PRODES

Promotion of Renewable Energies for Water Production through Desalination

www.prodes-project.org

Summary of Project Results

Intelligent Energy Europe

Acknowledgements

This publication has been produced as part of the ProDes project. The logos of the partners cooperating in this project are shown below and further information about them and the project is available on www.prodes-project.org

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Contents

Executive Summary

The ProDes project promotes the market development of desalination driven by renewable energies in Southern Europe. ProDes is co-funded by the European Commission through the Intelligent Energy Programme and has been supporting RE-Desalination through various activities like the development of a Road Map for the sector, training, networking activities and policy improvement suggestions.

Extensive information about ProDes, the partners and the results is published on the project website: www.prodes-project.org. This report summarises the main findings of the project.

In May 2009 the ProDes strategy session took place as part of the "Desalination and the Environment" conference in Baden-Baden, Germany. This event offered the opportunity to the ProDes consortium to present its activities and collect input about the barriers the companies of the sector are facing.

Based on that input and an extensive consultation process the Road Map for RE-desalination has been developed. It is one of the main project results. The final document has been widely distributed and it includes analysis of the technology status, its perspectives, the current barriers and a strategy to overcome them.

Then the project created a working group on Renewable Energy Desalination. The aim of the group is to promote the use of desalination powered by renewable energy as an environmentally friendly and decentralised solution for sustainable water supply. This group will also lead the implementation of the strategy outlined in the Road Map.

Regarding training activities, first the main aspects that should be addressed in a higher education course on desalination powered by renewable energy have been outlined. This summary offers the opportunity to any interested party to use it as a basis to develop a course adapted to their specific needs.

Within the ProDes project training courses for students were organised. There were two courses in each one of the target countries, Italy, Spain, Greece and Portugal, during the project lifetime reaching about 370 students. There were also courses for professionals organised. These were more focussed compared to the student courses and attracted more than 170 people from the target group.

The project developed and delivered also an e-learning course. This has proven to be very popular and attracted 190 participants from all over the world. Together with the other training activities, the e-learning course will continue to be offered after the end of the project and will be self-sustained by the fees paid from the course participants.

ProDes has developed a publication that presents a small collection of RE-desalination products that have demonstrated their capacity to operate in real conditions or in plants built for demonstration purposes. The aim is to help the development of the market that is still doing its first steps, by showing to a wide audience that there are various successful products that can cover the requirements of many different consumer groups.

A report aiming to support fund raising for product development has been elaborated and distributed to more than 40 companies in the field. The report is based on input from 8 structured interviews with product developers and the feedback from 4 investors.

A desk-based survey was performed to identify niche-markets in the involved countries. Within these markets, representative project development opportunities were highlighted and are presented a report as examples of cases where RE-desalination options would be suitable solutions which make financial sense and bring additional benefits for the consumer with high quality water and the environment through low-impact solutions. For the selection of the examples presented in this report, priority was given to public bodies where the project if implemented will have also high visibility.

Three potential international desalination markets have been studied for export opportunities to EU technology developers. This analysis will help companies to expand their international activities and to support their case to investors for backing their expansion efforts. The markets analysed are the Middle East and North Africa (MENA) region, with a profile on Morocco; the OCEANIA region, with a profile on Australia; and SOUTH AFRICA, with an in-depth report.

Regarding the legislative and institutional issues, first the framework conditions in the four target countries were analysed and improvements were suggested. Work was also done in the development of a support scheme. Technologies can be supported in three different stages. The research and development (R&D) stage, the demonstration stage and the market introduction and diffusion stage. In the ProDes study support schemes for technologies that are in the market introduction stage are suggested.

Finally a report has been developed that supports decision-makers to establish a clear framework addressing drinking water produced by desalination in order to protect the health of the consumer and the environment, while removing unnecessary administrative barriers.

All these activities and work are summarised in this report. However the full analysis is also availbale to be downloaded by the project website. The consortium is keen to respond to provide more information and clarifications to any interested party.

Strategy Session

On the 18th of May 2009 the ProDes strategy session took place, embedded into the "Desalination and the Environment" conference and Exhibition that was organised by the European Desalination Society (EDS) in the congress centre in Baden-Baden, Germany. The event started with a reception at 18:30, after the completion of the conference programme for the day. At 19:30 there was a 30 minute presentation that was followed by an extensive discussion with the event participants that was completed by 21:00.

The strategy session was very successful as it attracted more than 100 representatives from its main target groups, the industry and the research community. The General Secretary of the European Desalination Society Miriam Balaban welcomed the audience and introduced the ProDes panel and the event. Then, the project coordinator, Michael Papapetrou (WIP) provided an introduction to the ProDes project.

The main part of the panel contributions included short overview of the main RE-desalination technologies. Hendrick Müller-Holst (MAGE Watermanagement) introduced solar powered thermal desalination, Guillermo Zaragoza (Ciemat) the options of combining Concentrated Solar Power with desalination, Andrea Cipollina (UNIPA) PV and wind combined with Reverse Osmosis and Matt Folley (Aquamarine Power) closed this overview with explaining ocean energy powered desalination.

For initiating the discussion about the RE-desalination Road Map Marcel Wieghaus (ISE) presented the structure of the document, focusing on the main non-technological barriers identified by the working group. The ProDes consortium wanted to lead the discussion in this direction, because the real barriers faced by the people doing the work in the market should be the starting point of any market strategy. Also ideas on how to deal with these barriers were sought.

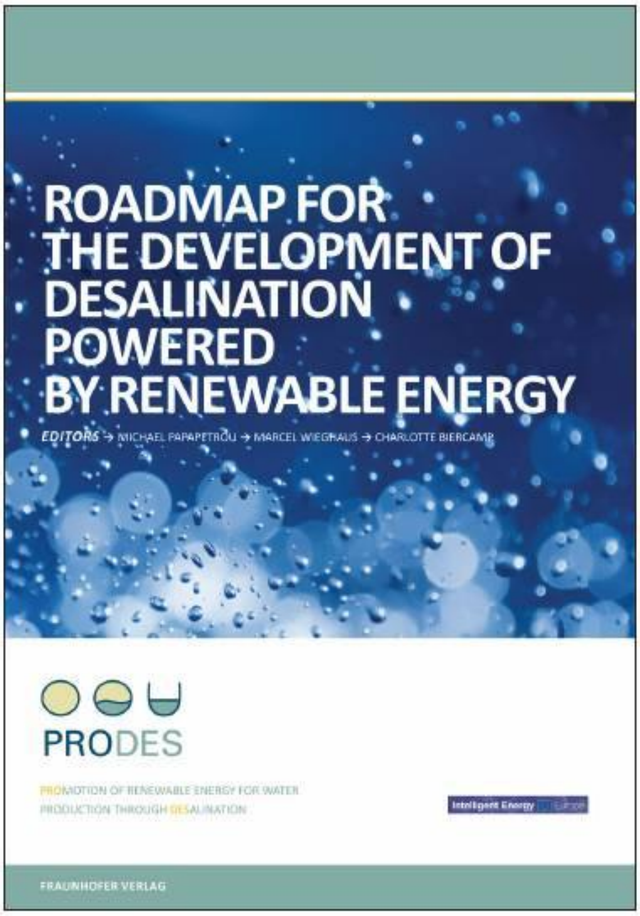
The main conclusion of the session was the identification of the need to formalise the RE-desalination community in a body that will represent the sector and will lobby for its interests. Other activities that have been identified as priorities from the discussion and the feedback sheets include the continuation of R&D but in a cooperative way, focusing on topics that can benefit all the community. Education and training activities covering all the field of RE-desalination should be also promoted. The general awareness about the technology should be improved through demonstration plants and a communication campaign. Finally, the companies active in the field need support to enter the promising markets in far away countries.

The recommendations from the discussions and the feedback sheets have been taken into account in the revision of the Road Map and in the further work within ProDes.

The RE-desalination Road Map

The Road Map for RE-desalination is one of the main project results. This document has been developed with input from all target groups and extensive review of existing work, carried out by the ProDes consortium. The final document has been widely distributed and a working group has been established as explained in the next section. This group will lead the implementation of the strategy outlined in the Road Map.

Here a brief summary of the barriers identified and the strategy to overcome them are provided. The Road Map provides in addition a summary of the technology status, prices and perspectives.



The world water crisis is one of the largest public health issues of our time. One in eight people (884 million people) lack access to safe drinking water. The lack of clean, safe drinking water is estimated to kill almost 4,000 children per day. Many regions of the world are turning to desalination of brackish and sea water in their effort to match the increasing demand with the available natural resources. The trend is intensified by climate change, which seems to be already affecting the water cycle resulting in long periods of drought. The desalination industry has responded well to the increasing demand and is constantly evolving by reducing the costs and reliably producing water of very high quality. Most innovations focus on reducing the energy demand, since this is associated with high operating costs. However, desalination processes will always require considerable amounts of energy. If conventional energy sources are used, they contribute to climate change, which, in turn, affects the water cycle and intensifies the original problem that desalination was intending to solve.

