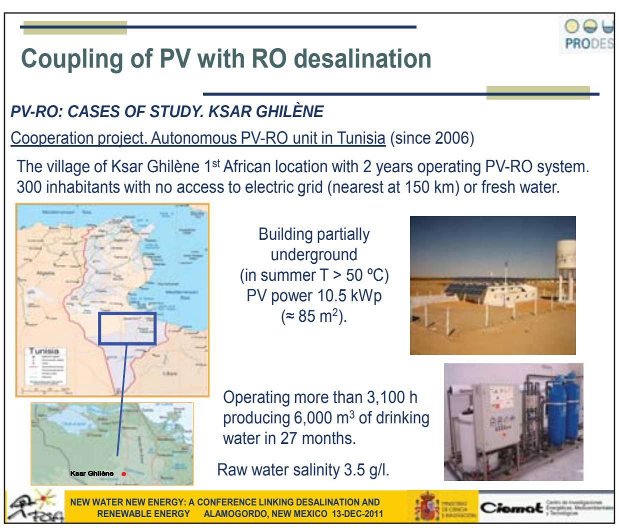

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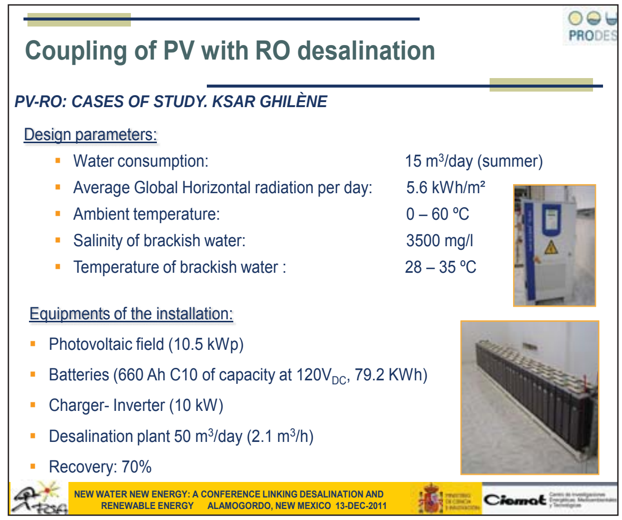

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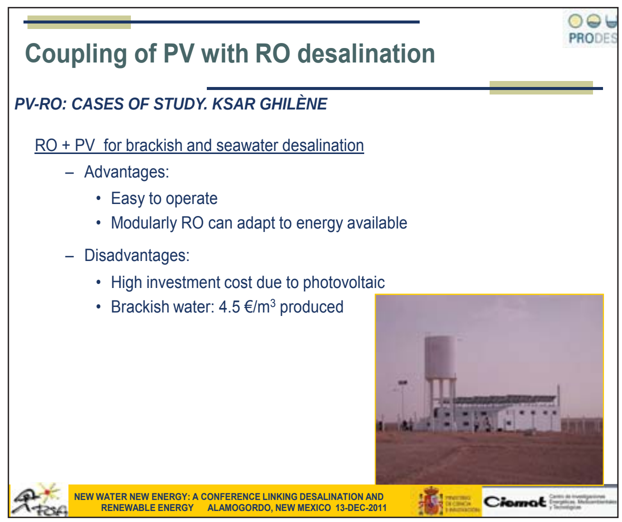

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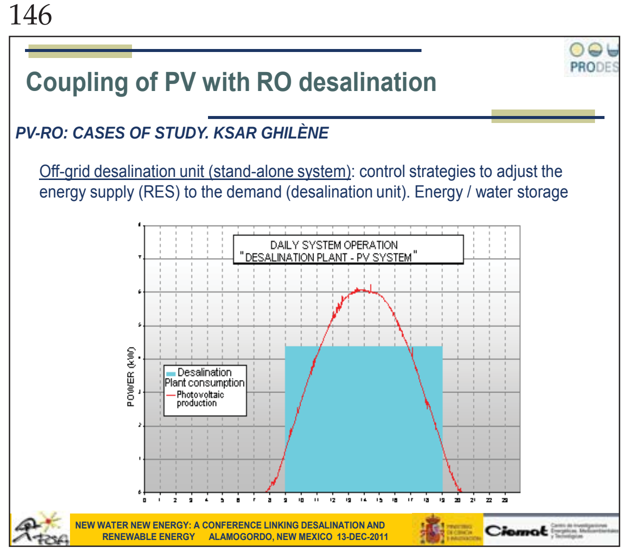

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Coupling of PV with RO desalination

PRODES

PV-RO: CASES OF STUDY. KSAR GHILÈNE — Design & operational data

	Water production (m^3)	Days of operation	Hours of operation
TOTAL Since June 06	**4,565**	**483**	**2,370.6**
1° year	**2,537**	**281**	**1,356.5**
2° year (Until March, 2008)	**2,028**	**202**	**1,014.1**
Mean 1° year	**6.9 m^3/day**	**23.4 days/month**	**3.7 h/day**
Mean 2° year	**7.4 m^3/day**	**22.4 days/month**	**3.7 h/day**

	Design	Real
Water production (m^3/year)	**4,200-4,500**	**2,537**
Days of operation/year	**320-350**	**281**

1° year: July 06-June 07
2° year: July 07-March 08

	Summer		Winter	
	Design	Real	Design	Real
Hours of operation/day	**7**	**4.25**	**5**	**3.3**

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Coupling of PV with RO desalination

PRODES

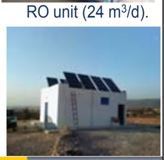
PV-RO: CASES OF STUDY. MOROCCO

Cooperation project. Autonomous PV-RO units in Morocco (since 2008)

Four PV-RO systems installed in 4 locations of Morocco.
Raw water is brackish water from inland wells (salinity 2.5 – 8.7 g/l).

Dessol®.

RO unit (24 m^3/d).



Co-funded by EU, MEDA-water programme.

PV field (4 kWp ≈ 36 m^2).

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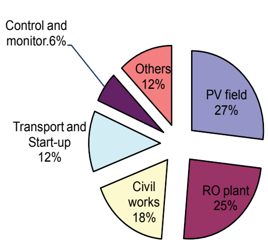
Coupling of PV with RO desalination

PRODES

PV-RO: CASES OF STUDY. MOROCCO

COSTS: Investment of one BWRO unit (1 m^3/h): 90.000 €

Total investment 360.000 €



Total water cost: 5.3 €/m^3

O&M: 3.5 €/m^3

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Coupling of PV with RO desalination

PRODES

CONCLUSIONS

LESSONS LEARNT:

PV - RO for brackish and seawater desalination (low water demands)

Advantages: 2 mature technologies, easy operation (power control system required), modularly RO can adapt to available energy.

Disadvantages: high investment cost, relatively non competitive prices of water produced (BW: from 5 to 9 €/m^3, SW: from 9 to 12 €/m^3).

- Main recommendations for RE desalination projects:

Design simple and tough, adapted to the local conditions (tailor-made project).

Elaboration of a specific control system, programmed for each particular case (reduces maintenance, maximizes water production and extends equipment life).

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Coupling of PV and Wind with RO desalination

PRODES

HYBRID WIND & PV- RO: CASES OF STUDY. MORENA

Hybrid wind & PV driven RO unit (since 2005)

MORENA system (energetically self-sufficient rural module) is a wind/PV/battery hybrid system powering a SWRO desalination unit (552 W) and a DC load.
System mounted in & on a container of 15 m^2 divided into 3 zones: one for the desalination unit and ERD, the battery bank and the electrical acquisition panels.

RO unit 154 l/h, 3.74 kWh/m^3. WT 890 W, PV array 600 Wp, battery 21 kWh.

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Coupling of PV and Wind with RO desalination

PRODES

HYBRID WIND & PV- RO: CASES OF STUDY. LAVRIO ISLAND

Lavrio island (Greece) – drinking water (2001)

SWRO hybrid autonomous system with photovoltaic solar energy and wind energy (0.13 m^3/h – 4 kWp – 900 W); CRES

Installed equipment:

- Photovoltaic field (36 modules; 4 kWp)
- Wind turbine (900 W)
- Batteries (capacity 1,800 Ah C100 24V_{DC})
- 2 Regulator-Inverter of 1.5 y 3.0 kW
- RO desalination plant of 3.2 m^3/d (recovery rate 20%)

Source: ADU-RES

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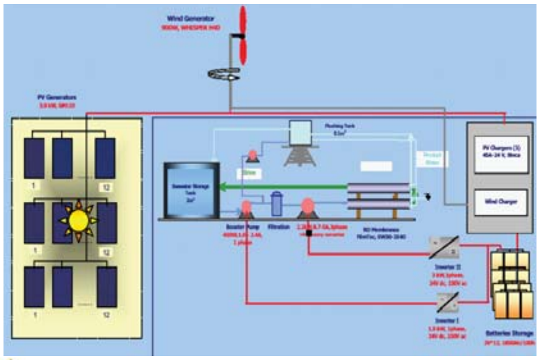
Coupling of PV and Wind with RO desalination

HYBRID WIND & PV- RO: CASES OF STUDY. LAVRIO ISLAND



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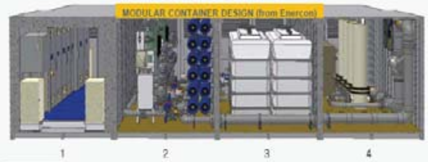
Coupling of Wind energy with RO desalination

In the recent years, few manufacturers/suppliers, in majority from the wind turbine industry, provide to the market compact Wind-RO solutions for electricity and water production.



1. Power and control container
2. Desalination/RO container
3. Water storage container
4. Pretreatment container

Wind RO Market

- Two German companies provide to the market compact W/T-RO solutions for brackish and SW desalination, in the range of 175 to 2000 m^3/day, fitted in containers. The systems can operate as stand-alone or connected to an electricity grid.
- A Danish company provides turnkey solutions for fresh water production with the use of wind turbines. The RO units are designed as containerized modules with production capacities from 10 to 3800 m^3/day.

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Coupling of PV and Wind with RO desalination

HYBRID WIND & PV- RO: CASES OF STUDY. KERATEA

CRES, Keratea, Greece, seawater, stand-alone
Desalination: 3 m^3/day RO plant
Power Supply: 1 kW W/T, 4 kWp PV, 1850 Ah/100h
Year of installation/operation: 2001
Unit Water Cost: >10 €/m^3

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Coupling of Wind energy with RO desalination

AEROGEDESA project. Pozo Izquierdo, Gran Canaria, seawater, stand-alone
Desalination: 19 m^3/d RO plant
Power Supply: 15 kW W/T, 190Ah battery bank
Year of installation/operation: 2003/4
Unit Water Cost: 3-5 €/m^3

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Coupling of Wind energy with RO desalination

Location	RO capacity (m^3/h)	Electricity supply	Year of installation
Ile du Planier, France	0.5	4kW W/T, no batteries	1982
Island of Suderoog, Germany	0.25 - 0.37	6kW W/T, no batteries	1983
Pozo Izquierdo, SDAWES	8 x 1.0	2x230 kW W/T, no batteries	1995
Tenerife, Spain; JOULE	2.5 - 4.5	30kW W/T, no batteries	1997/8
Loughborough Univ,UK	0.5	2.5kW W/T, no batteries	2001/2
Delf Univ., The Netherlands	0.2 - 0.4	Windmill, no batteries	2007/2008
Therasia Island, APAS RENA	0.2	15 kW W/T, 440Ah batteries	1995/6
Keratea, Greece PAVET Project	0.13	900W W/T, 4 kWp PV, batteries	2001/2
Pozo Izquierdo, Spain, AEROGEDESA project	0.80	15kW W/T, 190Ah batteries	2003/4
Heraklia island, Greece OPC programme	3.3	30 kW W/T off shore, batteries	2007
Island of Helgoland,Germany	40	1.2MW W/T +diesel	1988
Fuerteventura, Spain	2.3	225 kW W/T + 160 KVA diesel	1995
Syros island, Greece; JOULE	2.5 - 37.5	500 kW W/T, grid connected	1998
Milos island, Greece OPC programme	2 x 42	850kW W/T, grid connected	2007

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Coupling of Wind energy with RO desalination

SDAWES project. Pozo Izquierdo, Gran Canaria, seawater, stand-alone
Desalination: 8 x 25 m^3/d RO units
Power Supply: 2 x 230 kW + 100 kVA synchronous machine
Year of installation/operation: 2001

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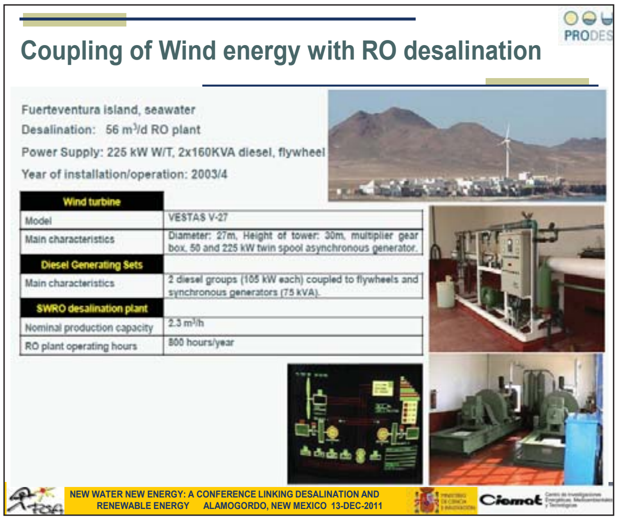

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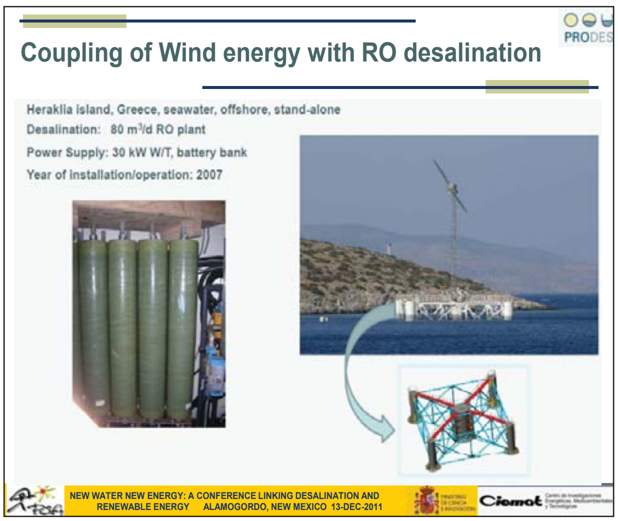

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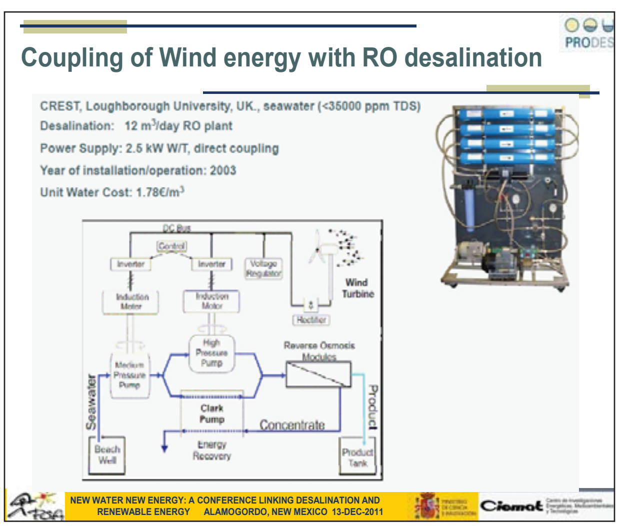

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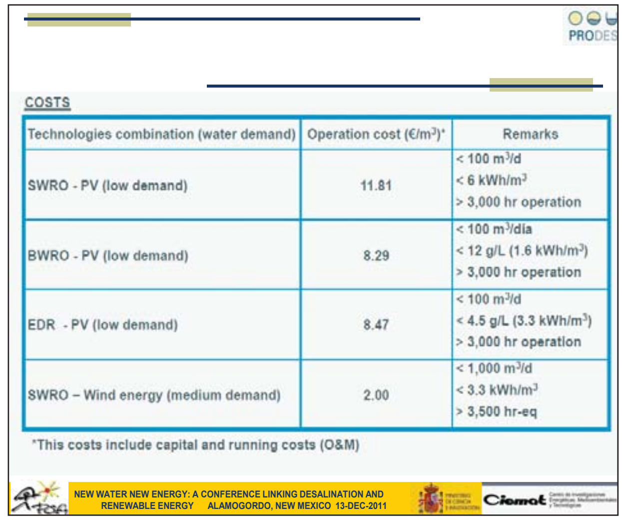

Technologies combination (water demand)	Operation cost (€/m³)*	Remarks
SWRO - PV (low demand)	11.81	< 100 m³/d < 6 kWh/m³ > 3,000 hr operation
BWRO - PV (low demand)	8.29	< 100 m³/dia < 12 g/L (1.6 kWh/m³) > 3,000 hr operation
EDR - PV (low demand)	8.47	< 100 m³/d < 4.5 g/L (3.3 kWh/m³) > 3,000 hr operation
SWRO – Wind energy (medium demand)	2.00	< 1,000 m³/d < 3.3 kWh/m³ > 3,500 hr-eq

*This costs include capital and running costs (O&M)

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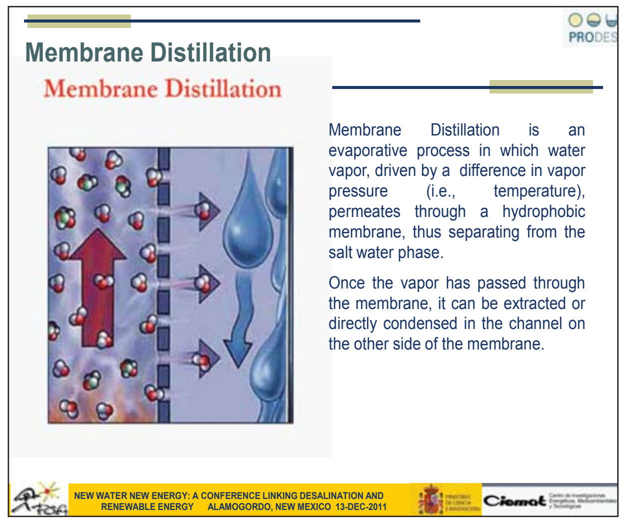

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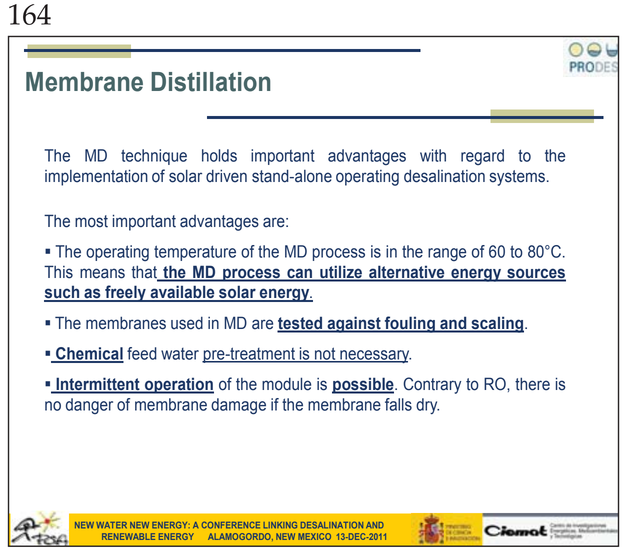

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Membrane Distillation

- **100%** theoretical **salt rejection**.
- **Lower operating pressure** than Reverse Osmosis process.
- **Reduced vapor space** compared to conventional thermal processes, thus **reduced volumes**.
- **System efficiency** and high product **water quality** are **almost independent from the salinity** of the feed water.

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Membrane Distillation

Heat Transport in MD

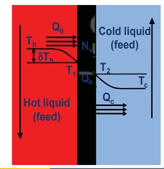
The heat flux is related to the passage of heat from the hot liquid to the cold permeate, and is characterized by three resistances in series:

1. Resistance from the hot bulk to the membrane surface, due to convective transport;
2. Resistance across the membrane, related to the transport of latent heat due to the vapor flux N_v and the conductive transport due to the thermal conductivity of the membrane and the fluid filling the pores (k_m);
3. Resistance from the membrane surface to the cold bulk, due to convective transport.

$$Q_h = h_h \cdot (T_h - T_1)$$

$$Q_m = Q_k + \lambda_{ev} \cdot N_v = k_m \cdot (T_1 - T_2) + C'_{T_m} \cdot \lambda_{ev} \cdot (T_1 - T_2)$$

$$Q_c = h_c \cdot (T_2 - T_c)$$



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Membrane Distillation

Contrary to membranes for RO, which have a pore diameter in the range of 0.1 to 3.5 nm, **membranes for MD have a pore diameter of about 0.2 mm**.

The separation effect of these membranes is **based on the hydrophobicity** of the polymer material constituting the membrane.

This means that up to a certain limiting pressure (bubble pressure) the membrane cannot be wetted by liquid water.

Molecular water in the form of **steam can pass through the membrane**.

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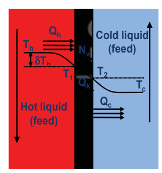
Membrane Distillation

Temperature Polarization in MD



$T_h - T_C$ = **Total temperature difference** available;

$P_1 - P_2 = f(T_1 - T_2)$ = **effective driving force** available for vapour crossing trough the membrane;

$T_h - T_1$ (dT_h) = "**driving force losses**" due to the **Temperature Polarization;**

$(T_1 - T_2)/(T_h - T_c)$ = **Temperature polarization coefficient**

Strictly related to the heat transfer coefficients from the bulk to the membrane surface and that through the membrane itself

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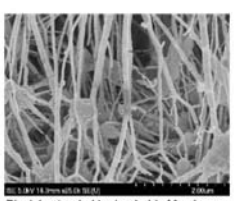
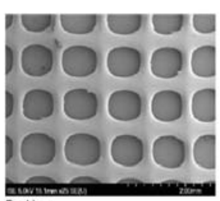
Membrane Distillation



Biaxial extended hydrophobic Membrane

Manufacturer :	GORE
Material:	PTFE
Average Poresize:	0.2µm
Thickness δ of membrane:	35µm
Wetting pressure:	4.9 bar
Porosity:	80%



Backing

Material:	Polypropylene
Thickness:	280µm
covered membrane area:	40%

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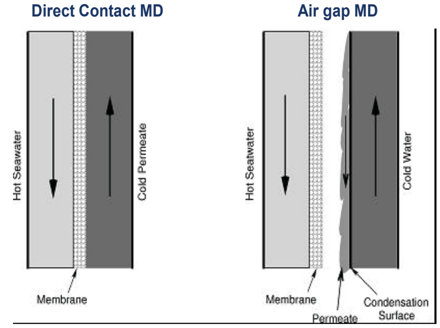
Membrane Distillation

Configurations of MD

Direct Contact MD **Air gap MD**



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Membrane Distillation

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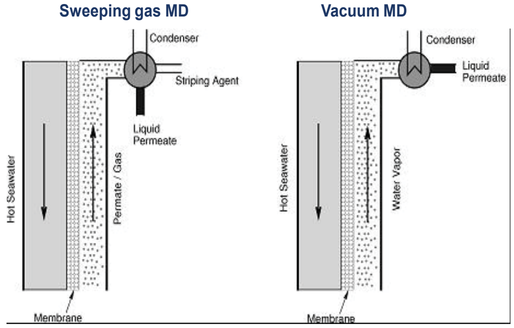
Configurations of MD



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Membrane Distillation

PRODES

Solar Powered MD

For the design of a solar-powered desalination system, the question of **energy efficiency** is very important since the investment costs mainly depend on the **area of solar collectors** to be installed.

Also the **power consumption** of the **auxiliary equipment** (for example, the pump) has an important influence on total system costs.

Therefore, the system design to be developed has to **focus on a very good heat recovery** to minimise the need of thermal energy required.

Heat recovery can be carried out by an external heat exchanger or by an internal heat recovery function, where the cold feed water is directly used as coolant for the condenser channel.

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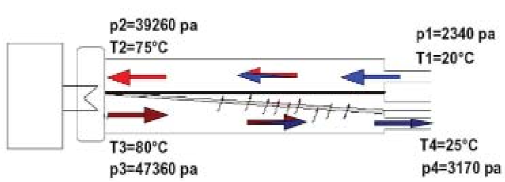
Membrane Distillation

PRODES

MD with internal heat recovery



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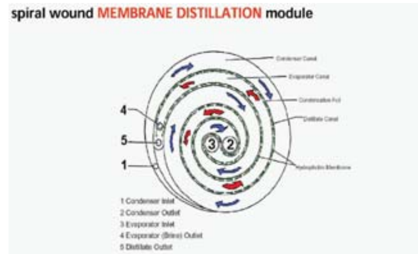
Membrane Distillation

PRODES

MD modules developed by the Fraunhofer Institute in Freiburg (Germany)

A possible design for a MD module is the formation of channels by spiral winding of membrane and condenser foils to form a spiral-wound module.



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Membrane Distillation

PRODES

Properties of MD-modules

- Dimensions: diameter 30-40 cm, height 85 cm
- distillate output 10-30 l/h (80°C evaprator inlet, 300 l/h feed flow)
- thermal energy demand about 90 to 200 kWh per m³
- Wide range of operation temperatures possible (50°C to 85°C)
- favourable behaviour under dynamic operation conditions
- no pre-treatment of feed water
- high quality of water because of distillation (conductivity of distillate 5 to 50 µS/cm)
- modular set up for systems from 100 to 20000 litres per day

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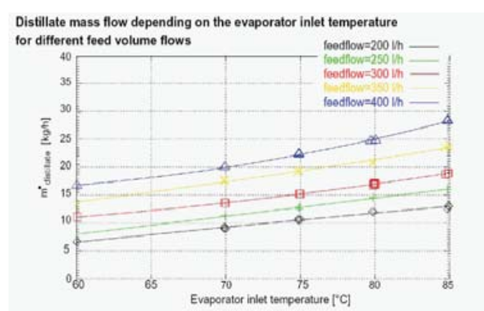
Membrane Distillation

PRODES



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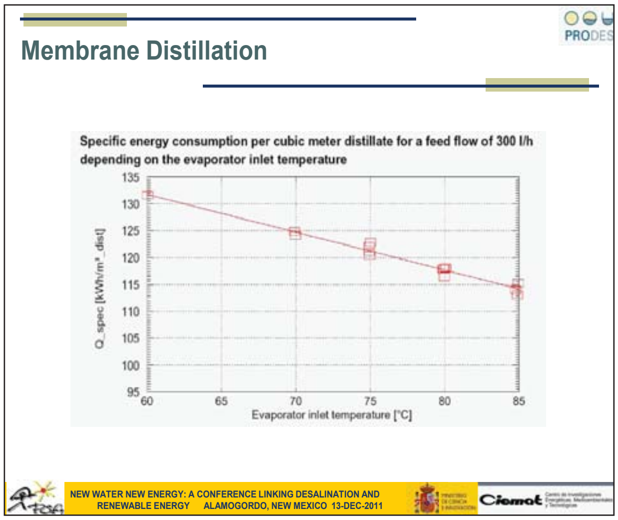

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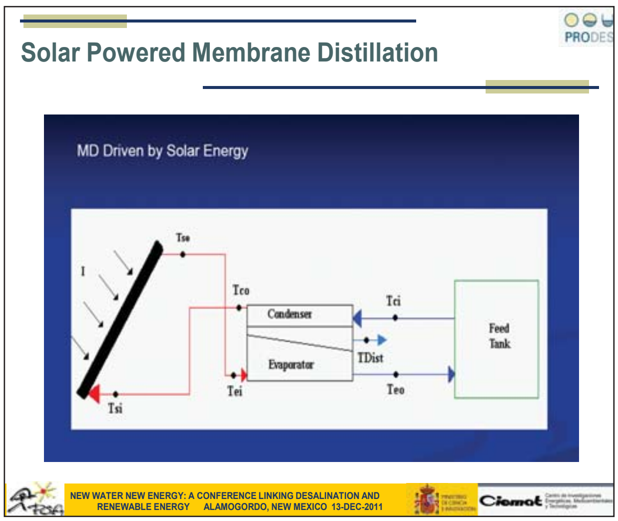

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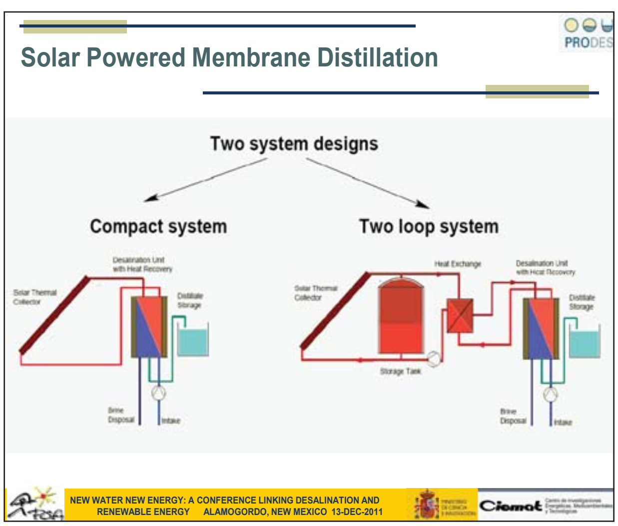

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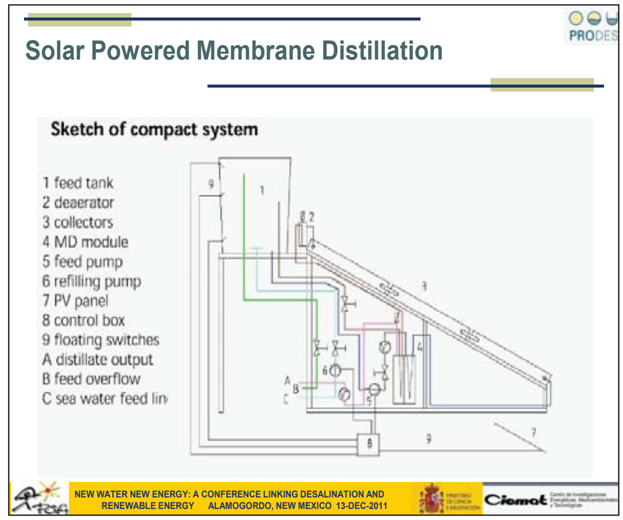

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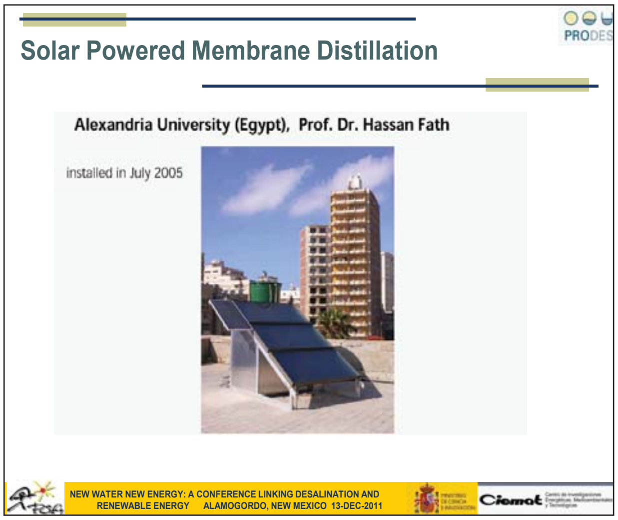

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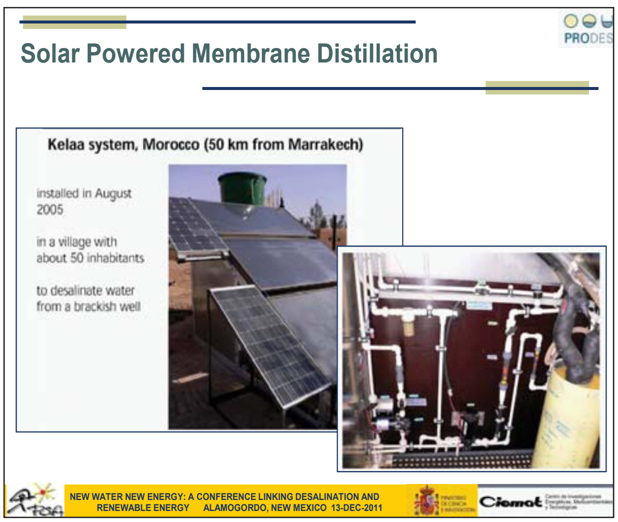

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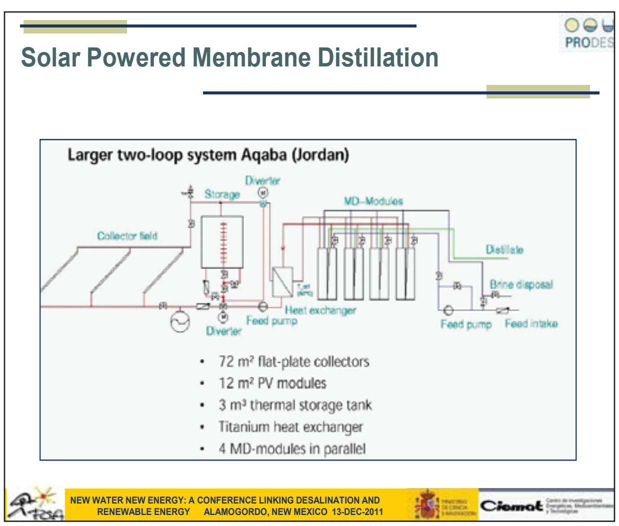

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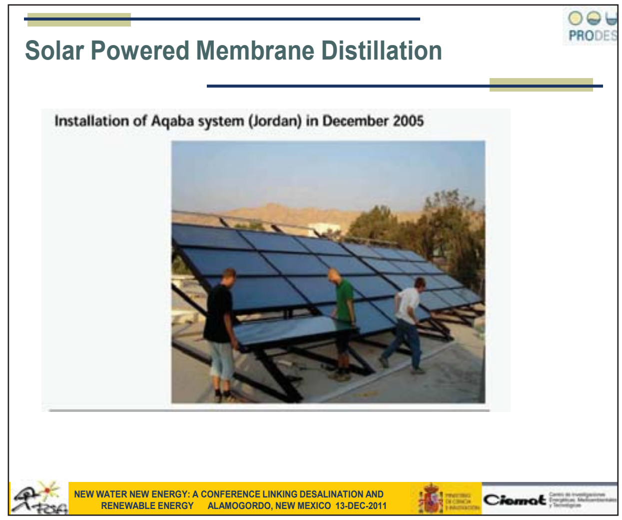

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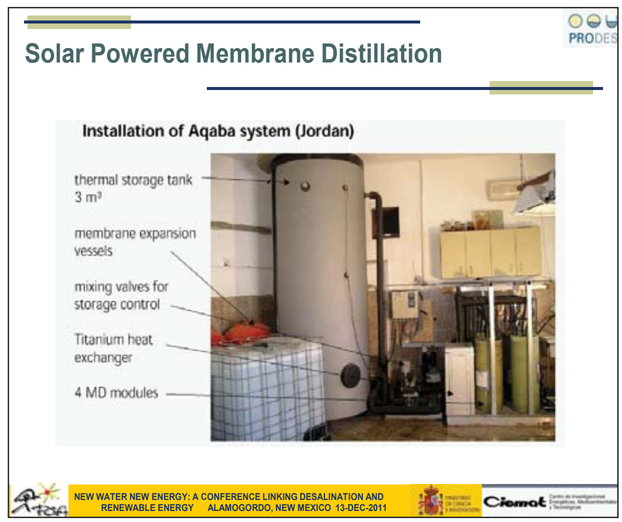

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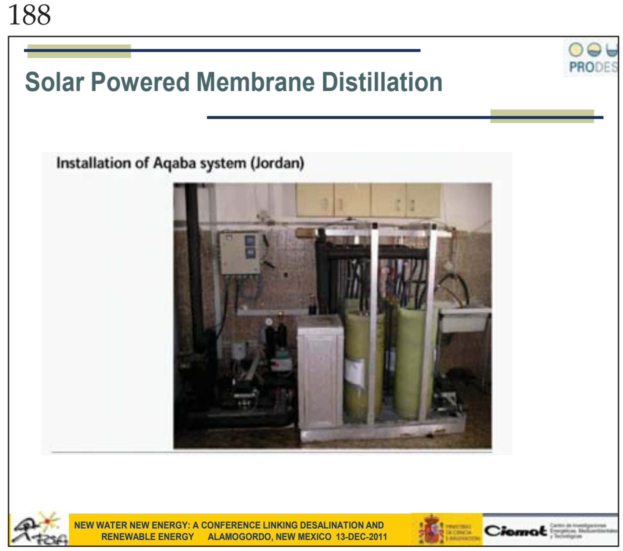

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THANK YOU
Vicente Subiela and Baltasar Peñate (Instituto Tecnológico de Canarias, Spain)
Andrea Cipollina and Giorgio Micale (University of Palermo, Italy)
Eftihia Tzen (CRES, Greece)
Marcel Wieghaus and Joachim Koschikowski (Fraunhofer Institute, Germany)
Michael Papapetrou (WIP, Germany)
PRODES
PSA
Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
MINISTERIO DE CIENCIA E INNOVACIÓN
Dr. Guillermo Zaragoza
Plataforma Solar de Almeria, Spain
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Renewable Energy Desalination: An Emerging Solution to Close MENA's Water Gap

Bekele Debele Negewo, World Bank

Dr. Bekele Debele is a Senior Water Resources Specialist at the World Bank. He has over 15 years of experience working on subjects ranging from water resources management, water supply and sanitation, irrigation, desalination and renewable energy to climate change impacts on water and agriculture sectors. Dr. Debele has published extensively in peer-reviewed journals and also has authored chapters in several books in similar fields. Before joining the World Bank, he worked in academia and private sector in Ethiopia, Ireland, and the U.S. While at the World Bank, Dr. Debele has worked in many regions, including South Asia, Latin America, Africa, and Middle East and North Africa. He has worked on, and led, many technical and policy oriented studies and projects in over 20 countries. Over the last two years, Dr. Debele has been leading a MENA region-wide flagship study on desalination and renewable energy nexus.

