Water, energy, desalination & climate change in the Mediterranean

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August 2008

In view of the underlying increase of water demand, the Mediterranean riparian countries have to grapple with several challenges: to sustainably manage limited water resources, to ensure access to drinking water by not-yet-serviced populations, and to urge the users to adopt water sparing behaviours. These challenges are all the more crucial as the tensions over water resources are likely to be exacerbated under the impacts of climate change. The forecast rise in temperature and drop in rainfall would lead, indeed, both to a reduction of resources and an increase in demand.

The first response to these evolutions consists in engaging water demand management policies likely to reduce losses and misuse, as well as manage the resource equitably while endeavouring to meet the various uses. However, in certain countries, an increase in supply, resting on a better management of the resource (increase in the exploitable potential, control of pollution…), or via non conventional forms of supply, also proves to be necessary.

Seawater or brackish water desalination, thus, constitutes one of the possible responses to adapt to the increasing shortage of water resources. However, while desalination techniques are now quite under control, their implementation requires large quantities of energy, under the form of heat or of electricity, both of which are costly and potential sources of GHG emissions.

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I. SYNOPSIS AND KEY MESSAGES

The significant decrease in costs makes desalination increasingly competitive. The capacity installed in the world is up by over 10% every year, on average. In the Mediterranean, the capacity installed could grow five or six fold by 2030 (from 5 million m^3/day in 2007 to about 30 million m^3/day by 2030). Some ten countries (insular countries, a country from the Northern rim (Spain), three energy-producing countries from the Southern rim), are -or will be- quite active in this field.

Desalination, per se, is not a sustainable development option; it is an alternative of adaptation to climate change which should be adopted only when all other "sustainable" possibilities have been tapped (in particular, rational use of water) and which should be limited to the production of drinking water for human consumption.

Any approach aimed at generalizing desalination would be tantamount to an easy solution and might as well lead to a “disaster scenario”. Indeed, large-scale desalination is a large power consuming option, an energy already used for pumping and water transfer. Practically all the additional electricity produced being of thermal origin, the risk of a high increase in GHG emissions is thus great.

However, low-CO2 emissions options are possible. On the one hand, the most energy efficient desalination options must be optimised: inverse osmosis, with optimisation in combination with fossil fuel-fired power stations, recovery of high-performance energies and improvement of existing installations. On the other hand, renewable energies (wind, solar photovoltaic and thermal, solar PSC with concentration applied to desalination, are pathways worthy of consideration for the future, even though they are met with all too familiar obstacles to any development of renewable energies (funding, competitiveness). The recourse to nuclear energy is a probable option in the medium term (time frame 2020), particularly within the framework of cooperation action with Libya, Algeria and Morocco.

More generally, in view of the size of the Mediterranean market, the development of an industrial sector for better water use, particularly on membrane-based technology, is one of the strategic options offered for the riparian countries. This technique applies to desalination and also has the advantage of being applicable to processes of recovery and re-treatment of wastewater for agriculture, re-potabilising and sustaining of aquifers.

Membrane-based technologies (filtration, de-pollution) and those of water treatment are complementary to desalination technology and less costly in terms of energy. Accordingly, a sufficiently diversified industrial supply in the matter is likely to both meet the urgent short term needs (increase in supply by desalination) and contribute in setting up long term options (re-use / re-treatment).

For the Southern and Eastern Mediterranean Countries (SEMC), the success of this strategy requires technology transfers and the provision of training which could be the centrepiece of a regional co-operation in the water sector. Moreover, its success will also depend on programmes of information and sensitisation of decision makers and the public at large as to water management and saving and the taking of sustainable "good decisions"