For desalination to remain a viable option in a world with a changing climate, renewable energy sources have to be used to meet at least part of its power requirements. The scientific community has been working for decades on optimising technological combinations where the desalination process is powered directly by renewable sources; thermal energy, electricity or shaft power. The industry is also recognising the potential and various companies are active in this field. The main elements of the Roadmap are summarised in a tabular format in the next pages, indicating the main barriers, their effects and the way forward.

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	• Promote cooperation between companies from the energy sector, water sector and other specialists to achieve fully functional integrated products • Promote cooperation within the RE-desalination field for achieving R&D results that will benefit the whole sector • Support development of standardized, reliable and robust systems offering competitive performance guarantees
Desalination development focuses on ever larger systems	→ Lack of components appropriate for small scale desalination plants, typical of many RE-D combinations	• R&D of components suitable for the smooth and efficient coupling of the existing desalination and renewable energy technologies • Support development of elements that will make RE-desalination robust for long stand-alone operation in harsh environments
Current desalination technology has been designed for use with a constant energy supply, however most RE provide variable energy supply	→ Increased capital and maintenance costs	• Support development of components and control systems that allow desalination technologies to deal better with variable energy input, hybrid systems and energy storage to reduce variability • Support development of co-generation systems that produce water and power
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	• Support development of detailed and reliable market analysis
SMEs lack the financial resources and local know-how to enter distant markets	→Difficulty to access some of the most promising niche markets	• Cooperation with agencies from EU countries in the target markets for organising trade missions • Facilitate collection and dissemination of relevant experiences and information in the RE-desalination community

[1] RE-D = renewable energy driven desalination

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	• Promote pricing structures and subsidy allocations that let the market choose the most efficient solution and encourage efficiency in the use of the water, while ensuring global access to safe water • Campaign for inclusion of RE for desalination in national schemes that support RE electricity generation
Lack of identified niche markets with the ability to pay for the full cost of the systems, which would demonstrate the technology attracting additional customers	→ No cash is generated that could be used for further product development, reducing the costs and improving the performance	• Identify niche markets and use existing support programs in combination with financing schemes to help users that are willing and able to pay for the technology
Institutional and Social		
Negative perception of desalination by the population	→ Opposition of local communities to installation	• Support development and implementation of a long-term and consistent communication strategy by the RE-desalination community
RE-D is a new technology and is typically small-scale, suitable for community-led water provision	→ RE-D is not commissioned because water authorities prefer familiar technologies and want to keep centralized control	• Facilitate organization of seminars, debates and other events related to RE-desalination involving engineers and decision makers from large institutions responsible for water and energy in the target countries
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

The main targets, resources and activities required to follow-up the strategies that have been identified are also summarised here. The key recommendation is to formalise the RE-desalination community into a body that will represent the sector and will lobby for its interests. This body is mentioned as the “RE-Desalination Association” in this document and the target is to have it established before 2012 and to include at least 20 members. The other activities identified as priorities include:

- Target a 3-5% share of the global desalination market by 2016
- Define the R&D priorities that will benefit the entire sector and promote these priorities to bodies that fund R&D, targeting R&D worth more than 100 million Euro in the period 2014 to 2020
- Support the wider establishment of RE-desalination education and training activities with the aim of reaching 2,000 students and 500 professionals per year within Europe by 2015.
- Coordinate the development of a comprehensive market analysis on a country by country basis, covering the four most promising markets by 2014
- Develop and promote appropriate legal structures and policies on a country by country basis, starting with the four most promising markets by 2015
- Raise awareness about the technology and demonstrate its market potential.

Renewable Energy Desalination - Working Group

The ProDes project created a working group on Renewable Energy Desalination. The aim of the group is to promote the use of desalination powered by renewable energy as an environmentally friendly and decentralised solution for sustainable water supply.

The work of the group will be guided from the Road Map that was published and can be downloaded from www.prodes-project.org. Example of its activities include, market analysis, training courses and promotion of policies and subsidy schemes.

Participation to the group is open and all relevant stakeholders are encouraged to register in www.prodes-project.org for receiving updates about the planned activities. There are already more than 100 registered members that will be meeting annually in events coordinated with the EDS conferences. The next meeting is planned to take place parallel to the “Desalination Industry - Action for Good” conference organised by the International Desalination Association in 16-18 May 2011 in Italy.

Contents of a Course on Desalination Powered by Renewable Energy

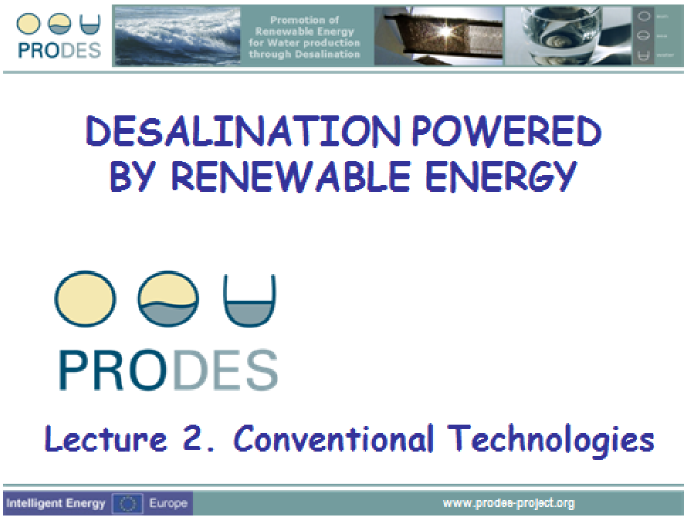
The main aspects that should be addressed in a higher education course on desalination powered by renewable energy have been outlined below. This summary establishes an overview on desalination technologies, renewable energy generation, and their combination. The course covers the theory basis but also some practical aspects, with the purpose of training engineers and scientists.

The material presented here is intended to act as a guideline for the implementation of specific courses. The contents can be adapted to configure different training courses that reach the needs of diverse target audiences.

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

<u>1. Introduction</u>

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



<u>2. Conventional desalination processes and technologies</u>

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

<u>3. Renewable energies in relation to desalination</u>

State of the art of renewable energy generation technologies and their application to desalination processes. [7.5%]

<u>4. Technologies for desalination powered by renewable energy</u>

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

<u>4.1. Solar thermal energy and desalination</u>.

<u>4.1.1. Solar stills</u>. 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%]

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

1. <u>Practical assessment of solar energy resource</u>

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. <u>Practical assessment of wind energy resource</u>

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. <u>Mass and energy balances in thermal desalination processes, with basic concepts of design</u>

Addressing the physics and chemistry basics of the desalination processes, and how they reflect on the design of the processes and technologies. [10%]

4. <u>Design of low temperature ($T < 80^oC$) solar thermal fields to be coupled to a membrane distillation / humidification-dehumidification desalination system</u>

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. <u>Design of intermediate ($80^oC < T < 200^oC$) solar thermal fields to be coupled to a multi-effect distillation (MED) plant</u>

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. <u>Process design of a conventional membrane desalination process</u>

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

7. <u>Design of a solar photovoltaic field to be coupled to a reverse osmosis desalination plant</u>

Photovoltaic panel characterization parameters. Technical description of solar photovoltaic plant components and configuration. Dimensioning for prescribed energy requirements. [10%]

8. <u>Design of a wind energy field to be coupled to a reverse osmosis desalination plant</u>

Wind energy turbine characterization parameters. Technical description of wind energy plant components and configuration. Dimensioning for prescribed energy requirements. [10%]

9. <u>Overview of demonstration installations</u>

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%]

Training course for students

Within the ProDes project training courses for students were organised. There were two courses in each one of the target countries, Italy, Spain, Greece and Portugal, during the project lifetime, from October 2008 until September 2010. In the first 15 months of the project the first round of courses for students were delivered. The table below gives an overview of the first round of courses in each country:

Country	Spain
Location	University of Almería (CIESOL) and Plataforma Solar de Almería
Time scheduling	From the 15th of May 2009 to the 9th of July 2009
Target group	Students from Master Course on Solar Energy organized by CIESOL, joint centre of University of Almería and Plataforma Solar de Almería (CIEMAT)
N° of participants	21
Course duration	40 hrs lectures/tutorials
Country	Italy
Location	University of Palermo, Palermo (Italy)
Time scheduling	From the 17th of March 2009 to the 23rd of July 2009 (with some weeks off for vacancies), usually lectures of 3 hrs once per week
Target group	Students from the Engineering Faculty of the University of Palermo
N° of participants	66
Course duration	35 hrs lectures/tutorials; 8hrs visit to the MED Trapani plant
Country	Greece
Location	Centre for Renewable Energy Sources & Saving, CRES, Greece
Time scheduling	29/10/2009 – 3/11/2009
Target group	Amongst others from the following Universities: AUA, NTUA, TEI of Athens, Aristotle University, University of Patras etc.
N° of participants	98
Course duration	32 hrs lectures/tutorials; 8hrs visit to: CRES Wind Park, CRES Energy Park in Keratea, AUA Solar Rankine cycle desalination plant in Marathonas.
Country	Portugal

Location	LNEG and FCT/UL facilities,
Time scheduling	September – December 2009
Target group	Students of the Master in Energy & Environment Engineering of the Faculty of Sciences of the University of Lisbon
N° of participants	26
Course duration	20 hrs lectures/tutorials – shorter because renewable energy topics were already covered within the Masters course

The next table gives the overview of the student curses second edition in each target country:

Country	Italy
Location	University of Palermo, Palermo (Italy)
Time scheduling	From the 3rd of March 2010 to the 19th of July 2010
Target group	Students from bachelor and master degree course on Chemical Engineering and master degree course of Environmental Engineering of the Eng. Faculty of University of Palermo
N° of participants	44
Course duration	39 hrs lectures/tutorials; 8hrs visit to the MED Trapani plant
Country	Spain
Location	School of Industrial and Civil engineering of the University of Las Palmas de Gran Canaria (Gran Canaria, Spain)
Time scheduling	From the 19th to the 30th of April 2010
Target group	Graduate and postgraduate students of the School of Industrial and Civil engineering of the University of Las Palmas de Gran Canaria and professionals
N° of participants	37
Course duration	11 days intensive course, with lectures from 16:00 to 20:00 and a final visit (6 hrs) to a pilot RE-desalination plant
Country	Greece
Location	Centre for Renewable Energy Sources & Saving, CRES (Greece)
Time scheduling	02/03/2010 – 05/03/2010

Target group	Students from the National Technical Univ. of Athens, NTUA, University of Patras, Technical University of Patras, Technical Univ. of Crete, University of Ioannina, Technical Institute of Chalkida, Institute of Piraeus, Technical Institute of Athens, City Univ. of London, UK, Heriot Watt Univ, UK, Univ. Complutense de Madrid, Spain.
N° of participants	46
Course duration	35 hrs lectures/tutorials; 5hrs visit to: CRES Wind Park, CRES Energy Park in Keratea
Country	Portugal
Location	Engineering Institute of the University of Algarve, Faro (Portugal)
Time scheduling	22nd February 2010 – 26th February 2010
Target group	Students of the Master in Mechanical Engineering - Energy & Building of the University of Algarve
N° of participants	31
Course duration	20 hrs lectures/tutorials – shorter because renewable energy topics were already covered within the Masters course

Students attending a theoretical lecture

Visit to the MED plant in Trapani

Visit to the salt ponds fed by the brine from the MED plant in Trapani

Courses for professionals

There were also courses for professionals organised. These were more focussed compared to the student courses and attracted a large number of people. The following courses were implemented:

• a 3 days Pro-course at Almeria by the PSA-CIEMAT, 19 to 21 October 2009, with an attendance of 23 professionals;

• a 2 days Pro-course at “Ordine degli Ingegneri della Provincia di Palermo” by the University of Palermo, 11 and 12 December 2009, with an attendance of 20 professionals;

• a 1 day Pro-course at CRES Central Building by CRES, 24 of February 2010, with an attendance of 34 professionals;

• a 2 days Pro-course at the University of Algarve by LNEG, IP, 24 and 25 of February 2010, with an attendance of 47 professionals;

• a 2 days Pro-course at “Ordine degli Ingegneri della Provincia di Agrigento” by the University of Palermo, 26 and 27 February 2010, with an attendance of 12 professionals.

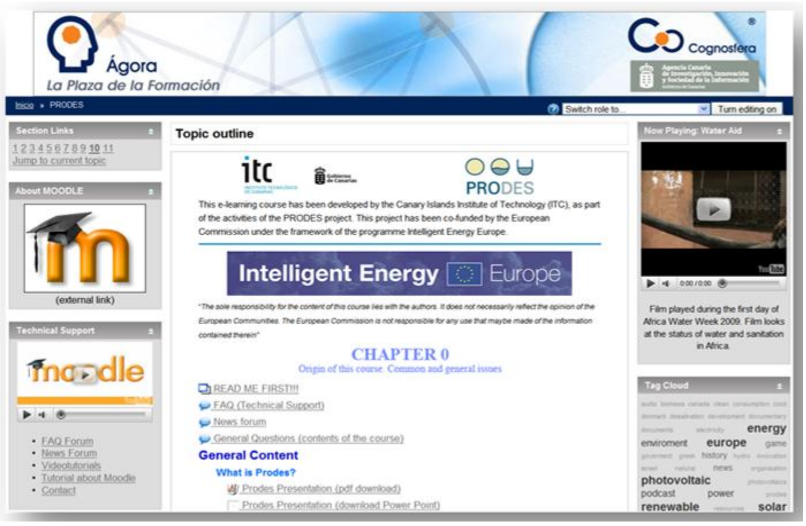
The scope of the courses was to provide professionals, experts, investors and researchers with the latest technological developments in Desalination and RES technologies, and their matching. The course programmes where adapted, in each country, both to the level of the attendants and to the duration of the course.

The courses reached a total of 136 professionals and were mainly directed to national attendants, exception for the course in Spain, which was directed to an international audience.

The e-learning course

The project has developed and delivered an e-learning course. This has proven to be very popular and attracted participants from all over the world. Together with the other training activities, the e-learning course will continue to be offered after the end of the project and will be self-sustained by the fees paid from the course participants.

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



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

The **Quiz** tool is used as on-line tests, which can consist of various questions types. Each Chapter (1 to 9) has one Quiz.

The **Forums** are the interactive part of the course; it is what makes this e-learning course a real course, not just an online book. Participation is key.

There are two main forums in CHAPTER 0; the one called **FAQ** is only for those doubts or problems relative to the use of the Moodle platform, and the **General Questions** forum for all those doubts about the course contents. The news forum is only for information about relevant events. One additional forum is activated in each Chapter.

The mandatory parts that all students must complete are: the 9 chapters with their quizzes, the practical case of chapter 10 and the participation in the forum of each chapter (at least one participation is required).

If students do not understand a word of a lesson, they can consult the **glossaries** for definitions of the main concepts of each chapter.

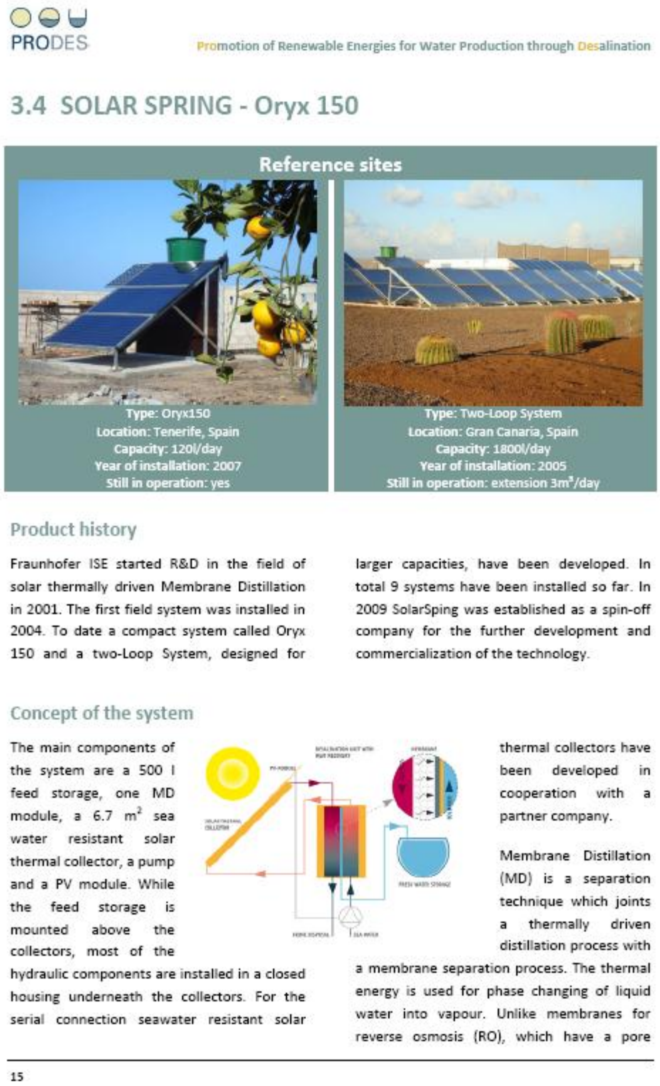
For **complementary training** students can go to the sections of **videos**, **podcasts**, **news**, visit the **suggested links** and **games**; 4 games with words related to desalination are available in order to learn in a constructivism form.

