INSTALLATION GUIDE FOR AUTONOMOUS DESALINATION SYSTEM (ADS): TASK BY TASK PLANNING AND IMPLEMENTING - PART II: IMPLEMENTATION

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ABSTRACT

This paper presents part II of the installation guide for Autonomous Desalination System (ADS): task by task planning and Implementation. Task by task guide for implementation process of ADS installation and O & M is covered in this part. It includes; (1) selection of ADS supplier (tender process, offers analysis, selection of bidder, bid finalization and contracting), (2) ADS installation and commission (preparation of ADS set-up, ADS transport & local delivery, ADS installation, and ADS commissioning), (3) ADS operation (monitoring ADS operation conditions, evaluation & supervision, changes in operation mode, handover & withdrawal, typical operational experience), (4) ADS maintenance (preventive maintenance, predictive maintenance, corrective maintenance), and (5) O & M staff training . The paper is extracted from ADIRA* project handbook.

Keywords: Autonomous Desalination System (ADS), RE, Desalination, Guide

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1- INTRODUCTION

The matching of RE sources to desalination processes is a technical challenge with major problems associated to their intermittent character and total system cost. Desalination systems have traditionally been designed to operate with a constant power input. Unpredictable and non-steady power inputs, of RE force the desalination plant to operate in non-optimal conditions and may cause operational problems. A small energy storage system can be added to ease the problem but this adds to total system cost. RE-desalination plant can be designed to operate coupled to the grid, and off-grid (standalone or autonomous). The latter, named Autonomous Desalination System (ADS) poses the problem of renewable energy variability because most renewable energy systems lack an inherent energy storage mechanism.

Over the last two decades, numerous desalination systems utilizing renewable energy have been constructed. However, most of theses systems have been built as research or demonstration projects and were consequently of small capacity. At the moment there are no large-scale ADS applications. Nevertheless, the continuous developments in both RE and desalination technologies will provide more reliable systems at cheaper prices. These trends are liable, however, to continue for the foreseeable future. The viability of any RE desalination combination will mainly depend on:

- RE potential at the particular site and the form of available energy, be it thermal, mechanical, electrical.
- The required production capacity from the desalination plant; that also determines the size of RE subsystem.
- The availability of Operation & Maintenance (O&M) experienced personnel.
- The total system cost.

This Installation Guide for Autonomous Desalination System (ADS): Task by Task Planning and Implementing aims to support local installation under different local conditions, and will draw attention to the important technical, social and economical aspects to be considered and the possible problems and solutions and actions to be taken. In part I of the ADS installation guide, [1], task by task planning was presented; including (i) site selection guide, (ii) desalination selection process guide, (iii) ADS economic & financing, (iv) social impacts & actors participation. Once the site, technology, actor's participation and local contacts have been decided, the specific process of installing and operating the system should be made according to the following suggested plan. A guide for process of ADS installation and O & M is covered in this part. It includes; (1) selection of supplier (tender process, offers analysis, selection of bidder, bid finalization and contracting), (2) installation and commission (preparation of ADS set-up, transport & local delivery, ADS installation, and commissioning), (3) ADS operation (monitoring operation conditions, evaluation & supervision, changes in operation mode, handover & withdrawal, typical operational experience), (4) ADS maintenance (preventive maintenance, predictive maintenance, maintenance), and (5) O & M staff training.

2- SELECTION OF SUPPLIERS

The selection of suppliers has to be made according to the regulation of the country and of the financing entities. Generally, this selection has to follow a tender procedure which includes; (a) call for tender, (b) offers analysis, (c) selection of bidder, and (d) bid finalization & contracting. This process can be explained as follows:

(a) Call for Tender Process

- ADS owner selects a team of specialized persons in the fields to write the tender documents; i.e. tender call specifications & conditions and tender call advertisement in both English and national (Local) languages. The Tender call advertisement is a summary of the tender call conditions & specification. It also includes the closing date (and hour) and address of submission. The tender call advertisement should be advertised in well known national / local news paper, international ADS magazine(s), the project and ADS owner web sites. Direct e-mail or mail / fax, and telephone calls to companies in the field may help spreading the advertisement as well as clarifying all inquires from interested companies.