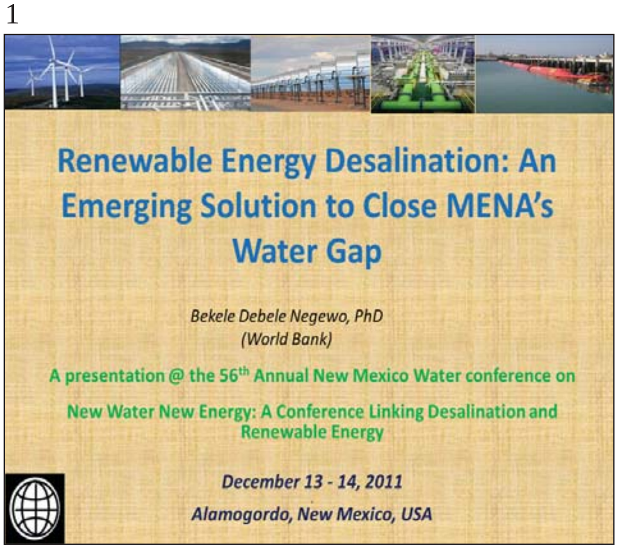
Relevant Papers:

Renewable Energy Desalination: An Emerging Solution to Close Middle East and North Africa's Water Gap *(http://wrri.nmsu.edu/conf/conf11/re-desal.pdf)*

MENA Regional Water Outlook, Part II, Desalination Using Renewable Energy, Final Report *(http://wrri.nmsu.edu/conf/conf11/mna_rdrens.pdf)*

PowerPoint Presentation **http://wrri.nmsu.edu/publish/watcon/proc56/Debele.pdf**

1



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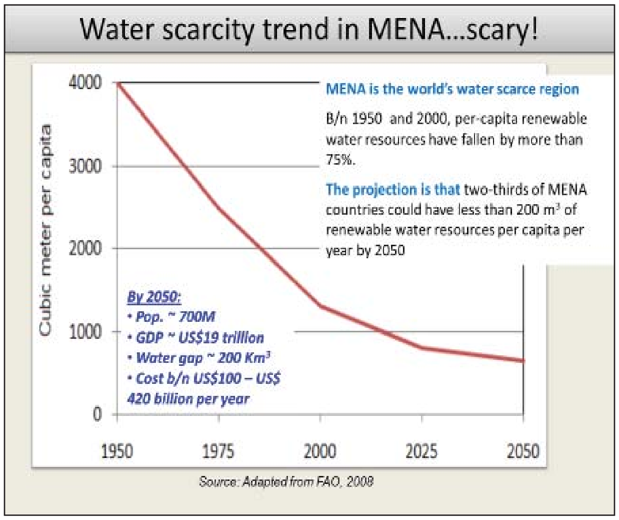
Water scarcity trend in MENA...scary!
4000
3000
2000
1000
0
Cubic meter per capita
1950
1975
2000
2025
2050
MENA is the world's water scarce region
B/n 1950 and 2000, per-capita renewable water resources have fallen by more than 75%.
The projection is that two-thirds of MENA countries could have less than 200 m³ of renewable water resources per capita per year by 2050
By 2050:
• Pop. ~ 700M
• GDP ~ US$19 trillion
• Water gap ~ 200 Km³
• Cost b/n US$100 – US$ 420 billion per year
Source: Adapted from FAO, 2008

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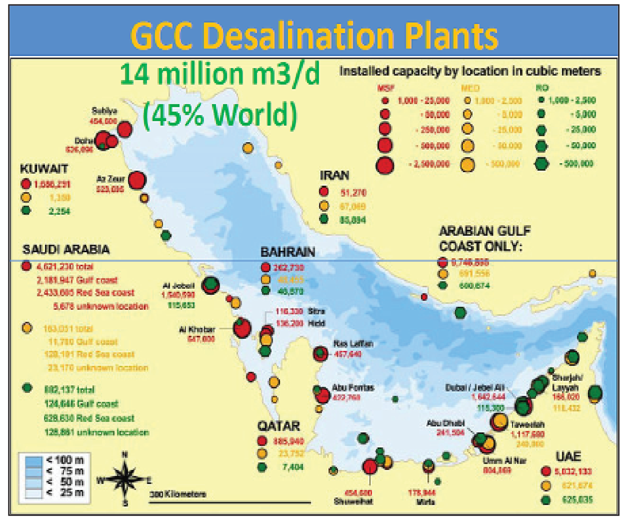
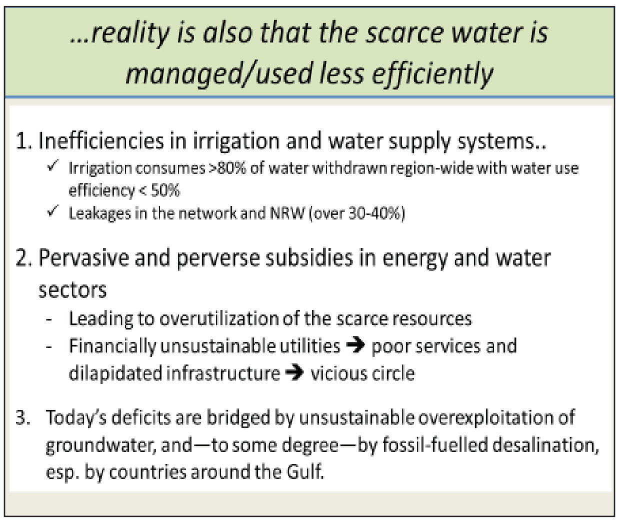

GCC Desalination Plants
14 million m3/d
(45% World)
Installed capacity by location in cubic meters
MSF
MED
RO
KUWAIT
IRAN
SAUDI ARABIA
BAHRAIN
ARABIAN GULF COAST ONLY:
QATAR
UAE
300 Kilometers

4


...reality is also that the scarce water is managed/used less efficiently
1. Inefficiencies in irrigation and water supply systems..
✓ Irrigation consumes >80% of water withdrawn region-wide with water use efficiency < 50%
✓ Leakages in the network and NRW (over 30-40%)
2. Pervasive and perverse subsidies in energy and water sectors
- Leading to overutilization of the scarce resources
- Financially unsustainable utilities → poor services and dilapidated infrastructure → vicious circle
3. Today's deficits are bridged by unsustainable overexploitation of groundwater, and—to some degree—by fossil-fuelled desalination, esp. by countries around the Gulf.

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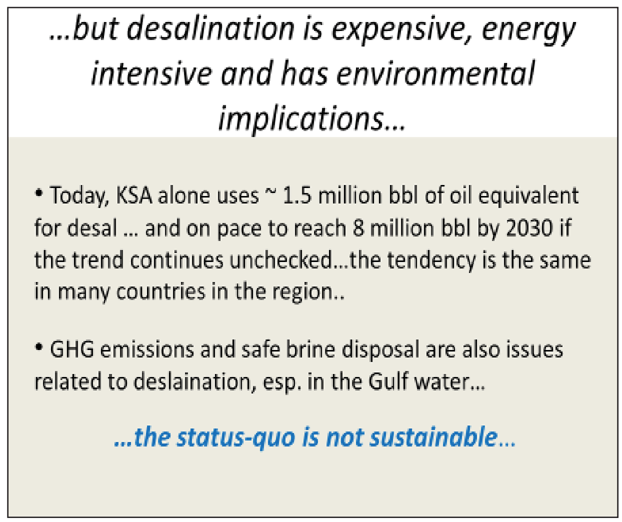
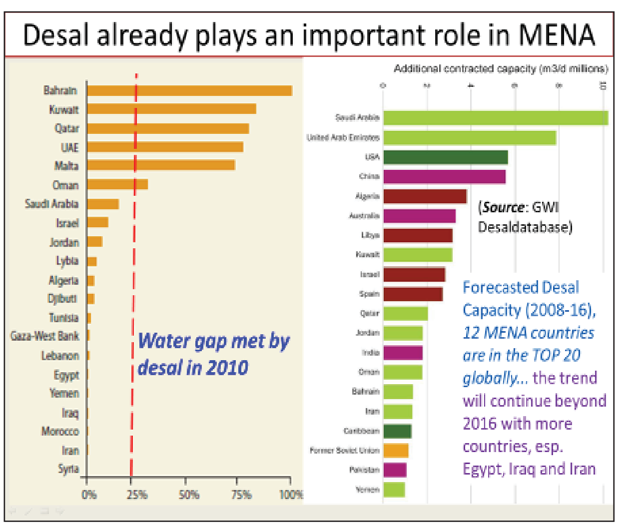
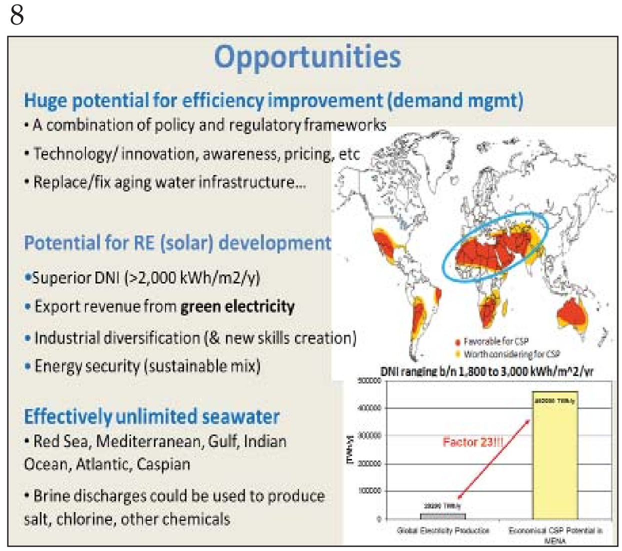

...but desalination is expensive, energy intensive and has environmental implications...
• Today, KSA alone uses ~ 1.5 million bbl of oil equivalent for desal ... and on pace to reach 8 million bbl by 2030 if the trend continues unchecked...the tendency is the same in many countries in the region..
• GHG emissions and safe brine disposal are also issues related to deslaination, esp. in the Gulf water...
...the status-quo is not sustainable...

5


Desal already plays an important role in MENA
Bahrain
Kuwait
Qatar
UAE
Malta
Oman
Saudi Arabia
Israel
Jordan
Lybia
Algeria
Djibuti
Tunisia
Gaza-West Bank
Lebanon
Egypt
Yemen
Iraq
Morocco
Iran
Syria
0%
25%
50%
75%
100%
Water gap met by desal in 2010
Additional contracted capacity (m3/d millions)
(Source: GWI Desaldatabase)
Forecasted Desal Capacity (2008-16), 12 MENA countries are in the TOP 20 globally... the trend will continue beyond 2016 with more countries, esp. Egypt, Iraq and Iran

8


Opportunities
Huge potential for efficiency improvement (demand mgmt)
• A combination of policy and regulatory frameworks
• Technology/ innovation, awareness, pricing, etc
• Replace/fix aging water infrastructure...
Potential for RE (solar) development
•Superior DNI (>2,000 kWh/m2/y)
• Export revenue from green electricity
• Industrial diversification (& new skills creation)
• Energy security (sustainable mix)
Effectively unlimited seawater
• Red Sea, Mediterranean, Gulf, Indian Ocean, Atlantic, Caspian
• Brine discharges could be used to produce salt, chlorine, other chemicals
Favorable for CSP
Worth considering for CSP
DNI ranging b/n 1,800 to 3,000 kWh/m^2/yr
Factor 23!!!

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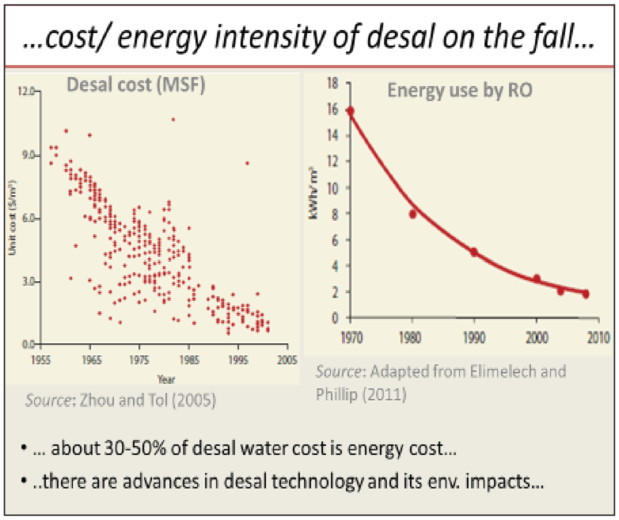

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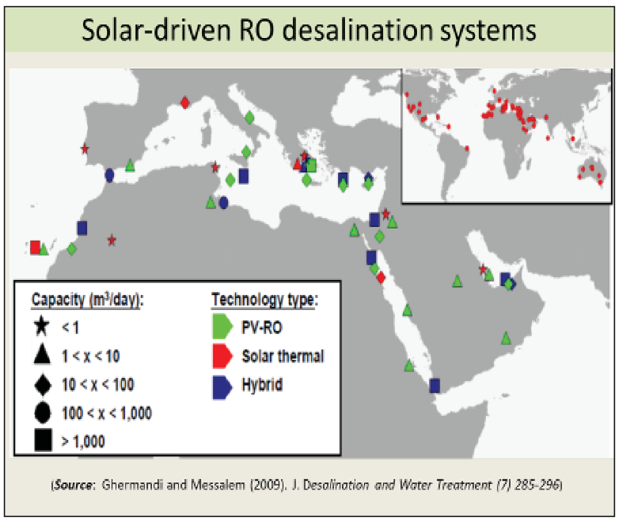

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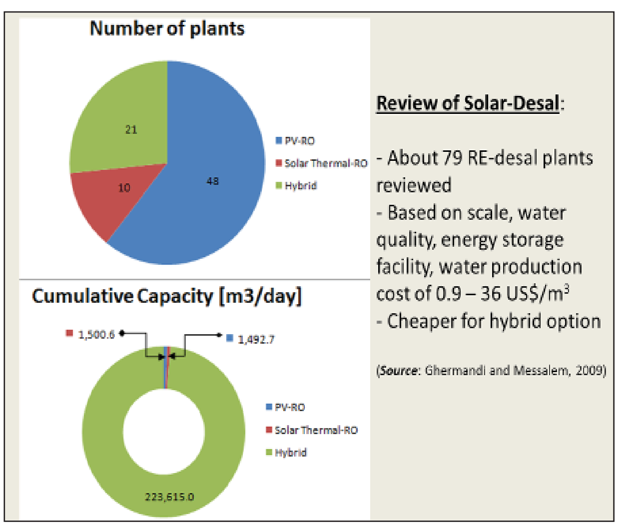

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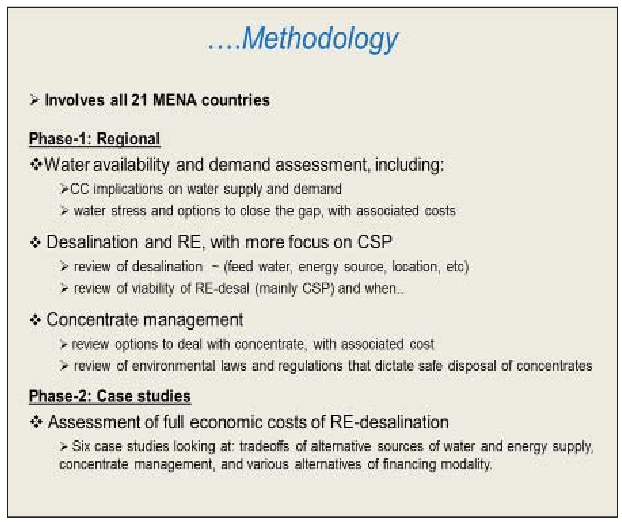

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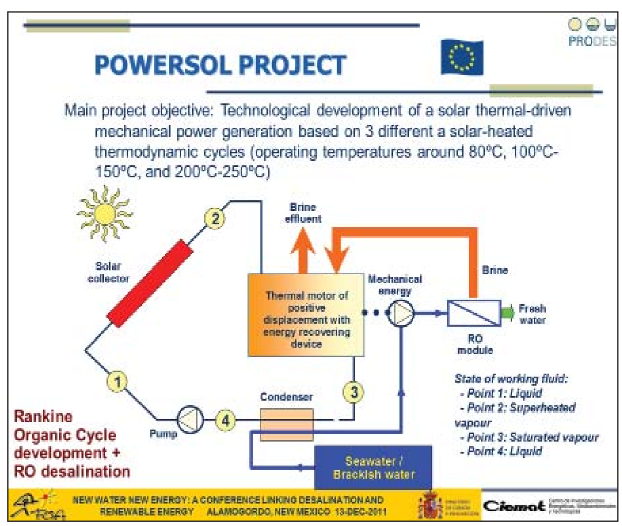

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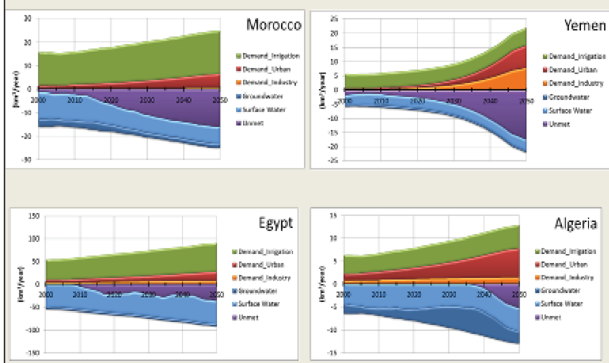
Country Specific Water Balance…examples



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Closing water gap … adaptation cost

	Water Shortage (MCM)	Costs (US$ mil)	(US$/m³)	(US$/capita)	(% of GDP 2020–30)	(% of GDP 2040–50)
UAE	3,189	3,116	0.98	716	2.36	0.79
Iraq	54,860	39,574	0.72	647	**7.56**	**2.52**
Saudi Arabia	20,208	15,849	0.78	271	1.41	0.47
Israel	3,418	2,788	0.82	265	0.49	0.16
Bahrain	383	335	0.87	248	0.78	0.26
Morocco	15,414	13,104	0.85	236	**4.72**	1.57
Libya	3,650	1,860	0.51	170	0.56	0.19
Qatar	246	158	0.64	170	0.2	0.07
Jordan	2,088	1,746	0.84	164	**4.04**	1.35
West Bank & Gaza	925	769	0.83	151	N/A	N/A
Oman	1,143	846	0.74	116	0.75	0.25
Kuwait	801	600	0.75	112	0.30	0.10
Egypt	31,648	11,321	0.36	76	2.44	0.81
Lebanon	891	363	0.41	72	1.19	0.40
Yemen	8,449	5,927	0.70	63	**11.82**	**3.94**
Malta	36	26	0.72	57	0.4	0.28
Syria	7,111	1,926	0.27	54	1.45	0.49
Iran	39,939	3,112	0.08	29	0.24	0.08
Algeria	3,947	83	0.02	1	0.01	0
Tunisia	837	17	0.02	1	0	0
MENA	199,183	103,520	0.52	148	1.61	0.54

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Closing about 200 km³/yr water demand gap is challenging and expensive

1) The basic principle was to use the least expensive water first and the most expensive water last.

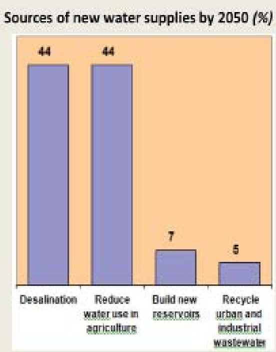
2) Demand management
- Improved irrigation (AWM)
- leakage reduction and tariff reform

3) Supply augmentation
- Water harvesting, reservoirs
- Reuse and desal

4) Cost vary b/n US$ 300 - 420 billion/yr by 2050, if desal is the only option;
- with cost optimized approach, the cost can be reduced to US$ 104 billion/yr

5) Costs vary significantly among countries…up to 6% of GDP per year

Sources of new water supplies by 2050 *(%)*



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PLANET EARTH: A WORLD OF WATER

NEW WATER NEW ENERGY: A CONFERENCE LINKING DESALINATION AND RENEWABLE ENERGY ALAMOGORDO, NEW MEXICO 13-DEC-2011

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Total Annualized Cost of Desalinated Seawater *(US$/m³)**

CSP-Desal

Feed water source	Desalination option MSF	MED	RO
Mediterranean	-	1.97–2.08	1.52–1.74
Red	-	1.88–1.98	1.58–1.66
Gulf	2.05	1.78–1.88	1.79–1.87
Ref. (conven. energy desal)	2.05	1.9 – 2.1	1.5-1.9

***Note**: based on desal capacity of 100,000 m³/day*
** the costs exclude scaled up environ. mitigation, and land and transport cost*
** = depending on site, scale, energy storage facility, unit costs of 0.9–32.0 US$/m³ have been reported for small scale RE-Desal plants …*

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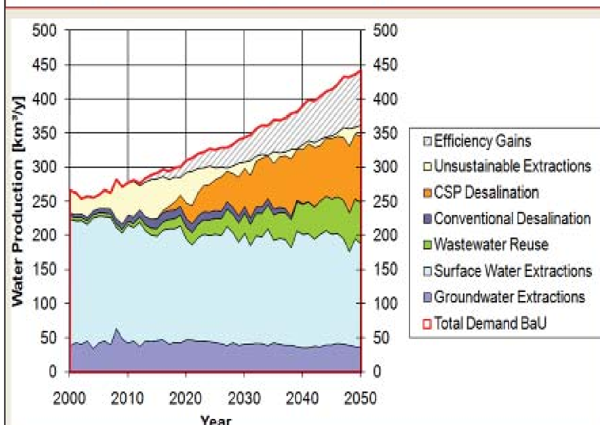
Closing demand gap … an optimized scenario



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RE can provide a win-win solution

- Coupling RE sources with desal could provide a sustainable source of potable water.
- With future advances in RE and desal technologies and economies of scale, RE may be a cost-effective alternative to conventional energy…

  …. b/c fossil fuel (GHG, limited resources, volatile and will be expensive due to competition).
- Increased RE use will reduce CO_2 emissions.
  - Using RE-desal could save up to 400 million tons of CO_2 equivalent emissions by 2050 …. scaling up RE use economy wide could cut emissions from 1.5 billion tons by 2050 (if current trends continued) to 265 million tons by the same year.
  - Can reduce volume of brine produced due to flexibility to employ RO instead of thermal desal…

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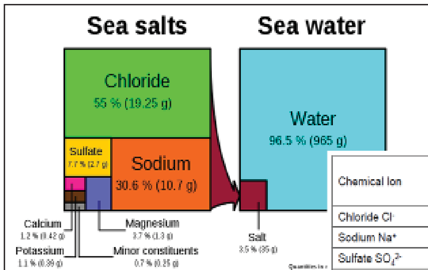

Chemical Ion	concentration ppm, mg/kg	part of salinity %	mmol/kg
Chloride Cl^-	19,345	55.03	546
Sodium Na^+	10,752	30.59	468
Sulfate SO_4^{2-}	2,701	7.68	28.1
Magnesium Mg^{2+}	1,295	3.68	53.3
Calcium Ca^{2+}	416	1.18	10.4
Potassium K^+	390	1.11	9.97
Bicarbonate HCO_3^-	145	0.41	2.34
Bromide Br^-	66	0.19	0.83
Borate BO_3^{3-}	27	0.08	0.46
Strontium Sr^{2+}	13	0.04	0.091
Fluoride F^-	1	0.003	0.068
TOTAL	35,151		

Seawater composition

Although salinity of seawater may well vary depending on the specific region of the world, the percentage composition of seawater is essentially constant throughout the world (i.e. the proportions of the major constituents are constant).

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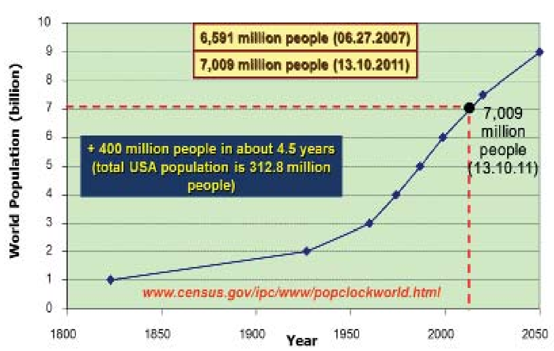
World population evolution



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Next steps..

Case studies/Report:

1. Summary of best practices in desal (technology selection, financing modality, brine management, etc)
2. Barriers against adoption of alternative energy and water supply options (policy, financing, etc)
3. Full economic analysis:
   - Algeria—InSalah
   - Egypt – Marsa Alam
   - Yemen—Taiz
4. On phase-1 report:
   - **Background material** WWW.WorldBank.org/mna/watergap
   - **Comments are welcome until Dec. 23, 2011**
   - **Launch for the 6th WWF 2012…**

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Bekele Debele Negewo: bdebelenegewo@worldbank.org

NCED Australia Research Update

David Furukawa, National Centre of Excellence in Desalination Australia

Professor David Furukawa was appointed Chief Scientific Officer for Australia's National Centre of Excellence in Desalination, Murdoch University, Perth, Australia. He was awarded an Honorary Professorship at the university in 2011. He is an internationally recognized expert in the field of membrane separation processes. He is past president and director of IDA and AMTA.

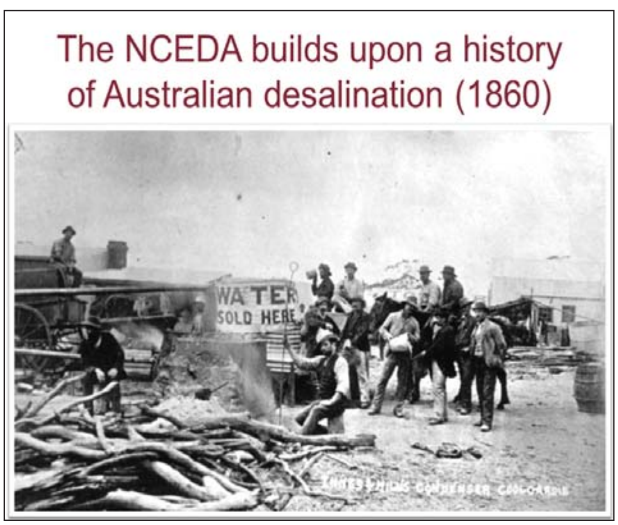
In 1992, he was named to the research advisory board of the National Water Research Institute and later became the RAB chair. Since its founding in 1991, NWRI has collaborated with over 100 partners around the world to fund efforts in research, education, and outreach related to water and marine environment projects.

In 1996, he and Ron Linsky, laid groundwork for the Middle East Desalination Research Centre, in Muscat, Sultanate of Oman and later became vice moderator of the Research Advisory Council. Organized under the auspices of the Multi-lateral Middle East Peace Process, this centre was developed to help countries in the region cooperatively solve common water problems.

Professor Furukawa is president of Separation Consultants, Inc., whose clientele includes water districts, city water utilities, private companies, engineering companies, national and international organizations.

PowerPoint Presentation **http://wrri.nmsu.edu/publish/watcon/proc56/Furukawa.pdf**

1



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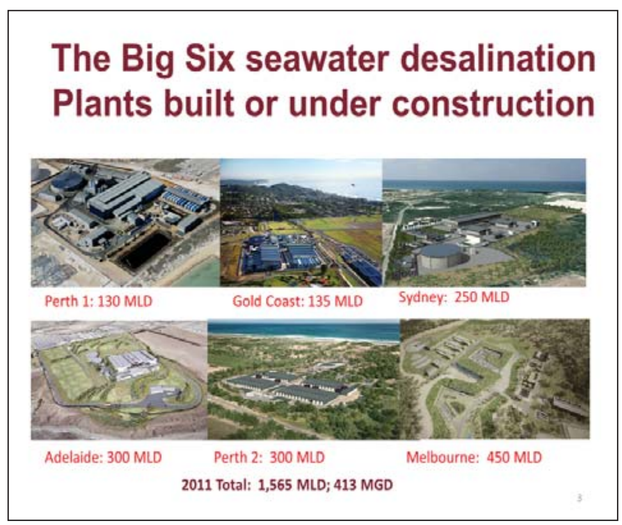

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The National Centre of Excellence in Desalination Australia

- Established in 2009
- $20m research funding over 5 years from the Federal Government's National Urban Water and Desalination Plan
- $3m for establishment of Rockingham Desalination Research Facility funded by WA Government

Australian Government
Water for the Future

THE GOVERNMENT OF WESTERN AUSTRALIA

4

The National Centre of Excellence in Desalination Australia

- Research Roadmap developed in 2010

5

The *Research Roadmap* developed priority research themes, validated by industry

- Pre-treatment
- Reverse osmosis desalting
- Novel desalting
- Concentrate management
- Social, environmental and economic issues

6

NCEDA research program objectives

Murdoch University Rockingham Campus

- Lead and coordinate national research
- Build national capacity, capabilities and international collaboration
- Advance the science of desalination

7

NCEDA mission

- To optimise and adapt desalination technology for use in Australia's unique circumstances
- To develop suitable desalination technology for use in rural and regional areas
- To improve efficiency and reduce the carbon footprint of desalination facilities and technologies

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NCEDA stakeholders are Australia's leading desalination and water research scientists

CSIRO
Curtin University of Technology
DEAKIN UNIVERSITY AUSTRALIA
ECU EDITH COWAN UNIVERSITY
Flinders UNIVERSITY
MONASH University
UNSW
The University of Queensland Australia
University of South Australia
University of Technology Sydney
Victoria University
The University of Western Australia
University of Wollongong

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NCEDA's 13 members collaborate in research projects with more than 50 industry partners, including:

10

10

NCEDA's international collaborators include:

11

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NCEDA industry engagement

Gold Sponsors

12

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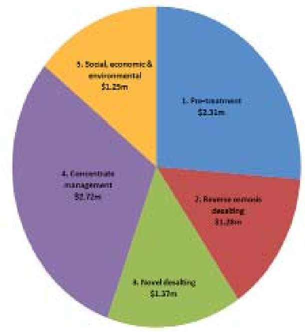
Investments



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Approved Projects in Three Funding Rounds

- 126 expressions of interest
- Centre funds invested: $9.6m in 33 projects
- In-kind contributions from Partners $18.5m
- Leveraged cash from industry $3.7m
- A total of $31.8m of research activity

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Funding Round 1

- Novel low grade heat driven desal (MEDx)
- High water recovery; ceramic membrane distillation
- Brine disposal management into inland ecosystems
- RO brine management; membrane distillation crystallisation
- Vibratory shear membrane technology; concentrate minimisation and recovery/recycle
- Public perception of/response to desalination
- Reuse of RO membranes
- Diatom nanostructure; predictive model for species sustainability
- Bio-organic membranes
- Membrane flocculation hybrid system for pretreatment; chemical use reduction and recovery

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Funding Round 2

- Cleaning guidelines for desalination membranes
- Universally applicable coatings/additives for RO and pretreatment membranes
- Tjuntjunjarra remote inland indigenous community solar/waste energy BW desal
- Silica removal to enhance recovery/brine volume reduction
- Fertilizers as draw solutes for FO
- Natural polysaccharide surface coating to mitigate fouling
- Non-brittle ceramic HF membranes
- CDI for inland brackish water desalination

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Funding Round 3

- Fibre optic sensor for water quality monitoring
- Transverse vibrational motion enhanced submerged hollow fiber crystalliser
- Modelling, monitoring and control of RO biofouling
- Smart materials for corrosion management
- Non-chemical pulsed power technology as antifouling pretreatment for RO
- Assisted FO for RO energy reduction
- Biofouling role of microbes in desalination system; from intake to RO membranes
- Continuous silica removal to increase water recovery
- Brine management guidelines
- Membrane adsorption bioreactor hybrid system to pretreat RO
- Optimisation/improvement of direct filtration pretreatment for organic and biofouling of RO membranes

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Emerging ideas: Capacitive deionisation

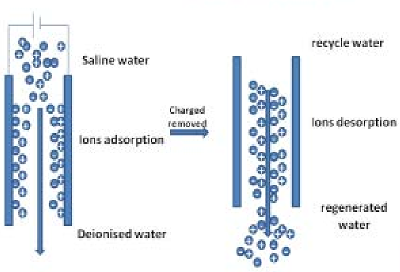

Photo: EWP/LT Green Energy

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Prof. Linda Zou, UniSA

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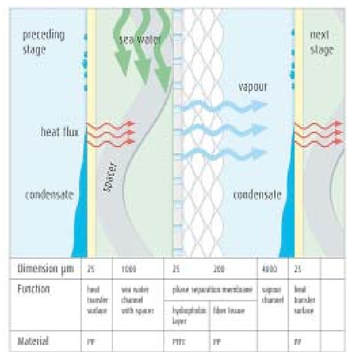
Emerging ideas: Robust, self sustaining, remote water



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Membrane Distillation by definition

A process in which a microporous, hydrophobic membrane separates aqueous solutions at different temperatures and compositions. The temperature difference across the membrane results in a vapour pressure difference. (Drioli, et al, J. Membrane Science, 33,277, 1987).