Within the ProDes e-learning course, five editions have been done with 190 registered students in total.

- 1st edition (from the 1st to the 14th March 2010), 3 groups with 61 students.
- 2nd edition (from the 5th to the 18th April 2010), 2 groups with 32 students.
- 3rd edition (from the 3rd to the 16th May 2010), 2 groups with 24 students.
- 4th edition (from the 31st May to the 13th June 2010), 2 groups with 37 students.
- 5th edition (from the 28th June to the 11th July 2010), 2 groups with 36 students.

Commercial Desalination Products

As explained also in previous sections of this document, for desalination to remain a viable option in a world with a changing climate, renewable energy sources have to be used for powering at least part of its requirements. The scientific community has been working for decades on optimising technological combinations where the desalination process is powered by renewable sources; thermal energy, electricity or shaft power. The industry is also recognising the potential and various companies are active in this field.



PRODES Promotion of Renewable Energies for Water Production through Desalination

3.4 SOLAR SPRING - Oryx 150

Reference sites

Type: Oryx150	Type: Two-Loop System
Location: Tenerife, Spain	Location: Gran Canaria, Spain
Capacity: 120l/day	Capacity: 1800l/day
Year of installation: 2007	Year of installation: 2005
Still in operation: yes	Still in operation: extension 3m³/day

Product history

Fraunhofer ISE started R&D in the field of solar thermally driven Membrane Distillation in 2001. The first field system was installed in 2004. To date a compact system called Oryx 150 and a two-Loop System, designed for larger capacities, have been developed. In total 9 systems have been installed so far. In 2009 SolarSping was established as a spin-off company for the further development and commercialization of the technology.

Concept of the system

The main components of the system are a 500 l feed storage, one MD module, a 6.7 m^2 sea water resistant solar thermal collector, a pump and a PV module. While the feed storage is mounted above the collectors, most of the hydraulic components are installed in a closed housing underneath the collectors. For the serial connection seawater resistant solar thermal collectors have been developed in cooperation with a partner company.

Membrane Distillation (MD) is a separation technique which joints a thermally driven distillation process with a membrane separation process. The thermal energy is used for phase changing of liquid water into vapour. Unlike membranes for reverse osmosis (RO), which have a pore

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There are several possible combinations of renewable energy with desalination. They are in various stages of development, while each one addresses different market segments.

ProDes has developed a publication that presents a small collection of RE-desalination products that have demonstrated their capacity to operate in real conditions or in plants built for demonstration purposes. The aim is to help the development of the market that is still doing its first steps, by showing to a wide audience that there are various successful products that can cover the requirements of many different consumer groups. Of course this is not an exhaustive collection and there are many other companies doing great work in developing and offering similar products.

The products presented in this publication are grouped in three chapters. Chapter 2 presents three different distillation systems, all of them using directly the solar energy. The products presented vary from simple solar stills to more sophisticated devices, and in general are small-scale plants targeted to individual users, like families. The table below gives an overview of these three products:

DIRECT SOLAR THERMAL SYSTEMS			
	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/m^2/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

Chapter 3 presents distillation systems also, but with more than one effects, which are powered indirectly from the sun with the use of solar collectors. These systems are more complicated but can also produce more water per module, targeting end-users with higher requirements. There were four products included in the publication as summarized in the table below:

INDIRECT SOLAR THERMAL SYSTEMS				
	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 TW5 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

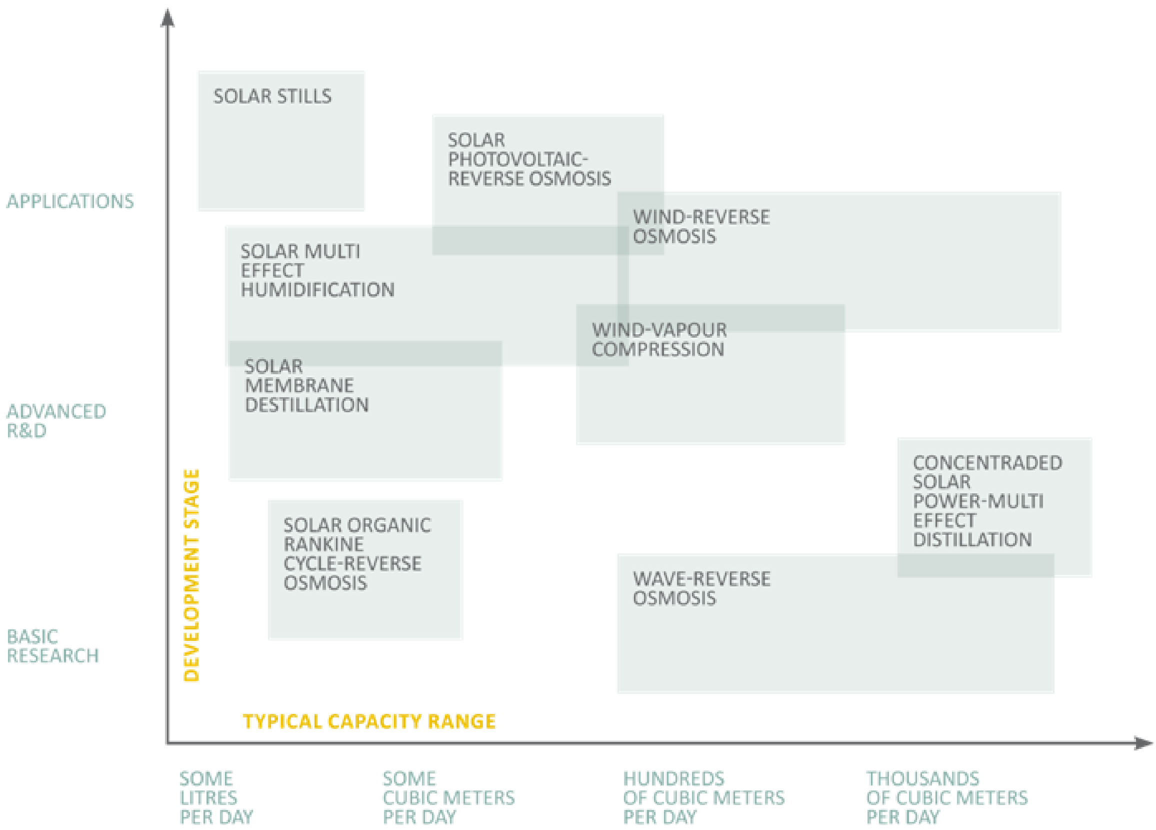
Finally, in chapter 4 the reverse osmosis systems are presented that have been quite popular over the past years because of the significant technological improvements. The size of these systems depends mainly on the energy source; smaller when combined with PV and larger with wind turbines. A mechanical vapour compression system powered by wind is also included in this chapter.

REVERSE OSMOSIS AND VAPOUR COMPRESSION SYSTEMS			
	4.1 DESSOL	4.2 Enercon	4.3 WME
Capacities available	3.5-20 m^3/d	300 - 1,200 m^3/day	100 – 1000 m^3/day
specific energy consumption	BW: 0.53-1.7 kWh/m^3	SW: 2,5 kWh/m^3	7 – 13 kWh/m^3
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

Investment Guidelines

A report aiming to support fund raising for product development has been elaborated and distributed to more than 40 companies in the field. The report is based on input from 8 structured interviews with product developers and the feedback from 4 investors. Here the executive summary of the report gives an overview of the topics covered and highlights the most important results.

Several combinations of desalination systems with Renewable energy have been developed and they are in different stages of development as visualized in the graph below. Therefore each technology and the companies working on their commercialization require different kind of support and should look for different type of investors.