- The tender call specifications & conditions, should cover:
    - (i) Tender call advertisement,
    - (ii) Scope of work,
    - (iii) <u>Civil works</u>, include; well digging (if needed) or feed water supply system, fences, Building / rooms for ADS operation & control panel, components and spare parts storage, operator & meeting room (if needed), ADS advertisement panel,
    - (iv) <u>Electro-mechanical works</u> which includes; specification of product water rate & quality, ADS type (RO, ED, MD, Thermal), Pre & post treatment, Electricity generating unit (PV, wind), power storage pipes and electricity connections, batteries & water storage tanks sizes, brine disposal methods, instruments and control devices. In all above items; the detailed specifications required should be included,
    - (v) <u>General Conditions</u> including; place of manufacturer (if needed), Codes to be used, equipment guarantee certificates, letter of credits, training needed, engineering drawings, time schedule, components and equipment catalogs and performance charts, O&M requirements, spare parts, training, and general conditions related to local requirements,
    - (vi) <u>Payment conditions</u>; includes the down payment and Bank Guarantee letter, periodical percentage of payment, last payment, and delayed payment for devices warrantee,
    - (vii) <u>Others</u>; the tender call conditions & specifications may also include introduction about the ADS owner, introduction about the ADS related project.

(b) Offers Analysis

At the tender call closing date, hour & place, the selected ADS team will receive the bidders both technical and financial offers (in two separate envelops). At least three offers should be received otherwise the call may be repeated – unless there is only less than three companies produce this type of ADS required.

The technical offers are opened one by one, in front of all bidders' representatives, and the received bids are documented in official minutes. The financial offers will be sealed and kept with ADS owner. The team, team leader and the bidders representatives will sign the minutes of the tender opening ceremonies. The team leader announces the date of opening the financial offers, after a suitable time (2-4 weeks) for reviewing the technical offers.

The ADS team leader will distribute copies of the technical offers to the reviewing team for evaluation. Each reviewer has to check if the received documents satisfy the tender call conditions & specifications. If some parts are not clear, official letters of clarification or clarification meeting. The offer that does not meet the tender conditions and specifications will be eliminated from the review.

The offers which agree with the tender call conditions & specifications will be technically evaluated with prioritization criterion. Each criterion will be give a marking value (weight) or percentage. These values will be added and the total represents the offer total technical value. Examples of the criterion for selection of tenders are given in Table (1). More criterions could, however, be added or deleted based on ADS.

In addition to the direct contacts between the members, meetings are needed for ADS reviewing team to discussion of the offers details and clarifications. However, the evaluation will be separate. In the last meeting, all evaluations will be compiled into one sheet where the average marks of the reviewers are averaged. The offers will then be ranked based on the top down numbers or percentage.

ADS evaluation team leader will contact the bidders to confirm the financial offers opening date. At that date, the sealed financial offers will be opened in the presence of the bidder's representatives and the financial offers total costs as well as cost break downs are tabulated. The minutes of this opening activity is signed by the ADS team members and the bidder's representatives.

The financial offers are reviewed and evaluated using some criterion for the evaluation including; the total financial offer, the break down, the equivalent values the local currency (or unified currency), Taxes, Customs …etc.