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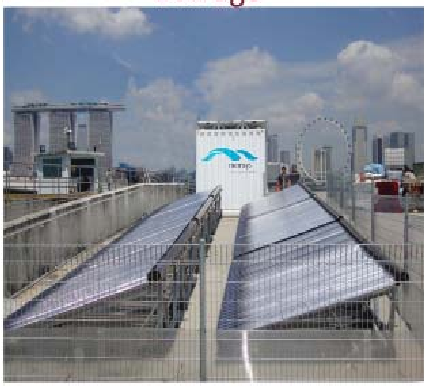
MD system at Singapore Marina Barrage



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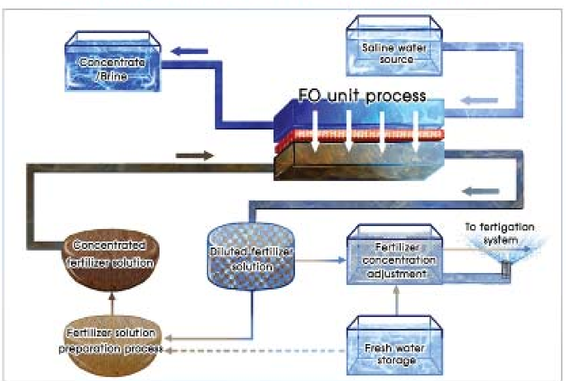
Emerging ideas: Fertigation



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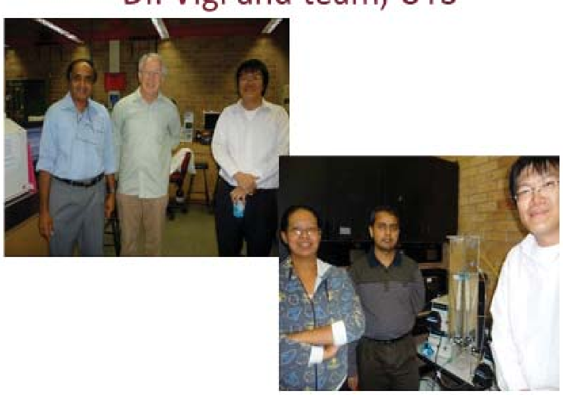
Dr. Vigi and team, UTS



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The Centre has taken a unique approach to commercialisation and industry involvement

- A share of IP revenues is reinvested in research
- Commercialisation potential is a key evaluation criteria for proposals
- The Centre sought widespread industry involvement in shaping and validating the *Roadmap*
- The Centre seeks a clear path to market for technological proposals

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Rockingham Desalination Research Facility

26

NCEDA Rockingham's concept design focuses on flexibility and service delivery

- Seawater and fresh water from underground provides a range of feedwater
- Instrumentation, automation, control
- Supporting worksho laboratories, offices, and administration

Mike Blackwood, Facility Manager (L) and Frank Olewniak, Project Manager

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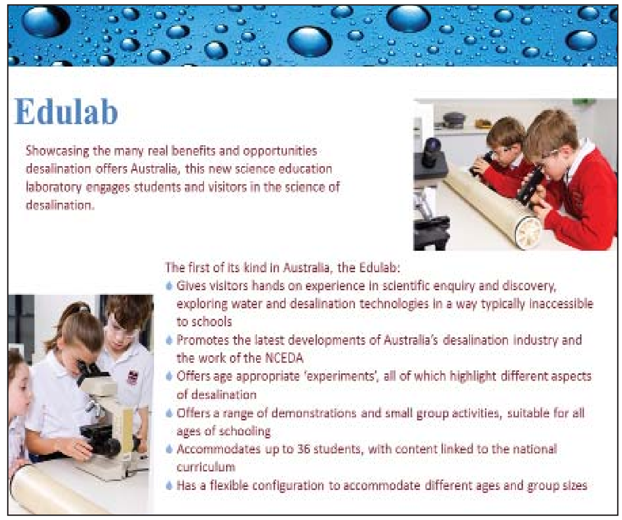

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QUESTIONS?

For more information:

www.desalination.edu.au

34

A problem

35

35

An idea

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Energy Efficient Strategies and Renewable Energy Utilization for Desalination

Joe Jacangelo, WateReuse Research Foundation

Dr. Jacangelo is a Vice President and Director of Research for MWH. He has 27 years of experience in the field of environmental health engineering, and has specialized in the areas of water quality and treatment, water and wastewater disinfection, membrane technology, renewable energy and public health. He has served as Technical Director, Principal Investigator, Project Manager or Engineer for over 80 water and wastewater projects. He has published over 100 technical papers and holds various positions within professional organizations such as American Water Works Association and the International Water Association. Dr. Jacangelo is also an adjunct faculty member at the Johns Hopkins University Bloomberg School of Public Health. In addition, he is the Chair of the Board of Directors for the WateReuse Research Foundation and a past board member of the American Water Works Association. Dr. Jacangelo served three years as a Peace Corps Volunteer in the Republic of the Congo.

PowerPoint Presentation **http://wrri.nmsu.edu/publish/watcon/proc56/Jacangelo.pdf**

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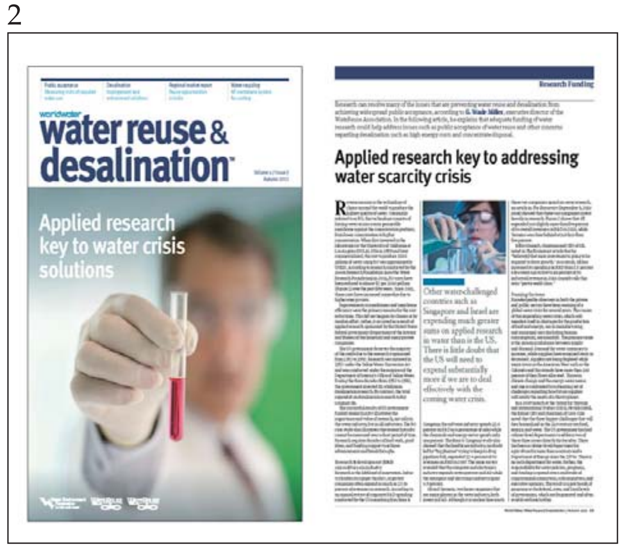

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Commitment to Research

$42 Million since 2001

4

Energy Efficient Strategies and Renewable Energy Utilization for Desalination

Jacangelo, Ph.D., REHS[1,2]
Arun Subramani, Ph.D. [1], Mohammad Badruzzaman, Ph.D., P.E. [1], Joan Oppenheimer, MSPH[1]

[1]MWH
[2]The Johns Hopkins University Bloomberg School of Public Health

5

Background

- The generation of energy is the single largest source of green house gas (GHG) emissions.
- Optimizing the energy of desalination and reuse processes has become a critical component in addressing energy consumption.
- Increasing renewable energy resource (RES) utilization and reducing GHG emissions has become an important goal for water utilities and agencies.

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Study Goals

- To develop a comprehensive knowledge-base with the most updated developments in energy minimization and renewable energy techniques.
- Prepare a guidebook based on the relevant practical lessons learned by global researchers, organizations and utilities.

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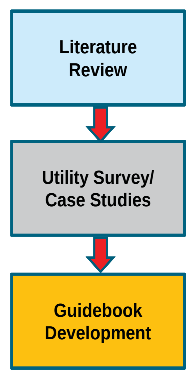
Project Summary



- Collect information on energy minimization strategies, technological advancements and economic analyses (*Water Research* 45: 1907, 2011).
- Document information on process, implementation strategies, regulation and policy.
- Provide information to utility and policy makers.

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Promising New Desalination Technologies

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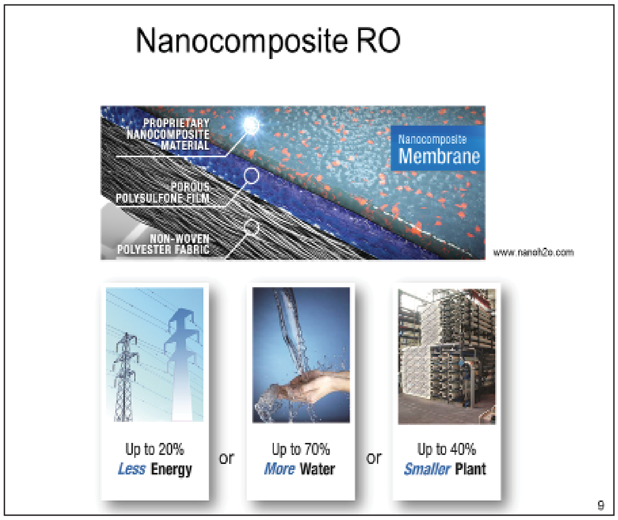

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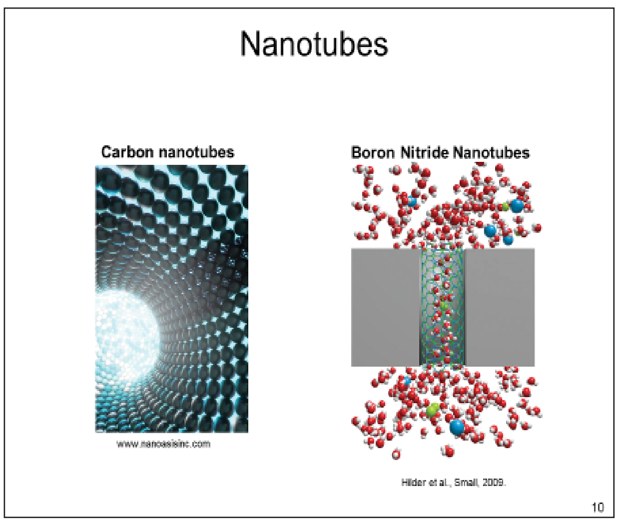

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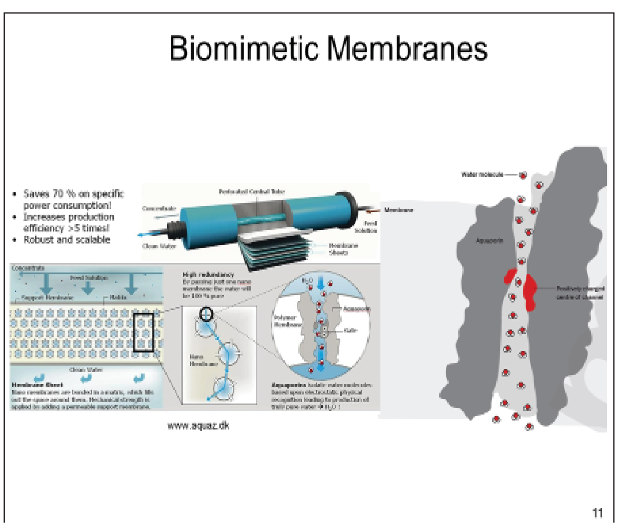

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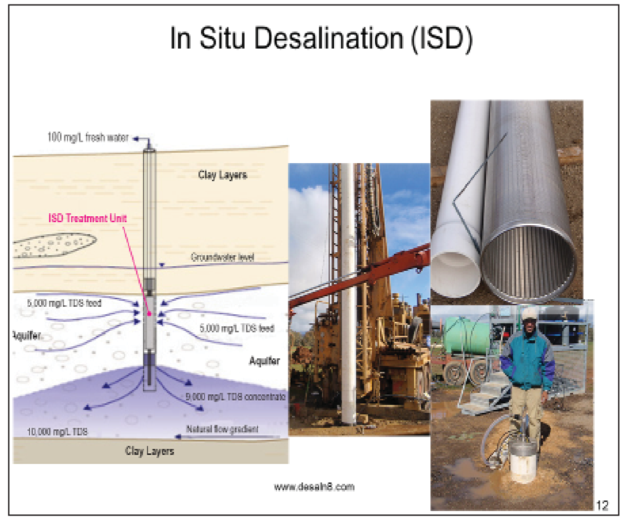

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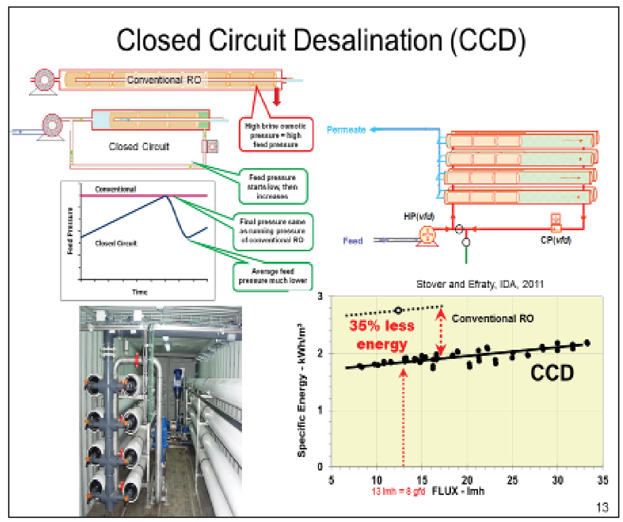

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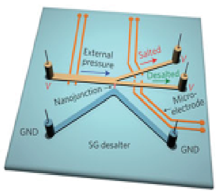
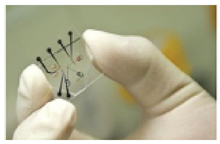
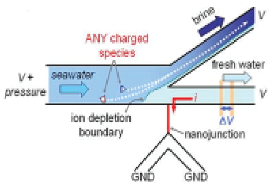
Ion Concentration Polarization







- **Ion concentration polarization**:
  - Absence of membrane and applied pressure.
  - Specific energy consumption similar to RO ~ 3.5 kWh/m^3 (Kim et al., *Nature Nanotechnology*, 2010).
  - 1,600 units fabricated on 8-inch wafer – 15 LPH of desalted water.

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Benefits of Renewable Energy Sources

- Renewable energy is carbon neutral
- Abundant resources
- Underutilized
- Decentralized facilities
- Ability to create new employment

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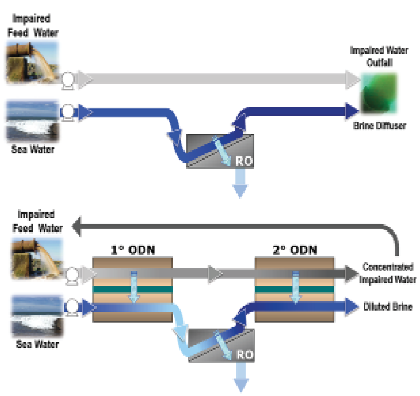
FO/RO Hybrid: Osmotic Dilution of Seawater



Cath et al., WateReuse Research Foundation, 2009.

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Challenges of Renewable Energy Sources

- High capital costs
- Local/region dependent
- Often require new infrastructure
- Requires funding and incentives
- Large footprint requirement
- Return-on-investment (ROI)

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Renewable Energy Utilization

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Established Renewable Energy Technologies

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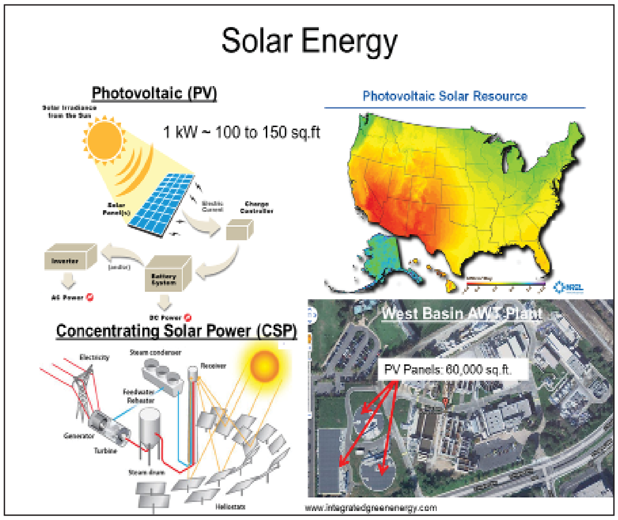

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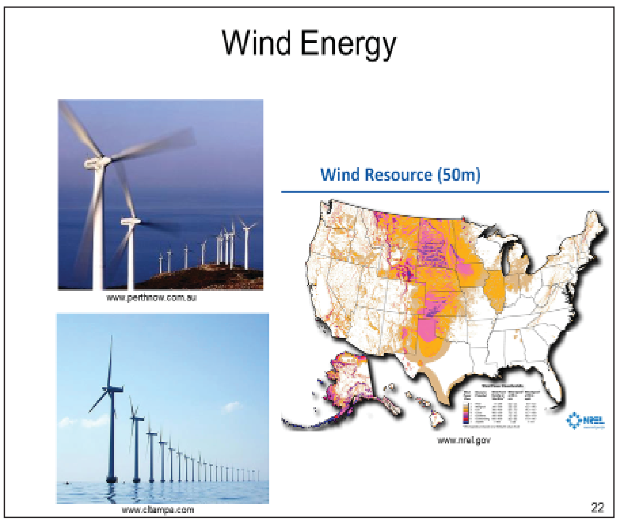

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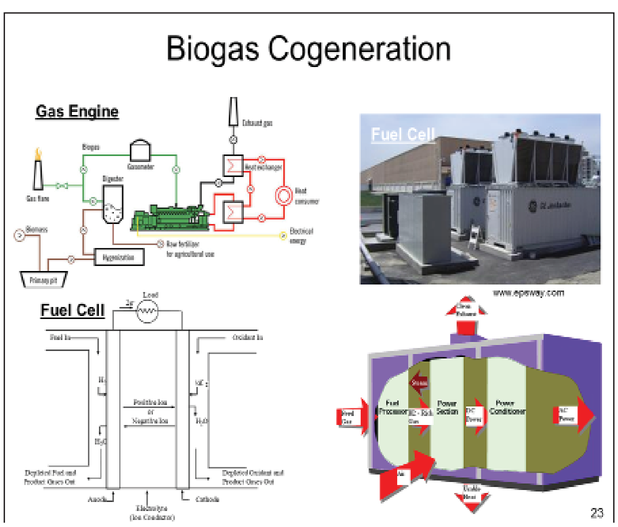

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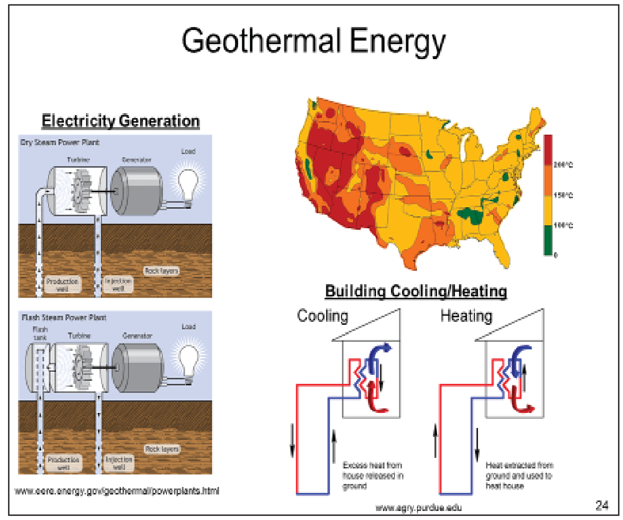

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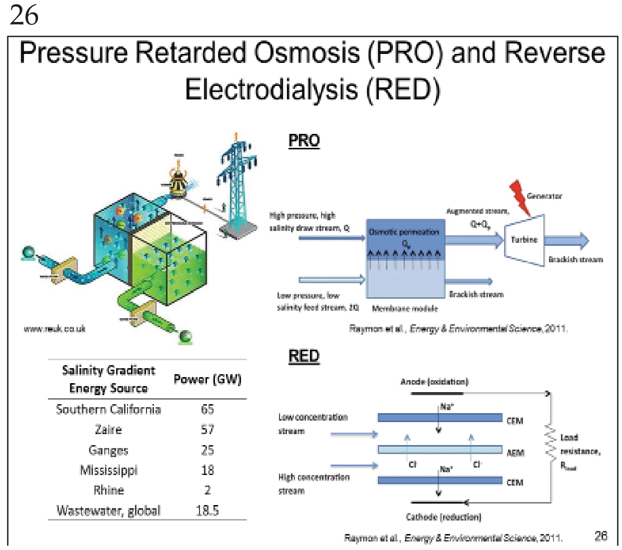

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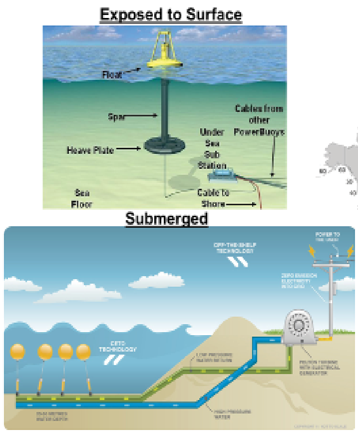
Wave Energy



Wave Energy Levels (kW/m of Wave Front)
www.oceanpowertechnologies.com

Carnegie Water Energy Limited

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Questionnaire Objectives

- Treatment process description
- Energy consumption for utilities using conventional energy source
- Energy consumption for utilities using renewable energy
- GHG emissions and tools used for quantification
- Economic evaluation for integrating renewable energy and implementation of energy efficient strategies
- Regulation and policy for energy management

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Utility Case Studies

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Utilities Participating in Study

Type of Plant	Capacity MGD	End Use	Feed TDS, mg/L	Permeate TDS, mg/L	Energy Consumption, kWh/m³
Reuse 1	30	GWR, IPR	850	30	NA
Reuse 2	11	IPR, Industrial	552	26	0.98
Seawater Desalination 1	38	DW	37,000 - 40,000	< 200	3.6
Seawater Desalination 2	66	DW	36,700	275	3.3
Seawater Desalination 3	88	DW	40,500	< 80	3.5
Seawater Desalination 4	36	DW	35,000	< 270	3.5 – 3.9
Seawater Desalination 5	25	DW	< 28,500	< 360	3.9
Brackish Desalination 1	3.5	DW	2,300	< 320	0.94
Brackish Desalination 2	8	DW	2,000	< 150	1

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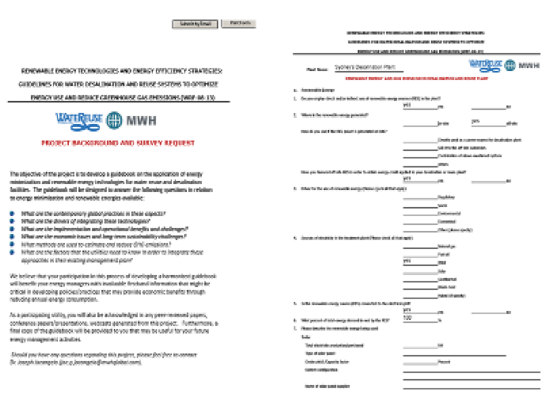
Survey Questionnaire



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Energy Consumption of Various Components of a Seawater Desalination Plant Participating in Study

Component	Energy Consumption, kWh/m³
Raw Water Pumping	0.39
Pretreatment & Desalination	2.865
Post Treatment	0.012
High service pump station	0.3
General (Buildings, heating, cooling)	0.04
Total Energy Consumption	3.607

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Reported Energy Minimization Strategies

- Energy efficiency of pumps monitored (pump efficiency curves) to determine if the pumps and motors are operating close to the best efficiency point (BEP).
- Older pumps and motors replaced with newer premium efficiency models.
- VFDs installed to control motor speed.
- Smaller RO trains and larger high pressure pumps utilized for seawater desalination.
- ERDs (pelton wheel, pressure exchangers) for seawater desalination were installed in the first pass.
- ERDs (turbochargers) for brackish water desalination were installed between the first and second stage to operate as a booster pump.

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Renewable Energy Employed by Utility Participants

Type of Plant	Renewable Energy	% Use of Renewable	Onsite/Offsite	Funding/Incentives
Reuse 1	Solar PV	20%	Onsite - Grid Connected	*Southern California Edison*
Reuse 2	Cogeneration	20%	Onsite - Grid Connected	*Energy Saving Fund (NSW Dept. of Env. and Climate Change)*
Seawater Desalination 1	Wind	100%	Offsite - Grid Connected	*Government*
Seawater Desalination 2	Wind	100%	Offsite - Grid Connected	*Energy Saving Fund (NSW Dept. of Env. and Climate Change)*
Seawater Desalination 3	None	0%	-	-
Seawater Desalination 4	None	0%	-	-
Seawater Desalination 5	None	0%	-	-
Brackish Desalination 1	Future Consideration	0%	Considering Onsite Solar PV/CSP	*Not Determined*
Brackish Desalination 2	Future Consideration	0%	Considering Onsite Solar PV	*Not Determined*

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Challenges for Utility Participants

Plant Type	ROI	Funding	Footprint	Integration	Permitting
Reuse 1	_	+	_	_	+
Reuse 2	_	+	+	_	+
Seawater Desalination 1	_	+	+	+	+
Seawater Desalination 2	_	+	+	+	+
Seawater Desalination 3	NO RENEWABLES UTILIZED				
Seawater Desalination 4	NO RENEWABLES UTILIZED				
Seawater Desalination 5	NO RENEWABLES UTILIZED				
Brackish Desalination 1	_	?	?	?	_
Brackish Desalination 2	_	_	+	?	?

"+" indicates "favorable condition"
"-" indicates "NOT favorable condition"
"?" indicates "NOT evaluated"

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Reported Renewable Energy Utilization Lessons

- Feasibility study essential before implementation at the utility scale.
- Footprint requirements for installation of solar PV reduced by installing solar panels on existing concrete tanks.
- Grid integration for solar PV panels improved by utilizing several inverters in parallel to provide continuous power supply.
- Government funding and support from utility board was key in the implementation of renewable energy resources.
- Risk shared in delivery of renewable energy: third party utilized to provide independent risk assessment.
- Specialized staff required within utility during the design and implementation phase.

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Guidebook

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The Purpose of the Guidebook is to Answer the Following Questions

- What resources are available as a utility manager to reduce energy consumption and implement renewable energy resources?
- What are the strategies available to reduce energy consumption in an existing or newly proposed plant?
- How are energy efficiency and GHG emissions monitored?
- What are the steps required for implementing renewable energy?
- What are the renewable energy technologies available for implementation at a large scale?
- What are the funding options available?
- What are the challenges involved during implementation of renewable energy resources?

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Components of the Guidebook

- Chapter 1: Introduction
- Chapter 2: Planning
- Chapter 3: Implementation of Efficient Energy Strategies
- Chapter 4: Utilization of Renewable Resources
- Appendices – Utility Surveys and Literature Review

Important information

Further resources and tools

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Implementation of Energy Efficient Strategies (Contents of Chapter 3)

- Distribution of energy consumption through treatment processes.
- Design strategies for energy minimization during design of seawater/brackish water/advanced water treatment processes.
- Pumping strategies for energy efficiency.
- Selection of energy minimization components for treatment processes.
- Strategies to reduce energy consumption with HVAC and lighting.
- Implementation of energy efficient strategies.

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Example: What you need to know while selecting ERDs (Contents of Chapter 3)

Criterion/Device	Pelton Wheel Turbine	Reverse Running Turbine Pump	Turbo Booster Pump	Pressure or Work Exchanger
Commercial Availability	Yes	Yes	Yes	Yes
Proven Technology for high salinity applications	Yes	Yes	Yes	Yes
Potential Energy Savings (Relative to each other)	Medium	Low to Medium	Low	High
Capital Cost (Relative to each other)	Low to Medium	Low to Medium	Low	High
O&M Costs (Relative to each other)	Low	Low	Low	Medium to High
Efficiency (Relative to each other)	Medium (84% to 90%)	Low to Medium (75% to 85%)	Low (55% to 60%)	High (95% to 97%)
Efficiency Curve Shape	Varies	Varies	Slopes downward at low flows	Flat
Efficiency at Changing Process Conditions (Effect of deviation from design point)	Efficiency reduces when flow rate changes from design point	Efficiency reduces when flow rate changes from design point	Efficiency reduces when flow rate changes from design point	Moderate impact on performance
Brine Mixing with Feed Water	None	None	None	About 2 - 3%
System Complexity	Low	Low	Low	High

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Implementation of Renewable Energy Resources (Contents of Chapter 4)

- Determination of resource availability.
- Available options for financing and incentives.
- Commercial technologies available.
- Leading renewable energy providers.
- Integration challenges and methods, consideration for grid integration.
- Handling resource variability.
- Permitting approach and requirements.

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Example: What you need to know while selecting solar PV cells (Contents of Chapter 4)

Parameter	Description
Cell efficiency	Percentage of solar energy falling on PV cells that is converted into electrical energy
Module efficiency	Combination of cell efficiency placed into a module
Energy yield	Output in kilowatt hours (kWh) over time
Typical module size	175 – 200 Watt: 3 feet by 5 feet
Common types of modules	Poly Crystalline, Mono Crystalline, Amorphous Silicon (thin film)
Module lifetime	Poly Crystalline ~ 40 years; Mono Crystalline ~ 50 years; Amorphous Silicon ~ 20 years

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Example: What you need to know about financing options available (Contents of Chapter 4)

- Third-party ownership with a power purchase agreement (PPA):
  - Provides utilities with the ability to benefit from renewable energy service contracts while avoiding the risks associated with ownership.
  - The utility enters into a contract with the vendor/electric company to install a renewable energy system.
  - The vendor/electric company deliver a set amount of power at an agreed price.
  - The third-party (vendor/electric company) is responsible for operation and maintenance of renewable energy system.

www.epa.gov/greenpower/buygp/solarpower.htm

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Resources Provided in the Guidebook

Web links

You will find information on:

- Performing energy audits.
- Best practices for energy efficiency.
- Software/Modeling tools for energy optimization and renewable energy implementation.
- GHG emissions monitoring and management tools.
- Financing options available for renewable energy implementation.
- Information on vendors providing state-of-the-art energy reducing technologies and renewable energy equipment.

Additional Resources

Handbooks for energy efficiency:
http://www.energy.ca.gov/reports/efficiency_handbooks/index.html, Last accessed: July 11, 2011.

Information on energy accounting, financing public sector energy projects, energy auditing, guidelines for hiring an energy service company and guidelines for hiring a construction manager can be found in the above web link.

Energy management guidebook for wastewater and wastewater utilities:
http://www.epa.gov/region9/water/energymgt/energy_mgt_guidebook_wastewater.pdf, Last accessed: July 11, 2011.

The guidebook provides a plan, do, check and act method for energy monitoring, energy minimization and energy improvement for public utilities. A copy of the guidebook can be found in the above web link.

Energy best practice guidebook for water and wastewater utilities:
http://www.werf.org/AM/Template.cfm?Section=Home&TEMPLATE=/CM/ContentDisplay.cfm&CONTENTID=10245, Last accessed: July 11, 2011.

The guidebook provides guidelines on energy use estimation, energy baseline calculation, management and technical best practices for water treatment, wastewater treatment, collection and distribution systems. A copy of the guidebook can be found in the above web link.

Software tools for energy efficiency best practices:
http://www1.eere.energy.gov/industry/bestpractices/software.html, Last accessed: July 12, 2011.

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Summary

- The evolution of renewable energy sources and development of novel processes and materials will continue to impact energy usage and production of GHG emissions.
- There are many common drivers, operational techniques and challenges for energy optimization or use of renewable energy sources irrespective of source water and end use.
- A guidebook was developed to provide information to utilities, designers and policymakers interested in implementing energy optimization strategies and renewable energy technologies.

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Acknowledgements

WateReuse Research Foundation (Project # 08-13)

California Energy Commission

Project Managers – Caroline Sherony (WateReuse Research Foundation), Paul Roggensack – California Energy Commission (CEC)

PAC Members

- Martin Vorum – National Renewable Energy Laboratory (NREL)
- David Yates – National Center for Atomic Research (NCAR)
- Stephen Fok – Pacific Gas & Electric (PG&E)
- Shahid Chaudhry – California Energy Commission (CEC)
- Andrew Tiffenbach – Bureau of Reclamation (USBR)

Participating Utilities

- El Paso Water Utilities Public Service Board
- Eastern Municipal Water District
- West Basin Municipal Water District
- Tampa Bay Water
- Sydney Water Corporation
- Water Corporation of Western Australia (Perth)
- Public Utilities Board, Singapore
- Ashkelon Desalination Facility

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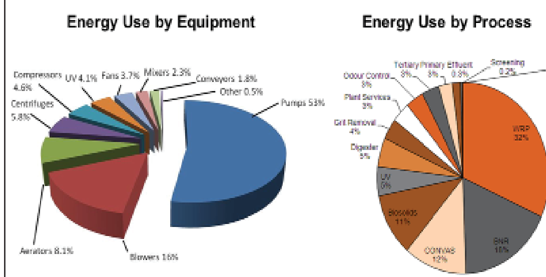
Energy Usage-Reuse



- Pumps consume the most energy.

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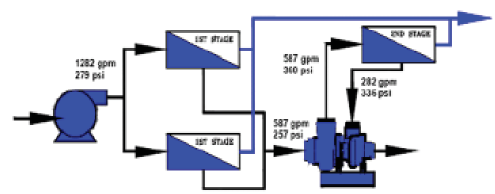
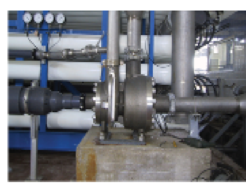
Energy Recovery-Brackish Water Desalination



www.energyrecovery.com



- Energy recovery/interstage booster pump in one device.
- Low Pressure TurboCharger (LPT) reduces the required boost to the high-pressure pump.
- Zero energy cost for interstage pumping.