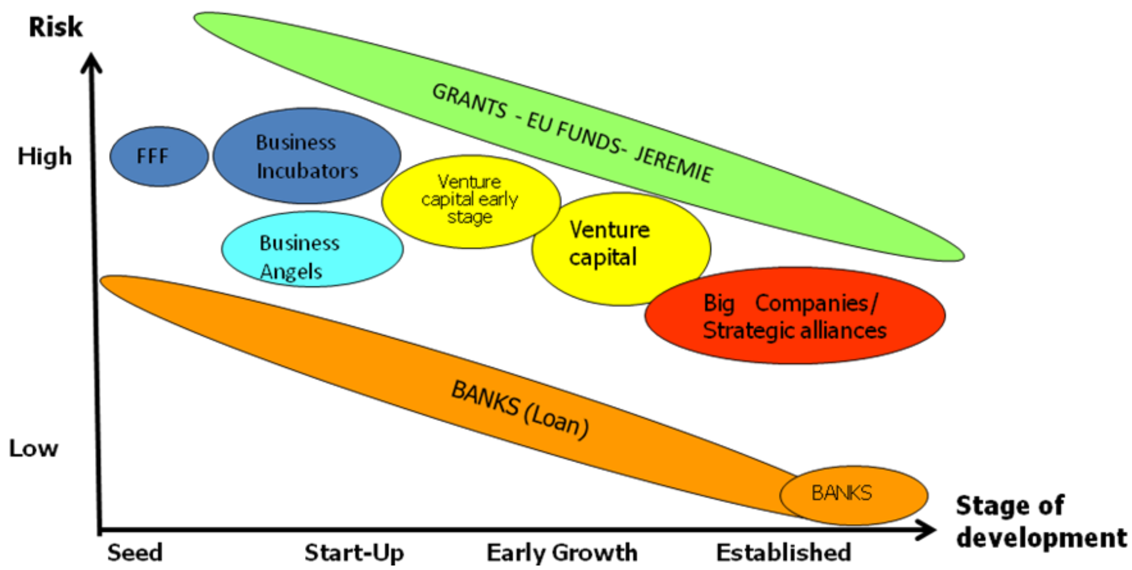


Therefore, in the first part of this document, it was important to imprint the funding requirements set out by the technology providers. A survey among companies in the field aimed in defining and analyzing the nature and size of the funds technology providers require to develop their products as well as examining the methods they followed to raise the funds necessary so far. A broad range of technology providers were approached, covering different technologies and being in different stages of development. Although the questions referring to the size of the funds invested or further needed were not answered by many companies, there is valuable information regarding the nature and the origin of the aforesaid funds.

Most developers collaborated in the beginning with a research institution or university to develop the project and after that they formed a company. The early stages of the project seem to be more easily financed by government funds. In the later stages of development more sophisticated sources of financing are required, thus the development of a business plan is important.

In Chapter 2, the basis for understanding the investment process is set, the relation between the company's development stage and the funds required as well as the different types of funds and/or investors that better fit the funding needs of each stage. Every company goes through different stages of development during its life cycle, each stage presenting different capital requirements. Financing may come either from own funds or external sources.

Before starting seeking financing for a business, it is important to know the available options as well as their terms and requirements. Although there are many options, a company may only qualify for a few of them. These options depend (among other factors) on the company's stage of development, its credit history and how established it is in the market, the milestones achieved by the company, the investment risk level and the amount required. The graph below visualizes the types of funds available according to company's financing stage.



The philosophy and requirements of each type of fund providers are further analyzed in the last section of this chapter.

In Chapter 3, the focus is put on investors' point of view, bringing in light their knowledge and experience as well as their requirements when it comes to financing renewable energy desalination projects. Capital Connect Consultants contacted investors from the area of Investment Banking and Venture Capital. This survey was held through structured interviews.

In the first part of the survey, Investors commented on the outcomes of the technology survey. They all agreed on the decision of most developers to rely to own funds in the early stage of the development or to seek funds and grants from Local, National, Federal and Supranational Agencies. Nevertheless, the more advanced the project is, the more diverse the sources of funding can be; external financing from the Banking sector, venture capitalists or private equity funds may be interested in participating. Therefore, the second part of this survey investigated the predisposition of Investors in this specific industry as well as the key factors they pay attention to when evaluating an investment opportunity.

Finally, this procedure resulted in certain recommendations and tips for the developers regarding the issues and the actions they should take care of when they call for fund raising and prepares their Business Plan for financing. These are summarised below:

If it is difficult to define the market potential on a local level, try to extrapolate the figures needed by gathering data regarding:

- the water consumption nationally and locally
- the energy consumption nationally and locally
- the percentage of water deriving from desalination nationally and internationally
- the percentage of energy from RES nationally and internationally
- the areas in need of water and energy locally
- the global trends regarding Water (i.e."Blue Gold", water funds, etc.) and Energy

If it is difficult to convince on the success of the venture, try to provide assurances from other sources. You may need:

- To present letters of intent from the users (i.e. from citizens to convince the local authorities, from hotel units to convince municipal authorities, etc).
- To build on the competitive price of the water produced compared to existing situation or methods so far used for water supply
- To validate the economies of scale

If the project is in a very early stage and it is difficult to prove that the technology works, show both the theoretical approach and the practical proof of the process.

Chapter 4 is dedicated to the development of a step-by step guide for building a Business Plan. This guide is general as it has to cover different technologies, companies being in different stages of development and having different financing requirements or even different situations among countries. Examples have been used to clarify specific topics.

A business plan is a blueprint for how the business will run and reveals the future direction the business will take. In case of fund raising, it is a prerequisite since it is the sole document needed to sell the venture as an investment opportunity to potential investors and partners.

Therefore, the quality of the business plan is crucial for winning the attention of the investors; numbers reveal that only one out of 20 business plans are read by prospective investors beyond the executive summary and only 6 out of 1000 business plans get funded. The quality of the business plan is not only reflected by the right content, but also by external factors of format / presentation such as the organization into logical and clearly defined sections, thorough research and documentation and even a writing style that maintains reader's interest.

As writing a Business Plan is a skill, it is strongly advised either that the companies have assigned an expert to prepare it or at least have reviewed the initial document by professional consultants.

The last step is the preparation for the meeting and the presentation to the investors. The key elements investors pay attention at when judging the quality of a business plan is described in short below:

There are 4 key areas that will ascertain the quality of a business plan. These areas, as considered by most categories of prospective investors (venture capitalists, private or strategic investors, banks) are:

(a) Vision

- Is the opportunity described large enough to generate significant return?
- Does the venture get the 'big picture"?

(b) Clarity

- Is the market problem/opportunity clearly identified?
- Does the solution offered clearly fit the objectives?

(c) Experience

- Is the management team qualified to solve the problem and sell the company or the product?

(d) Risk

- Market Risk: Market Size, Adoption, Competition
- Technology Risk: Does it work?
- Financial Risk: Enough Money? Strong Co-Investors? Adequate collateral?
- Execution Risk: What can go wrong?
- Management Risk: Experienced and flexible?.

This paper intends to inform both parts, technology developers and investors' groups on the needs, the requirements and the possibilities of each one of them; major reasoning is based on the current situation regarding RES powered Desalination systems, taking into consideration the framework conditions, the separate legislation for 2 sectors (Renewable Energy and Desalination), the technologies currently available and the fact that the market is still missing a major breakthrough case proving the efficiency and the viability of the combination of the 2 technologies.

Project Development Opportunities

A desk-based survey was performed to identify niche-markets in the involved countries. Within these markets, representative project development opportunities were highlighted and are presented a report as examples of cases where RE-desalination options would be suitable solutions which make financial sense and bring additional benefits for the consumer with high quality water and the environment through low-impact solutions. For the selection of the examples presented in this report, priority was given to public bodies where the project if implemented will have also high visibility.