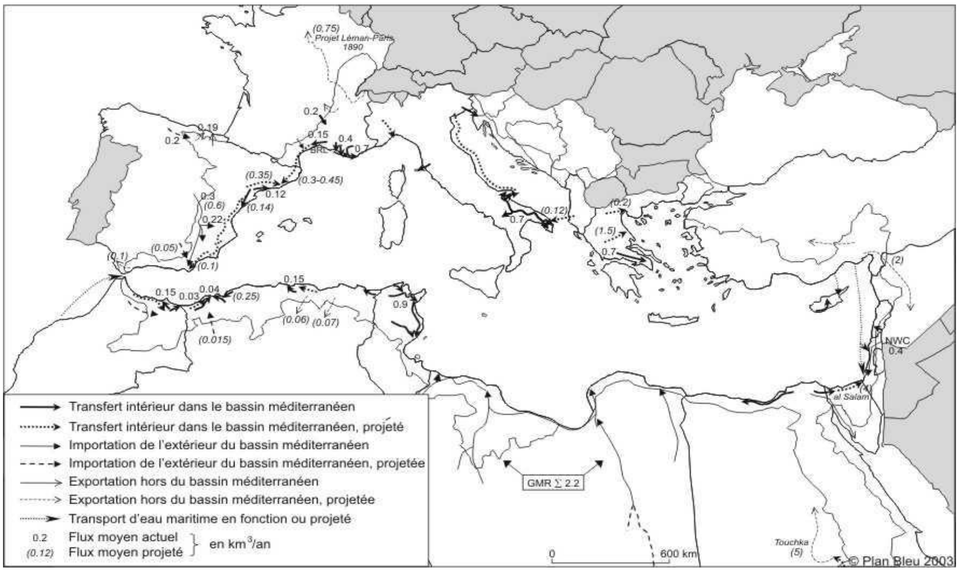
II. GENERAL INTRODUCTION

Context

The Mediterranean riparian countries have to grapple with increasing pressures on their water resources. Right now, in some of them (Libya, Cyprus, Malta…), water abstractions have neared, if not already exceeded, the threshold of renewable resources. Water shortages, whether circumstantial or structural, are set to worsen. The drop in rainfall, already observed, induces a reduction of mobilisable water resources and the tensions over these resources are likely to be exacerbated by the impacts of climate change.

Fresh water needs, in particular those related to drinking water, are on the increase. The arid countries are already in a situation of scarcity, with a risk of aggravation into shortage. The increase in needs is not only connected with demographic growth, but also with economic development (industry), and is very largely dominated by the agricultural sector (irrigation, development). Domestic consumption is, in fact, relatively minimal (14 % Mediterranean-wide in 2005), compared with total water consumption. In the SEMC, considering the relative exhaustion of conventional resources, it is necessary that water management public policies integrate, on the one hand, a component related to the management of demand and, on the other hand, the development of new non conventional alternative resources, such as reuse of wastewater and desalination of sea water or brackish water.

Indeed, the desalination of sea water or brackish water constitutes one of the possible responses.



In the Mediterranean, industrial production of fresh water by desalination of sea water or of brackish groundwater started mainly in situations of insular isolation (Malta, Balearic Islands, Cyprus…), coastline situations (Libya) and desert situations (Algeria). These industrial water productions have gradually developed both in volume and in performance. The techniques needed are today well under control and further developing, but their implementation requires significant quantities of energy, under the form of heat or of electricity, both of which are costly and represent sources of GHG emissions.

Objectives of the chapter

This chapter seeks to:

- take stock of the current activities (practices, water volumes produced…) in matter of desalination in the Mediterranean[1];
- outline the prospects for the development of desalination in Mediterranean countries;
- analyse the current situation and future prospects of renewable energies and energy efficiency in the total energy supply for desalination;
- address the economic, environmental and social issues related to the various possible options of desalination as a measure of adaptation to climate change;
- highlight the lessons learnt from past and current experience and propose the main criteria to be borne in mind when considering investment in desalinationt.

Information sources/ Methodology

This chapter is based on a body of information collected from the literature available on the subject, as well as on discussion with several desalination actors. Representatives of several industrialists of the sector were consulted (Sidem Entropie, Veolia, Suez Environnement Degrémont, CEA Cadarache, Société 3MW), together with actors of the energy sector in Morocco (ONEP) and in Tunisia. Besides, information derived from the daily press has been used in the part analysing the situation of the countries.

This was complemented by information collected by Plan Bleu as part of conducting the national reports on the "management of water demand" and on "energy efficiency and renewable energies" for purposes of monitoring the Mediterranean Strategy for Sustainable Development (MSSD) in 2007.

Content of chapter

The first part of this chapter takes stock of the status of desalination in the world and seeks to elicit where the Mediterranean stands in a context of climate change. Emphasis is laid, particularly, on the increasing energy consumption for water and the share necessary for desalination for the time frame 2020-2030. Besides, desalination technologies and market trends are analysed. Afterwards, the costs, impacts and environmental risks connected with desalination are presented.

The second part offers an overview of the water situation and projects, both underway and in the pipeline, in some ten representative or leading countries in the Mediterranean.

In a third part, we will consider the likelihood of a desalination free from CO^2 emissions based on renewable energies or nuclear power. Re-treatment of wastewater -which is not sufficiently tapped- and using technologies close to desalination represent another significant pathway for the future.

A last part outlines prospects of industrial and economic development related to desalination, for employment, training and human resources, as well water-related trades in Mediterranean countries.