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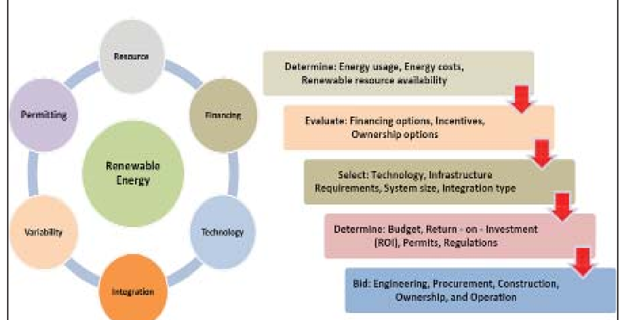
Components and Steps for Renewable Energy Utilization



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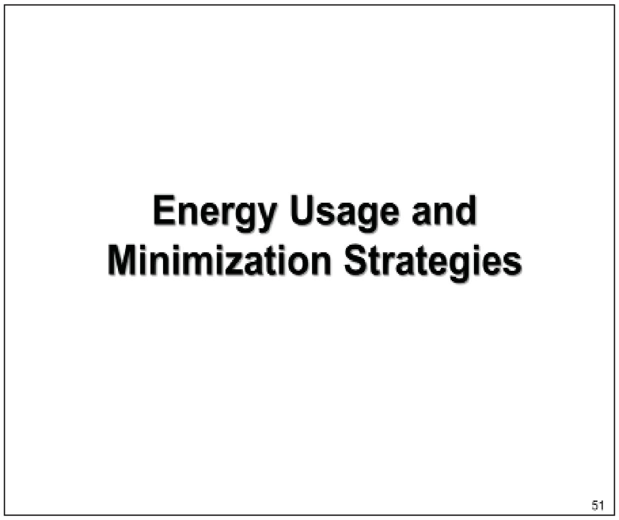

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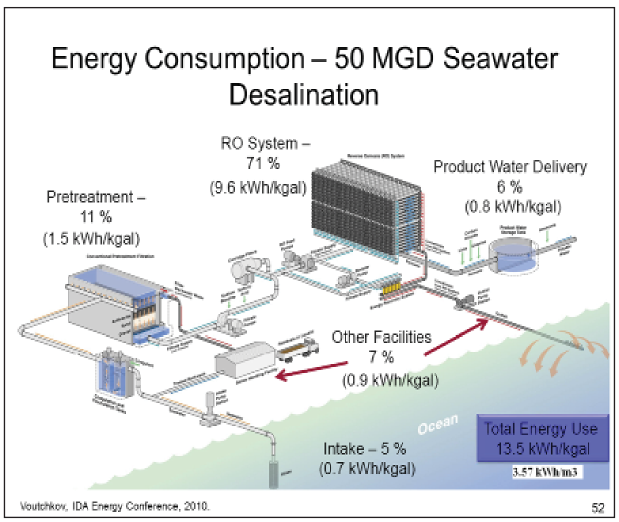

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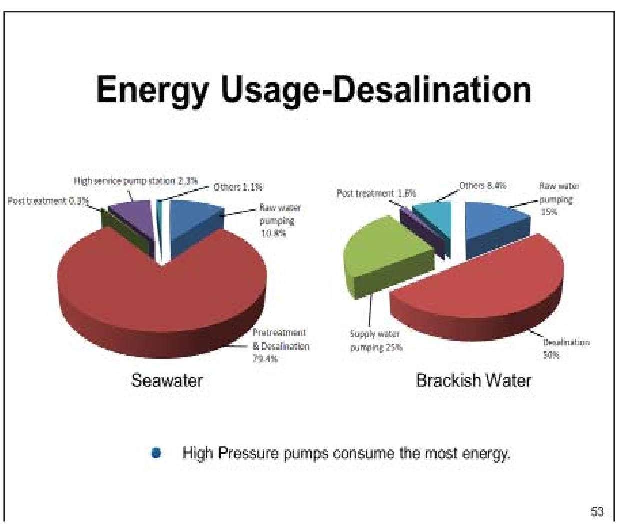

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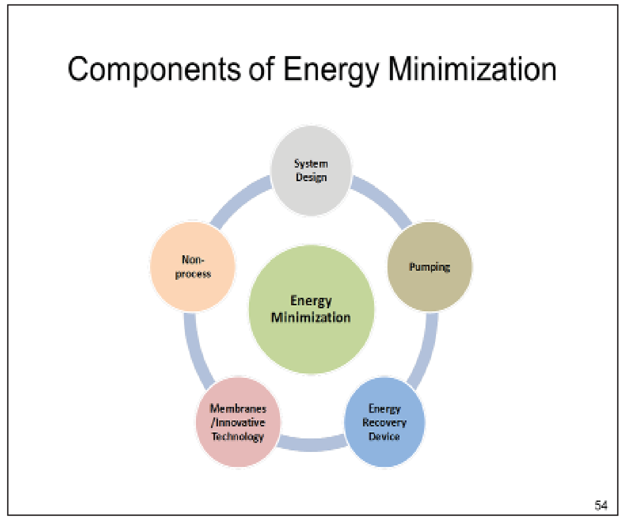

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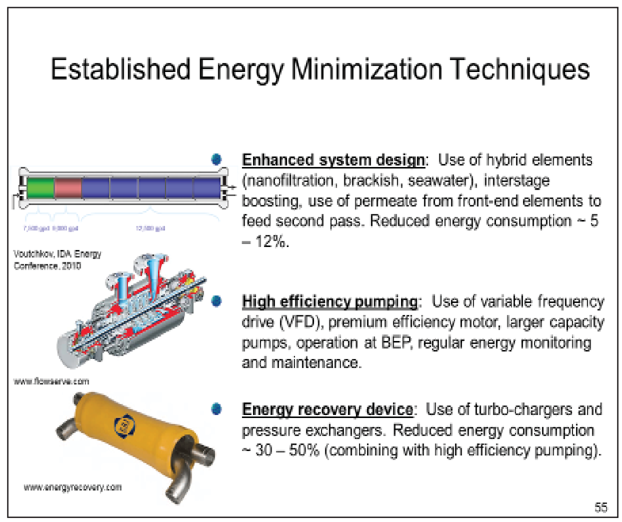

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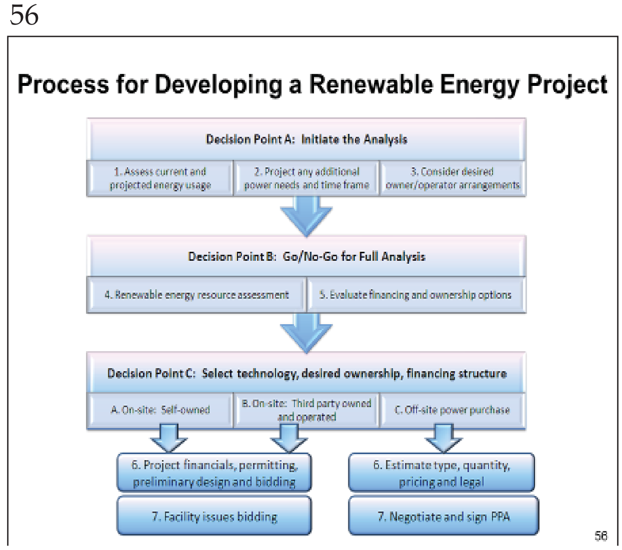

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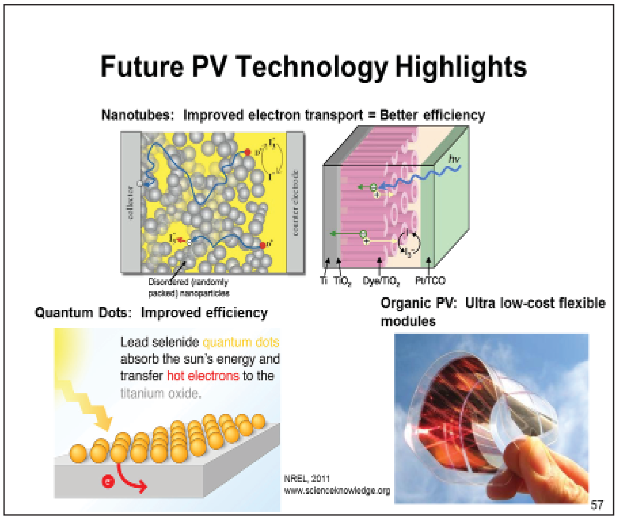
Future PV Technology Highlights
Nanotubes: Improved electron transport = Better efficiency
Disordered (randomly packed) nanoparticles
Ti TiO2 Dye/TiO2 Pt/TCO
Quantum Dots: Improved efficiency
Lead selenide quantum dots absorb the sun's energy and transfer hot electrons to the titanium oxide.
Organic PV: Ultra low-cost flexible modules
NREL, 2011
www.scienceknowledge.org
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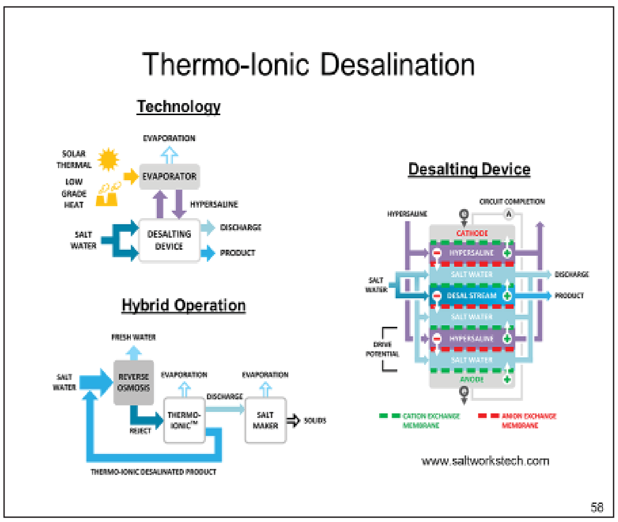
Thermo-Ionic Desalination
Technology
EVAPORATION
SOLAR THERMAL
LOW GRADE HEAT
EVAPORATOR
HYPERSALINE
SALT WATER
DESALTING DEVICE
DISCHARGE
PRODUCT
Hybrid Operation
FRESH WATER
SALT WATER
REVERSE OSMOSIS
EVAPORATION
EVAPORATION
DISCHARGE
REJECT
THERMO-IONIC™
SALT MAKER
SOLIDS
THERMO-IONIC DESALINATED PRODUCT
Desalting Device
CIRCUIT COMPLETION
HYPERSALINE
CATHODE
HYPERSALINE
SALT WATER
DESAL STREAM
SALT WATER
HYPERSALINE
SALT WATER
ANODE
DISCHARGE
PRODUCT
SALT WATER
DRIVE POTENTIAL
CATION EXCHANGE MEMBRANE
ANION EXCHANGE MEMBRANE
www.saltworkstech.com
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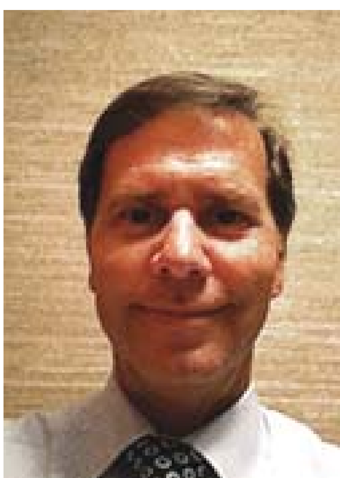
Reclamation Rural Water Act:
Southwestern Navajo Rural Water Supply Project & Solar Groundwater Desalination Research

Kevin Black and Mitch Haws, Bureau of Reclamation

Kevin Black Sr. is a Native American Affairs Specialist with the Bureau of Reclamation's Phoenix Area – Native American Affairs Office. He has been with the Bureau of Reclamation for 27 years and 3 years as a contractor. Kevin received a bachelor's degree in business management from the University of Phoenix and has complete graduate studies in water resource management at Arizona State University.



Mitch Haws is a Water Agreements Planner with the Bureau of Reclamation's Phoenix Area – Program Development Division. He has worked for the Bureau of Reclamation for 29 years in various functions from materials engineering, grants and contracting, and for the past 10 years has been working in water resources development and planning. Mitch received a bachelor's degree in business administration and management from Grand Canyon University.

Mitch has been researching various water and energy issues as it relates to real concerns of the Bureau of Reclamation which includes: The Moisture Balance Drought Index (formerly the Hydroclimatic Index); the energy and water nexus in Arizona; renewable energy for water transmission; and is now researching new techniques for using renewable energy for desalination in an off grid setting.

PowerPoint Presentation http://wrri.nmsu.edu/publish/watcon/proc56/Black-Haws.pdf

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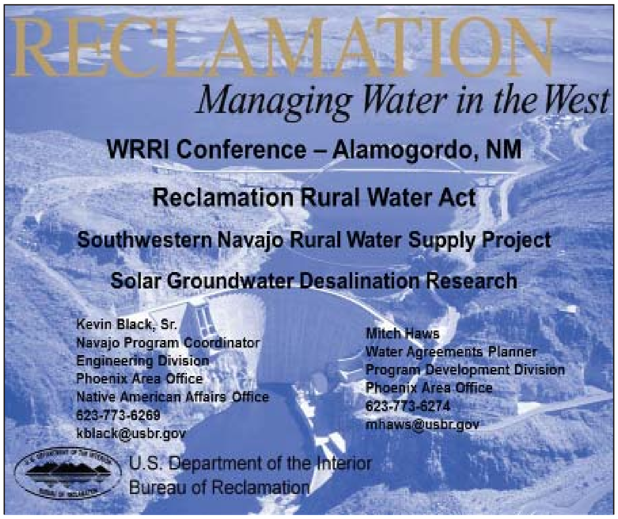

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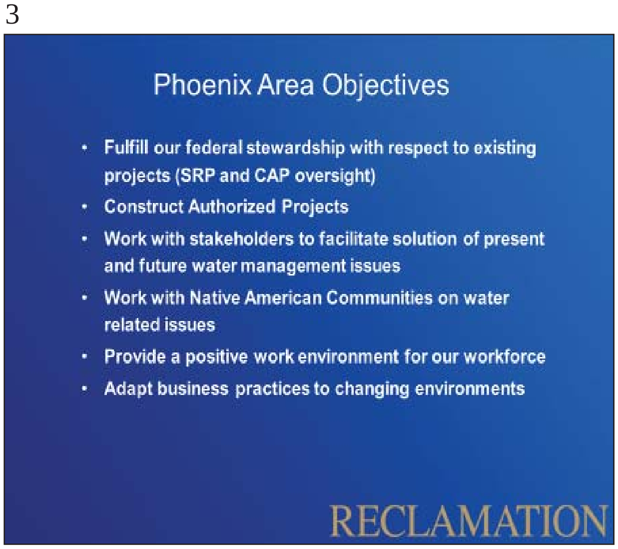

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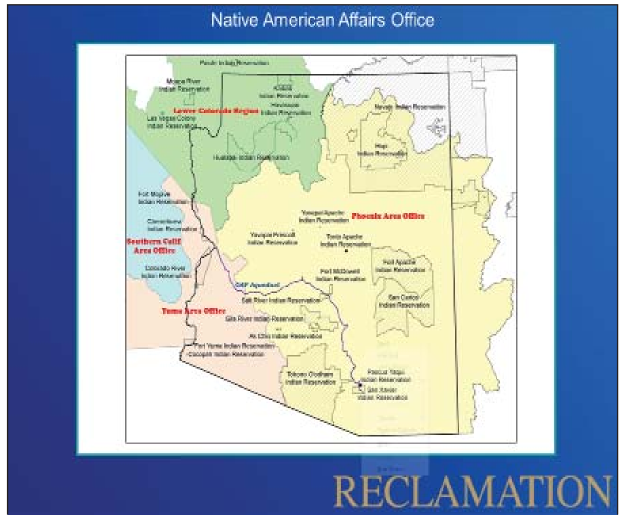

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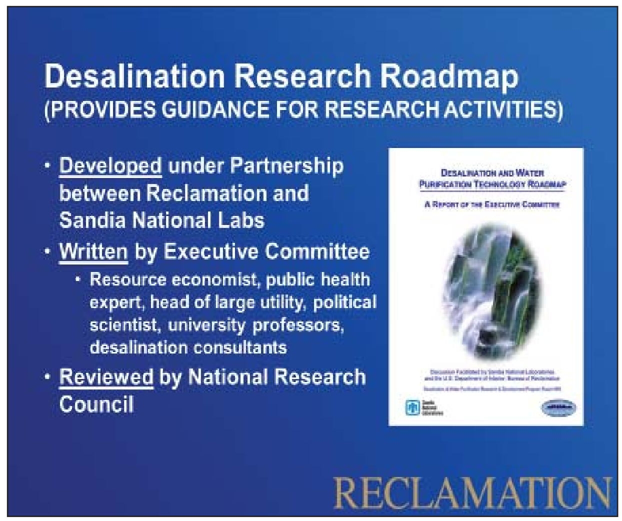

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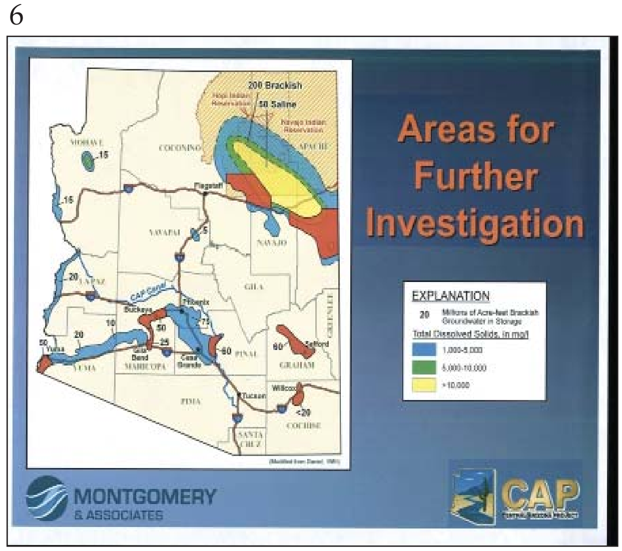

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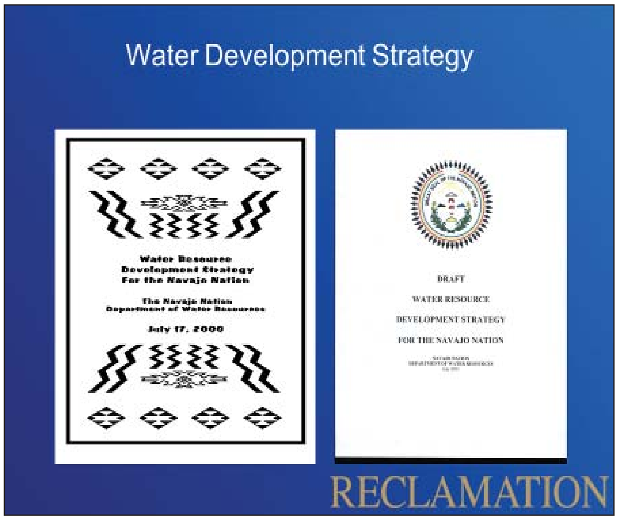
Water Development Strategy
Water Resource Development Strategy For the Navajo Nation
The Navajo Nation Department of Water Resources
July 17, 2000
DRAFT
WATER RESOURCE
DEVELOPMENT STRATEGY
FOR THE NAVAJO NATION
RECLAMATION

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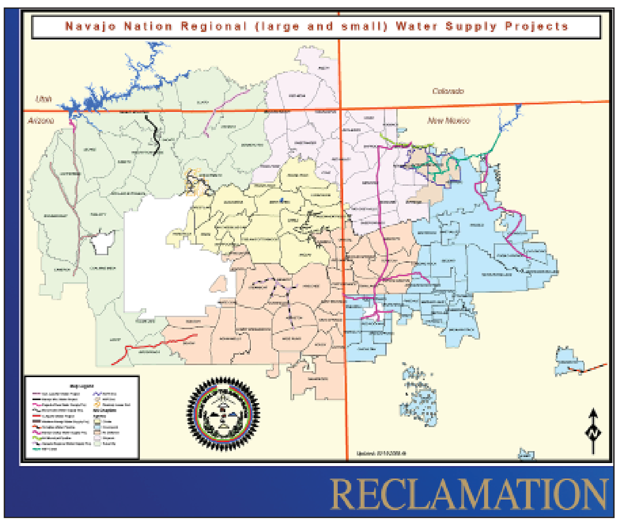
Navajo Nation Regional (large and small) Water Supply Projects
Utah
Colorado
Arizona
New Mexico
RECLAMATION

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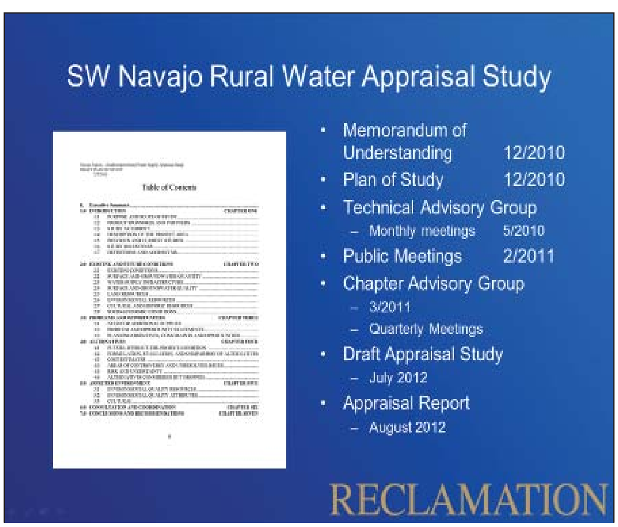
SW Navajo Rural Water Appraisal Study
Table of Contents
Memorandum of Understanding 12/2010
Plan of Study 12/2010
Technical Advisory Group
– Monthly meetings 5/2010
Public Meetings 2/2011
Chapter Advisory Group
– 3/2011
– Quarterly Meetings
Draft Appraisal Study
– July 2012
Appraisal Report
– August 2012
RECLAMATION

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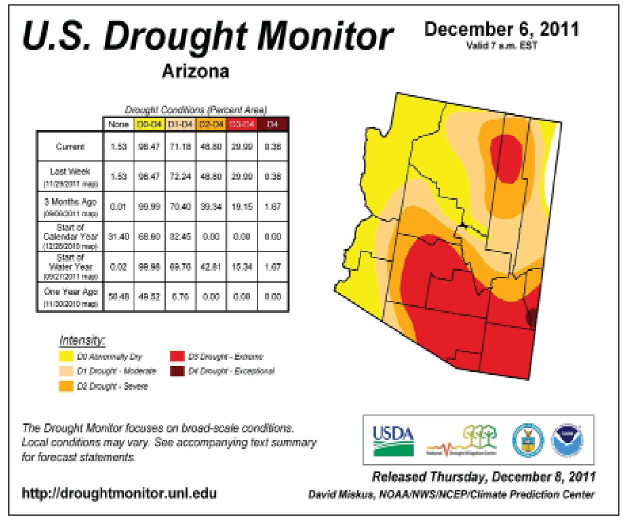
U.S. Drought Monitor
December 6, 2011
Valid 7 a.m. EST
Arizona
Drought Conditions (Percent Area)
None D0-D4 D1-D4 D2-D4 D3-D4 D4
Current 1.53 98.47 71.18 48.80 29.99 0.38
Last Week (11/29/2011 map) 1.53 98.47 72.24 48.80 29.99 0.38
3 Months Ago (09/06/2011 map) 0.01 99.99 70.40 39.34 19.15 1.67
Start of Calendar Year (12/28/2010 map) 31.40 68.60 32.46 0.00 0.00 0.00
Start of Water Year (09/27/2011 map) 0.02 99.98 69.76 42.81 16.34 1.67
One Year Ago (11/30/2010 map) 50.48 49.52 6.76 0.00 0.00 0.00
Intensity:
D0 Abnormally Dry
D1 Drought - Moderate
D2 Drought - Severe
D3 Drought - Extreme
D4 Drought - Exceptional
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.
USDA
Released Thursday, December 8, 2011
David Miskus, NOAA/NWS/NCEP/Climate Prediction Center
http://droughtmonitor.unl.edu

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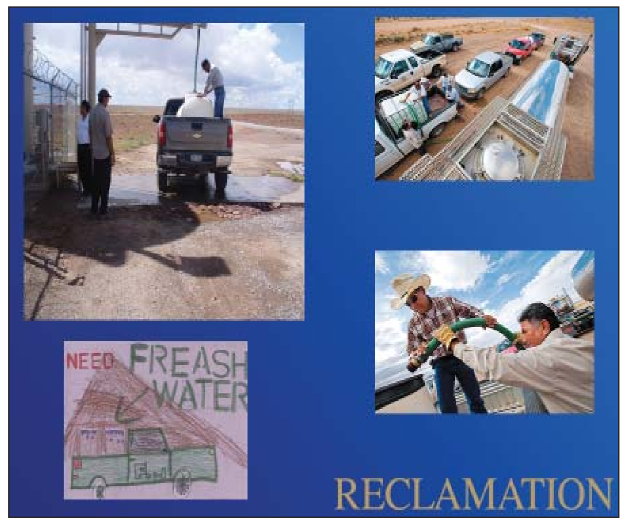
NEED FREASH WATER
RECLAMATION

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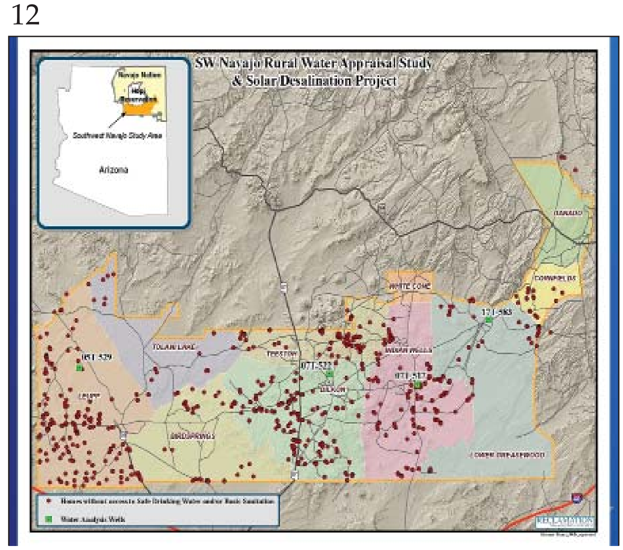
SW Navajo Rural Water Appraisal Study
& Solar Desalination Project
Arizona
TOLANI LAKE
BIRDSPRINGS
Homes without access to Safe Drinking Water and/or Basic Sanitation
Water Analysis Wells

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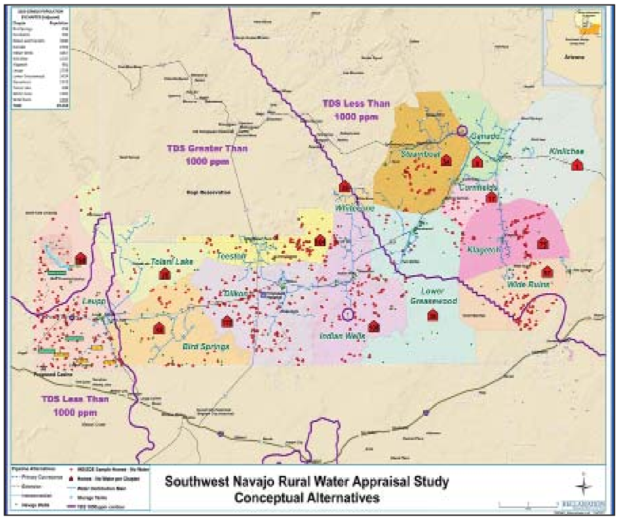

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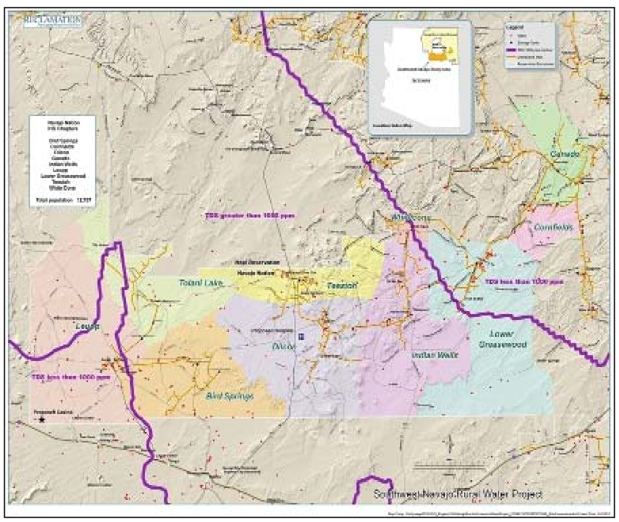

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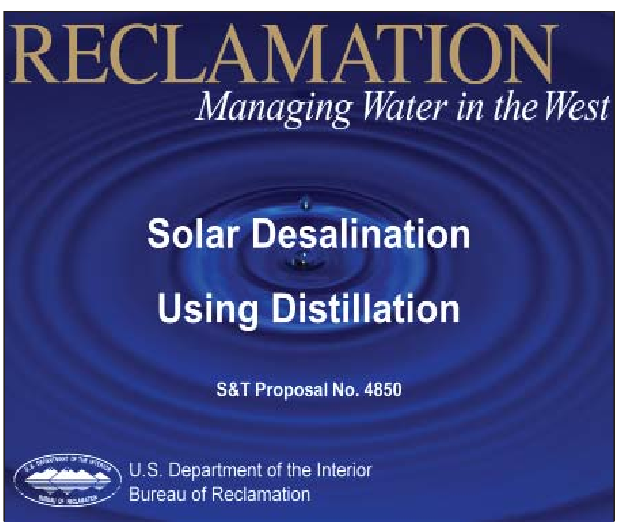

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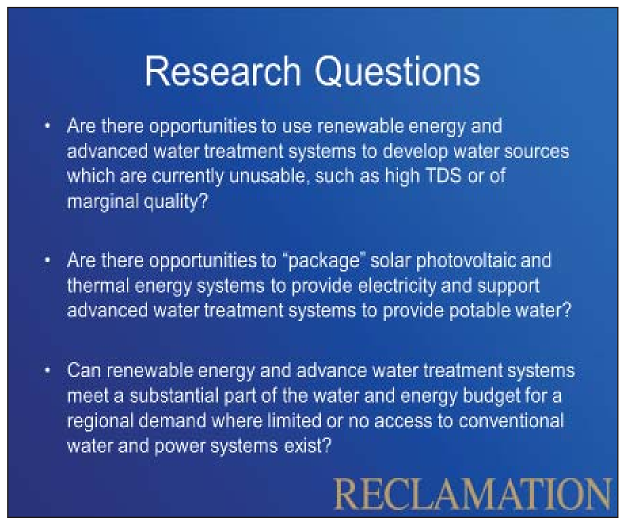

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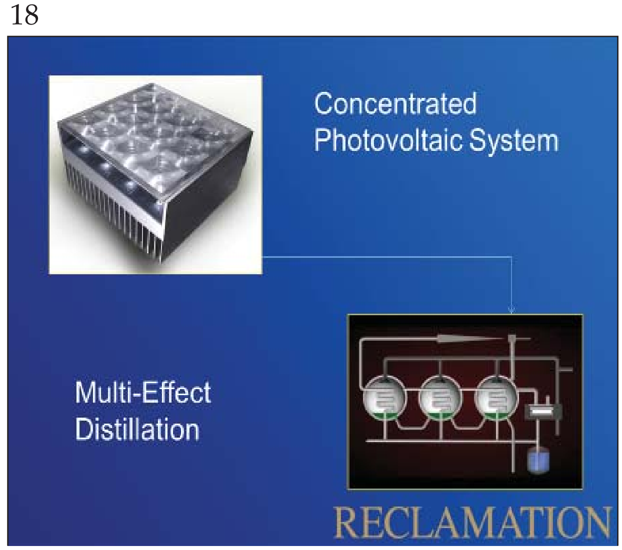

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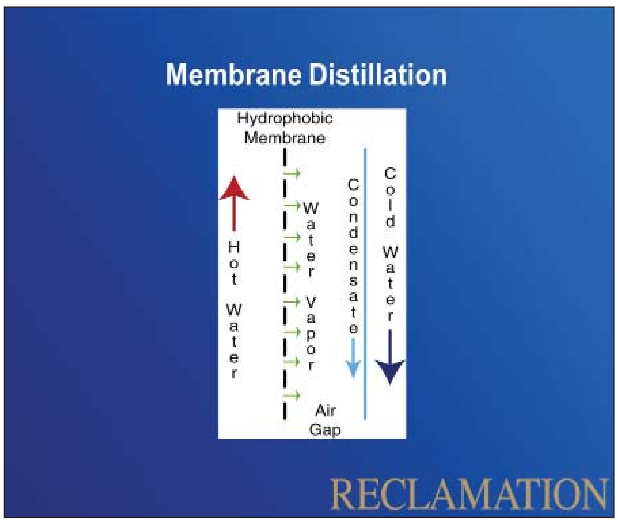

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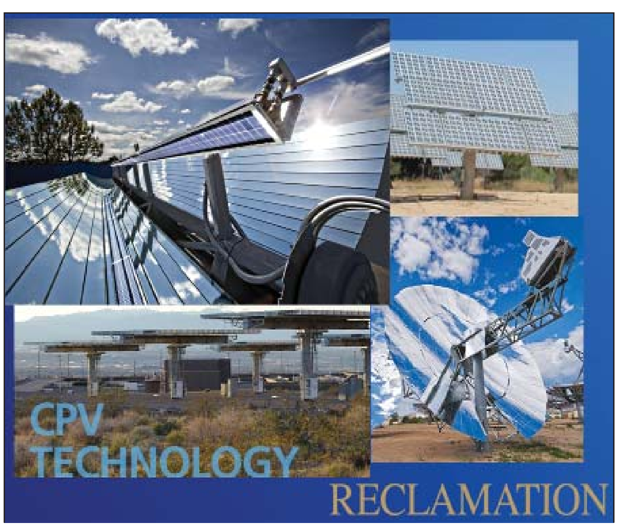

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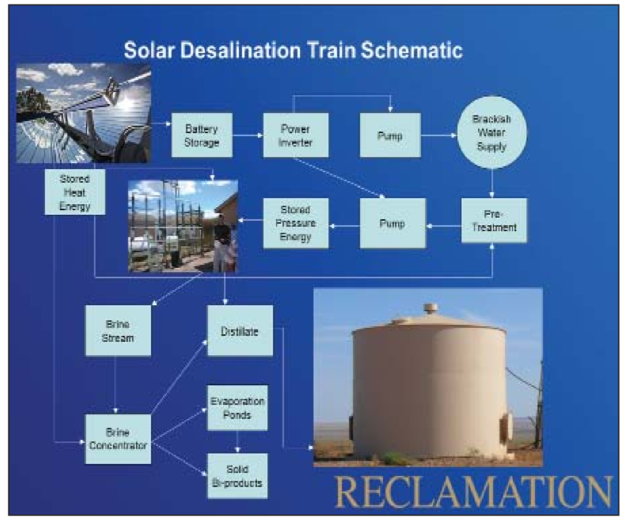