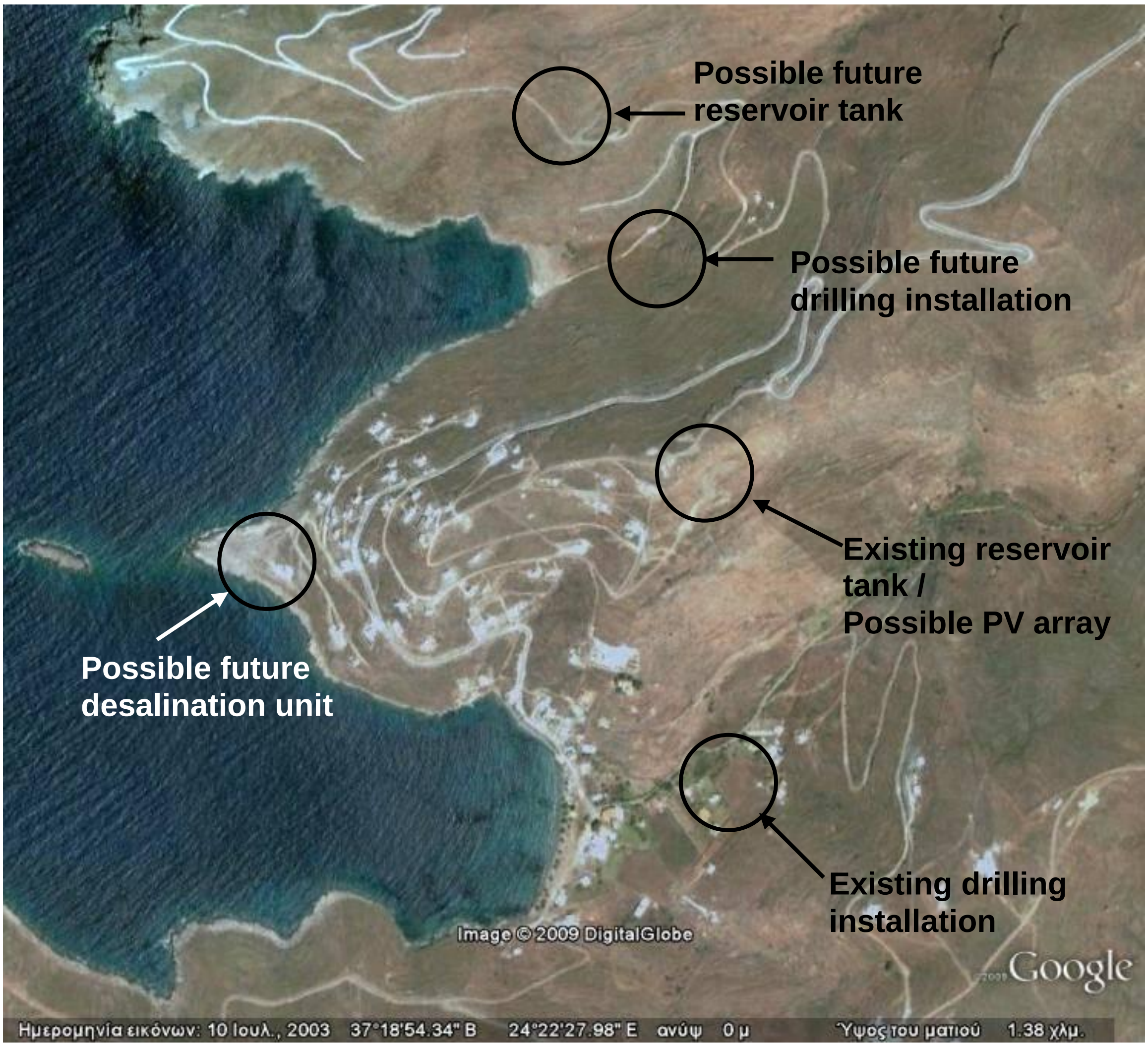
The concrete examples do demonstrate that in the current market conditions and with the technologies available in the market there are already several cases where the application of RE-desalination is feasible. Main barrier is the lack of knowledge about these options and this report helps to overcome this barrier.

In Greece a small community on an island was examined (picture in the next page) and it was shown that the solar energy reverse osmosis plant can deliver water at comparable cost with conventional desalination, taking into account the feed-in tariff for the PV system. Most importantly, the cost of water from the PV-RO would be much cheaper than the conventional option if the real cost of electricity was taken into account and not the heavily subsidized diesel generated grid electricity.

In Italy it was shown that the waste heat from bio-gas turbines, fed by the bio-gas produced in the anaerobic digester of the sewage treatment plant can be used to drive the multi-effect humidification desalination system. This would deliver the deionised water used in the sewage plant for industrial scopes with lower cost than the method currently employed. Several other options were also examined including stand alone RE-desalination systems and the comparison gives interesting results.

In Spain the application of reverse osmosis powered by wind and PV was considered for a small island in the Canaries (picture above). The cost would be only slightly higher than the current solution of water transferred through a pipe in the sea. However, it would be a more reliable solution and the quality of the water would be higher.

Finally in Portugal, the installation of a solar thermal multiple effect humidification in a small touristic island has proven to be a cost effective solution, providing water around 43% less costly than of the current boat transported water used for bathing and washing. It would also provide 8-9 times less costly water for drinking than the present bottled water solution, while reducing the ecologic footprint of the island.

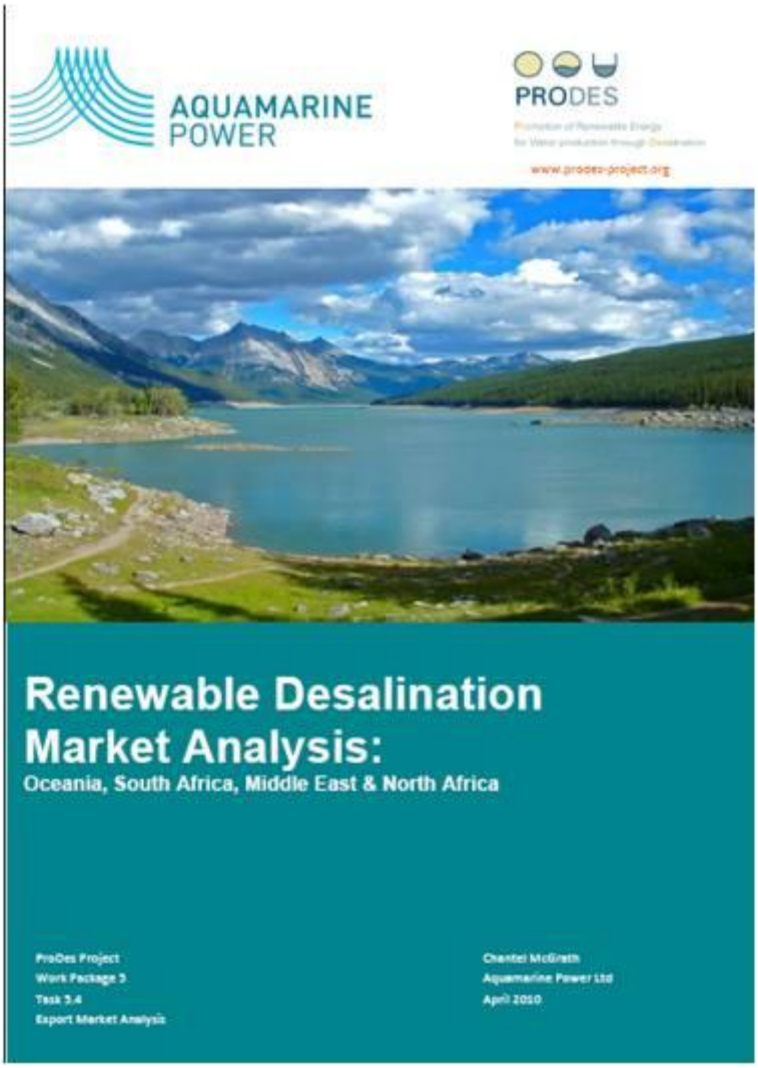


It is important though to stress that these are just examples. The costs mentioned for the desalination and energy systems are indicative and cannot be taken as the actual costs of the equipment. Also the calculated costs of the water produced are very strongly dependant on the specific conditions of the chosen examples. The actual cost in another location or by employing slightly different technology could be lower or higher.

Export market analysis

Three potential international desalination markets have been studied for export opportunities to EU technology developers. This analysis will help companies to expand their international activities and to support their case to investors for backing their expansion efforts. The markets analysed are the Middle East and North Africa (MENA) region, with a profile on Morocco; the OCEANIA region, with a profile on Australia; and SOUTH AFRICA, with an in-depth report.

These regions and countries have been selected because they are experiencing water scarcity and climate change issues. Each report provides details on the economic and governmental structures, the power sector, renewable energy legislation, the water sector, recent investment and a summary of the renewable desalination market potential. The overall aim has been to immerse RE- Desalination developers in the economic, regulatory and market operations of each region so they can develop a balanced market view on the potential exportation opportunities.



Oceania is a very diverse region containing highly developed countries such as Australia as well as the less developed Pacific Island nations. Although in some countries there is little water scarcity in general the region suffers from a lack of fresh water. Therefore, there is a high demand for desalination projects in the region which is supported politically due to concerns regarding the impact of climate change. This support stems from a variety of perspectives ranging from an egalitarian perspective in Australia, where the highly educated population recognise that climate change will be problematic, to the more immediate concerns of the low-lying pacific islands where climate change could result in them disappearing within the next century. A consequence of this political support is that there are a large number of sources of potential funding for renewable energy desalination projects, which are in many cases supported by government targets.

The diversity of the region is matched by the diversity of potential renewable energy desalination projects. Although there is some variation across the region, there is in general a good supply of renewable energy including solar, wind and wave power. Large-scale projects are supported for municipal water supplies, where the presence of a firm electricity grid mean that the renewable energy and desalination processes do not need to be intimately tied together. There is also potential for small-scale projects for off-grid water supplies because of the large number of off-grid communities. Furthermore, suitable small-scale projects may range from technologically complex solutions for remote Australian communities to less complex solutions for communities on the smaller pacific islands.