Table (1) Examples of the criterion for selection of tenders

	General	Mechanical Works	Electrical Works	Instrumentation & Control	Civil Works
1	Bidder Previous Experience	ADS design	Motors	Measuring Devices	Fences and its Ancillaries
2	Bidder Financial Stand	Materials Used	Operation & Protection Panel	Monitoring & Data Records	Water Well
3	ADS Schedule	Submerged Pump	Electricity Generation Unit		Tanks and its Ancillaries
4	Engineering Drawings	Connecting Pipes	Storage Batteries		Building and its Ancillaries
5	PW specification	Auxiliaries	Materials Used		Advertising Panel
6	ADS Technology				
7	ADS Performance				
8	Environmental Impact				
9	Manufacturer Origin				
10	Maintenance & Spare Parts				
11	Future Extension				
12	Training				
13	Equipment Guarantee				

(c) Selection of Bidder(s)

Bidders financial offers are ranked in top-down order. In general, for all accepted technical offers, the lowest financial offer will be chosen as the selected one. However, there may be a strong reason(s) that put another offer to the top even if it is not the least cost. An example for this case, in some countries there may be a national law that support national bidder and give them privilege over the foreign bidder, within X % higher offer.

After through discussion of the ADS team, the final decision will be taken, written and signed by the team. ADS team leader will inform the ADS owner or the funding authority of the team decision. Once he gets their approval, the team leader (or the authorized person) will officially inform all bidders with the final decision. There should be one awarded bidder and one or two (in order) as standby.

It should be indicated that all theses activities should be well documented, signed by those who have to sign, informed by all to be informed.

(d) Bid Finalization & Contacting

After the awarded bidder has been selected, a series of technical meetings will be carried out, between ADS team and the awarded bidder (contractor), in order to discuss the details and the final design, schedule, bill of quantities, and agree on the necessary action plan. Technical discussions may include new ideas to improve the proposed design from the supplier in order to be adapted to the local conditions. Visits to the site and suppliers may be needed at this stage to finalize the design and select out of alternatives (if needed). Adjustment of the technical drawings, some design re-calculations might also be needed at this stage. The updated design might need schedule and technical drawing updating. All should be approved by both the ADS owner and contractor.

A draft of the contract is written by specialized lawyer (either in English or local language or both). The contract will be reviewed, updated and finalized by both parties. The contract will identify the role of both parties. For the contractor; site preparation, civil works, the equipment delivery, installation, testing, unit overall commissioning, O & M, staff training and documents to submit (such as Bank guarantee, catalogs, equipment specifications, …etc. For ADS owner, the payment schedule, supervision, etc.). Two originals of the contract are signed and stamped by both parties. One copy is kept with each party. Note that the tender call documents, all correspondences and agreements could be part of this contract.

(e) Local Actions

ADS owner or the contractor should contact local and national authorities for different permits to install the ADS unit as feed water well digging, construction of civil works, use of sea water & intake system, brine disposal location, possible electrical power connection to grid, …etc. Contacts to ministries of water, environment and energy as well as local city councils, governorate staff, local NGO(s) and local community heads should be carried out. It might be advisable to sign a protocol of cooperation (or similar agreement with local / national authorities) and get them involved as part of the process.

3- ADS INSTALLATION & COMMISSIONING

a- Preparation of ADS Set-up

It is recommendable to celebrate a preliminary meeting and a field visit for ADS installation team and the contractor to discuss the steps to be performed and the action plan to take place. The meeting should focus on the basic elements of the system installation as all scheduled tasks, the selection of components to be imported or locally supplied, state of feed water source, pipes system, optimum system layout considering the local users necessities for fresh water access, wind and solar conditions, and destination of brine and address the feed water source, …etc. The quality of the site feed water had to be analyzed and the results provided to all parties specially the ADS manufacturing company to re-adjust the system design accordingly. Similarly, the auxiliary and supporting systems, the water & energy consumption for pumping and the different proposed solutions and alternatives within the scope of the project should be addressed.

The site preparation requires also specific actions; (i) pavement of the land & the concrete foundations and fences, (ii) construction of labor, storage and control panel room(s) and other civil works, (iii) water connection for feed water supply and brine disposal, (iv) water tanks insulation if needed, (v) electrical connection for the pumps and data acquisition system, and other components. Installed the ADS is followed-up by the system commissioning and start-up.