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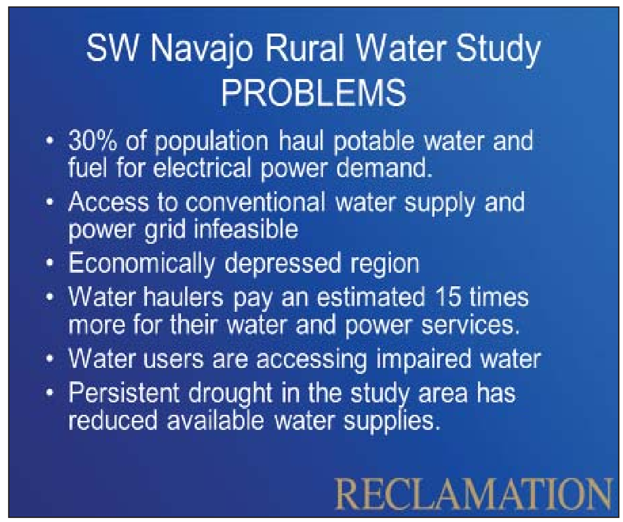

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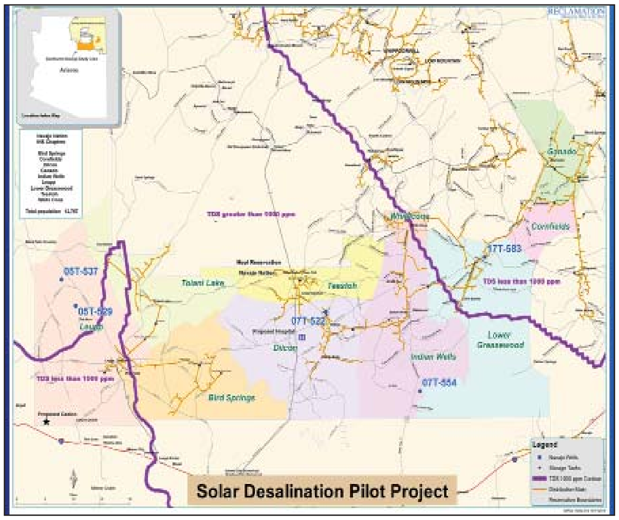

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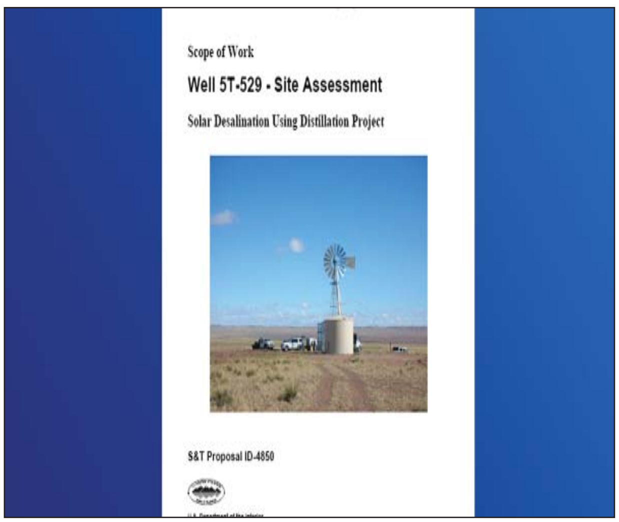

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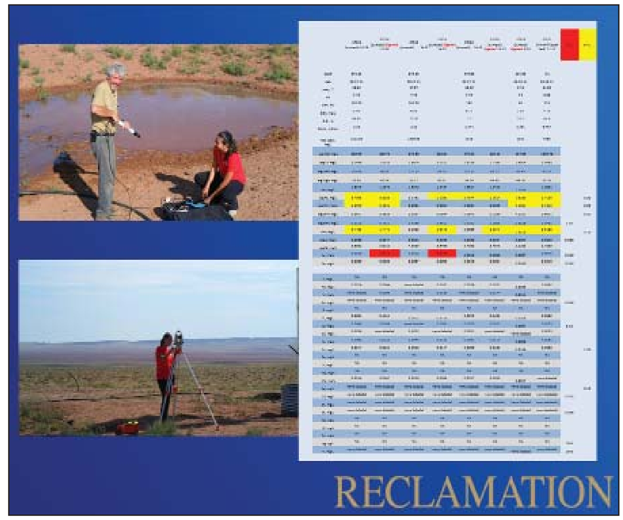

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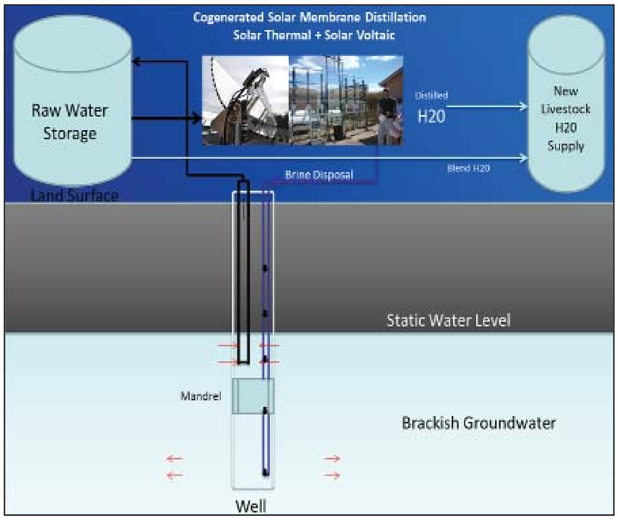
Cogenerated Solar Membrane Distillation
Solar Thermal + Solar Voltaic
Raw Water
Storage
Distilled
H20
New
Livestock
H20
Supply
Brine Disposal
Blend H20
Land Surface
Static Water Level
Mandrel
Brackish Groundwater
Well

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Questions?
RECLAMATION

Renewable Energy Applications in Water Desalination

Ali Abbas M. Al-Karaghouli (Al-Qaraghuli), National Renewable Energy Laboratory

Professor Ali Al-Karaghouli is currently a Principal Research Engineer dealing with renewable energy applications and science and technology partnerships at U.S. National Renewable Energy Laboratory (NREL) since Dec. 2007. His areas of expertise are solar heating & cooling, solar desalinations, energy conservation in buildings, and solar PV system design. Al-Karaghouli was the author of the comprehensive study of Renewable Energy in the Middle East and North Africa (MENA) in 2007, supported by the German Ministry of Environment.

Al-Karaghouli has served as a Technical Advisor and a Consultant on Renewable Energy at the United Nations Environmental Program in West Asia UNEP/ROA (2006-Dec. 2007). He was a professor of mechanical engineering and Director of the Energy Research Center at the University of Bahrain from 1998-2006. He has also served as the Director of the Energy and Environmental Research Center in Baghdad-Iraq (1997-1998), Director of the Solar Energy Research Center in Baghdad-Iraq (1993-1997), Director of the Regional Center for NSRE Information Network for the ESCWA Region (1990-1995), Chairman of Engineering Department at the Solar Energy Research Center (1988-1993), Chairman of Agriculture Applications Department at the Solar Energy Research Center (1983-1988), Design Engineer at Sun System Inc. Eureka, Ill, USA (1976-1978), and as a Design Engineer at the State Organization for Construction and Industrial Design- Ministry of Industry, Iraq (1968-1975).

Al-Karaghouli was a post-doctorate at Washington State University (Feb.-June, 1983) and has a PhD in mechanical engineering from Washington State University (1983). Other degrees include MS in mechanical engineering from Bradley University (1976), and BS in electrical engineering from the University of Mosel–Iraq (1968). He holds four patents, is the author of two books, and has more than ninety published papers in the field of renewable energy and energy conservation.

Relevant Papers

•Economic Analysis of a Brackish Water Photovoltaic-Operated (BWRO-PV) Desalination System *http://wrri.nmsu.edu/conf/conf11/economic_analysis_BWRO-PV.pdf*

•*Technical and economic assessment of photovoltaic-driven desalination systems http://wrri.nmsu.edu/conf/conf11/photovoltaic_desal_systems.pdf*

•*Renewable Energy Opportunities in Water Desalination http://wrri.nmsu.edu/conf/conf11/renewable_energy_water_desal.pdf*

•*Economic and Technical Analysis of a Reverse-Osmosis Water Desalination Plant using DEEP-3.2 Software http://wrri.nmsu.edu/conf/conf11/reverse_osmosis_deep.pdf*

•*Performance and Economic Analysis of a Medium-Size Reverse-Osmosis Plant using HOMER and DEEP-3.2 Software*

•*Solar and wind opportunities for water desalination in the Arab regions http://wrri.nmsu.edu/conf/conf11/solar_wind_desal_arab.pdf*

PowerPoint Presentation http://wrri.nmsu.edu/publish/watcon/proc56/Al-Qaraghuli.pdf

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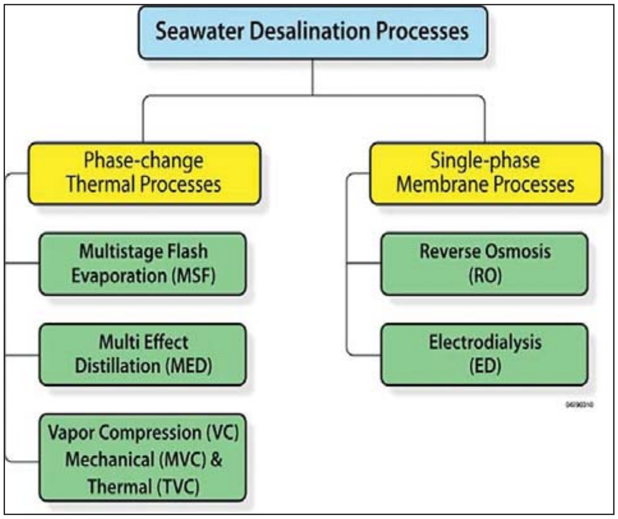

2

Solar Water Desalination *(cont.)*

I-Phase-change processes

a. Multi-stage flash distillation (MSF).

b. Multi-effect distillation (MED).

c. Vapor compression (VC), thermal (TVC) and mechanical (MVC).

Other phase change desalination processes include **solar still distillation**, **humidification/ dehumidification, membrane distillation** and **freezing.**

II-Membrane Processes

a. Reverse Osmosis (RO).

b. Electrodialysis (ED & EDR).

There are also three other membrane processes which are not considered desalination processes but are relevant. These are: **Microfiltration (MF), Ultrafiltration (UF), and Nanofiltration (NF).** The **ion-exchange process** is also not regarded as a desalination process, but is generally used to improve water quality for some specific purposes.

NATIONAL RENEWABLE ENERGY LABORATORY 3

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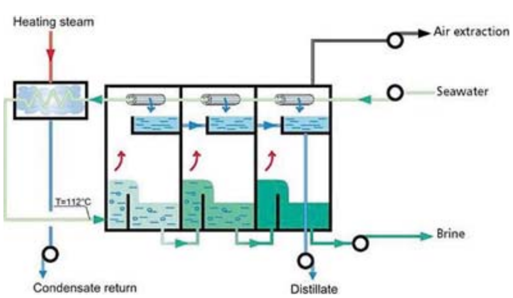
Distillation Processes *(cont.)*

Multi-stage flash distillation (MSF)

When the seawater is heated (90 to 110 C) and discharged into a chamber maintained at slightly below the saturation vapor pressure of the water, a fraction of its water content flashes into steam. The flashed steam condenses on the exterior surface of the heat-exchanger tubing. The condensed liquid drips into trays as hot fresh-water product



NATIONAL RENEWABLE ENERGY LABORATORY 4

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MSF Power consumption and fresh water cost

Typical unit size: 50,000 to 70,000 m^3 /day

Top brine temperature: 90 C to 110 C

Typical gained output ratio (G.O.R) range between 6 to 8

G.O.R = kg of distillate/ kg of steam

Power consumptions:

Electrical energy: 4-6 kWh/ m^3

Thermal energy: 190 kj/kg (G.O.R =12.2) & 390 kj/kg (G.O.R =6)

Electrical equivalent for thermal energy: 9.5 to 19.5 kWh/ m^3

Total equivalent energy consumption: 13.5 to 25.5 kWh/ m^3

Cost range of product water: The average unit cost has fallen from about 9.0 \$/m^3 in 1960 to about 1.0 \$/m^3 at present.

NATIONAL RENEWABLE ENERGY LABORATORY 5

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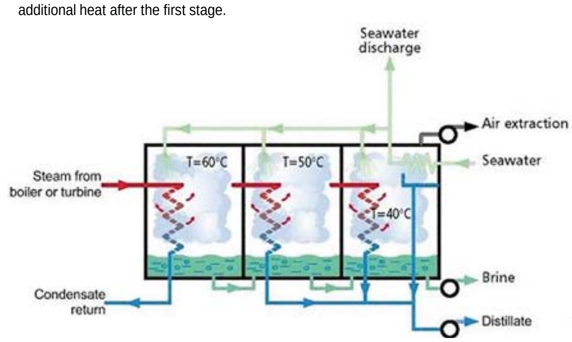
Distillation Processes *(cont.)*

Multi-effect distillation (MED)

MED units operate on the principle of reducing the ambient pressure at each successive stage, allowing the feed water to undergo multiple boiling without having to supply additional heat after the first stage.



NATIONAL RENEWABLE ENERGY LABORATORY 6

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MED power consumption and fresh water cost

Typical unit size: 5,000 to 15,000 m^3 /day

Top brine temperature: 66 C to 72 C

G.O.R ranges between 8 and 12

Power consumptions:

Electrical energy: 1.5 to 2.5 kWh/ m^3

Thermal energy: 230 kj/kg (G.O.R =10) & 390 kj/kg (G.OR =6)

Electrical equivalent for thermal energy: 5.0 to 8.5 kWh/ m^3

Total equivalent energy consumption: 6.5 to 11.0 kWh/ m^3

Cost range of product water: The production cost of the MED process has fallen from 10.0 \$/m^3 in the 1950's to about 1.0 \$/m^3 today.

NATIONAL RENEWABLE ENERGY LABORATORY 7

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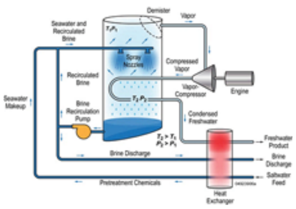
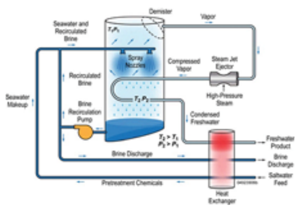
Distillation Processes *(cont.)*

Vapor-compression distillation

The heat for evaporating the water comes from the compression of vapor, rather than from the direct exchange of heat from steam produced in a boiler. Two primary methods are used to condense vapor so as to produce enough heat to evaporate incoming seawater: a mechanical compressor (MVC) or a steam jet (TVC).



MVC System



TVC System

NATIONAL RENEWABLE ENERGY LABORATORY 8

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MVC and TVC Power consumption and fresh water cost

MVC Process
Typical unit size: 100 to 3000 m^3 /day
Top brine temperature: 74 C
Total equivalent energy consumption: 11.0 kWh/ m^3 based on 3000 m^3 / day capacity
TVC Process
Typical unit size: 10,000 to 35,000 m^3 **/day**
Top brine temperature : 70 C
G.O.R : 12
Power consumptions:
Electrical energy: 1.8 kWh/ m^3
Thermal energy: 187 kj/kg(G.O.R =12)
Electrical equivalent for thermal energy: 9.4 kWh/ m^3
Total equivalent energy consumption: 11.2 kWh/ m^3
Cost range of product water: The unit production cost ($/ m^3) of the VC process has also decreased considerably over time, from 5.0 $/$m^3$ in 1970 to about 1.0 $/$m^3$ at present .

NATIONAL RENEWABLE ENERGY LABORATORY 9

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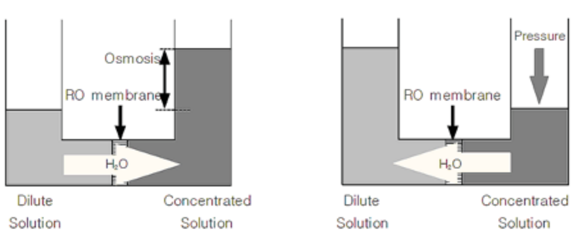
Membrane processes / Reverse Osmosis (RO) Process

Theory of Reverse Osmosis Membrane

When two water (or other solvent) volumes are separated by a semi-permeable membrane, water will flow from the volume of low solute concentration, to the volume of high solute concentration.
The flow may be stopped, or even reversed by applying external pressure on the volume of higher concentration. In such a case the phenomenon is called **reverse osmosis.**



NATIONAL RENEWABLE ENERGY LABORATORY 10

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RO Process- Cont.

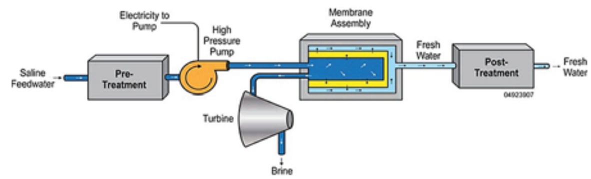
A typical RO system consists of four major subsystems:

Pretreatment: Removing suspended solids, adjusting the pH, and adding a threshold inhibitor to control scaling

Pressurization: Pump raises the pressure of feed water to an operating pressure appropriate for the membrane and the salinity of the feed water.

Separation: The permeable membranes inhibit the passage of dissolved salts while permitting the desalinated product water to pass through.

Stabilization: pH adjustment (from a value of about 5 to close to 7) and disinfection is employed to kill any bacteria, protozoa and virus that have bypassed the desalination process into the product water. Disinfection may be done by means of ultraviolet radiation, using UV lamps directly on the product, or by chlorination or chloramination (chlorine and ammonia).



NATIONAL RENEWABLE ENERGY LABORATORY 11

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RO process - cont.

Membrane specifications:

RO membrane must be **freely permeable to water**, **highly impermeable to solutes**, and **able to withstand high operating pressures**. It should **ideally be tolerant of wide ranges of pH and temperature** and should be **resistant to attack by chemicals like free chlorine and by bacteria.**

Membrane materials:

Polymers of either **cellulose acetates** (cellulose diacetate, cellulose triacetate, or combinations of the two) , **or polyamide polymers**.

Membrane types:

Two types of RO membranes commonly used commercially are : **spiral-wound (SW) membranes and hollow-fiber (HF) membranes.** Other configurations, including tubular and flat plate-frame designs, are sometimes used in the food and dairy industries.

NATIONAL RENEWABLE ENERGY LABORATORY 12

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RO Power consumption and fresh water cost

Typical unit size: 24,000 m^3 /day

For Seawater RO (based on 41,500 ppm)
Electrical energy consumption: about 5 kWh/m^3

For brackish water RO (based on 5000 ppm)
Electrical energy consumption : 2.1 kWh/m^3
Water Production cost:
The average unit cost ($/$m^3$) of RO system have declined from 5.0 $/$m^3$ in 1970 to less than 1.0 $/ m^3 today. A decline in cost is reported, to $0.55/$m^3$ for a large RO project in Florida (USA).

NATIONAL RENEWABLE ENERGY LABORATORY 13

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Energy requirements of the four main industrial desalination processes

	MSF	MED-TVC	MED	MVC	RO
Typical unit size $m^3 d^{-1}$	50,000 - 70,000	10,000 - 35,000	5,000 - 15,000	100 - 2500	24,000
Electrical Energy Consumption kWh m^{-3}	4 – 6	1.5 – 2.5	1.5 – 2.5	7 - 12	3 – 5.5
Thermal Energy Consumption kJ kg^{-1}	190 (GOR =12.2) – 390 (GOR =6)	145 (GOR =16) – 390 (GOR =6)	230 (GOR =10) – 390 (GOR =6)	None	None
Electrical Equivalent for Thermal Energy kWh m^{-3}	9.5 – 19.5	9.5 – 25.5	5 – 8.5	None	None
Total Equivalent Energy Consumption kWh m^{-3}	13.5 - 25.5	11 - 28	6.5 - 11	7 - 12	3 - 3.5

Source: WANGNICK CONSULTING (2010)

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Filteration

Microfiltarion (MF).

MF is ideal for removing: suspended solids and turbidity, bacteria and protozoa .Applied pressure operation is 30 to 500 kPa. Particle size removed 0.1-0.5 micron. Mostly used in the pharmaceutical industry.

Ultrafiltration (UF)

UF removes oils, colloidal solids , and other soluble pollutants and turbidity, and remove bacteria, protozoa and some viruses. Applied pressure operation is 30 to 500 kPa. The minimum particle size removed between 0.005 – 0.05 micron. Produced waters from the oil and gas industries can be effectively treated to remove oil and recycle the water.

Nanofiltration (NF)

NF membrane removes: turbidity , color , hardness , synthetic organic contaminant , sulfur , and virus . NF membrane operates under applied pressure between 500 to 1000 kPa. The minimum particle size removed between 0.0005- 0.001 microns. It is considered to be the state of the art in water purification.

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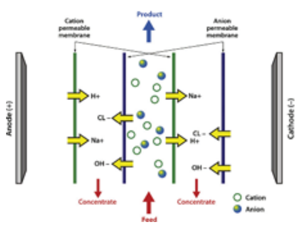
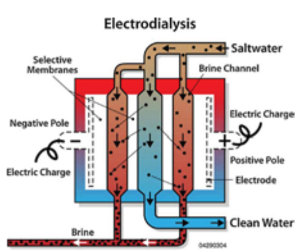
Membrane water desalination (cont.)

Electrodialysis (ED & EDR)

Electrodialysis (ED) is an electrochemical separation process that uses electrical currents to move salt ions selectively through a membrane, leaving fresh water behind.





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Combined heat and power (CHP) and hybrid desalination systems

Cogeneration or Combined heat and power (CHP):
It is the simultaneous production of electricity and the utilization of “waste” heat for water desalination or any other heating requirements.

Hybrid desalination systems: It is the use of more than one desalination process in one plant. A number of hybrid desalination systems have been proposed over the past years.

Examples are combination of:

- MSF, MED or VC with SWRO.
- RO, ED and UF.
- RO, UF and MSF or MED.
- VC with MSF or MED.

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ED power consumption and fresh water cost

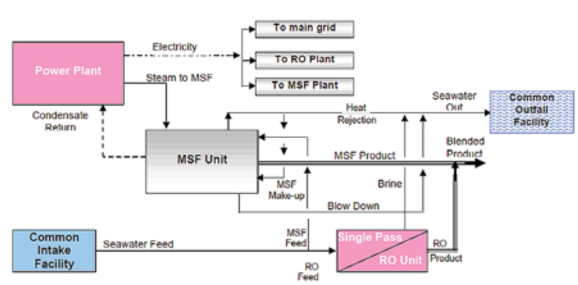
For ED (based on brackish 2500ppm)
Electrical energy consumption: about 2.64 kWh/m^3

For ED (based on brackish 5000ppm)
Electrical energy consumption: about 5.5 kWh/m^3

Water production cost:
ED unit for brackish water desalination has gone down from 3.5 \$/m^3 in the 1960’s to the average unit cost about 0.6 \$/m^3 at present.

18

Combined heat and power plant



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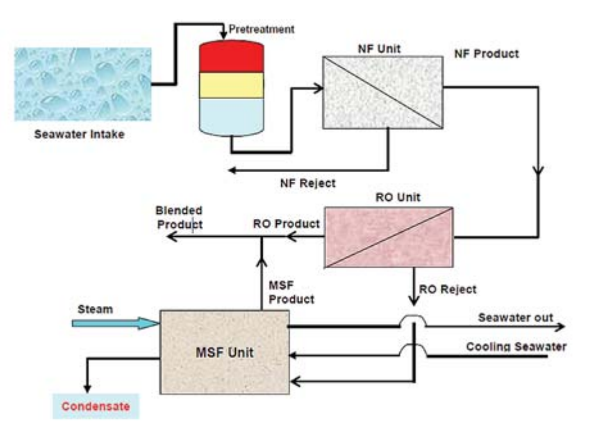
Hybrid system



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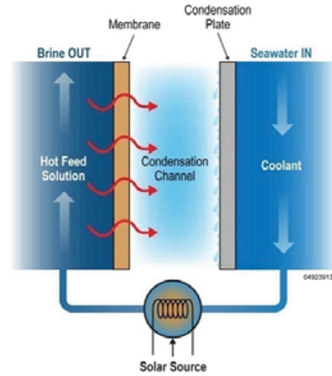
Other desalination processes / Membrane distillation (MD) Process

MD is a separation/distillation technique, where water is transported between hot and a cool stream separated by a hydrophobic membrane, permeable only to water vapor.



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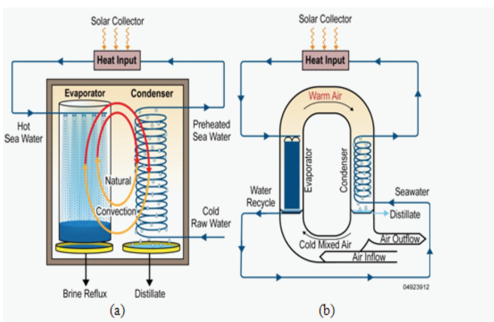
Other desalination processes / H-D System



Humidification-dehumidification systems: (a) open-water closed-air cycle, and (b) open-air closed-water cycle (modified from [64].

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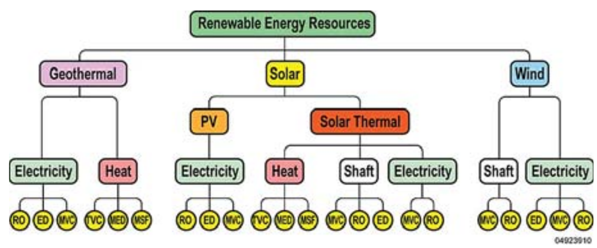
Renewable Energy Water Desalination

Desalination with renewable energy systems

Using desalination technologies driven by renewable energy sources (RES) is a viable way to produce fresh water in many locations today. As the technologies continue to improve—and as fresh water and cheap conventional sources of energy become scarcer renewable energy technology desalination will become even more attractive.



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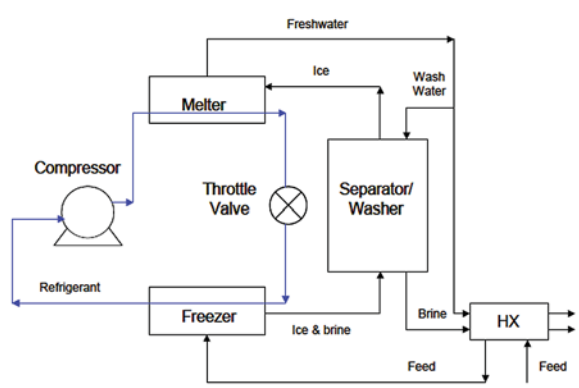
Other desalination processes / Freezing process

Freezing process depends on the fact that when ice crystal form, the dissolved salt is naturally excluded.



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Solar Water Desalination

Solar assisted desalination systems

Solar energy can drive the desalination units by either thermal energy and electricity generated from solar thermal systems or electricity generated by PV systems. The cost distribution of solar distillation is dramatically different from that of Reverse Osmosis and MSF. The main cost is in the initial investment. However, once the system is operational it is extremely cheap to maintain and the energy has little or even no cost. It is divided to two parts:

I- solar thermal assisted systems.

II-Solar photovoltaic assisted systems.

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Solar Water Desalination *(cont.)*

Solar thermal assisted systems

I-Direct solar thermal desalination system

The method of direct solar desalination is mainly suited for small production systems, such as solar stills, in regions where the freshwater demand is low. This includes:

▪simple solar still.

II-Indirect Solar thermal desalination

▪.Solar pond assisted desalination

▪Concentrated solar power (CSP) desalination

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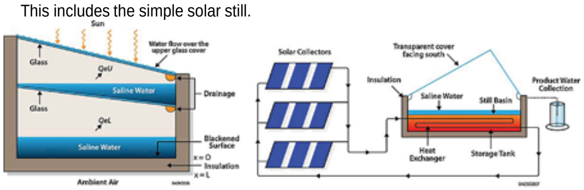
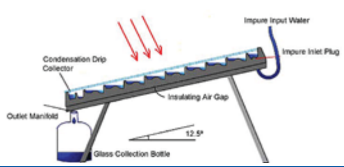
Solar Water Desalination *(cont.)*

I-Direct solar thermal desalination system

The method of direct solar desalination is mainly suited for small production systems, such as solar stills, in regions where the freshwater demand is low. This includes the simple solar still.





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Solar Water Desalination *(cont.)*

II-Indirect Solar thermal desalination

Indirect solar thermal desalination methods involve two separate systems: the collection of solar energy, by a conventional solar converting system, coupled to a conventional desalination method. This include:

- Solar ponds assisted desalination
- Concentration solar thermal (CSP) desalination

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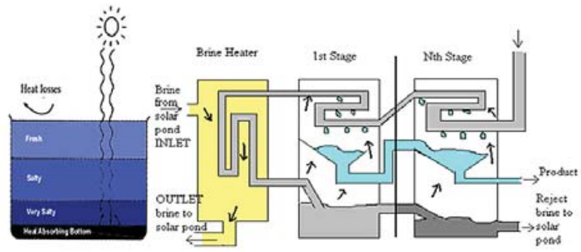
Solar Water Desalination *(cont.)*

Solar ponds assisted desalination

Salinity gradient solar ponds are a type of heat collector as well as a mean of heat storage. Hot brine from a solar pond can be used as industrial process heat (e.g. as a heat source for vaporizing feed water in MSF or MED desalination)



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Solar Water Desalination *(cont.)*

Concentration solar thermal systems

Concentrating solar thermal power technologies are based on the concept of concentrating solar radiation to provide high-temperature heat for electricity generation within conventional power cycles using steam turbines, gas turbines, or Stirling and other types of engines. The CSP plant consist of two parts: one collect solar energy and convert it to heat and another convert heat to electricity. For concentration, most systems use glass mirrors that continuously track the position of the sun.

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Solar Water Desalination/Concentrating Solar power systems

The four major concentrating solar power (CSP) technologies are:

- **Parabolic trough**
- **Fresnel mirror reflector**
- **Power tower**
- **Dish/engine systems.**

Trough System | Tower System | Dish System | Linear Fresnel System

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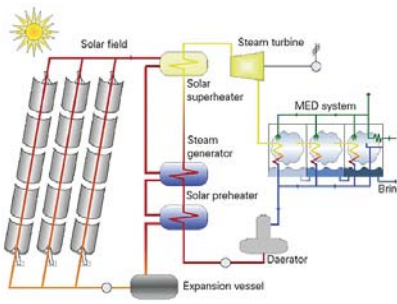
Solar Water Desalination/Concentrating Solar power systems

Concentration solar thermal (CSP) desalination

Parabolic trough coupled with MED desalination unit

A typical parabolic trough configuration combined with a MED system where steam generated by the trough (superheated to around 380ºC) is first expended in a non condensing turbine and then used in a conventional manner for desalination.



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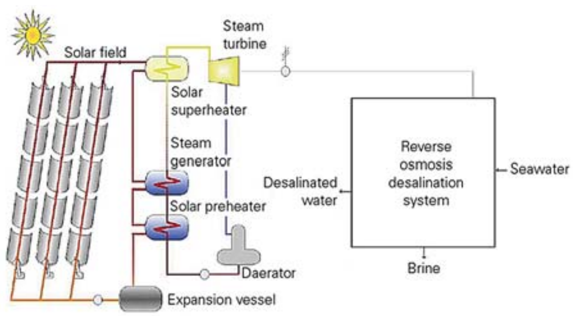
Solar Water Desalination/Concentrating Solar power systems

Parabolic trough coupled with RO desalination unit

In this case as well as in MED, the steam generated by the solar plant can be used through a steam turbine to produce the electric power needed to drive the RO pumps.



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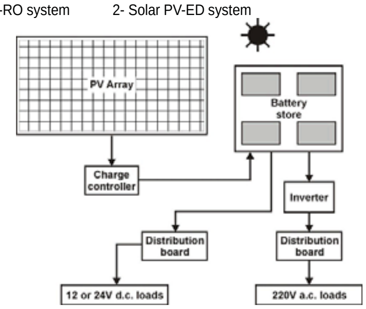
Solar Water Desalination *(cont.)*

Solar PV desalination system

Any photovoltaic system consists of a number of PV modules, or arrays. The other system equipment includes a charge controller, batteries, inverter, and other components needed to provide the output electric power suitable to operate the systems coupled with the PV system. PV system can be classified to:

1- Solar PV-RO system 2- Solar PV-ED system



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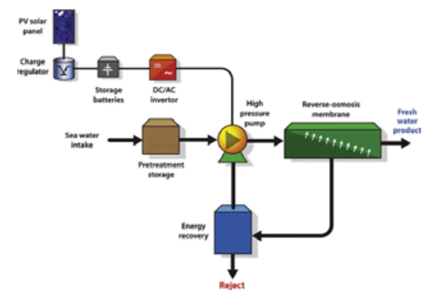
Solar Water Desalination/ Solar PV *(cont.)*

PV-RO systems applications

PV-powered reverse osmosis is considered one of the most promising forms of renewable-energy-powered desalination, especially when it is used in remote areas. Therefore, small-scale PV-RO has received much attention in recent years and numerous demonstration systems have been built. PV seawater RO production cost ranges from 3.9 to7.89 US$/m³ . Also for a PV/RO brackish-water desalination unit, a water cost of about 2.5 to 7.0 US$/m³.



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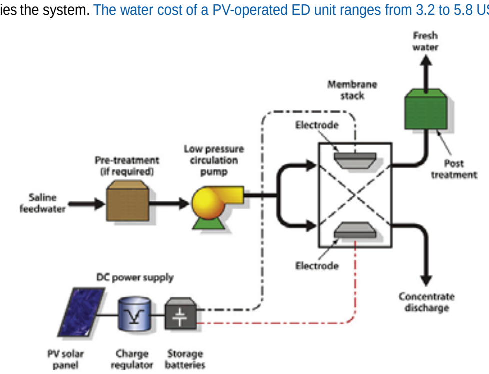
Solar Water Desalination/ Solar PV *(cont.)*

PV-ED applications

ED uses DC for the electrodes therefore the PV system does not include inverter which simplifies the system. The water cost of a PV-operated ED unit ranges from 3.2 to 5.8 US$/m³.



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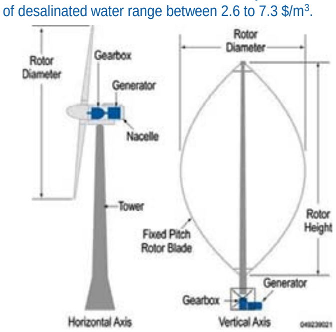
Wind/ Desalination systems

Wind turbines can be used to supply electricity or mechanical power to RO,VC and ED desalination plants. Like PV, wind turbines represent a mature, commercially available technology for power production. Wind turbines are a good option for water desalination especially in coastal areas presenting a high availability of wind energy resources.