South Africa is the most developed country in sub-Saharan Africa. However, the political history of the country means that there is a wide range of living standards across the country, which is mirrored in the access to fresh water. Although it is recognised that desalination will have a significant role in providing universal access to fresh water, there is currently less enthusiasm for renewable energy desalination projects due to the perceived high project costs. This is currently exasperated by the very low cost of electricity against which renewable energy projects must compete. In addition, the region suffers from a significant shortage of skilled personnel, at both the technical and managerial levels, which creates challenges for the successful completion of new projects. However, if the political perspective were to change then South Africa has an abundance of renewable energy that could be exploited to power desalination projects.

The Middle East and North Africa (MENA) region contains many states where the cultural and political systems are very different from those in Europe. This can create problems when trying to initiate renewable energy desalination projects in the region and the challenges associated with this potential barrier should not be under-estimated. In addition, many countries in the region have vast reserves of oil and gas and are currently heavily dependent on this energy source. This means that in many countries in the region there is limited support for renewable energy and research in this area is underfunded. However, this perspective is slowly changing and the region is starting to accept that it must diversify away from oil in the future. A consequence of the large revenues from oil and gas mean that there is potentially a large funding pool for the development of new technologies.

The MENA region has a large renewable energy resource, primarily solar and wind energy that could be exploited to power desalination projects. In addition, the region has a significant shortage of water and that the situation is expected to worsen due to predicted population growth and increased industrialisation. Consequently, the region is ideally suited for the development of renewable energy desalination projects where there is political will. Morocco is an example of a country in the region that has recognised the need for increased exploitation of its renewable energy resource and also has a shortage of fresh water.

Legislative and Institutional Issues

The framework conditions in the four target countries were analysed and improvements in the legislative and institutional structures were suggested. A summary for each country is provided below:

Greece

Following the examination of the energy and water framework in Greece, it is obvious that both are too complicated and a significant time is required for obtaining the licenses necessary to build an RE-desalination plan.

The new Law for RES aims to accelerate the procedures but it is too early to evaluate its effectiveness.

Water framework in some cases is clear but it seems that there are many exceptions or lack of knowledge, so in several cases is not followed completely.

The most important step for the development of RE Desalination in Greece, seems to be the development of a specific framework for the desalination of brackish and seawater. In this framework the desalination units should be separated in thermal and membrane processes and based on specific parameters such as the installed power, the quality of the produced water, environmental impacts, should be categorized for the determination of the legislation requirements and procedures. By this way the implementation of a framework for RE Desalination will be straightforward and the procedures will be simplified. Since in Greece, as in many other Mediterranean areas, to provide green electrification and potable water supply is a priority, it is vital to obtain simple, fair and prompt procedures for the development of the projects.

Additionally, other important aspects that should be taken in consideration are as follows:

- Priority should be given to the implementation of projects concerning small autonomous RE Desalination units in remote areas, such as in small islands. (The new RES Law, Law 3851/2010, already provides priority on the licenses authorization for the implementation of RE desalination projects).

- Based on the Law 3010/2002 and the JMD 15393/2002 and JMD 13727/2003, public or private projects and activities are obtained in categories and sub-categories according to their impacts on the environment. Desalination units with a water capacity of 100 m^3/day are characterized as projects that may cause serious risks for the environment, while units of less than 100 m^3/day characterized as projects which, without being seriously hazardous for the environment, must be subject to general specifications, terms and restrictions for reasons of environmental protection.

Based on the above, units of less than 50 m^3/day, are proposed to belong at Category C; projects and activities, which may cause an insignificant risk or nuisance or degradation to the environment.

Finally, is proposed, units of less than 10 m^3/day developed for Municipal Use, be exempted from the licenses procedures, and follow specific rules regarding technical and environmental aspects. The construction and operation of the system should be only under the responsibility of the Municipality.

Regarding the tariff system, the price of water could not exceed the water cost. According to the Water Framework Directive water should be charged at a price which fully reflects the services provided. Provision of water could not be a profitable investment. On the other hand RES exploitation is a profitable investment with, in most cases, significant feed-in-tariffs. Based on the above, the price of the water produced from RES Desalination plants, also, could not exceed the water costs, (including initial cost, O&M cost, environmental cost, etc). Thus, specific subsidies or feed-in tariff issues regarding RES plants combined with desalination, should be considered for those units that offer to the public benefit.

All the above issues have been reported and/or discussed with the Greek Ministries, (Ministry of Environment, Energy, and Climatic Change, Ministry of Economy, etc). Some of them have been taken already into consideration.

Italy

A complete and complex framework has been depicted for the use of Renewable Energy in Italy. As in most Western Countries, also in Italy the growth of RE technologies is showing a very significant economical and technological fast development.

This is mainly related also to the fact that RE are largely supported by governmental financing schemes, which act in many directions, from the incentives for small private installation to the promotion of industrial installation and green certificates.

A general overview of authorization procedures, incentive schemes and operational regulations has been reported and discussed thoroughly in the report.

On the other side, water resources are regulated by a clear legislative framework, with specific reference only to conventional sources. Seawater desalination has been used in few regions in Italy as an important alternative to conventional sources, as in the case of Sicily where it covers up to 25% of total water need (for instance during drought periods). Nevertheless no clear regulation exists for the use of such technologies, and ad-hoc laws have been issued for the construction of large desalination plants. Also incentives are not defined on a national basis, and Regional Governments regulate the use of such resource and the way to guarantee the operation of desalination plants under a regime of economical non-competitiveness.

Recently, the project financing scheme has been proposed for the construction of new large desalination plants, but none has been adopted yet to real cases.

Spain

The most relevant conclusions from the legal and institutional analysis of RE-desalination in Spain are the following:

1. 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) and the identified fees has allowed this high development of the RE sector
2. Different institutions share the responsibility of promoting and regulating the RE sector. Specific mention is made to, control centre of renewable energies (CECRE, June 2006), a worldwide pioneering initiative to monitor and control RE electricity. This centre allows the maximum amount of electricity production from RE sources, to be integrated into the power system under secure conditions.
3. Spain has a long and intensive experience in desalination:
    - The first Europe's desalination plant was built nearly 46 years ago (Canary Islands).
    - Spain is the largest user of desalination technology in the Western world.
    - Spain is the fourth-largest user of desalination technology in the world, with more than 700 plants, producing approximately 1.6 millions of cubic meters of water each day.
    - In Spain there has been a strong public investment in recent years in desalination: 1,945 millions of € within the AGUA program.
4. There are interesting 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.
5. The promotion of RE powered desalination could have a specific legal regulation in the future, given the high interest and favourable reality of the RE and desalination sectors. Thus, it makes a lot of sense to joint both technologies. This question was specifically discussed in the seminar in June 2010 among the IDAE (www.idae.es), CIEMAT-PSA and ITC. The IDAE representatives were very receptive to the suggestion of creating a specific subsidy to desalinated water produced by RE resources. They agreed to include desalination in the next Plan for Renewable Energy in Spain (2011-2020)
6. Some of the current legal conditions can facilitate the procedures for RE desalination systems:
    - The Autonomous Regions are able to develop simplified procedures for the authorization of RE installations smaller than 100 kW, case of small wind and/or PV powered systems.
    - The Environmental Impact Assessment is not required for desalination units under 3,000 m^3/day. This limit is high enough for RE desalination.

7. The main PRODES outcomes (roadmap, commercial desalination products, databases…) can be used to promote RE desalination through legislative and administrative actions by disseminating the mention results to the main stakeholders:
    - Decision makers, who probably will have a limited idea about RE desalination
    - Public companies related to water / energy management
8. As soon as the oil prices increase on the short term, the possibilities of promotion desalination powered by renewable energies projects will increase also. Thus, it is time to prepare the future by disseminating the very interesting findings of the ProDes project to the private sector also, trying to suggest the creation of joint collaborations between energy companies and desalination companies. This situation will boost the inclusion of more specific legal conditions that support RE desalination actions.

Portugal

- Portugal does not present relevant water scarcity problems. Local scarcity problems are mainly related to inefficiencies in the water distribution system (leakages, e.g.), rather than in resources shortage;
- In the present context, and given the existing water production infrastructures, desalination does not present economical advantages in the scope of large production systems, mainly based in dam reservoirs and underground captation. A good example is the investment made in the Alqueva dam, whose capacity covers the needs previewed for the Southern region;
- Water production and distribution Infrastructures have been developed mainly after public owned private companies, whose investments are secured on a water distribution monopoly base, impeding private consumers located in areas served by the water distribution network to develop private water captation projects (mandatory connection to the public network);
- Such development scheme is traduced in low (indirectly subsidized) water prices;
- The wide coverage rates attained with the present water production and distribution system, gathered with the mandatory connection to the public distribution system, render difficult the development of private desalination plants;
- One other aspect regards the classification of sea water as a public resource, which implies the payment of higher exploitation fees compared to underground water resources, considered private when the captation occurs in private property;
- The licensing of water captation and use activities is a disperse process and, regarding desalination, 3 years were required for the development of the sole private project under operation in Portugal Mainland. On the other hand, no specific procedures exist for desalination;

- Yet, the new water framework directive, implying the compliance of ecological objectives for the coming years, may limit the exploitation of this common surface and underground resources. In this context, desalination might become a solution for overcoming limits in the exploitation of common resources, has previewed in the National Strategy for Sustainable Development;
- A new feed-in tariff regime is under preparation, allowing the access to feed-in tariffs for systems up to 500 kW in auto-consumption regime, which renders more viable the use of RE based desalination systems.