As per the contact, and according to the scheduled, the contractor starts his civil works, the transportation of equipment from the manufacturer to the ADS installation site. Some equipment might be locally available or manufactured and others may be imported. All these should be taken into account in the project schedule. These imported components have to be shipped to the site under the supervision of the contractor. Cautions have to be taken during these processes specially for handling sensitive devices and components. The contractor organizes and carries out the transport of the container from port to the site.

b- ADS Installation

The organization of the set-up of the components and the necessary work for components testing and commissioning preparation should be reviewed and discussed with the project manager. This includes piping plans for the complete installation, the foundations of the components, the construction & installation of water tanks (feed, product & brine), the controlling components, the measuring devices and data acquisition system As far as possible, standard components with no or low energy consumption to be used with some of the features to be modified and adapted to the needs of ADS installation as follows;

- Civil works:
    - Foundations of the selected components,
    - Construction & installation of buildings, water tanks (feed, product),
- Hydraulic part:
    - Final design of installation (Piping adaptation for the complete installation, for the three main circuits: feed water, fresh water and rejected flow)
    - Improvements / actions for the feed water system
    - Identification of the best location for the brine disposal system
- Electrical part:
    - Security aspects: protection for high voltage devices, earth wire installation
    - Final design of electric installation

- Control & monitoring part:
    - Final definition of control philosophy) and selection of control system elements
    - Final selection of variables to be monitored
    - Final selection of measuring devices and data acquisition system

The ADS set-up could be very well supported by local authorities, NGOs and community, in dealing with difficulties and unexpected problems. The set-up should be performed in very close collaboration with these parties, and a helping hand missing somewhere to be made available in an easy and co-operative atmosphere.

c- ADS Commissioning

The set-up and start of operation will take place once the unit's components is installed and interconnected in the site. The installation of the measuring devices, controlling equipment and the co-ordination of the set-up work is carried out by the contractor under the supervision of the ADS team. Each component will be tested separately first in order to assure its own operation modes and performance. This is followed by testing sub-group of components, followed by testing the whole ADS. Some amendments to the set-up to improve the performance may be needed. The plant is then set into commissioning stage and state of operation.

It might take few days to reach steady state operating conditions (as to heat up the storage tank in thermal unit). Afterwards the parameters of the control devices are to be determined and adapted to the operating conditions. After a first period in which the system is left to equilibrate, the system well be investigated again for operation and hand over.

Starting from the day of commission, a regular analysis of measuring data has to be performed. Several problems may arise and may prevent continuous operation (as the stability of the electricity supply). These and similar problems will be overcome by specialized operation staff. The acquired data has to be regularly evaluated and in very close co-operation between operator, contractor & ADS team, the results of the evaluation have to be used to optimize the operation strategy of the whole system.

d- Hand Over and Withdrawal

If an outside entity (as NGOs) initiates the implementation of an ADS and they do not plan to operate it for themselves, the hand over to the further operator has to be planned thoroughly. Apart from securing suitable mechanisms of organization and for financing, they should provide long term support and technical assistance to the community and/or the operator.

4- ADS OPERATING

(a) Monitoring ADS Operation Condition

The ADS unit operational data is monitored to ensure its reasonably operation. Common data collected in the demonstration units are the following:

(i) Temperatures (feed, product, brine, storage tank, pump lub. oil),
(ii) Pressures (feed water, before and after pumps, filters & membranes),
(iii) Flows: mainly feed water inlet, fresh water outlet, and brine outlet,
(iv) Local conditions: ambient temperature; wind speed; solar irradiation on collector area,
(v) Conductivities: especially in fresh water, and at least, periodic measurements in feed water,
(vi) Power: in the generation system (PV panels & wind mill units) and in the load system (batteries, desalination unit, feed water pump…).

This wide set of data is not necessary in fresh water supply plants, where the most important values to be controlled are quality and quantity of fresh water, and of course the specific energy consumption (heat and/or electricity consumed per cubic meter of produced water). Nevertheless, different problems may arise from coupling a desalination plant to a renewable energy source. Each desalination system has specific problems when it is connected to a variable power system, [1]. For example;

- RO system has to cope with the sensitivity of the membrane regarding fouling, scaling as well as unpredictable phenomena due to start-stop cycle and partial load operation during periods of oscillating power supply.
- The VC system has considerable thermal inertia and needs to consume a great deal of energy to get to normal working point.
- ED system has the same problems as RO about the sensitivity of membranes regarding scaling and fouling and is not able to desalt seawater.