Several small wind turbine to drive MVC , RO and ED systems existed today and the reported cost of desalinated water range between 2.6 to 7.3 $/m³.



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Geothermal / Desalination systems

The earth's temperature varies widely, and geothermal energy is usable for a wide range of temperatures from room temperature to well over 300°F. Geothermal reservoirs are generally classified as being either low temperature (<150°C) or high temperature (>150°C). Low temperature geothermal sources can be used in solar thermal desalination plant such as MED, whereas high-temperature geothermal fluids can be used to generate electricity to drive RO or ED plants.

Several geothermal /desalination system have been demonstrated. The reported cost of water from this system is about **$2.0/ m^3.**

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Most common and promising RE/desalination technologies

System	Typical Capacity	Energy Demand	Potable Water Cost	Technical Development Stage
Solar still	< 0.1 m^3/day	Passive solar	$ 2 to 8/ m^3	mature
Solar MEH	1 to 100 m^3/ day	Thermal: 100 kWh/ m^3 Electrical: 1.5 kWh/ m^3	$ 3 to 8/m^3	Application and advanced R&D
Solar MD	0.15 to 10 m^3/day	Thermal 150 to 200 kWh/ m^3	$12 to 18/m^3	Advanced R&D
Solar CSP/MED	>5000 m^3/day	Thermal 60 to 70 kWh/ m^3 Electrical 1.5 to 2 kWh/ m^3	$2 to 3/m^3 (prospective cost)	Advanced R&D
PV/RO	<100 m^3/day	Electrical BW: 0.5 to 1.5 kWh/ m^3 SW: 4 to 5 kWh/ m^3	BW: $4 to 8/m^3 SW: $6 to 10/m^3	Application and advanced R&D
PV/EDR	<100 m^3/day	Electrical: $3 to 4 kWh/m^3	BW: $4 to 10/m^3	Advanced R&D
Wind/RO	50 to 2000 m^3/day	Electrical: BW: 0.5 to 1.5 kWh/m^3 SW:4 to 5 kWh/m^3	Units under 100 m^3/day BW: $4 to 6/m^3 SW: $6 to 8/m^3 Unit of 1000 m^3/day $2 to 5/m^3	Application and advanced R&D
Wind/MVC	<100 m^3/day	Electrical: SW: 12 to 15 kWh/m^3	$5 to 8/m^3	Basic research

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Recommendations

- Cost of desalinated water moved close to conventional water supply and expected to decrease the production cost in future.
- A number of technological upgrades and innovations in the past few years have resulted in reduced cost of desalted water to below $1.0/m3. Some RO plants reports a $0.52/ m3 cost.
- The hybrid desalination systems are proved to be technically feasible, economically attractive, and environmentally favorable.
- Renewable energy /desalination systems are currently economic and widely used in remote areas.
- The continuous increasing costs of fuel costs in recent years enhance the chance of using renewable energy in large capacity water desalination plants.
- Use of renewable energy sources including such as wind, solar and geothermal resources have a huge environmental impacts and should be considered as a sustainable fresh water source.

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Two Top-ranked Project Descriptions

Breakout group spokespeople presented their proposed projects in plenary session. After all presentations had been made, each conference participant voted for their favorite projects. Each participant received five votes and could attach those votes to any of the proposed projects, using all five votes for one project, or any combination thereof, as desired.

The project receiving the most votes by conference participants was a solar project entitled, "Design of a high yield integrated concentrated photo voltaic and solar thermal systems that produces power and supports advanced water treatment of brackish water to serve remote and rural communities water and energy needs." The project resolves a chronic water and power shortage for small remote/rural communities. It introduces a viable model to meet the water and power needs of disbursed rural populations. The benefits of this project would be the improvement of public health through the development of reliable high quality drinking water and water/power for economic development. The optimized project design achieves sustainability within the capacity of a population to pay operation, maintenance, and replacement costs for reliable access to power and water.

The project receiving the second most votes was a water resources project entitled, "Desalination technologies and trace contaminants." For rural communities, the benefits of this project include: education for health protection; understanding of treatment needs and costs, and the development of local water supplies. For industrial technology developers, the project would assist in market identification. For Reclamation, the project develops strategies for future priorities and fund allocation, and helps develop future water supplies.

The Project Receiving the Most Votes by Conference Participants: Solar Project

Title

Design of a high yield integrated concentrated photo voltaic and solar thermal system that produces power and supports advanced water treatment of brackish water to serve remote and rural communities water and energy needs.

Needs the Project Meets

Resolves a chronic water and power shortage for small remote/rural communities; introduces a viable model to meet the water and power needs of disbursed rural populations.

Benefits of Project and Expected Outcomes

Improves public health through the development of reliable high quality drinking water and water/power for economic development. Optimized project design achieves sustainability within the capacity of population to pay operation, maintenance and replacement costs for reliable access to power and water.

- Outmigration to be reduced
- Transferrable model that can be applied in other communities
- Improved environmental impacts
- Drought mitigation
- Reduced vulnerability and risk to climate change

Research Objectives

Define a system that integrates solar and advanced water treatment to produce (potable and non-potable) water and power to meet the demands of a small/rural community; a sustainable system within the user's capacity to pay operation, maintenance and replacement costs; minimizes waste generation and, integrates an operational system that manages the control of the cogeneration of power and water from both a demand and supply management perspective.

Research Approach (numbered by task)

1. Analysis of (3) communities to capture a control group of poor condition, marginal condition and sustainable condition
2. From pre-commercial and commercially available solar systems define the best energy and advanced water treatment technology portfolio as a package system to meet defined water and power demand
3. Produce additional water as a storage of excess power produced from the solar energy system
4. Define a control system that optimizes the operation and user data interface
5. Define system design that minimizes brine disposal
6. Report of findings in a Guidebook defining the planning process and system parameters

Estimated Project Budget and Schedule

$520,000

Proposed Partners

Reclamation, University of Arizona, University of British Columbia (RES'EAU WaterNet), ProDes, Kll, Inc./ Suns River, and others to be defined.

Known Prior Research on This Topic

Various

The Project Receiving the Second Most Votes from Conference Participants: Water Resources Project

Title

Desalination technologies and trace contaminants

Needs the Project Meets

- Aquifers with high salinity can also hold trace contaminants (ppb vs. ppm)
- ClO_4^-, As, radioactivity, Cr, others
- Constituents could change over years of use
- Rural communities have limitations
- Impacted by recent MCLs
- Limited finances mean low technical experience
- Little funding for consultant studies
- Need assistance from Reclamation and other federal or state agencies

Benefits of Project and Expected Outcomes

- Rural communities
  - Education for health protection
  - Understand treatment needs and costs
  - Develop local water supplies
- Industrial technology developers
  - Market identification
- Reclamation
  - Strategies for future priorities and fund allocation
  - Help develop future water supplies

Research Objectives

- Identify potential community locations looking toward new brackish groundwater sources
- Assemble known water quality and water availability information about those sources
- Evaluate limitations of desalination technologies relative to trace contaminants
- Advise technology choices
- Outreach to potential users

Research Approach (numbered by task)

1. Collect available information
   1.1. Aquifer locations, depths, and extents
   1.2. Water quality analyses
2. Identify data gaps
   2.1. Spatial distribution of information
   2.2. Missing constituent analyses
   2.3. Analytical interferences
3. Produce report
   3.1. Technology recommendations for water chemistry combinations

Estimated Project Budget and Schedule

$326,000 + IDC; 24 months

Proposed Partners

[none provided]

Known Prior Research on This Topic

[none provided]

List of Project Summaries

On the second day of the conference, break-out groups met for the morning and completed Project Description Sheets for their projects. Each group decided how many and which of their projects would be presented in the afternoon plenary session and who would be their spokesperson. All project summaries are provided below, whether the project was presented in the plenary session or not.

Action

1. BGNDRF external actions for improved integrated renewable energy/water purification and desalination research and testing

2. BGNDRF internal actions for integrated renewable energy/water purification and desalination research and testing

Environmental Impacts

1. Development of cost-effective enhanced evaporation techniques

2. Conversion of concentrate stream to food, feed and biofuel

3. Development of cost-effective re powered small brackish water /wastewater treatment systems for stand-alone rural communities

4. Pilot project at schools to demonstrate renewable energy, water, wastewater systems

   Project Description Sheets submitted but projects were not described during the plenary session:

   1. Combining concentrate with wastewater to produce algae biofuels

   2. Guidance document for selection and operation and management of small sustainable water/ wastewater systems

Geothermal

1. A survey of existing geothermal power plants and direct use facilities to determine near-term feasibility to cascade geothermal and heat energy water for desalination

2. Recovery of minerals from geothermal brines

3. Development of a users' guide for assessing feasibility of geothermal technologies for small-scale, brackish desalination systems

Infrastructure

Technical and economic comparison of reverse osmosis and electrodialysis brackish water desalination units powered by hybrid wind/photovoltaic systems

Institutional Considerations

1. Guidance manual on financial implementation of renewable energy-desalination projects - options and implementation

2. Characterization of the brackish groundwater source in the United States

3. Brackish groundwater treatment technologies

4. Identify and characterize stakeholders and their role in renewable energy/desalination implementation

Solar

Design of a high yield integrated concentrated photo voltaic and solar thermal system that produces power and supports advanced water treatment of brackish water to serve remote and rural communities water and energy needs

Water Resources

1. Desalination technologies and trace contaminants
2. Tapping on unutilized waste heat energy available in power generation facilities for co-generation of water

Wind

1. Guidebook for implementation of renewable energy for desalination for small systems
2. Which high-risk wind research projects are suitable for further exploration?

   Project Description Sheets submitted but projects were not described during the plenary session:

   1. Hybrid wind with vertical solar for desalination
   2. Capture of more atmospheric processes in wind energy assessment approaches
   3. Direct use of mechanical energy from wind power for desalination
   4. Grid independent green PC technology for energy optimization (patent-pending)

Audience Suggestions

After each of the eight breakout groups presented their best projects, the floor was opened to the audience to suggest projects or ideas related to the conference. The six suggestions are listed below:

1. A suggestion was made to use the excess heat from refineries to drive the desalination process, and then use the purified water within the refinery.
2. An audience member suggested moving water from the Midwest to where it is needed in the West. Wells could be used as a source to pump the excess water to the West.
3. To make the full use of water more comfortable, schools and community-scale projects could use highly purified wastewater as a drinking water source. This could be made a requirement for new subdivisions and the costs could be integrated into the development of the subdivision.
4. A concern was expressed that pumping brackish groundwater could lead to earthquakes. This could be reduced or stopped by closing the gap in the ground.
5. Pilot projects at schools are a good idea and everyone is challenged to come up with a shovel ready project using quality brackish water from existing wells. It was pointed out that the pueblos are at the front of environmental sciences and provide a good location for training opportunities.
6. The speaker pointed out that produced waters [water co-produced with oil and gas] are available in New Mexico, Texas, Colorado, and Wyoming. The water, when treated, could be used in rural communities.

ACTION

Action Project 1

Title

BGNDRF external actions for improved integrated renewable energy/water purification and desal research and testing

Needs the Project Meets

Preparing the BGNDRF facilities and test areas for accelerating research and testing opportunities with multiple groups and agencies for integrated renewable and distributed energy water and wastewater treatment for improved energy, water, and cost efficiency.

Benefits of Project and Expected Outcomes

Increases opportunities for additional funding and coordination of efforts with many groups

Research Objectives

Establish marketing, communication, and outreach plan for BGNDRF that can help coordinate funding, projects, etc. on integrated renewable energy and water treatment issues

Research Approach (numbered by task)

Develop a marketing, communication, and outreach plan for integrated renewable energy/water treatment research and testing

- Establish communication plan that can be used to increase knowledge about BGNDRF capabilities that includes info on testing conducted, up to date pictures, general results, etc
    - Develop communication materials for political reps, for Department of Energy/Department of Defense Environmental Protection Agency/others consideration
    - Develop groups that should be contacted and given updates: WaterReuse/American Water Works Association/American Membrane Technology Association/MSSC
- Develop outreach to other research groups including for Department of Energy/Department of Defense/ Environmental Protection Agency and industry that are also looking at renewable energy and water treatment and desalination.
- Establish an integration review group to help BGNDRF make contacts with other federal agencies and industry groups

Estimated Project Budget and Schedule

$0 - $20,000

Proposed Partners

Develop an action team of industry, federal, and research experts to help review proposed plans and options developed

Known Prior Research on This Topic

Coordination is always helpful

Action Project 2

Title

BGNDRF internal actions for integrated renewable energy/water purification and desalination research and testing

Needs the Project Meets

Preparing the BGNDRF facilities and test areas for research and testing of integrated renewable and distributed energy water and wastewater treatment for improved energy, water, and cost efficiency

Benefits of Project and Expected Outcomes

- It provides an improved ease of coordination of technology testing and accelerates ability to test quickly at BGNDRF
- Provides a marketing benefit to potential users, providing ability to have results validated by independent third party

Research Objectives

Not research objective but improves ability to accelerate testing opportunities

Research Approach (numbered by task)

1. Develop standardized testing for integrated renewable energy/water treatment testing technologies
    - Utilize Federal Remediation Tech. Roundtable format and approach, and EPA/ETV approach as basis
2. Develop approach to provide a methodology for “performance verification” of technologies being tested and evaluated
    - Utilize EPA/ETV approach and report format as a basis
3. Develop “Master Plan” for integrated renewable energy/water treatment testing areas at BGNDRF
    - Consider layout of plumbing, electrical, communication
    - Integrate weather data collection needed with existing met station data collection
    - Consider pad and site layouts for 10-30 gpm water treatment options
    - Look at designs and layouts that will allow use of solar, wind, geothermal renewable energy considerations for water pretreatment, treatment, and concentrate management
4. Comparative analysis of technology attributes of water and energy technologies
    - Establish energy efficiency, waste energy of energy technologies
    - Establish water efficiency, waste water of water treatment technologies
    - Data can be used to help technology developers in integrating with other technologies

Estimated Project Budget and Schedule

Up to $30K

Proposed Partners

Develop an action team of industry, federal, and research experts to help review proposed plans and options developed

Known Prior Research on this Topic

Number of other federal programs that can be used as templates to help accelerate cost and performance assessments for technology developers

ENVIRONMENTAL IMPACTS

Environmental Impacts Project 1

Title

Development of cost-effective enhanced evaporation techniques

Needs the Project Meets

Small/stand-alone communities all around; Increases options of disposal concentrate from reverse osmosis system in inland areas

Benefits of Project and Expected Outcomes

Will increase water supply options for small communities by making membranes systems feasible in inland areas. It will also benefit large volume producers as well (after concentrate have been further concentrated using other techniques.

Research Objectives

Increase evaporation rates cost-effectively in order to reduce land areas required for final concentrate disposal.

Research Approach (numbered by task)

1. Set up WAIV system at BGNDRF
2. Develop/test other system that will increase surface area (continuous loop fabric system, nebulizers, etc.)
3. Investigate using solar energy to drive motors/fans as part of system

Estimated Project Budget and Schedule

$500,000; two years

Proposed Partners

Water utilities (multistage salinity coalition)

Known Prior Research on This Topic

(Israeli research publications)

Environmental Impacts Project 2

Title

Conversion of concentrate stream to food, feed, and biofuel

Needs the Project Meets

Concentrate management

Benefits of Project and Expected Outcomes

This proposal offers a target-rich approach in a two-step process. The first step involves water purification/desalinization, and the second step involves consuming the reject highly saline water for further use. Consequently, the process leaves behind zero reject water, avoiding the costly disposal process that is currently in practice. In short, this proposal offers a system to convert the reject saline water into a highly desirable algae product from which many other benefits can be achieved. These benefits include production of algae biomass that can be converted to biofuels, methane and other by-products such as omega 3, food, feed, fertilizers, vitamins, and other chemicals.

Research Objectives

The goal of this proposed work is to demonstrate a technology which delivers potable water with a minimum reject brine stream by integrating multiple technologies in a unique combination, where waste products from concentrate stream become the raw material for energy production (biofuel and methane).

Research Approach (numbered by task)

1. Evaluation of electrodialysis reversal (EDR) process performance at highest possible removal in order to remove total dissolved solids (TDS) as much as possible. Currently, conventional separation percentage of total dissolved salts in EDR technology is about 40-60% per stage. Depending on the saline/brackish water quality, in most cases EDR systems are designed to desalinate water in multiple stages, which results in higher capital expenditure (CapEx) costs. In general, relatively high CapEx cost of desalination technologies has limited the practical employment of saline and brackish water desalination. Any attempt to reduce CapEx will result in greater utilization of desalination technologies. The objective of this set of experiments is to understand EDR stack limitations under operating conditions that contribute to high current density and high salinity removal for a long period of time. This way, EDR process can be operated at the highest possible removal in order to remove as much TDS as possible.

2. Evaluation of EDR process at highest possible recovery rate in order to minimize the concentrate stream flow. The objective of this task is to maximize the recovery rate of the EDR process to reduce the volume of concentrate steam. Based on the results of Task 1, which investigates the high removal conditions, baseline EDR tests will be performed to find out the highest LSI for calcium carbonate and highest calcium sulfate saturation level for typical brackish groundwater found in the southwest US. Various influent waters with TDS of 500 to 10,000 mg/L will be tested to investigate maximum recovery rate while EDR is operating under highest possible removal rate (Task 1). The experiment will be performed using commercial GE ion-exchange membranes. Influent water will be taken from BGNDRF's groundwater wells, the TDS of which are between 1000-5000 mg/L. The product and blow down flow rate will be set at 7.5 and 2.2 gmp. Voltage and current in the EDR stack have been calculated based on the preliminary tests.

3. Algae strain identification and biofuel production. The objective of this task is to use concentrate obtained from the previous tasks and grow algae for biofuel and other by-products such as fertilizer and animal feed. Different species of algae known to be well grown in saline conditions will be obtained. These species of algae will be cultured on Bold's Basal Medium and f/2 Medium under a fume hood with sterilized conditions. A factorial experiment based on completely randomized design (CRD) with three replications will be designed. Treatments are appropriate media, concentrate, and distilled water as control. 25 ml of

these species grown in media will be added to 250 ml of concentrate, media and distilled water. They will be grown under 16-hour light and 8-hour dark condition. Biomass from algae will be collected after two weeks of growth by centrifuging and removing water. Biomass will be dried and weighed. Analysis of variance (ANOVA) and means will be compared using multiple comparison method. Subsequently, the best species of algae grown with saline concentrate will be selected.

4. Pilot plan of algae biomass production in BGNDRF. The selected algae species will be evaluated in small pond using concentrate in BGNDRF. Depending on outcome of result obtained from lab and small ponds, a pilot plant methane production unit can be installed in next phase of research.

5. Final report.

Estimated Project Budget and Schedule

Budget for the proposed project for three years is estimated to be $450,000

Proposed Partners

[none provided]

Known Prior Research on This Topic

This idea is novel. Little work, if any, has been published in the area of concentrate management using algae. Some preliminary lab work has been done by the researchers at Institute for Energy and the Environment at New Mexico State University. The results indicated there is a possibility of using concentrate as a source of nutrient for growing algae biomass.

Environmental Impacts Project 3

Title

Development of cost-effective renewable energy (RE) powered small brackish water/wastewater treatment systems for stand-alone rural communities

Needs the Project Meets

Small/stand-alone communities all around having no access to water and/or energy.

Benefits of Project and Expected Outcomes

Replicable systems; good quality water; safe wastewater disposal; clean surroundings; health benefits; economic growth

Research Objectives

Development of technology/system that is cost effective robust/smart, easy to use/operate/maintain, and sustainable.

Research Approach (numbered by task)

1. Standardizing water pumping practices based on available renewable energy sources with small scale wind / PV / CPV / CSP, etc.

2. Feasibility of using established low tech water (filtration, coagulation, disinfection)/wastewater (septic tanks, oxidation ponds, trickling filters etc.) treatment processes/combination of processes with a wide range of source brackish water/wastewater quality

3. Coupling RE source with the water systems
4. Optimizing system performance over broad range of water quality
5. Evaluating potential of selling/hauling water to nearby communities
6. Developing operations and management manual & providing/capacity building for the operators/end users
7. Follow up to debug/improve system performance

Estimated Project Budget and Schedule

$150,000 - $200,000

Proposed Partners

Reclamation, universities, water/wastewater research organizations, small communities, Indian Tribes

Known Prior Research on This Topic

Suggested water/wastewater treatment systems and renewable energy technologies are already established/proven.

Environmental Impacts Project 4

Title

Pilot project at schools to demonstrate renewable energy, water, wastewater systems

Needs the Project Meets

Education of rural communities on benefits and mechanics for using renewable energy/water/wastewater treatment systems. Demonstrate safety of using recycled water for playground/garden/agricultural purposes. Rural communities can get exposure to systems without individual investment first.

Benefits of Project and Expected Outcomes

Test the economic and social feasibility of treating brackish water using renewable energy.

- Promote water conservation through reuse
- School and children will educate parents on the benefits
- Demonstrates practical benefits and encourages careers in science (environment, engineering, chemistry, and biology

Research Objectives

Social to:

- Determine operations and management needs/limitations of a system in a rural community.
- Understand acceptance/demand for such systems in rural communities.
- Maximize sustainability of systems

Research Approach (numbered by task)

1. Identify a system that can serve a school of 300 students. Renewable energy+wastewater treatment and reuse. Also recovery of sludge and concentrate.
2. Identify a school with commitment to participate in the project, including qualified staff
3. Survey parents' attitudes toward this type of system
4. Develop the school's capacity to maintain the system
5. Identify uses for recycled water, sludge, and concentrate including sports fields, garden, trees for reuse; compost sludge – available for community; concentrate – building materials/playgrounds
6. Work with school to integrate into the curriculum
7. Determine parents/community interests in procuring more systems
8. Local banks to finance possibly

Estimated Project Budget and Schedule

$200,000

Proposed Partners

System producer; Reclamation, Texas office; Water Reuse Research Foundation;university rural sociology department; agriculture extension service (for growing grass and determining crops)

Known Prior Research on This Topic

Couldn't find any

Environmental Impacts Project 5 (project summary submitted but not described at plenary session)

Title

Combining concentrate with wastewater to produce algae biofuels

Cities that have brackish groundwater or produce a concentrate from brackish water treatment can use this water as a resource with municipal wastewater to produce biofuel. The nutrients and organic matter present in the wastewater and the salts present in the concentrate will produce an excellent environment for algae to grow at a very low cost.

Benefits of Project and Expected Outcomes

Replicable systems/good quality water supply, safe wastewater disposal, clean surroundings, health benefits, economic growth. The benefit of this project is to convert a waste-product into a resource to produce water and/or energy.

Research Objectives

The objective of this project is to determine the feasibility of mixing reverse osmosis concentrate and wastewater to produce algae that could be used for biofuel production.

Research Approach (numbered by task)

1. Determination of candidate types of algae (literature review)
2. Different combinations of concentrate/wastewater to improve growth
3. Comparison with different methods of algae growing

Estimated Project Budget and Schedule

$200,000 for the first year

Proposed Partners

Jalal Rastegary, PhD

Known Prior Research on This Topic

[not provided]

Environmental Impacts Project 6 (project summary submitted but not described at plenary session)

Title

Guidance document for selection and operations and management of small sustainable water/wastewater systems

Needs the Project Meets

Reducing cost of small system and keeping them functional

Benefits of Project and Expected Outcomes

Improving cost-effectiveness of small systems

Research Objectives

Produce document than contains information about conditions/circumstances when "off the shelf" systems can be used without extensive engineering/pilot testing

Research Approach (numbered by task)

1. Identify water qualities suitable for standard reverse osmosis systems
2. Identify situations where "off the shelf" systems will not be suitable (i.e., silica, arsenite)
3. List expected capital and operating cost versus system capacity

Estimated Project Budget and Schedule

$250,000; one year

Proposed Partners

Texas Water Development Board

Known Prior Research on This Topic

Texas Water Development Board RFP

NOTE: similar document/project should be executed for wastewater treatment systems

GEOTHERMAL

Geothermal Project 1

Title

A survey of existing geothermal power plants and direct use facilities to determine near-term feasibility to cascade geothermal and heat energy water for desalination

Needs the Project Meets

Provide information from current geothermal facilities to apply in categorizing geothermal fluids and in order to match potential desalination applications.

Benefits of Project and Expected Outcomes

Project will provide a better understanding of the economic and technical potential for pairing existing geothermal facilities with desalination applications, including economic recovery of minerals.

Determine pretreatment requirements and provide preliminary information on most promising desalination technologies to use.

Research Objectives

Identify opportunities for geothermal and desalination applications. Identify regulatory, marketing and business challenges to implementing geothermal-desalination projects.

Research Approach (numbered by task)

1. Identify existing facilities
2. Literature search
3. Solicit stakeholder input for survey
4. Develop and apply survey tool
5. Interpret results
6. Prepare report

Estimated Project Budget and Schedule

$150,000; 12 months

Proposed Partners

[not provided]

Known Prior Research on This Topic

[not provided]

Geothermal Project 2

Title

Recovery of minerals from geothermal brines

Needs the Project Meets

Reduces the amount of material to be reinjected into reservoir; identifies potential revenue streams to offset the cost of the project.

Benefits of Project and Expected Outcomes

Value of recovered minerals could reduce the cost of water production; removal for minerals in pretreatment could simplify desalination of the water.

Expected Outcomes

A process for recovering specific minerals from a specific geothermal brine would be developed; the cost of recovery of specific minerals would be estimated.

Research Objectives

Identify minerals that might have market value (lithium, boron, zinc, gold, others); Identify processes for removing specific minerals.

Research Approach (numbered by task)

1. Review literature existing minerals in geothermal brines and means of recovery.
2. Collect brines from existing geothermal installations and perform analyses.
3. Chose two promising brines and perform separations.
4. Prepare final report.

Estimated Project Budget and Schedule

$299,000; one year

Proposed Partners

UTEP, Witcher & Associates

Known Prior Research on This Topic

Susan Juch Lutz, Jeffrey B. Hulen, and William L. Osborn, Gold-Bearing Arsenide and Other Production-Well Scales from the Salton Sea Geothermal Field, California, Proceedings, Twenty-Sixth Workshop on Geothermal Reservoir Engineering Stanford University, Stanford, California, January 29-31, 2001.

Willem P.C. Duyvesteyn, Recovery of Base Metals from Geothermal Brines, Geothermics, 21 (5/6) 773-739, 1992.

W. Bourcier, S. Martin, B. Viani, and C. Burton, Developing a Process for Commercial Silica Production from Geothermal Brines, Geothermal Resources Council Transactions, 25, August 26-29, 2001.

Geothermal Project 3

Title

Development of a users' guide for assessing feasibility of geothermal technologies for small-scale, brackish desalination systems

Needs the Project Meets

We do not know of a screening document that users can access to help them determine applicability of the use of geothermal resources in a desalination project.

Benefits of Project and Expected Outcomes

Allow the desalination community to determine if it could be technically and economically feasible to use geothermal resources as part of a small-scale brackish desalination project. Expected Outcomes: because of the synergies gained from using a constant renewable energy source in the desalination process, more communities will be able to economically increase their production of water.

Research Objectives

1. There are two main types of geothermal resources (conductive and convective) and multiple desalination processes including reverse osmosis (RO), multi-stage flash distillation (MSF), multiple-effect distillation (MED), mechanical vapor compression (MVC), electrodialysis (ED)/electrodialysis reversal (EDR), and nanofiltration (NF). The objective of this research would be to develop guidelines for when synergies could be gained by using the water, power generation, heat, and/or cooling provided by geothermal processes in a desalination process.

2. Educate the public.

Research Approach (numbered by task)

1. Review existing guidance documents for small scale geothermal and desalination processes.

2. Develop a matrix of geothermal and desalination technology requirements

   - Energy generated or required
   - Water temperature
   - Water quality parameters

- Depth of water resource
- Brine disposal options

3. Develop typical project profiles
4. Case examples
5. Project budgeting guidance

Estimated Project Budget and Schedule

$250,000; 12 months

Proposed Partners

[none provided]

Known Prior Research on This Topic

1. National Resource Council, 2008. Desalination: A National Perspective. Washington DC: National Academy Press.
2. European Renewable Energy Council. Key Issues for Renewable Heat in Europe (K4RES-H). Key Issue 5: Innovative Applications: Geothermal Utilization for Seawater Desalination
3. UNESCO-EOLSS Integrated Power and Desalination Plants Project: Encyclopedia of Desalination and Water Resources DESWARE
4. W. Teplitz-Sembitzky. Sept. 2000. The Use of Renewable Energies for Seawater Desalination – A Brief Assessment
5. K. Bourouni, R. Martin, L. Tadrist, M.T. Chaib. Heat transfer and evaporation in geothermal desalination units. 1999. Applied Energy, Vol 64, Issues 1-4.
6. (Funded by KFW)

INFRASTRUCTURE

Infrastructure Project 1

Title

Technical and economic comparison of reverse osmosis (RO) and electrodialysis (ED) brackish water desalination units powered by hybrid wind/photovoltaic (PV) systems

Needs the Project Meets

The demand for fresh water is increasing due to population growth, change of life style, and industrial growth. As a result, there is a reduction in the volume of available fresh water resources, requiring the use of impaired water supplies. In order to meet the increasing demand for fresh water resources, we need a better balance of water management (including water conservation and recycling) and sustainable development of new water resources. This project utilizes an integrate hybrid renewable energy-desalination system designed for sustainable development of new water resources by the following approach:

- Suitable desalination technologies to treat brackish water resources. Both pressure driven (RO) or nanofiltration (NF) and electrically driven (ED or EDR) technologies are good candidates.
- A hybrid wind/PV system provides more consistent daily and year round performance and reduces the need for back-up fossil fuel generation.
- Characterize the efficiency and cost effectiveness of RO compared to ED.

Benefits of Project and Expected Outcomes

The novel aspect of this project is the use of both wind and solar energy in a hybrid renewable energy generation system. The major advantages of a solar/wind hybrid system are the following:

- Different and opposite patterns in terms of wind and solar resources (wind common at night when solar energy is not available), making solar/wind complimentary solutions
- Less reliance on one method of power production
- More consistent power generation
- Reduces the need for high cost energy storage technologies, resulting in a cost-effective power supply

Unlike other renewable energy resources, the combined solar/wind system is that it allows for the use of either RO or ED, which are the most energy efficient technologies available for brackish water desalination.

Another important outcome of this project is that both RO and ED units are major technology and currently used in brackish water desalination, but there is no availability of sufficient information about the economic comparison of these two processes when they are powered by hybrid renewable system.

Expected Outcomes Includes

- Knowledge of how to integrate a system consisting of two renewable energy sources and a desalination technology
- A detailed understanding of the technical aspects of both desalination and renewable energy (wind and solar) technologies.
- Quantify the economic benefits of the wind/ photovoltaic/reverse osmosis system and wind/ photovoltaic/electrodialysis system including: advantages, limitations, power consumption, and the cost of fresh water produced.
- The above information will help in choosing the suitable system for the available site and water condition.

Research Objectives

The goal of this project is to study the technical feasibility and suitability of hybrid integrations of wind and solar renewable energy resources with desalination processes. The objectives of the project can be summarized as follows:

- Review the state of the art of wind and solar technologies and development trends.
- Review of RO and ED/EDR desalting systems for integration with wind/solar hybrid.
- Evaluation of the feasibility and benefits of the utilization of RE for power supply to stand-alone water desalination units through the reduction of fossil fuel consumption.
- Study the performance of RO and ED desalination units when they are coupled to renewable energy resources.

- Study the quality and cost of the fresh water produced from each process.
- Assessment of the effectiveness, reliability, operational and maintenance (O&M) requirement, and cost of the RE technologies.
- Study the environmental benefits resulting from using renewable energy as power source for desalination units.
- Understand variable desalination operation based on availability of wind/solar

Research Approach (numbered by task)

1. Overview of wind and solar technologies
   - Overview of wind technology with emphasis on the types wind turbines, turbine designs, available sizes, power production, limitations, market, applications and environmental advantages and disadvantages.
   - Overview of solar PV with emphasis on PV theory, solar cell types, PV systems types, market and environmental benefits.
   - Overview of the hybrid RE systems with emphasis on the reliability of power production.
2. Overview of desalination processes
   - Overview of reverse osmosis (RO) desalination systems with emphasis on theory, system components, performance and market.
   - Overview of electrodialysis/electrodialysis reversal (ED/EDR) desalination systems with emphasis on theory, system components, performance, and market.
3. Overview of brackish water with emphasis on characteristics, habitats, total dissolved solids (TDS) content, and geographical availability of wind and solar energy.
4. Compare RO vs ED technologies as functions of feed water chemistry and product quality requirements.
5. Design conceptual, integrated hybrid renewable energy-desalination system design based on the suggested desalination system capacity, water chemistry, product water requirements, and availability of wind/solar and resulting power generation.
6. Conduct a feasibility study using available software to predict system performance and fresh water production cost and environmental benefits for a range of operating conditions (i.e. availability of wind/solar).
7. Submit recommendations for pilot or demonstration of integrated RE-desalination system.

Estimated Project Budget and Schedule

We anticipate this will be approximately a one-year effort, with a project budget approximately equal to the billable rate for one full-time researcher, $200,000.

Proposed Partners

National Renewable Energy Laboratory, Reclamation, General Electric

Known Prior Research on This Topic

Carta, J.A., González, J., Subiela V. 2003. Operational analysis of an innovative wind powered reverse osmosis system installed in the Canary Islands. Solar Energy 75:2003:153.

Subiela, Carta, González. 2004. The SDAWES project: lessons learnt from an innovative project. Desalination 168:2004:39–47.

ADU -RES Project 2005. (INCO -CT -2004-509093) Coordination Action for Autonomous Desalination Units based on Renewable Energy Systems, "Report on the status of autonomous desalination units based on renewable energy systems."

Peñate, B., Castellano, F. Ramírez, P. 2007. PV-RO Desalination Stand-Alone System in the Village of Ksar Ghilène (Tunisia). Proceedings of the IDA Conference, Maspalomas (Gran Canaria Island) October 2007

Essam Sh. Mohamed, G. Papadakis, E. Mathioulakis and V. Belessiotis. (2008) A direct coupled photovoltaic seawater reverse osmosis desalination system toward battery based systems – a technical and economical experimental comparative study; Desalination, Volume 221, Issues 1–3, 1 March 2008, Pages 17–22

E. Brauns, Salinity gradient power by reverse electrodialysis: effect of model parameters on electrical power output, Desalination 237 (2009) 378–391

Enercon. Enercon desalination systems – sustainable solutions for drinking water production. http://www.enercon. de/www/en/broschueren.nsf/vwwebAnzeige/1008C1

E9AED 7CAA 5C1256FC 7003776B9/$FILE /DesalinationSystems_Booklet_English.pdf, downloaded the 1.12.2009

INSTITUTIONAL CONSIDERATIONS

Institutional Considerations Project 1

Title

Guidance manual on financial implementation of renewable energy (RE) - desalination projects - options and implementation

Needs the Project Meets

1. Identifies sources of public financing for an RE-desalination project.
2. Identifies potential sources of private financing
3. Identifies tax and other incentives available to these types of projects
4. Identifies opportunities for exporting power/heat energy from oversized RE segments of a project as a co-generation project.