In conclusion, the present good development of the water production and distribution infrastructures, based on sufficient surface and underground resources, renders difficult the new investments. In this context, desalination is not viewed, at present, as an economically viable technology for large scale water production.

Private investment in desalination plants is restricted by the mandatory connection to the public distribution network, which presents high coverage rates.

Desalination is regarded as an alternative solution within the new water framework, which will impose restrictions to the exploitation of common water resources.

Changes in the feed-in tariff scheme for RE based electricity production will allow the access to medium range power systems in a grid disconnected mode, which will render easier the access of RE powered desalination to the subsidized tariffs.

Subsidy scheme

In this study support schemes for the desalination of water using renewable energy are proposed.

Water scarcity is a severe problem in many regions of the world today. One solution to this problem is desalination of salt water. However, conventional desalination plants are powered with fossil fuels and therefore generate environmental problems. The environmentally friendly alternative is renewable energy driven desalination (RE-desalination). But RE-desalination is more expensive than conventional desalination and therefore much less used. To promote RE-desalination and to help it enter the market, efficient support policies have to be developed and applied.

Technologies can be supported in three different stages. The research and development (R&D) stage, the demonstration stage and the market introduction and diffusion stage. In this study support schemes for technologies that are in the market introduction and diffusion stage are developed. The focus is on southern European countries.

By reviewing existing support policies for electricity, heat, desalination and RE-desalination, a number of problems have been identified that can harm the efficient implementation of support schemes. This leads to different requirements that should be met by a support scheme to be successfully established:

- To give security to the investors, the support scheme has to be a long term incentive. The investor should know in advance how much money he will get for what time period. To encourage this, long term targets should be defined for the share of RE-desalination in every target country.
- However, the aim of a support scheme is to introduce RE-desalination into the market, but not to support it forever. Therefore, the support should gradually decrease (degression) and end after a well defined time period.
- To make sure the amount of degression of the support is appropriate the support scheme should be amended regularly to adapt it to the changing water generation cost of RE-desalination.
- To promote a wide range of different technological solutions, the amount of support should vary regarding technology, capacity and raw water quality.
- To benefit easily from the support scheme, investors should face as little administrative steps as possible. To this aim administrative and legal barriers should be removed.
- Only installations of new plants should be promoted, because the aim of the support scheme is to increase the installed capacity. Old plants should already be cost efficient.
- RE-desalination should not be over supported. The aim should be to install RE-desalination plants only in locations where no other solution like water saving or recycling is possible.

Independently from the support scheme chosen these recommendation should be included.

Additionally, it is important to implement framework conditions in the target countries, which help to promote RE-desalination effectively. Today, conventional desalination is subsidized. These subsidies have to be abolished. Fossil fueled desalination should not be supported with subsidies but on the contrary be taxed for its negative externalities. However, this will lead to an increase in water price and can lead to the problem that some consumers might not be able to pay for the amount of water they need for living. To avoid this, the water pricing system should be changed to a life line rate. With a life line rate the vital amount of water is cheap. The more water an individual or a family consumes, the more expensive becomes a unit of water. This has also the advantage to give an incentive for water saving.

Six support schemes to support RE-desalination are developed and discussed in this study:

- The first scheme is to promote RE-desalination with a production subsidy, which works as follows: For every m^3 of water a RE-desalination plant produces, the owner gets a fixed amount of money from the government. This money reduces the water cost for the investor and he can sell the water to a competitive price.
- The second scheme is to give an investment subsidy. With this subsidy the investor gets a share of his investment cost from the government.
- A feed in tariff for water is the third scheme. The government passes an act that obligates the water grid operator to buy the water from RE-desalination. Furthermore, the water grid operator has to pay the RE-desalination plant owner a bonus on top of the market price for every m^3 freshwater generated by RE-desalination.
- The fourth scheme is a quota scheme for water. The government fixes a certain share of the desalinated water that has to be produced by RE-desalination. Everybody who produces fresh water from RE-desalination gets certificates for his produced water. These certificates can be sold to operators of fossil fueled desalination. Every water supplier of fossil fueled desalination needs to produce the demanded share of RE-desalinated water or has to buy the equivalent in certificates.
- The fifth scheme is to implement an obligation. Every new desalination plant has to be powered with renewable energies. This is a special case of the quota scheme. The quota in this case is of 100%.
- The sixth option is based on the idea that to desalt water, RE-desalination first produces energy from renewable energy sources. These are already supported in many European countries. The energy production by RE-desalination plants could be included into the existing support schemes. Only minor changes in the policies would have to be made.

To evaluate these schemes to support RE-desalination, a benefit value analysis is made. This analysis leads to the conclusion that a feed in tariff for water is the best support scheme. The second and third best options are production subsidies and investment subsidies respectively. The result of a benefit value analysis is only an indicator and not a clear result, because the decision maker has to make subjective choices during the analysis. Therefore another decision maker might come to a different result. The decision makers of countries that want to implement a support scheme should repeat the analysis with their own preferences.

An improvement of the support could be achieved by a combination of support schemes. The feed in tariff has the disadvantage that it is not very well suited to support the simplest of all RE-desalination technologies: solar stills. Moreover, RE-desalination plants are extremely investment cost intensive, while the operation cost is relatively low. Especially individuals that are interested in small scale RE-desalination plants might not be able to bear the investment cost. To overcome these problems the feed in tariff could be combined with an investment subsidy. The investment subsidy also achieved a very good result in the value benefit analysis and can resolve the problems associated with a feed in tariff for water.

Another promising combination of support schemes could be an obligation combined with either a production or an investment subsidy. This combination has the advantage towards the combination feed-in tariff/investment subsidy that it assures that each newly installed desalination plant will be powered by renewable energy sources. It will therefore lead to a faster increase of the share of RE-desalination in the desalination market.

If a target country cannot, does not want to, or needs more time to implement a support scheme for RE-desalination, renewable energy driven desalination could at least be included in existing policies for energy to get some support without much effort for the policy makers.

This study suggests several possibilities to promote renewable energy driven desalination and demonstrates how to evaluate their potential for a given application. However, a general solution for every case cannot be given. Every target country should analyze which of the proposed schemes is most suitable in their specific case.

Legislative Guidelines

A report has been developed that supports decision-makers to establish a clear framework addressing drinking water produced by desalination in order to protect the health of the consumer and the environment, while removing unnecessary administrative barriers. The most critical points identified are:

Relating to water quality:

- Guidelines should prescribe pre-treatment of blending water prior to mixing and recommend employing a series of disinfection and pathogen control measures rather than reliance solely on the desalination process for disinfection.
- Standardised operation and monitoring procedures should be included in the guideline.
- Guidelines for RE-Desalination should include approval systems for quality standards.
- Guidelines should outline mandatory disinfection procedures for desalinated water.
- Guidelines should state minimum levels for magnesium and calcium in order to prevent corrosion.

Relating to environmental protection:

- A guideline should preclude RE-Desalination installations for extremely sensitive ecosystems.
- Guidance should recommend subsurface source water intake wherever possible.
- Guidelines should contain regulation of concentrate discharge.
- Guidelines should recommend the use of MF and UF pre-treatment systems wherever possible.
- Guidelines should make clear which environmentally friendly chemicals are safe to use.
- Guidelines should set standards of treatment procedures before discharge for chemical cleaning solutions from all membrane cleanings.
- Environmental assessments as well as health issues should be linked to the permitting process. The assessment should take into account the "alternative" means of drinking water production, thus factoring in the potential positive effects of RE-desalination.

Relating to administrative aspects:

- A clear institutional framework and water sector organisation and a transparent legal framework should be created, facilitating a close cooperation between public authorities in energy and water sectors and with private developers.

- Simplified, streamlined processes to obtain a license for independent water production by renewable energy should be designed and included in the legislative guidance.
- Financial support schemes should be developed and implemented.

The conclusions drawn from the analysis of health, environmental and administrative aspects regarding guideline development for RE-Desalination are general recommendations of elements to be included in the national frameworks. These have been derived from an extensive literature review. For application in country-specific circumstances of course further work, adaptation to the country specific conditions and update according to the latest scientific developments is required.