(b) Evaluation & Supervision

In order to assure that the system is sustainable in social, ecological and economic regards, ADS project has to be continuously evaluated. This will assess building up expertise and collect additional arguments for the introduction of ADS. The projects should be evaluated systematically using qualitative and quantitative methodology. Usually the operators carry the responsibility for evaluation and to react to problems with measures to optimize or to enlarge the system performance and economy. However, from a scientific point of view it can also be done by external members of a project team.

(c) Changes during Operation Mode

Several unexpected operational handicaps may cause the need for changes in the operation strategy as it was planned before setting-up of the system. Example of this could be to fix a windshield around the ADS unit in order to decrease wind losses from the solar collectors in thermal system, and fix additional insulation on the pipes. Another example for solar stills units, it may observe during testing, Figure (1) that the product water and brine temperature are above the feed water. A system for energy recovery could be used to improve the unit performance.

Figure (1) Testing and Improving still efficiency through the recovery of lost energy with product water and brine

(d) Typical Operational Experience, [2]

Appendix (A), [2], summarizes typical operational experiences & lessons learned from selected ADS applications.

5- ADS MAINTENANCE, [3] & [4]

(a) Introduction

The performance of the ADS unit should assure to be very satisfactory, nearly as designed. Looking at the data, the low performance may indicate the failure or malfunction of component(s). The ADS unit may either shut down or isolate and open the failed component for maintenance.

There are three main types of maintenance; (a) preventive maintenance, (b) predictive maintenance, and (c) corrective maintenance. These three types will be discussed below for a typical ADS component; pumps.

(b) Preventive Maintenance

Preventive maintenance aims at preventing unscheduled equipment failure. Depending on the circumstances, an unscheduled failure will be very inconvenient and can be extremely costly. A successful program of preventive and routine maintenance will reduce equipment failures, extend the life of the equipment, and reduce the overall O & M costs. The preventive maintenance should be carried out, in general, as per the manufacturer's recommendations. For pumps, it includes; daily visual inspection of the various parts, monthly check lubrication of bearings (if any), monthly check of packing and seals for wear (the first sign of wear is a loss of the pressure and eventually water leaks), motor and pump alignment for proper torque transfer, and pump mounting. Example of preventive maintenance of plunger pump is shown in Table (2).

A thorough maintenance inspection should be scheduled annually and may include; cleaning of the pumps, check (replacement) of bearings and drive belts for indirectly coupled pumps, annual inspection of motor (temperature and vibration).

Table (2) Example of preventive maintenance of plunger pump, [10]

Frequency	**Daily**	**Weekly**	**50hrs**	**500hrs**	**1500 hrs**	**3000hrs**
Oil level	✓					
Oil leaks	✓					
Water leaks	✓					
Belt/pulley		✓				
Pluming		✓				
Initial oil change			✓			
Oil change				✓		
Seal change					✓	
Valve change						✓
Accessories					✓	

Detecting wear in the early stages can reduce repair costs and downtime. Prolonged operation with worn parts can result in costly repairs. Wear parts, such as shaft seals, bearings, and casing wear rings have defined service lives and should therefore be replaced per the manufacturer's recommendations.

(c) Predictive Maintenance

Predictive Maintenance is scheduled based on the analysis of data collected during the monitoring of the condition of the component, not necessarily on any set maintenance program. ADS pump, for example, requires close monitoring of the performance, noise, vibrations, and temperature of the motor. Overheating of motors, for example, is a sign of bad bearings, mechanical overload (plugged pump outlet or locked rotor), or insulation failure in the motor windings. Leakage of water, on the other hand, is a sign that the mechanical seal needs replacement. Noise is an indication of cavitations, rubbing and bad bearings, while vibration is an indication the beginning of a failure.