Benefits of Project and Expected Outcomes

Provides a clear road map for the project planners to identify and involve potential sources of financial assistance, tax incentives and commercial opportunities at the start of the project. This will enable the planners to fashion the project from the start of fully exploit all avenues of financing and particularly to start incorporating the technical features of the project necessary to meet the requirements of the financial stakeholders, particularly if commercial power sales are expected.

Research Objectives

The expected outcome of this research effort is a guidance manual that will assist project planners in locating and involving sources of financing, tax incentive programs and commercial opportunities early in a project's life.

Research Approach (numbered by task)

1. Identify the financial institutions traditionally offering public sector financing.
2. Identify federal and state tax incentives, rebates or other offsetting programs that would help defray the initial capital expenditure (CapEx) of the project.
3. Identify potential for commercial revenue for a project that may be suited to a co-generation approach.
4. Publish a guideline document that would be made available to any renewable energy - desalination project planning entity to assist them in setting up the initial contacts for a project and establishing the initial lines of communication.

Estimated Project Budget and Schedule

$100,000; 12 months

Proposed Partners

Reclamation, National Water Research Institute, Electric Power Research Institute, etc.

Known Prior Research on This Topic

None

Institutional Considerations Project 2

Title

Characterization of the brackish groundwater source in the United States

Needs the Project Meets

The project will provide a basis for planning the development of desalination plants and identifying areas with a strong renewable energy resource. The project will provide characterization of brackish water sources.

Benefits of Project and Expected Outcomes

The project will result in:

- a clearinghouse of data resources regarding the availability and depth to brackish groundwater
- a clearinghouse of data resources on the quality and constituents of the brackish groundwater sources
- identified potential demand locations for desalination technology in the United States
- identified known limitations on the development of brackish groundwater resources, i.e., issues with interstate compact agreements

The benefits of the clearinghouse would be the collection of existing data that is currently available in numerous locations. Data sources will include the oil drilling community logs and water well drilling logs and any other drilling logs and findings that were submitted to state agencies. Part of the effort will include collecting the information where available and creating a means for agencies and others to self report this information. Proprietary information will be generalized as necessary to make this information available.

The benefits of this clearinghouse would be a quick reference guide for planners, developers, and municipalities to identify locations where desalination could be a viable alternative for water supply. By overlaying the renewable energy resource maps the evaluation would be able to consider where renewable energy could be integrated into the desalination process.

Research Objectives

Create a self-sustaining clearinghouse for identification of the brackish groundwater source in the United States.

Research Approach (numbered by task)

1. Clearinghouse: The approach could consist of identification of data sets that are available and the collection of those resources to place in the clearinghouse. Taxonomy will need to be created and some standardization of the meta-data will be needed.

2. Potential Demand: This task of the project would require identification of projected water demands by location and the unavailability of other water resources such as groundwater or surface water supplies.

3. Limitations of Development: This analysis could consider overlaying interstate river compacts, endangered species compacts, or other constraints of development.

4. Overlaying Renewable Energy Resource Maps: The Renewable Energy layers are readily available from the National Renewable Energy Laboratory.

The clearinghouse could be seeded with data collected under this project and then a method and process could be available for self-submittal of relevant data by state agencies or other organizations.

Estimated Project Budget and Schedule

$200,000; two years

Proposed Partners

USGS

Known Prior Research on This Topic

[none provided]

Institutional Considerations Project 3

Title

Brackish groundwater treatment technologies

Needs the Project Meets

Identify best technologies; develop and evaluate novel technologies, fundamental understanding of scaling issues specific for brackish water, and link technology to water source characterization.

Benefits of Project and Expected Outcomes

Novel treatment schemes for brackish water, brine minimization, understanding of scaling phenomena, energy and resource requirements.

Research Objectives

To evaluate and develop technologies to treat brackish water and dispose brine (the project will identify best and state-of-the-art technologies based on the array of source water and energy/resources available); to understand scaling mechanism and minimize its effect of process performance; to minimize the energy and resource needs for brackish water desalination.

Research Approach (numbered by task)

1. Acquire/develop database of brackish water characteristics, nationally.
2. Identify current state-of-the-art and future technologies.
3. Understand interaction between specific brackish water and technology.
4. Evaluate technologies based on performance indicators (water quality, recovery, energy, resources)

Estimated Project Budget and Schedule

$500,000; four years

Proposed Partners

Local and federal agencies, membrane and systems manufacturers, scale inhibitors, and chemical companies

Known Prior Research on This Topic

University of Nevada Reno, Colorado School of Mines, Yale University

Institutional Considerations Project 4

Title

Identify and characterize stakeholders and their role in renewable energy (RE) - desalination implementation

Needs the Project Meets

Stakeholders: federal, non-governmental organization (NGO), private, universities

1. Identifies the key stakeholders necessary for the successful implementation of an RE-desalination project.
2. Identifies the role of each of the stakeholders in the successful implementation of an RE-desalination project.
3. Generates protocol for participation and communication between stakeholders.
4. Generates required changes in institutional mores and practices to move projects forward to completion.

Benefits of Project and Expected Outcomes

Provides a clear road map for project to surmount the institutional hurdles expected in every project but more so in RE-desalination. It is expected that RE-desalination will require more than the usual amount of regulatory oversight expected for a single purpose water treatment plant (WTP). Thus it is critical for the water purveying agency (municipal, regional, authority, etc.) to have clear direction and a current knowledge of the stakeholders who will be involved, in addition to those that may have a single focus interest, such as environmental groups, taxpayers associations, etc. It is more important for an RE-desalination project to involve all of the stakeholders from day one, thus it is essential that all the nationally based stakeholders, as well as local stakeholders be involved from the onset of the project.

Research Objectives

The expected outcome of this research effort is a tabulation of the nationally based stakeholders that should be reviewed and updated frequently. The project initiator will then have at their fingertips the tool necessary to involve the appropriate stakeholders so that initial conversations and planning for the project can move forward with open discourse, and stakeholder buy-in at every planning milestone.

Research Approach (numbered by task)

1. Identify the federal agencies that may be involved through current legislative mandate in an RE-desalination project.
2. Identify any NGOs that may have involvement by charter, mission statement, etc.
3. Identify financial/legal organizations that express an interest in having a stake in the proposed project.
4. Identify academic institutions that have active programs that would benefit the project through their involvement.

5 Develop the roles in a RE-desalination project for each of the stakeholders.

6. Publish a guideline document that would be made available to any RE-desalination project planning entity to assist them in setting up the initial contacts for a project and establishing the initial lines of communication.

Estimated Project Budget and Schedule

$150,000; 18 months

Proposed Partners

Reclamation, National Water Research Institute, Electric Power Research Institute, etc.

Known Prior Research on This Topic

None

SOLAR

Solar Project 1

Title

Design of a high yield integrated concentrated photovoltaic and solar thermal system that produces power and supports advanced water treatment of brackish water to serve remote and rural communities water and energy needs.

Needs the Project Meets

Resolves a chronic water and power shortage for small remote/rural communities; introduces a viable model to meet the water and power needs of disbursed rural populations.

Benefits of Project and Expected Outcomes

Improves public health through the development of reliable high quality drinking water and water/power for economic development. Optimized project design achieves sustainability within the capacity of population to pay operation, maintenance and replacement costs for reliable access to power and water.

- Outmigration to be reduced
- Transferrable model that can be applied in other communities
- Improved environmental impacts
- Drought mitigation
- Reduced vulnerability and risk to climate change

Research Objectives

Define a system that integrates solar and advanced water treatment to produce (potable and non-potable) water and power to meet the demands of a small/rural community; a sustainable system within the user's capacity to pay operation, maintenance and replacement costs; minimizes waste generation and, integrates an operational system that manages the control of the cogeneration of power and water from both a demand and supply management perspective.

Research Approach (numbered by task)

1. Analysis of (3) communities to capture a control group of poor condition, marginal condition and sustainable condition.
2. From pre-commercial and commercially available solar systems define the best energy and advanced water treatment technology portfolio as a package system to meet defined water and power demand.
3. Produce additional water as a storage of excess power produced from the solar energy system.
4. Define a control system that optimizes the operation and user data interface.
5. Define system design that minimizes brine disposal.
6. Report of findings in a Guidebook defining the planning process and system parameters.

Estimated Project Budget and Schedule

$520,000

Proposed Partners

Reclamation, University of Arizona, University of British Columbia (RES'EAU WaterNet), ProDes, Kll, Inc./ Suns River, and others to be defined.

Known Prior Research on This Topic

Various

WATER RESOURCES

Water Resources Project 1

Title

Desalination technologies and trace contaminants

Needs the Project Meets

Aquifers with high salinity can also hold trace contaminants (ppb vs. ppm)

- ClO_{4^-}, As, radioactivity, Cr, others
- Constituents could change over years of use
- Rural communities have limitations
- Impacted by recent MCLs
- Limited finances mean low technical experience
- Little funding for consultant studies
- Need assistance from Reclamation and other federal or state agencies

Benefits of Project and Expected Outcomes

1. Rural communities
    - Education for health protection
    - Understand treatment needs and costs
    - Develop local water supplies
2. Industrial technology developers
    - Market identification

3. Reclamation
   - Strategies for future priorities and fund allocation
   - Help develop future water supplies

Research Objectives

- Identify potential community locations looking toward new brackish groundwater sources
- Assemble known water quality and water availability information about those sources
- Evaluate limitations of desalination technologies relative to trace contaminants
- Advise technology choices
- Outreach to potential users

Research Approach (numbered by task)

1. Collect available information
   1.1. Aquifer locations, depths, and extents
   1.2. Water quality analyses
2. Identify data gaps
   2.1. Spatial distribution of information
   2.2. Missing constituent analyses
   2.3. Analytical interferences
3. Produce report
   3.1. Technology recommendations for water chemistry combinations

Estimated Project Budget and Schedule

$326,000 + IDC; 24 months

Proposed Partners

[none provided]

Known Prior Research on This Topic

[none provided]

Water Resources Project 2

Title

Tapping on unutilized waste heat energy available in power generation facilities for co-generation of water

Needs the Project Meets

Utilization of an untapped energy resource for water production. This stretches the fuel used in the power generation process to also concurrently produce water.

Benefits of Project and Expected Outcomes

The waste energy in power generation facilities (e.g., waste-to-energy plants; fossil fuel, natural gas and coal fired power generation facilities) are at the moment not transferable to a centralized location, to maximize its utilization. Power generation facilities can tap on this waste energy to operate water generation facilities (e.g., membrane distillation, membrane processes) for its in-house use. It is estimated that waste heat energy can be as much as 50-70% of the heat energy generated at power generation facilities. Tapping on the waste heat energy to co-generate water, can reduce the cost of water production.

Research Objectives

Marrying the power generation and water production facilities, to produce cost efficient water.

To develop a strategy going forward on how to optimize the nexus between renewable energy power generation and water production.

Research Approach (numbered by task)

1. Create an inventory of existing power generation facility
    - Type of power generation technology adopted (collect information of layout of facility; where the waste heat is centered in the facility, etc.)
    - Source of water supply for the power generation facility (e.g., groundwater, seawater, surface water)
    - Location of facility (close to water demand – communities in need of water)
2. Evaluation of viability of co-generation in existing power generation facility (e.g., coal fired, gas fired, fossil fuel and nuclear power technology facilities and any existing renewable energy facilities)
    - Review in terms of technical feasibility, economic viability, and compliance with existing and possibly new environmental regulations.
    - Review policies and legislative framework to allow power generators to also produce water.
    - Identify opportunities for co-generation at a scale (including smaller and remotely located communities) for brackish groundwater desalination
3. Develop guidelines for new power generation facilities; with the view to co-generate water.
    - Innovative design of power facilities to accommodate water production
    - New financing model for purchase of power and water from cogeneration facilities, with additional focus on renewable energy desalination
    - Land use planning to maximize use of infrastructure to co-generate power and water

Estimated Project Budget and Schedule

$500,000; 24 months

Proposed Partners

Power generation facilities (e.g., waste-to-energy plants; fossil fuel, natural gas and coal fired power generation facilities)

- Water treatment process vendors
- Policy makers and land use planners to rethink land use planning and funding structure for projects
- Regulators (energy, water and environment)
- Municipalities and small community users

Known Prior Research on This Topic

1. Information on waste energy in power plants – "Working Document of the National Petroleum Council Global Oil & Gas Study (July 18, 2007)"

   http://www.npc.org/Study_Topic_Papers/4-DTG-ElectricEfficiency.pdf

2. Memstill membrane distillation – a future desalination technology (Desalination 199 (2006) 175–176)

   Jan H. Hanemaaijera, Jolanda van Medevoorta, Albert E. Jansena, Chris Dotremontb, Eric van Sonsbeekb, Tao Yuanc, Luc De Ryckb

WIND

Wind Project 1

Title

Guidebook for implementation of renewable energy for desalination for small systems

Needs the Project Meets

There is currently no guidance for small systems that would like to employ wind, solar or other renewable energies when considering desalination alternatives. While information exists for large systems, there is a need for those that are off the grid. If renewable energy (RE) is to be employed on a more widespread basis for small systems, then clear, concise and tailored guidance is warranted.

Benefits of Project and Expected Outcomes

1. A better understanding of renewable energy options, challenges, and directions so that small systems can make informed decisions when undertaking a desalination project.
2. Greater rate of implementation success for small-scale RE-desalination.
3. Ultimately, higher water quality for disadvantaged and off-the-grid small communities.
4. Provides a peer-reviewed decision making tool to manage risk associated with implantation of RE-desalination.

Research Objectives

To provide guidance in planning and implementation of RE-desalination specific to small systems investigating alternatives for water supply where the energy component is off the electrical grid.

Research Approach (numbered by task)

1. Collect information on all available components associated with a RE-desalination project (including RE-collection methodology, electrical coupling and conditioning techniques, identification of suitable process equipment, water storage, and concentration disposal).
2. Describe opportunities for package systems.
3. Assess approaches to quantify of RE-resources.
4. Provide methodology to assess costs associated with both RE sources and desalination technology in terms of capital, operation and management, and total water costs.
5. Provide guidance on ownership and financing alternatives.
6. Develop criteria for go/no go decision making on RE-desalination implementation.
7. Information should be drawn from current and proposed practices around the world.
8. Describe issues associated with permitting RE-desalination for small systems.

Estimated Project Budget and Schedule

$200,000; one year

Proposed Partners

Electric Power Research Institute, Water Research Foundation, Rural Electric Association, ProDes, NCED

Known Prior Research on This Topic

Guidance has been developed for large systems via the WateReuse Research Foundation, but none specific to small systems.

Wind Project 2

Title

Which high-risk wind research projects are suitable for further exploration?

Needs the Project Meets

The group determined that there isn't a good understanding of work being done on high-risk wind energy ideas – at the university level, in government, in private industry; in the U.S. or globally. A central directory of these high-risk ideas would serve as a tool for researchers and funders to use to see what work is being done, to avoid potential duplication of efforts, and to determine what ideas are not being explored. The projects could be categorized by technology type and could serve to catalyze related but not identical projects, as well as further work on some of these potentially viable high-risk projects.

Benefits of Project and Expected Outcomes

The expected outcome would be a document that identifies and describes the various high-risk wind energy research projects and who's working on them; includes links to the researcher conducting the work/inventor proposing the idea(s). The benefit would be time savings on the part of researchers and improved knowledge about the range of wind energy projects underway, as well as greater exploration of possibly overlooked viable ideas. Could help identify knowledge gaps and future research needs.

Research Objectives

Identify the high-risk wind energy research underway in the U.S. and globally. Include universities, government, private industry; U.S. and non-U.S. organizations.

Research Approach (numbered by task)

1. Identify who is doing wind research and locate descriptions of projects
2. Assemble descriptions of the candidate research projects
3. Identify a time-frame: only active research, or include projects from previous years?
4. Assemble an assistance team to determine which projects are high risk and offer greatest potential for further exploration
5. Review the research projects to identify whether they're high risk
6. Prepare a database or spreadsheet listing projects, descriptions, lead researchers, organizations, and hyperlinks to research description/organization
7. Prepare report including information on projects
8. Assistance team reviews/approves report
9. Publish/submit final report

Estimated Project Budget and Schedule

$70,000 ($60,000, graduate or post-doc student; $10,000, assistance team review time); report published electronically

Schedule: one year

- Months 1-3: Tasks 1 through 4 (identify work underway through assembling assistance team)
- Months 4-6: Tasks 5 and 6 (review projects and decide which are high risk/high return, prepare draft database/spreadsheet of projects)
- Months 7-9: Tasks 7 and 8 (prepare report on findings; assistance team review report and provide comments)
- Months 10-12: Task 9 (finalize and publish report)

Proposed Partners

American Wind Energy Association, American Water Works Association, Electric Power Research Institute, Virginia Center for Wind Energy – James Madison University, Alternative Energy Institute – West Texas A&M

Known Prior Research on This Topic

Unknown

Wind Project 3 (project summary submitted but not described at plenary session)

Title

Hybrid wind with vertical solar for desalination

Needs the Project Meets

Wind power generation is highly variable and a hybrid system can provide a more consistent power supply. Locations for wind power generation are often not considered suitable for solar power generation. Research at the Massachusetts Institute of Technology (MIT) has demonstrated that solar power production under low light conditions can be optimized with photovoltaics mounted on vertical structures. The vertical alignment of the photovoltaics allows for power production from ambient light along with direct sunlight. Using vertical structures for wind generation can allow for solar power production in regions with low solar incidence.

Benefits of Project and Expected Outcomes

The project would provide more consistent power production to operate a desalination system and allow for solar power production to be used in regions not considered suitable for solar power.

Research Objectives

The proposed research will evaluate the ability to generate solar power using the structures required for wind power production and desalination. Vertical solar power production will be optimized for the structures to capture both direct sunlight and ambient light. The feasibility of using vertical solar power in regions not considered suitable for solar power production will be evaluated. Methods to optimize the use of power generated from a hybrid wind power/vertical solar power production for desalination will be evaluated.

Research Approach (numbered by task)

1. Vertical access wind turbines can produce power at lower wind speeds as compared to horizontal access wind turbines. These structures will be screened to determine which ones are suitable for vertical solar power production

2. The structures associated with wind production and water storage will be used to mount a vertical solar power production system. The optimal configuration of the vertical solar collection system for power production will be evaluated using a computer program developed at MIT.

3. A bench-scale system will be built and evaluated under different light and wind conditions. The alignment of the vertical solar power system will varied based on output from the computer optimization step.

4. The results from task 3 will be used to determine methods to use the power generated for a desalination facility.

5. A model will be developed to assess the feasibility of using a hybrid wind/vertical solar system for off the grid desalination of brackish water with reverse osmosis.

6. Prepare a final report with recommendations for scale-up to a field study.

Estimated Project Budget and Schedule

$100,000; one year

Proposed Partners

Department of Energy, MIT

Known Prior Research on This Topic

Existing hybrid wind/solar projects and ongoing research at MIT.

Wind Project 4

Title

Capture of more atmospheric processes in wind energy assessment approaches

Needs the Project Meets

Wind is affected by many atmospheric processes occurring not only at the wind project site but elsewhere, i.e., 10’s of kilometers (e.g., clouds and elevated terrain interactions) vertically and 100’s of kilometers (e.g., passing low-pressure systems) horizontally. Current wind energy assessment efforts (short period measurements of wind and small-scale CFD model application) come up so short in that they pretty much ignore the atmosphere. These limitations, resulting from untreated atmospheric processes, in developing wind/energy information will add to unknown risk for the investor and, thus, stint wide-scale growth of wind projects.

Benefits of Project and Expected Outcomes

There are quite a few benefits of employing atmospheric physics based wind energy assessment methods two of the main benefits are listed below:

Benefits:

1. Wind information is provided not only at the height(s) of actual wind turbines but also at multiple locations to cover a large area to cover wind projects

2. Wind information can be provided at a fraction of the time, i.e., a full year of wind information can be created in 30 or fewer days

3. Wind information can be produced at a fraction of the cost. For example, an 80-m wind collection effort can cost as much $80,000, compared to only $20,000 for the simulation based efforts

Expected Outcomes:

1. Accurate estimation of wind energy production for a specific year with monthly average wind speed or monthly energy production

2. Accurate capture of diurnal variation of wind energy for the year and for each month
3. Detailed and accurate estimation of long-term energy production with minimum year, average year, and maximum year; investors

Research Objectives

Test and validate atmospheric domain configuration strategies, determine effective ways to capture of all the relevant atmospheric physics without the cost of computational burden.

Research Approach (numbered by task)

1. Choose a site (an active wind project development will be desirable) with actual site wind measurements for comparing the simulation output with the site measurements for a) model validation b) simulation bias correction.
2. Set up an optimal atmospheric model domain, acquire the parallel computational resources, and complete simulations for ten years
3. Develop a wind energy assessment analysis and a report based on the simulation output and validation results

Estimated Project Budget and Schedule

$130,000; eight months

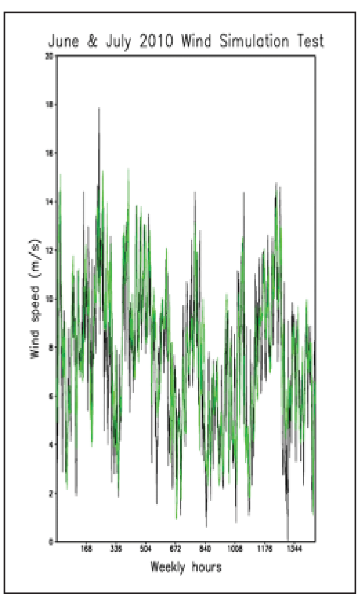
Proposed Partners

National Renewable Energy Laboratory for providing site measurements and independent validation of the simulation results

Electric Power Research Institute for providing site measurements and/or independent validation of the simulation results

Known Prior Research on This Topic

WindForces (www.windforces.com) has developed a cutting-edge atmospheric simulation technology for wind energy applications with the required atmospheric models, computational resources, etc.



WindForces is looking to develop independent validation studies based on the research already conducted.

Some comparison results for a wind project site in Oklahoma are summarized in the figure:

The simulation was conducted for a site in Oklahoma at the 56-m height. The difference as a percent for June is ~5% and July is ~1.7% and for the two month average is less than 4%.

Wind Project 5

Title

Direct use of mechanical energy from wind power for desalination

Needs the Project Meets

Wind energy conversion to electricity is inefficient and storage of highly variable electrical production is expensive. Investigations to use mechanical energy more efficiently i.e., use it directly without converting it to electricity may improve the cost effectiveness and therefore the employment of wind energy. Storage of mechanical energy could also be done more effectively than storage of electrical power. There is a need for further investigation of the concept.

Benefits of Project and Expected Outcomes

Identify technical barriers and opportunities to use mechanical energy from wind sources at small-scale brackish desalination facilities. Direct use of mechanical energy could allow for more effective wind power collection at both low and high wind speeds that cannot be captured with electrical energy. Storage of mechanical power could provide a consistent power source for a desalination system.

Research Objectives

Investigate and test the use of mechanical energy from wind turbines directly for a small brackish water desalination facilities. A key objective will be the use of a mechanical power storage system to provide a consistent power source for desalination.

Research Approach (numbered by task)

1. Literature review to identify ongoing and completed work
2. Development of a prototype for a wind power mechanical desalination system with storage of mechanical power to provide a consistent power source.
3. The prototype will be evaluated under varying wind speeds (either simulated or actual) to determine the efficiency of energy recovery and ability to store power.
4. Evaluate the data collected and prepare a final report with recommendations for a field evaluation.

Estimated Project Budget and Schedule

$200,000; two years

Proposed Partners

National Renewable Energy Laboratory, Reclamation, Department of Energy

Known Prior Research on This Topic

Considerable research has been done on the storage and use of mechanical power for pumps. This research should be applied for desalination.

Wind Project 6

Title

Grid independent green personal computer (PC) technology for energy optimization (patent-pending)

Needs the Project Meets

This technology shows the potential to significantly change the renewable energy sector for the better by offering the following three key benefits:

1. It will not require the power grid to build large scale renewable energy projects
2. Project developers will not require traditional power purchase agreements to build utility scale projects
3. The system pays for a large part of the energy storage system without increasing the cost of energy production

Benefits of Project and Expected Outcomes

This technology makes personal computers (PCs) "green" by which PCs, cloud/server clusters, etc., draw more than 90% of energy at the generation source (e.g., wind farms). PCs are accessed via internet using a PC-specific connector box unique to each PC. PC owners have control over their PCs—they can turn them on/off—as if they are residing in their homes/offices.

This technology offers wholesale energy rates to consumers that will last for the life of the renewable project and beyond. For example, a municipality with 500K personal computers, can save at least $15M per year. Depending on the location where retail rates may be higher, those savings can be as high as $60M per year.

As an example, a 100-MW wind/solar energy farm can support up to 300K personal computers and by pooling the cost of all those 300K power supply boxes, within all those PCs, an energy storage system (battery) can be fully paid for and the chaotic nature of renewable energy production stabilized, without having to increase the cost of energy production.

The technology leads to the development of highly energy efficient, grid independent, and cost-effective utility scale renewable energy projects globally. Energy efficiency results from the ability to choose sites with abundant natural resources and the ability to avoid energy losses in transmission/distribution. Grid independence results from the fact that these renewable projects no longer need the power grid as back up energy source. Cost effectiveness results from wholesale prices offered directly to the consumers.

With an estimated count of 2 billion PCs worldwide, the total energy required by these PCs may be on the order of a staggering 500GW of installed wind capacity at the 40% energy conversion efficiency.

Research Objectives

The objective is to develop a new personal computer (PC) that will use only 5-10% of grid supplied energy as opposed to 100% as it is currently. In doing so, renewable energy project development, including wind, will grow significantly.

Research Approach (numbered by task)

Fifteen (15) personal computers will be made compatible for this energy optimization technology concept so they are able to draw most of the energy (90+%) from a wind farm site. Energy consumption will be determined, using power meters, on the PC customer end as well on the energy consumption end to reach the research objectives stated above.

Estimated Project Budget and Schedule

$150,000; 12 months

Proposed Partners

M-TEC at New Mexico State University

North American Wind Research & Training Center at Mesalands Community College

Known Prior Research on This Topic

This is a patent-pending technology that is in the initial stages gathering strategic development and investment partners. Please contact James Stalker, the inventor, for further details at jrstalker@respr.com or 575-571-6354.

Presentation Abstracts

Selective Salt Recovery from Reverse Osmosis Brine Using Inter-stage Ion Exchange

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Presentation Abstract 1

A treatment for reverse osmosis (RO) concentrate is proposed to recover salts and increases water recovery. The process utilizes cation and anion exchange to exchange all ions in the concentrate stream for sodium and chloride. The sodium chloride stream can be treated further by a second reverse osmosis stage or another volume reduction technique to recover additional fresh water. The second stage concentrate can be used as ion exchange regeneration solution. Regeneration solutions from the cation and anion exchange columns are mixed to precipitate specific salts. Several phases of research were performed to prove the concepts behind this process. First, resin selectivity was characterized under ionic strength conditions common to RO concentrate ion by performing batch isotherms. A MATLAB model was developed to predict breakthrough curves. Regressions developed from the batch tests were used in conjunction with the MATLAB model to predict the number of bed volumes to breakthrough of calcium, magnesium, and sulfate. Model and regressions were verified by column experiments. Second, simulated cation and anion regeneration solutions were combined to precipitate salts, which were analyzed to determine their constituents. Finally, the process was tested with a continuously operated pilot scale system. Mixing of simulated and pilot generated cation and anion regeneration solutions spontaneously precipitated calcium sulfate when mixed at pH below 4.5 and mixed carbonate salts when pH was not adjusted. The pilot system can produce 12 kg of precipitate per cubic meter of RO concentrate and recover approximately 45% of the calcium and 28% of the sulfate.

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Wastewater Reuse at Holloman AFB

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Presentation Abstract 2

Saving Water through the Energy Conservation Investment Program

Holloman is one of the bases in the Air Force extensively adapted to its desert environment with base wide xeriscape landscaping and the use of artificial turf on exercise and parade fields. The 47 acre golf course is the only large area of irrigated ground and up until September 15, 2011 was irrigated with potable drinking water. In 2011, Holloman installed a treated wastewater reuse system for irrigation of the golf course, replacing more than 70 million gallons per year of potable water. This amounts to more than 15% of Holloman's annual water demand.

The funding for this project came from the Department of Defense Energy Conservation Investment Program (ECIP). ECIP is unusual in the DoD as it is a straightforward business based investment program that requires a Savings-to-Investment Ratio (SIR) greater than 1.25 and Simple Payback of less than ten years. Projects that meet the return on investment requirements of ECIP bypass the traditional long lead time budgeting process, thus rapidly increasing military facilities' efficiency.

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Treating High TDS Brackish Water in Sandoval County, New Mexico

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Presentation Abstract 3

In 2009, Sandoval County investigated treatment of a brackish groundwater source for potable water use. The county proposed to develop a wholesale water utility and provide water for the area and the city of Rio Rancho, New Mexico, with 5 million gallons per day to support area growth for 40 years.

The brackish water presented significant treatment challenges, with 12,000 milligrams per liter of total dissolved solids (TDS); extremely high levels of calcium, silica, magnesium, arsenic, and boron, as well as radionuclides; and a temperature exceeding 125° F. A multi-stage treatment process approach was developed using a combination of coagulation/sedimentation, warm lime softening, media filtration, weak acid ion exchange, and reverse osmosis to produce potable water and three distinct waste streams, two of which could produce marketable byproducts.

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Marketability and Selective Recovery of Salts from Brackish Water Desalination

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Presentation Abstract 4

An alternative to concentrate disposal is the identification of potential beneficial uses and markets for salts contained in concentrate, along with the development of innovative technologies for selective recovery of those materials. This research can then be applied to specific situations where concentrate disposal options might otherwise prohibit or severely reduce the feasibility of inland desalination.

A market analysis report was prepared to identify and document potential markets for reuse of salts and brine produced from concentrate. The market analysis report evaluated recovery of dry salts and direct use of concentrate brine by industries that use brine solution as industrial feedstock. Other factors included in this analysis are the uses of salt and market conditions and obstacles and barriers that must be overcome to marketing salts and brine.

Current concentrate management strategies produce a mixed salt waste that has no commercial value. Ion exchange (IX) has been investigated at the University of New Mexico as an intermediate step in a reverse osmosis (RO) system. Combining the IX regenerant waste streams causes salts to precipitate, which can then be recovered. Pilot testing has been conducted to optimize the exchange process, the regeneration process, and the mixing/precipitation process to control the recovery of specific salts.

The purpose of this presentation is to present the results and conclusions of the market analysis report and the results of current research on the use of ion exchange to selectively separate individual salts for potential sale.

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Non-Commercial Thinning Effects on Runoff, Infiltration, and Sediment Yield in a Mixed Conifer

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Presentation Abstract 5

Thinning mixed conifer forests has raised interest because it may increase runoff and sediment yield. However, there is little research that shows non-commercial thinning causes more runoff, infiltration, and sediment yield. The objective of this study was to determine whether non-commercial thinning practices decrease runoff and sediment yield and increase infiltration in mixed conifer forest stands. We accomplished our objective by the use of rainfall simulations. Treatments were control and non-commercial thinning with scattered slash. Study results showed that thinning did not have a significant effect on time to peak runoff, runoff initiation, runoff, infiltration, nor sediment yield. However, site (valley vs. ridge) significantly affected runoff ratio and sediment yield. Runoff ratio and sediment were high at the valley site where litter depth and litter cover were low. Results from this study indicate that thinning overstocked mixed-conifer forests does not represent a risk of increasing runoff and sediment yield.

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Presentation Abstract 6

WITHDRAWN

Use of Low Quality Water for Algal Production: Constraints

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Presentation Abstract 7

The large number of sunny days and mild climate in the southwestern U.S. has led to significant interest in developing technologies which take advantage of these resources such as solar power generation and algal biofuels production. While some of these technologies have no significant water use (i.e., solar photovoltaic power generation) others have a large consumptive water use (i.e., solar thermal power generation and algal biofuels production).

Growth of algae for production of biofuels is the subject of much current research in NM because of the warm, sunny climate and the availability of low cost land. However, algae are grown in aqueous suspensions in open ponds which generates evaporative water losses; annual pan evaporation rates in southern NM range up to nearly 10 ft/yr. Proposals to date have described use of low quality municipal wastewaters, produced water from oil recovery, and ground water from untapped brackish aquifers.

A consumptive water use for algal growth will introduce factors that have not been fully considered to date. These include: 1) water requirements and the availability of water for the process, 2) salt management and disposal, and 3) ownership of water rights and the value of water lost to evaporation. This paper reviews the impact of salinity on evaporative losses and algal growth. It discusses salt production and disposal options associated with algal production. Finally, it gives an overview of the water rights issues related to use of low quality water sources for algal farming.

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An Urban Water Needs Strategy: Proper Water Pricing, Conservation, Rainwater Harvesting & Greywater

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Presentation Abstract 8

Recently the city of Rio Rancho, NM, installed a $39M arsenic remediation plant to bring city water to EPA standards. An additional $2M is being spent on a reverse osmosis system for an out-of-compliance well. These projects were paid for by federal grants with no impact on local water pricing. The authors have lived off-grid for over four years in Rio Rancho, the past two without hauled water. Based on our own usage, only 1-2% of EPA-compliant city water is actually used for human consumption (drinking, cooking, etc.). In other areas of NM water supply is becoming critical and new well fields, piping over large distances, surface water treatment plants, desalination, and other high-cost remedies are being proposed to increase supply. Yet, despite the recent drought, only Albuquerque and Santa Fe have rainwater harvesting rebate programs, and these are insufficient. The authors propose a state-wide rainwater harvesting rebate that covers gutters, utility pumps and large water tanks, covered by increasing water fees. The rebate could be applied to the user's water bill or state income tax. We believe a goal of removing lawns, gardens, and trees from purified city water in five years could be met with a combined rebate/education program. Finally, we examine the possible impact of large-scale rainwater harvesting from malls and big box stores high-quality water supply for selected areas.