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[1] The term "Mediterranean" is used to designate the following countries: Morocco, Algeria, Tunisia, Libya, Egypt, Israel, the Palestinian Territories, Lebanon, Syria, Jordan, Turkey, Cyprus, Malta, Greece, Albania, Montenegro, Bosnia-Herzegovina, Croatia, Slovenia, Italy, Monaco, France, Spain. The study will focus in particular on the Southern and Eastern Mediterranean Countries (SEMC): Morocco, Algeria, Tunisia, Libya, Egypt, Israel, the Palestinian Territories, Lebanon, Jordan, Syria (and Turkey).

In conclusion, the chapter proposes a scenario "to be avoided", presents performance and monitoring indicators, as well as five project decision-making and appreciation criteria for investors, before finally considering Euro-Mediterranean cooperation.

III. CLIMATE CHANGE, DESALINATION, WATER AND ENERGY: GLOBAL STATUS AND POSITION OF THE MEDITERRANEAN

1. STATUS OF DESALINATION ON GLOBAL LEVEL, AND WHERE THE MEDITERRANEAN STANDS

Water desalination is a fast-growing sector in the world. The installed capacity reports an annual increase by over 10% on average. This is due in part to the significant drop in costs which makes desalination increasingly competitive.

Out of 70 cities of more than one million inhabitants without direct access to additional fresh water resources, 42 are located on the coast. Moreover, 39% of the world population, that is 2.4 billion inhabitants, live within less than 100 km from the sea. These two factors make of the desalination of sea water and brackish water a veritable alternative resource. It can represent a solution against the overexploitation of aquifers in coastal areas, a response to certain strategic risks, such as prolonged droughts or cuts in water supply. There are even studies in progress in non arid zones aimed at securing the supply of such large cities as London or New York, based on desalination plants which could be prompted to address drought episodes.

Today, over 15000 desalination plants in 120 countries produce about 40 million m^3/day, of which three quarters provided by sea water and one quarter by brackish water. Out of these 40 million, 75% are intended for consumption and 25% for industrial or agricultural use. It is worth recalling that the global capacity of drinking water production is about 500 million m^3/d.[2]

While in 2004, experts predicted that global sea water desalination capacity would increase by 100% by 2015, these forecasts seem today to have been underestimated. China and India, for which the forecasts advanced a desalination activity of approximately 650.000 m^3/d by 2015 have already exceeded these forecasts. China recently announced 1 million m^3/d of treated sea water by 2010 and up to 3 million m^3/d by 2020. At the current rate of doubling up of the production every 10 years, specialists predict that this production will soar to 50 or 60 million m^3/d before 2015, and could grow a further twofold by 2025. Sixty (60) per cent of the fresh water needs of the countries of the Persian Gulf are met by desalination of sea water. Saudi Arabia alone generates 20 % of the global production. But, desalinisation does not concern only the rich and desert Gulf States, where the largest installations operate. In Australia, a third of the fresh water consumed by the city of Perth is generated by this technique.

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[2] These figures are orders of magnitude given for the sake of information. For most countries, there are no official statistics available on the subject.

In the Mediterranean, industrial production of fresh water by desalination of sea water or of brackish groundwater began initially in situations of insular isolation (Malta, Balearic Islands, Dalmatia, Cyprus, Cyclades…), coastline situation (Libya) and desert situation (Algeria), and is today expanding quite rapidly all around the Mediterranean. Algeria and Spain have clearly chosen this option to resolve their shortage problem. Spain ranks in fourth position globally.

In most Mediterranean countries, it is anticipated that the quantity of desalinated water will report an upswing. Indeed, renewable water resources are limited, but there is abundant salted water, as well as energy -on the short term- in oil rich countries.

As of now, the Mediterranean accounts for about a quarter of global desalination. By 2030, the region will probably approach the current figure of global desalination (that is, from 30 to 40 million m^3/d).

2. ENERGY FOR WATER IN THE MEDITERRANEAN: WHAT IS THE SHARE OF DESALINATION?

Energy and water being interrelated, energy needs for water strongly increase for pumping, transfer, treatment and desalination. They are set to double up within 10 years and will exceed, by 2025, twenty per cent (20%) of the total demand on electricity for the SEMC (10%, all Mediterranean riparian countries considered). This specific trend amplifies the overall trend towards an increase in energy demand in the SEMC, while at the same time tensions on the supply side are increasing.

Climate deterioration is already significant. In Morocco, there has been observed, over the last 20 years, a drop by 20% in rainfall and in water inflows in hydropower dams. This generates an additional deficit of up to 45% in power production, as the use of water in dams is arbitrated in favour of irrigation, and the level of water in the dams is lower, contributing to a reduction in the energy generation. This deficit must be made up for by electricity of a thermal origin, with the negative consequence of an increase in GHG emissions, thus exacerbating the climatic "vicious circle".