(c) Corrective Maintenance

Good practices in predictive and preventive maintenance will strongly reduce the necessity of corrective actions. Nevertheless, some common corrective activities should be mentioned:

- Hydraulic part:
  - Correction of small leakages, typical in water circuits, especially where there is high pressure or screw connections.
  - Replacement of components: case of dirty filters, membranes, etc.
- Energy part:
  - Replacement of damaged elements. In PV systems, the weakest part is in the converters (charge controller, inverter) especially when operation is under high temperature / humidity conditions.
- Other parts:
  - Treatment on rusted surfaces of metallic components.

6. O&M STAFF TRAINING, [3] & [4]

At each site, the responsibility for the ADS lays with either the site manager and/or operator(s). They will carry out the day-to-day operation and maintenance of the system and call specialists when a greater level of expertise is required. These people should have a good level of knowledge about ADS, components and water/energy storage. There is a necessity to train them to be able to cope with the requirements the system poses on them, [9]. Training will be carried out in class rooms (knowledge), workshop (skills) in addition to the On the Job Training (OJT). It is important to realize that training is a process which has to be repeated continuously. The over all aims of the training are to; (i) ensure long lasting operation of the ADS, (ii) increase user satisfaction, (iii) prevent or minimize problems arising from inappropriate use and wrong expectations, and (v) react to arising problems in a competent way, [3] & [4].

For the process of training, several steps have to be carried out in order to make sure each O&M staff member receives the kind of training s/he needs to ensure the sustainability of the system, i.e., training will be different (adapted) to each member to be trained. The design of the training process consists of; 1- Situation Analysis, 2- Training Needs Assessment for each group of trainees, 3- Planning of the training for each group of trainees, 4- Realization, and 5- Evaluation of the training.

For each step the social and economic aspects of all kinds of trainees have to be considered as well as the technical requirements of the ADS unit. A checklist was propose, [10], with important questions that have to be asked in order to develop a training that helps to bridge the gaps between people and technology optimally, Table (3). An example of training contents can be found in Table (4).

Table (3) Example Training Checklist, [3] & [4]

Who	Who are the stakeholders that are involved with the ADS? What is their role concerning the project and the long-term sustainability (e.g. operation and maintenance, administration, use etc.)?
What	Which are the goals of the project and how can they be supported by training? What kind of problems can arise in the course of the project and which of them can be addressed or prevented by training?
When	Training Schedule: At which stage of planning and installation? Before, while or after?
How	Methodology?
By whom	Trainers?
Where	Location? Timing? Can everyone reach this location? Is there enough space?
Evaluation	Indicators, methods, time of sampling?
Resources needed?	Financial resources? Time? Knowledge and qualification of the trainers? Material? What is needed? What is available?

Table (4) Example training contents for end users, [3] & [4]

General Information about the benefits of the ADS	- Drinking clean water protects family members from sickness. - Accessible safe water saves women's and kid's time, improves welfare of women and provides more time for family care or income-producing activities. - The renewable energy source reduces costs and enhances sustainability It also has to be made clear that: - Improved water supply will only lead to benefits if linked with proper use - The community must assume responsibility for the ADS - Water is precious and is worth paying
Organizational Information	- the general organization of the ADS. - Ownership and responsibility.