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Treatment and Use of Oil and Gas Produced Water as a Media Substrate for Algae Cultivation for Biofuels

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Presentation Abstract 9

Cultivation of high-productivity algae for biofuels is estimated to require significant quantities of water, by some estimates reaching limiting levels of water use at 270 billion gallons yr-1 (BGY) of water (evaporative losses, southwestern US) per 1 BGY of product algal lipid (Pate et al., 2011). Because many lipid-producing algae are salt-tolerant, oil and gas produced water is a likely candidate for growing algae. New Mexico alone produced 33.5 million gallons of oil and gas produced water in 2007 (Clark and Veil, 2009). Limiting factors for growth of these algae include high total dissolved solids (above 40,000 mg/L for many algae), high bicarbonate (above 400 mg/L), high metals such as copper (<1 mg/L is desired), and the presence of organic constituents (volatile and semivolatile organics) and well treatment additives (surfactants and biocides). Treatment of these waters to remove certain organic and inorganic constituents prior to use is being tested at a field site in Jal, NM. In addition, several high-salt and high-bicarbonate tolerant strains, including Nannochloropsis Salina are being tested in the laboratory at Pecos. Output water quality as a result of several different treatment steps contains reduced levels of divalent cations, organic constituents, but some increased levels of trace metals as a result of handling processes. Results of algae strain testing will also be discussed.

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LA-UR-11-11937

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Geothermal Resources Suitability for Desalination in New Mexico

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Presentation Abstract 10

Geothermal resources may provide significant advantages over other renewable energy for desalination. Geothermal energy operates 24 hrs per day and 365 days per year. With the same stream of geothermal water production, geothermal can provide electricity for pumps and the grid, a heat source for distillation processes, and a brine or brackish water source for desalination. Also, the geothermal reservoir provides a suitable confined and permeable sink for disposal of desalination brine. A common geothermal classification system applies temperature. Low temperature resources are less than 90oC, intermediate temperature resources are 90 to 180oC, and high temperature resources are greater than 180oC. Low temperature resources utilize direct-use technology. Intermediate and high temperature resources are suitable for conversion of heat to electricity. Temperature when combined with the subsurface heat transfer mechanism and geologic setting provides a viable approach to match desalination markets and technology with geothermal resources. Convective systems are shallow, generally small volume, and structurally controlled geothermal resources. Conductive systems are deep-seated, very large volume and stratigraphically controlled resources. Convective systems are best suited for small-scale desalination, while conductive resources are suitable for medium- and large-scale desalination. A real economic advantage may accrue even with production and injection wells deeper than 2,000 to 3,000 m depth since conductive and intermediate temperature resources provide electricity, process heat, a brackish water supply, and a brine injection reservoir. However, risk is higher because deep drilling is involved. Also, there are resource leasing, permitting, and royalty issues that are not associated with other renewable energy.

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Brackish Water as a New Medium to Maximize Biomass of Microalgae

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Presentation Abstract 11

Rising fuel costs and global warming have led policy makers and scientists to look for an alternate, less costly, and beneficial approach to fuel production. Algae are a cost effective substitute for biofuels which also consume CO2 during fermentation serving a beneficial purpose in counteracting global warming. The production of biomass is made more efficient by utilizing brackish water which does not consume potable water sources for algae production. The purpose of this research is to find an optimal combination of algae type and medium which will maximize the increase in algae biomass. It is hypothesized that the algae type and the brackish water solution used to grow it are the two factors which affect the increase of biomass. As a result of factorial analysis in this research, it was revealed that the combination of brackish water with Chlorella Microalgae (UTEX- 1230) maximized the percentage of biomass. Inland brackish water was deemed a suitable resource in the production of biomass when used as a medium to grow algae.

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Use of Hybrid Photovoltaic/Thermal (PV/T) System for Water Desalination

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Presentation Abstract 12

Photovoltaic System for Desalination (PV-T) is a system invented by UTEP that combines a special kind of photovoltaic system that is cooled by desalination feed water. El Paso and southern New Mexico are located in an area with high photovoltaic (PV) energy potential. According to NREL, the solar energy potential for a renewable energy project in this region is in the very high range of 6-6.8 kWh per m2 per day.

Water desalination is an energy-intensive process, due to the high water pressure needed to pump water through reverse osmosis membranes. A solar photovoltaic system could greatly contribute to the reduction of electrical costs during the period of highest time-of-use rates charged by electrical utilities. PV power can be used during the period of peak demand; grid power can be utilized during periods of low demand.

Conventional PV systems suffer from loss of efficiency when the PV cells heat up. PV cells absorb solar energy from both the infrared and the visible spectra, but only energy from a portion of the visible spectrum is converted to electrical energy. Heat is produced by the portion of incident solar energy that is not converted to electrical energy. Heating causes the efficiency of PV cells to drop typically about 0.5% per degree C. The loss in efficiency can be restored if the PV cells are cooled. Use of the recovered thermal energy from the PV cells to heat the desalination feed water is beneficial in reducing the power required for desalination.

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Evaluation of Pecos River Salinity Inputs Near Roswell, NM

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Presentation Abstract 13

Los Alamos National Laboratory, in collaboration with the Carlsbad Irrigation District, is conducting a study to identify salinity inputs to the Pecos River in the Roswell Basin. In 2010 and 2011, specific conductance measurements were made along a 30 mile stretch of the Pecos River and 15 miles of tributaries near Roswell. Also, water samples collected from 182 sites were analyzed for major ion content.

Preliminary results indicate the salinity of the Pecos River steadily increases within most of the Bitter Lakes National Wildlife Refuge (BLNWR) east of Roswell. In the northern portion of the BLNWR, the increases are a result of diffuse seepage of subsurface saline waters into the river. However, discrete salinity inputs also occur from drainage of Bitter Lakes surface waters into the river in the southern portion of the refuge. Below the BLNWR, the Rio Hondo and the outflow from Lea Lake (Bottomless Lakes State Park) also constitute significant salinity inputs to the Pecos. Taken together, the salt inputs from the BLNWR, the Rio Hondo, and Lea Lake are about equal in magnitude, and they more than triple the salt flux in the Pecos River under normal flow conditions. When considering block water releases from Fort Sumner reservoir and storm events, the 30-mile river stretch from the northern end of BLNWR to the Lea Lake outflow is estimated to contribute 40% to 50% of the total salinity that enters Brantley Reservoir north of Carlsbad, with approximately 60 wt% of the added salinity being sodium chloride.

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Soil Thermal Properties Under Contrasting Soil Textures, Soil Moisture Regimes and Water Quality

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Presentation Abstract 14

Knowledge of soil thermal properties is needed to quantify the vapor flow through the vadose zone and to prepare efficient irrigation management strategies for semi-arid areas such as Southern New Mexico. This study was conducted to compare and quantify the thermal conductivity (λ), thermal diffusivity (α), thermal resistivity (r), and volumetric specific heat capacity (C), of loamy sand, sandy loam and sandy clay loam textured soils using tap water and lagoon treated wastewater. Core and bulk soil samples were collected from each soil types form West Mesa, West of Las Cruces and USDA-ARS, Jornada Experimental Range, NM. Soil water characteristic curves were obtained at 0, -0.3, -1, -3,-5, -10, and -15 bars suctions using pressure plate apparatus after saturation with tapwater and wastewater from the West Mesa holding ponds. Once core equilibrated to an applied suction, soil thermal properties were determined using KD2 probe (Decagon Devices, Inc.). The λ was higher and r was lower for sand than loam and clay soils for cores saturated with both tapwater and wastewater. The λ, C, α, were lower and r was higher for cores saturated with treated wastewater than with tapwater especially at lower soil water potentials (-5, -10, and -15 bars). The results of the study showed that the application of treated wastewater reduces heat conductance to lower depths and could reduce the evaporation of soil moisture. However, there is a need to simultaneously consider the effect of soil salinity due to treated wastewater application on root growth and vegetation sustenance.

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Design and Piloting of a Brine Minimization System for Concentrate Disposal

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Presentation Abstract 15

The East Cherry Creek Valley Water and Sanitation District is constructing a 10 MGD brackish water reverse osmosis project to provide a new renewable water source. The District evaluated several concentrate disposal alternatives including discharge to the local wastewater treatment plant, direct surface water discharge, evaporation basins, deep well injection and brine minimization and zero liquid discharge. Objections from local agencies, regulatory issues and cost ultimately resulted in the District selecting a combination of brine minimization and deep well injection as the concentrate disposal approach for the project.

The treatment process consists of a two stage low pressure reverse osmosis (RO) skid, followed by a two stage brine minimization RO skid. The brine minimization process relies on pH suppression and scale inhibitors to eliminate a lime or caustic soda softening process typically used prior to treatment with a secondary RO system. Eliminating the softening process and maintaining residual pressure throughout the RO and deep well injection system significantly reduced the capital and expected operating costs. Pilot work at recoveries up to 97% was performed to determine cost effective balance between brine stability, acid dose, and overall recovery. A geochemical conditions analysis was performed for the deep well formation zones to identify potential precipitation reactions that can lead to high injection pressures and low capacity.

This presentation will discuss the design and pilot testing of the brine minimization process and the geochemical analysis of the deep well injection zones.

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Solar Powered Desalination

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Presentation Abstract 16

The world's supply of water is enormous, about 97% is found in oceans and is too salty to drink, the remaining 3%, 2.997% is locked up as ice at the poles and glaciers or in groundwater. Sunpower Systems Corporation has invented a solar collector called "SMARTROF" which is patented worldwide generates steam using solar energy to the invented GREEN PUMP. It uses an overhead cable sun-tracking system that provides rigidity to the trough structure so that the structure itself can be much less expensive than other solar trough systems. The parabolic reflector in the SMARTROF collector focuses sunlight at high intensity upon a heat receiver tube in which water is passed that produces steam at high temperature and pressure. The steam is piped to the Kinetic Pump, which is patented worldwide. The Pump is simple but effective. It has no turbines, gearboxes, standard hydraulic pistons or rotating shafts. It uses a principle that was overlooked by previous researchers in the field. It can efficiently pump water to a pressure that is considerably higher than the applied steam pressure. DESAL combines the SMARTOF, the Green Pump and proven reverse-osmosis (RO) technology to allow the economic production of fresh water from seawater or brackish water using solar energy. This is accomplished by using SMARTOF concentrated solar energy to produce steam, which can be used to directly pump high-pressure seawater into RO desalination units using the green Pump.

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Poster Abstracts

A Hybrid Photovoltaic/Thermal (PV/T) System for Water Desalination

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Poster Abstract 1

Photovoltaic System for Desalination (PV-T) is a system invented by UTEP that combines a special kind of photovoltaic system that is cooled by desalination feed water. El Paso and southern New Mexico are located in an area with high photovoltaic (PV) energy potential. According to NREL, the solar energy potential for a renewable energy project in this region is in the very high range of 6-6.8 kWh per m2 per day.

Water desalination is an energy-intensive process, due to the high water pressure needed to pump water through reverse osmosis membranes. A solar photovoltaic system could greatly contribute to the reduction of electrical costs during the period of highest time-of-use rates charged by electrical utilities. PV power can be used during the period of peak demand; grid power can be utilized during periods of low demand.

Conventional PV systems suffer from loss of efficiency when the PV cells heat up. PV cells absorb solar energy from both the infrared and the visible spectra, but only energy from a portion of the visible spectrum is converted to electrical energy. Heat is produced by the portion of incident solar energy that is not converted to electrical energy. Heating causes the efficiency of PV cells to drop typically about 0.5% per degree C. The loss in efficiency can be restored if the PV cells are cooled. Use of the recovered thermal energy from the PV cells to heat the desalination feed water is beneficial in reducing the power required for desalination.

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Culturing Microalgae from Desalination Concentrate Reusing Anaerobic Digested Sludge as Nutrient to Improve the Net Energy Ratio

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Poster Abstract 2

Biodiesel can be produced from microalgae; the net energy ratio for microalgae biodiesel is slightly positive as 0.93 MJ consumed/MJ produced by using fresh water, brackish groundwater and chemical nutrient. The objective of this article is to improve the net energy gain in microalgae biodiesel by reusing concentrate from desalination and anaerobic digested sludge (ADS) as water medium and nutrient suppliers. To ensure the right species, microalgae were seeded and cultured from desalination evaporation pond from brackish groundwater national desalination research facility, NM, USA. Two reactors (R1 and R4) were used. The initial conductivity of R1 and R4 were 19320 and 19120 μS/cm respectively. The initial volume of concentrate in R1 and R4 were 2.87 and 2.99 L respectively. 50 mL of ADS was fed into R1; 50 mL of Bold's Basal Medium (BBM) was fed into R4 every day. Reactors were brought outside to expose Sunlight from 9:30 am to 4:30 pm every day except public holidays. Microalgae growths were recorded in photographs, microscopic images, and dry weights. Experiments shown microalgae were growing well in desalination concentrate with both ADS and BBM. With our estimate, the net energy ratio is improved from 0.93 to 0.90 MJ consumed/MJ produced by reusing desalination concentrate and ADS into microalgae production by minimizing energy required for BBM and concentrate disposal; the concentrate disposal cost is 15% of total desalination cost for inland desalination which ranges from 1.18-10.04 $/m3.

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Solar Membrane Distillation

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Poster Abstract 3

Water scarcity is among the most serious, long-term challenges in the world. To an ever increasing degree, sustainable water supply depends on the utilization of water of impaired initial quality. This is particularly true in developing nations and in water-stressed areas such as the American Southwest. The most plentiful impaired water resources are brackish ground water and seawater. In both, salt is the primary contaminant of concern. Reverse osmosis (RO) is the most widely utilized membrane-based method for separating salt from water. RO treatment costs have become competitive with thermal desalination methods, even in seawater applications. However, both conventional thermal distillation and RO are energy intensive processes, exhibit economies of scale that discourage decentralized or rural implementation, require enhanced expertise for operation and maintenance, and are susceptible to scaling and fouling unless extensive feed pretreatment is employed. Membrane distillation (MD) processes, driven by low temperature thermal or vapor pressure gradients, can potentially overcome many of the drawbacks associated with conventional thermal distillation and RO desalination. This presentation describes the development and testing of a solar-driven, MD process. A prototype of the process, using only off-the-shelf components, has been successfully deployed in the field. MD can operate using low-grade, sub-boiling temperature heat sources. When it is driven by solar energy it does not require highly concentrating collection devices, non-aqueous working fluids, complex temperature control systems, nor extensive operational expertise.

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Monitoring and Modeling the Hydrologic Connectivity Between Headwaters and Their Snow-Melt Driven IR

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Poster Abstract 4

The hydrologic connectivity between upland water sources, floodplain valleys downstream, and groundwater may be an important determinant of hydrologic resilience in the face of climate variability. The objective of this study is to characterize the hydrologic interactions occurring in three watersheds of northern New Mexico. These watersheds are characterized by the use of traditionally-irrigated systems driven by snow-melt runoff. In order to better understand the hydrologic interactions between uplands and associated valleys, we are using a combined field data collection and multi-modeling approach to characterize the hydrologic connectivity of the study sites. We are monitoring different components of the water budget including precipitation, soil moisture and temperature, river and canal flow, groundwater levels, and different climate variables. Field data collected are being used to calculate water budgets at the field, valley, and watershed scales. Also, field data collected are being used to parameterize different physically-based models. For instance, the Root Zone Water Quality Model is being used to simulate crop irrigation – deep percolation relationships at the field scale. Observed and simulated deep percolation results are being related to shallow-groundwater level fluctuations observed at the field and valley scales. A system dynamics approach is being taken to integrate results obtained at the field and valley scales into a watershed scale model. Preliminary results suggest that there is a strong hydrologic connectivity between snow-melt driven runoff in the headwaters and the recharge of the shallow aquifer in the valleys, mainly driven by the use of traditionally-irrigated agriculture systems.

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Effects of Operating Conditions on the Efficiency of EDR Systems

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Poster Abstract 5

Water supply all over the world is being stressed due to increased demand and limited availability. The overall use of water in agricultural, industrial, and domestic areas, coupled with the need for water to produce energy, makes it difficult to evaluate various options and prepare additional sources of clean water. Hence, working on this field in order to provide potable water from saline and brackish water is worthwhile. Electrodialysis Reversal (EDR) is one of the technologies used for desalinating brackish and saline waters. EDR uses electrical fields to transport ions through ion exchange membranes. In the recent years due to the higher recovery rate of EDR compared to Reverse Osmosis, interest in EDR has increased. The focus of this study is to develop a model to predict the effects of various operating conditions, such as temperature, pressure, conductivity, voltage, and current density, on the efficiency of EDR. A huge database collected from a pilot-scale system, located at the Brackish Groundwater National Desalination Research Facility (BGNDRF) in Alamogordo, NM, will be analyzed. The planned method will keep all conditions constant except the condition whose effect is under study. By using this technique, the relationship between each parameter and the efficiency will become clear. Among all operating conditions, the two most important factors are voltage and current density. Since it is desired to have the highest efficiency at the lowest cost, knowing about optimum voltage and optimum current and the relationship between them is of higher importance in comparison with other factors.

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Mathematical Models Explaining Ion Selectivity in Electro-Separation Processes

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Poster Abstract 6

Researchers have always been looking for different methods for brackish water treatment using desalination processes. Electrodialysis (ED) is an electrochemical separation processes that have proven its capability in desalination. This technique is based on ion transport through ion exchange membranes under the effect of an electrical field. Since most brackish water sources do not have drinking water standards due to excess amount of one or some species, it is worthwhile to study selective removal of some target ions. Because of this purpose it is needed to know that which parameters affect removing monovalent or divalent ions selectively. In this research, selective removal of different ions in the ED process is studied using an appropriate mathematical model. The irreversible thermodynamic (IT) is used as an approach for ion transport model which can explain the transport of ions and water through the membrane. The IT theory explains a mathematical mean for relating the flux of species through the membrane to the interfacial concentrations of these species, as well as the external driving forces. In addition, during this study the Maxwell-Stefan equation is used for multicomponent diffusion. Using these tools, the selectivity for different ions is determined. By studying the effective factors in selective removal of different ionic species, the optimized selectivity conditions can be verified. Determining the most important factors in selectively separating of the monovalent ions from multivalent ions or vice versa is essential in different industries such as food, chemical, and pharmaceutical industries.

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Determination of Limiting Current in Full-Scale Electrodialysis Reversal

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Poster Abstract 7

The empirical determination of the limiting current density (LCD) for an electrodialysis reversal (EDR) system is based upon generally accepted equations relating current density to the concentration of the diluate stream and the mass transfer coefficient, where specific membrane and system-flow properties influence the empirically determined correlations. Thus far, researchers have focused primarily on identifying the LCD of benchtop-scale EDR systems using single-solute solutions. However, in the treatment of brackish waters, the concentration and chemical makeup of the feed water will vary significantly from source to source, requiring site-specific evaluation of the limiting current density. In full-scale field operations, the hydrodynamics and feed water compositions are much less ideal than lab-scale, and their determination may require improved methods.

Results from full-pilot scale EDR research on natural brackish waters in Alamogordo, New Mexico, indicate significant differences from the generally published results concerning the LCD's dependence on diluate concentration, composition and flow velocity. Understanding the basis of these variations could reap large benefits, as the LCD determines the efficient use of electrical current, and the required membrane are for a desired product water quality. These two factors, membrane area and electrical input, are the largest contributors to the capital and operating costs of an EDR system.

Developing the methods to accurately determine the LCD of a full-scale EDR system will allow for the optimization of parameters to reduce the total cost of inland brackish-water desalination, making brackish water a feasible water resource in the years to come.

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Vegetation Dynamics in a Chihuahuan Desert Shrubland Receiving Saline-Sodic Industrial Effluent

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Poster Abstract 8

Land application of treated, saline-sodic wastewater is potentially a low-cost desalination process that could mitigate environmental degradation of surface waters such as the Rio Grande. However, impact of this anthropogenic disturbance on soils and native flora are not adequately known. Lagoon-treated saline-sodic industrial effluent was land-applied from 2002-2005 to a Chihuahuan Desert shrubland to assess the changes in soil quality and subsequent growth of seven indigenous intershrub space herbaceous plant species, vis-à-vis an adjacent non-irrigated area. After four years, effluent irrigation increased soil saturation extract salinity (electrical conductivity), but not above 4 dS/m required for a saline soil. However, effluent irrigation resulted in sodic soil conditions (sodium adsorption ratio > 13). On the irrigated plot, the sodium adsorption ratio was 10 to 15 times higher than on the non-irrigated plot, and reached a maximum of 35 at a soil depth of 7.5 cm. There was a decline in plant species diversity under highly sodic irrigated conditions, and Lepidium virginicum produced the highest biomass of all species. Similar aggressiveness of other Lepidium sp. in high-Na or alkali conditions reported in other studies suggests that L. virginicum was able to exploit an edaphic niche not useable or tolerated by the other herbaceous species. While invasiveness of the apparently natrophilic L. virginicum may lead to a loss of native biodiversity, potential ecological value of this species must be considered in the overall management objectives of land application of saline-sodic wastewater to Chihuahuan Desert vegetation communities.

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Evaluating Salt Quality Requirements in Electrodialysis Metathesis

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Poster Abstract 9

Electrodialysis metathesis (EDM) is a component in the zero discharge desalination (ZDD) process that maximizes water production and salt recovery. EDM is used to treat reverse osmosis (RO) and nanofiltration (NF) concentrates from brackish water. EDM has four-compartment repeating cells for circulation of a feed-diluate stream of depleted salt, a concentrated stream of mixed-sodium anion salts, a concentrated stream of mixed-chloride cation salts, and sodium chloride. The concentrated solutions are formed when an electrical potential is applied to the cell. Typical cations present in an EDM system for brackish water treatment include sodium, magnesium and calcium. Typical anions are chloride, sulfate and bicarbonate.

The early precipitation of calcium sulfate in one of the concentrate compartments can adversely affect the potential recovery of other useful salts, such as Na2SO4, MgCl2, and MgSO4, from the EDM process. This can be prevented by selecting optimum parameter conditions and good quality salt. The amount of impurities such as calcium and sulfate ions present in the salt can increase the potential for calcium sulfate formation in the EDM concentrate compartments. On the other hand, a specification for high purity salt can adversely increase the energy footprint and cost of brackish water treatment by the ZDD process. This paper presents preliminary results on the evaluation of salt quality requirements for EDM treatment of RO/NF concentrates from brackish water.

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Solar Powered Desalination

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Poster Abstract 10

The world's supply of water is enormous, about 97% is found in oceans and is too salty to drink, the remaining 3%, 2.997% is locked up as ice at the poles and glaciers or in groundwater. Sunpower Systems Corporation has invented a solar collector called "SMARTROF" which is patented worldwide generates steam using solar energy to the invented GREEN PUMP. It uses an overhead cable sun-tracking system that provides rigidity to the trough structure so that the structure itself can be much less expensive than other solar trough systems. The parabolic reflector in the SMARTROF collector focuses sunlight at high intensity upon a heat receiver tube in which water is passed that produces steam at high temperature and pressure. The steam is piped to the Kinetic Pump, which is patented worldwide. The Pump is simple but effective. It has no turbines, gearboxes, standard hydraulic pistons or rotating shafts. It uses a principle that was overlooked by previous researchers in the field. It can efficiently pump water to a pressure that is considerably higher than the applied steam pressure. The diagram below schematically shows the layout of the components. DESAL combines the Smartrof, the Green Pump and proven reverse-osmosis (RO) technology to allow the economic production of fresh water from seawater or brackish water using solar energy. This is accomplished by using Smartrof concentrated solar energy to produce steam, which can be used to directly pump high-pressure seawater into RO desalination units using the green Pump.

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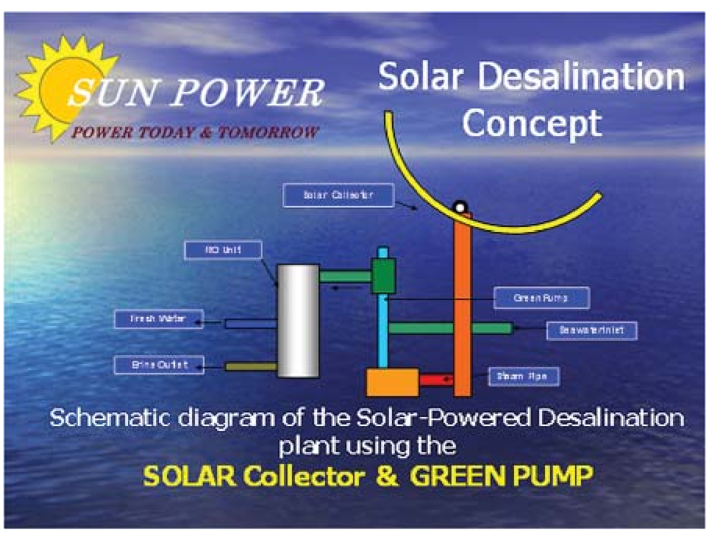

Energy and Mass Flow in Solar Membrane Water Purification

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Poster Abstract 11

The objective of the research is to identify and simulate key optimization parameters controlling energy usage and production rate of purified water in a solar membrane distillation system. We have built bench-scale, small pilot-scale and a full pilot-scale units as testing and validation platforms for the theoretical work. Lab-scale has been used to determine the membrane distillation mass transfer coefficient, k, related to the water flux through the membrane. This coefficient allows for predictive, theoretical modeling of the mass flux. On the small-pilot system, heat exchangers are implemented to recycle heat to the incoming air, thus lowering system energy use. The incoming air is heated by the hot brine and hot wet air. At this scale, the primary goal is to determine the efficiency gains provided by using the heat exchangers so it can be applied to the full pilot-scale system deployed at our Marana (Arizona) field site. The Marana system includes an automated system that operates circulating pumps in the system's loops to adjust to heat availability and optimal use. Determining the time to turn the module pumps on allows the feed temperature to the module to be decoupled from the solar insolation variation. In addition, the data from the Marana site provides the data on which to build a simulation model to identify the limiting processes for final scale-up to commercial implementation.

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ZDD – Achieving Maximum Water Recovery

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Poster Abstract 12

Increasing population, decreasing water supply, and droughts are leading to increased competition between users of freshwater. The Zero Discharge Desalination (ZDD) process maximizes the volume of product water from a brackish source while minimizing impacts to the environment caused by waste disposal. ZDD has been evaluated at several locations including New Mexico, Texas, California and Florida. ZDD technology utilizes a combination of Electrodialysis Metathesis (EDM), a variant of electrodialysis, and reverse osmosis (RO) or nanofiltration (NF), as well as various forms of pre-treatment techniques. Previous pilot studies have demonstrated overall water efficiencies of 95-98% on brackish ground water with sparingly soluble calcium sulfate and moderate silica levels. The University of Texas at El Paso's Center for Inland Desalination Systems (CIDS) was awarded funding from the US Bureau of Reclamation's DWPR program. This effort is a collaborative project between CIDS and Veolia Water Solutions and Technologies and the project is located at the Brackish Groundwater National Desalination Research Facility. During Year 1, the team successfully demonstrated a new ZDD design that utilized NF instead of RO membranes to eliminate a silica removal system. The feed water had about 3,000 mg/L TDS and the treated water was below 800 mg/L TDS. The recovery by NF and EDM was 98% compared to 75% recovery by conventional RO. A larger ZDD system was designed for Years 1 and 2. In Years 2 and 3 the team will operate the larger system, evaluate waste stream optimization, and evaluate the potential for incorporation of renewable energy.

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Decentralized, Autonomous Water Treatment in the Navajo Nation

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Poster Abstract 13

The Navajo Nation covers 27,000 square miles, mainly in northeastern Arizona, but also in New Mexico and Utah. This vast area has a population of 174,000 inhabitants, which translates to a density of only 6 inhabitants per square mile. Low population density coupled with water scarcity and impairment makes providing access to adequate supply a daunting challenge. The population relies primarily on groundwater which is often in deep aquifers and of brackish quality.

Consequently, a large fraction of the population hauls water from remote wells at high cost. In addition, the lack of grid-delivered electricity in many areas further complicates delivery of basic water and power services. This paper discusses a large project undertaken by the Bureau of Reclamation in collaboration with the University of Arizona and the Navajo Nation to investigate and deploy autonomous (off-grid) systems to pump and treat brackish groundwater using solar energy. The process utilizes a membrane distillation technology to potentially supply both livestock and potable water in small volume, remote installations. An analysis of the economic efficiency of the desalination unit was conducted to assess the viability of sustainable financial support from the community for the system. The study also surveyed water haulers in the region to determine the distance traveled to secure potable water and water for livestock to establish a baseline for comparison of water hauling methods versus local desalination system deployment.

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Interannual Snowpack Variability in the Upper Rio Grande Basin and its Relation to Warm and Cool Episodes of the El Niño-Southern Oscillation

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Poster Abstract 14

Meltwater from mountain snowpack in the Upper Rio Grande Basin is a vital source of surface water for irrigated agriculture in New Mexico. Over the last decade, there has been large interannual variation in snow cover and snow water equivalent (SWE), which has resulted in years of severe water shortages (e.g., 2002 and 2011) and years of relative abundance (e.g., 2010). Understanding how warm and cool episodes of the El Niño-Southern Oscillation (ENSO) impact snow cover and SWE can help water managers and farmers prepare ahead for a productive or unproductive snow year. Using data from the Moderate resolution Imaging Spectrometer (MODIS) sensor onboard the Terra and Aqua satellites, we show the variability in snow cover over the Upper Rio Grande on the anniversary date, April 1st, from 1999 to 2011 and relate this to annual streamflow from 23 high elevation sub-basins. For this same 12 year period, we compare snow cover and peak streamflow to cold (La Niña) and warm (El Niño) ENSO episodes. Results indicate that unproductive snow years are associated with La Niña episodes while productive snow years are associated with El Niño episodes. Historical records of SWE data can be also be used to compare productive/unproductive years with ENSO episodes. We present preliminary data from this analysis for the last 50 years.

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Appendix A

RECLAMATION
Managing Water in the West

U.S. Department of the Interior
Bureau of Reclamation

New Water New Energy – Project Description Sheet

Goal: Develop project descriptions for research projects that innovatively couple renewable energy to brackish desalination systems for small communities.

Breakout Objectives:

1) identify U.S. research needs concerning new approaches and techniques applicable to inland, small-scale, low-cost rural brackish desalination (surface water, groundwater, and waste water) projects using renewable energy sources;

2) identify research priorities for projects that can be conducted at the BGNDRF or elsewhere;

3) identify potential collaborations for proposed projects; and

4) broadly distribute the results of the conference so that others may also fund good ideas.

Breakout Group Name & Authors' Names:

Title:

Needs the Project Meets:

Benefits of Project and Expected Outcomes:

RECLAMATION
Managing Water in the West

U.S. Department of the Interior
Bureau of Reclamation

Research Objectives

Research Approach (numbered by task):

Estimated Project Budget and Schedule:

Proposed Partners:

Known Prior Research on This Topic:

New Water New Energy – Participant Instructions

Tuesday, December 13th - Sgt. Willie Estrada Civic Center

1 pm – 6 pm **Plenary Session**

6:30 – 8:30 pm **Dinner for Expert Groups**
instructions for Wednesday morning

Wednesday, December 14th

Brackish Groundwater National Desalination Research Facility

Suggested process for each breakout group

8:00 meet at the Research Facility, go to breakout rooms based on assignment
8:15 introductions and review of morning schedule
8:30 brainstorm needs, identify data gaps, and record on flip charts
9:00 list proposed research projects on flip charts
9:30 assign individuals or teams to write one project description sheet for each idea
11:00 choose top two group project descriptions and select group spokesperson to present to afternoon plenary session
12:00 return to Civic Center for lunch

Civic Center

12:00 – 2:00 lunch; keynote, posters, and networking

Breakout group presentations and comments from audience
2:00 – 2:15 Wind Group
2:15 – 2:30 Solar Group
2:30 – 2:45 Geothermal Group
2:45 – 3:00 Action Group
3:00 – 3:15 Infrastructure Group
3:15 – 3:30 Water Resources Group
3:30 – 3:45 Environmental Impacts Group
3:45 – 4:00 Institutional Group
4:00 – 4:30 Audience Suggestions
4:30 – 4:45 Plenary vote for two best projects
4:45 – 5:00 Wrap-up

General Instructions

- All the project descriptions and brainstorming information will be available in conference proceedings and in a document on the internet May 2012.

- Participants should bring their own laptops – Wi-Fi is available at the Civic Center and at the Research Facility. A password is not required at the Civic Center. A password will be provided at the Research Facility.

- The facilitators will be provided with a printer.

- Each group will have a flipchart, pens, tape or other fastening materials for use during brainstorming/discussion.

- Note that the individual names on each project description sheet will be removed in the final conference proceedings

- Each group will have 3-4 hours to (1) brainstorm project needs, (2) identify data gaps, (3) identify potential projects, and (4) breakout into sub teams (maximum of 3 per group) to complete the Project Description Sheets.
    - Discussion of items needs, data gaps and potential projects should be recorded using flipcharts;
    - Have a 'parking lot' chart to record ideas not related to the discussion
    - Individuals can fill out as many of the Project Description Sheets as desired;
    - Each project is a separate Project Description Sheet
    - **Group needs to decide on a spokesperson for the group, and two (2) projects to discuss at the afternoon plenary session.**

- All Project Description Sheets should be filled out electronically and sent via email to: coklett@nmsu.edu Please include your group name in the subject line.

- There will be a 1-page or more summary of group discussions, based on flipcharts written by each facilitator. This information will be included in the final conference report.

- Facilitators will be responsible for printing the top two Project Description Sheets for your individual breakout group for presentation at the Wednesday afternoon plenary session.

- Audience voting will be done after all breakout groups have presented their top two projects. Each participant will have five dots they will place against the projects they like. The top two will be announced at the end of Wednesday's plenary session.

New Water New Energy – Facilitator Instructions

Tuesday, December 13th - Sgt. Willie Estrada Civic Center

1 pm – 6 pm **Plenary Session**

6:30 – 8:30 pm **Dinner for Expert Groups**
instructions for Wednesday morning breakouts

Wednesday, December 14th

Brackish Groundwater National Desalination Research Facility

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4:00 – 4:30 Audience Suggestions
4:30 – 4:45 Plenary vote for two best projects
4:45 – 5:00 Wrap-up

General Instructions

- Facilitators should bring their own laptops – Wi-Fi is available at the Civic Center and at the Research Facility. A password is not required at the Civic Center. A password will be provided at the Research Facility.

- Facilitators will be provided with a printer and a printer driver will be loaded onto your laptop at the dinner.

- Facilitators will be provided with a flipchart and pens, tape or other fastening materials for use during brainstorming/discussion.

- Review the Participant Instructions with the group members and ensure everyone understands them;
    - Remind the participants that the names will be removed from the final Project Description Sheets in the conference proceedings

- Each group will have 3-4 hours to (1) brainstorm project needs, (2) identify data gaps, (3) identify potential projects, and (4) breakout into sub teams (maximum of 3 per group) to complete the Project Description Sheets.
    - Discussion of items needs, data gaps and potential projects should be recorded using flipcharts;
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