	- Role of the key person/guard/caretaker. - Amount of water available for every household. - Distribution among the households and persons responsible for the distribution and controls.
Technical Information	- Components of the ADS: e.g. the desalination unit and its most important features; the renewable energy source and its most important features (e.g. the solar panel, the battery); displays informing about the state of the water supply. - Use of the ADS: e.g. the steps to withdraw the water from the system; pre treatment and post treatment; what kind of problems can arise from inappropriate use; how to determine whether there is enough water in the tank; dangers such as high pressure in the RO-Unit. - Maintenance and Monitoring: e.g. flushing operation to clean the membrane, the regular cleaning of the PV-Module, the cleaning of taps or the removal of brine; who to contact in case of problems and how
Quality, quantity and availability of water and restrictions of the ADS	The restrictions in the use of water have to be explained thoroughly and it has to be made sure that every user accepts these in order to prevent disappointment. - The water has a very high quality, but if it stays in the tank too long, bacteria can grow. - The amount of water that is produced per day is restricted. - If there is no wind/no sun, no water can be produced. - The ADS produces a noise that might be disturbing
The wise use of water	The water produced by the ADS is likely to be still a scarce resource and the users have to be made aware of that. It is important that they do understand that they must not waste this. - The wise use of water: ways of saving water and ways of keeping the water clean; suitable and unsuitable uses of water.
Payment	- How costs arise and modes of payment.

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Appendix (A)

Operational experiences & lessons learned from selected applications, [2]

Plant	Experience & lessons Learned
1- PV-RO unit in Lampedusa - Italy	The ADS unit uses sea water to produce 5 m^3/hr of <500 ppm water quality, and was designed for reliable commercial operation. The battery and PV panels were sized so that electricity needs are covered by PV energy alone during summer most days. In case of bad weather and night operation, the unit is supported by network. The following basic issues were taken into account during the design stage:- • The PV panel is the most expensive component of the plant. Battery and inverters must warranty easy starting of any pump of the plant. • Maximum water is produced in summer, and water production cost must be minimized. The plant has had a successful operation for more than five years, proving that with an improved sizing and without any incentive, it is feasible to produce a sell water at prices definitely lower than from other water resources, like water transportation. Yet, improvement of some specific parts are always possible (e.g. pump with lower maintenance requirements, lower energy requirements, improved mechanical transmission motor / pumps, ..etc) has been operating satisfactorily, producing fresh water of adequate quality since 1990. In 1992, the plant went through long stop, due to a serious damage in the sea water aspiration system that causes damage to some membranes. Another stop was in the summer of 1993, due to inverter substitution, without any serious effect. The unit was operated under the supervision of water utility of part time experienced staff. This situation leads to some advantages, including; • Operation by part time employees is possible (lower operation cost). • Experts were available for purchasing spare parts, for O & M planning and managing. • There was a direct interest of the utility to produce and sell desalted water with profit. Special attention should be paid to the following: • plant has to be fully automatic, reducing the staff requirements and increasing system reliability • Daily inspection of the plant is necessary • The specifications of the membrane manufacturer have to be exhaustively observed.
2- Wind–Diesel–RO Plant at Jandia, Fuerteventura, Spain	As indicated above, the unit serves an isolated village in isolated island of Canary island far from the grid and far from other communities. The plant produces 56 m^3/day from sea water and is driven by a 225 kW wind energy converted and two 160 kVA diesel engines.

	The system has operated without any major trouble since 1995. However, due to the fact that the wind turbine nominal output is much larger than required for the system demand, 100 kW of dump load was installed. Therefore, the part of energy produced by the wind turbine has over the period considered. An important issue addressed during the operational phase was the involvement of a local operator. Apart from the involvement of the various bodies acting in the joint effort, it was vital that an operator from the village itself was engaged in the operational phase of the project.
***Solar Thermal MES Plant in Abu-Dhabi* (*United Arab Emirates*)**	The solar energy intensity attracts the use of ADS in the Gulf area. The plant consists of Multi Effect Stack (MES) evaporator for 80 m^3/d. The heat is supplied from 1862 m^2 (1.75 m^2 x 1064) bank of evacuated tube solar collectors and accumulator for heat storage. The reported experience for the first ten years of operation indicated that the plant had suffered from deterioration: - In its performance due to scale of the evaporator tubes. - Breakdown of pumps and other equipment. - Decline in the collector efficiency due to dust accumulation which was difficult to remove completely. - In the heat accumulator performance due to decline in insulation performance. Many forced shut down took place, most of them due to problems related to evaporator pumps and their motors. Since no stand buy pumps are available, the plant was stopped for long period of time. Some typical problems associated with solar collector field were as follows: - break of solar collectors panels during water jet cleaning of the collector field - water leakage through collector air vent which required replacement of the float ball inside - water leakage through the joints between adjacent collector panels - corrosion in the header of several collector panels The collector field had proven to be more than adequate for winter operation, where the daily amount of solar radiation is smaller than summer and decidedly excessive during summer operation. This condition made it essential to put most of the blocks in operation during winter, but a number of blocks (usually 2) during summer. The collector field does not appear to be adequately optimized for the plant location. The water jet collector cleaning system was able to dislodge and remove the loosely attached dust particles, but was not able to remove a thin layer of sticky fine dust particles which accumulated over time.

	The acid cleaning system which was originally incorporated in the evaporator has proved to be in-adequate for cleaning all evaporator tube bundles. With original system, cleaning was most effective just for the tube bundle of the brine heater; the succeeding evaporator tube lying beneath the heater was not adequately cleaned. The acid cleaning system was modified and a new acid pump was used and very good results were obtained. The Plant in general had a successful operation for more than 10 years, proving that with an improved sizing; it is feasible to produce water of sufficient quality at reasonable cost.
Wind-RO Plant in Therasia **(*Greece*)**	The plant was commissioned in the Mediterranean to operate in remote site (with severe water problem as cost of transporting water from Santoriny Island cost 15 Euros/m^3) away from the grid (autonomous). The wind – RO plant has a daily capacity of 200 Li/hr. RO unit is driven by 15 kW wind turbine, with battery / rectifier and inventor. Some of the problems mentioned during the unit operation are: - Presence of debris on the surface of the sea water in the bore hole, the hole was sealed and the immersed pump is contained within stainless steel grate. - Sea water and product water had a bad smell; a charcoal filter was added and removed the nuisance. - The variation of membrane pressure with battery voltage was a problem. A high pressure control may be necessary if this problem became important. - The wind turbine was over powerful, but supplied plenty of energy at low wind speed. - Air purge from filters needs to be facilitated The use of 15 kW turbine to power a sea water desalination unit has been made possible, combining good overall system efficiency and minimum electricity storage. The system works satisfactory, although it could be improved. From the published short experience, the following remarks can be made: - The use of battery system was necessary for autonomous unit. - In order to avoid the reduction of membrane efficiency, due to clogging, the RO unit needs to be run a minimum of 30 minutes per 24 hours. This means that the system has to be sized with sufficient battery storage to account for low wind periods. - To avoid losses due to voltage transformation, the battery voltage was chosen high (120 V). - The losses due to inverted have been avoided as this has been removed; since DC motor from high pressure pump is used.

	Furthermore, the system manufacturer concluded that the development of a wind desalination system should be considered on small to medium scale systems. Larger desalination systems are connected to local electricity grid, in which case development work on the interface between wind energy and desalination techniques is no longer relevant. The experience the system manufacturer obtained from this project has shown that emphasis for further development must be on: - Reliability and acceptable maintenance requirements for remote sites - Total system cost (function of overall water output, specific energy – kWh/m^3 of fresh water) and - Appropriate wind power to desalination interfaces.
PV-RO Plant in Almera, Spain	This is a brackish water RO unit developed at Almera University site to demonstrate the technical feasibility and reliability using solar PV energy driver. The unit is 2.5 m^3/d driven by 23.5 kWh with energy storage. From operational point of view, the accumulated hours of operation were 700 hrs for the first five months (about 5.0 hrs/d). The maximum daily. A major problem which causes the low unit availability and outage was the poor quality of raw water, especially its high content in iron. The daily removal of the filters and the frequent cleaning of the membranes disrupt the normal operation of the unit and increase the maintenance and operation cost. The unit operated for 32 months. It is considered as well designed; however, the frequent failures of some components decreased its effective utilization. The unit can be operated in a stand alone way whenever the raw water quality fits the plant design requirements. Nevertheless, some basic control was required to ensure a plant proper operation and plant lasting.