Water needs are markedly on the increase for the Mediterranean sub-regions of the Southern rim (Maghreb and Egypt) and of the Eastern rim (Middle East, with Turkey and Israel). Between 1998 and 2030, irrigated areas would increase by 38% in the South and 58% in the East, and water demand -all sectors considered- would grow by over 15% by 2025 for the whole Mediterranean countries, with a marked contrast between the North (with zero growth) and the South and East with significant growth (+ 32% by 2025). The current needs have already required major structures, in terms of dams and pumping works (77 m^3/s in the aquifer of the Nile Delta, 60 m^3/s in the vicinity of Milan, at the heart of the plain of Pô, over 10 m^3/s in the plain of Mitidja for the supply of Algiers), and will require in the future even more investments and energy consumption.

Thus, **dependence on energy for the mobilization of water** is particularly acute in the arid countries. **The level of water abstractions** is quite significant there, above all for irrigation purposes. Pumping and transfer induce an extremely strong dependence on electric energy, as the needs grow and tend to fall back on increasingly costly energy resources (ground resources, transfer from remote resources, treatment, desalination).

Power consumption for water mobilisation and treatment varies according to the countries and regions. It accounts for 5% of power consumption in the Northern Mediterranean Countries (NMC) and for between 8.5 and 13% (that is, about 10% on average) in the Eastern and Southern

Mediterranean Countries (SEMC) (with about 15% in Israel). These rates are set to rise in the developing countries which will be required, in order to address the growth of their population, to undertake more complex drillings, dams and transfers, as well as to increasingly resort to sea water desalination.

For desalination alone, if we were to look upon the issue in terms of electric output, a volume of desalinated water of 30 million m^3/d in the Mediterranean by 2030, with a ratio of 3.3 kWh/m^3, would amount to an electric output dedicated to desalination of 5000 MWe, that is 8 to 10 gas combined cycle power plants, or 4 to 5 nuclear units.

Water pumping and transfer consume much energy, as evidenced by a few major works, such as the "Great Man-Made River" project in Libya. In Tunisia, SONEDE (National Water Distribution Utility) reckoned about 200 GWh in 2004 for water management. In Spain, the initial lift of the "Trasvase Tage-Segura" (66 m^3/s, abstracted from the Altomira dam) consumes a power of 202 MWe. The energy cost of water conveyance in Israel was quantified as an annual power of 1.3 GWh. In France, power consumption for water mobilisation and treatment stood at 15 TWh in 2003, that is 3.4% of the national consumption.

In 2000, for the Mediterranean countries as a whole, power consumption for water may be estimated as in the range of 5.6 % to 6.7% of the power demand. By 2030, there would be, for the SEMC, some 48 km^3 of additional water to manage, that is 200 km^3 in total. Power consumption would be likely to reach (based on a ratio of 1 kWh/m^3) 250 TWh for water management, that is about 20% of the power consumption.

For the NMC, power consumption for water would stand, based on a ratio of 0.7 kWh/m^3, for 133 km^3/year, at 93 TWh, which accounts for about 5% of the total power consumption. For the Mediterranean countries as a whole, power consumption for water would thus amount to 250 + 93 = 343 TWh, which would account for approximately 10% of the total power consumption by 2030.

It is worth noting that water transfers now take place from the inner regions of the countries, mountainous zones and dams, to the more arid or urbanized coastal areas. In future, there could also be transfers of desalinated water from coastal areas to the inner country. Desalination by large-scale plants installed in coastal zone, with desalinated water transfer over a long distance, can increase energy consumption for transfer purposes. It is, therefore, required to conduct an energy and economic optimisation, on a case-by-case basis, according to the users' and transfer needs.

3. DESALINATION: PROCESSES, CONSTRAINTS, TRENDS

Water desalination processes may be classified in two broad categories: (i) thermal processes, by evaporation or by distillation; and (ii) separation by membrane or inverse osmosis. Box 1 presents these processes. The technical constraints met by operators are outlined in Box 2.

Distillation holds certain assets: modularity of investment likely to reach high capacity, robustness of the process, compatibility with the know-how available in the energy sector in the Middle East, significant availability (99%), smaller ground imprint, reduced infrastructure cost, relative independence of the quality of incoming water and better environmental impact of effluent (absence of chemical effluent). Thermal techniques used to represent, until a few years ago, the main technology employed in the world. These techniques -being worthwhile when thermal energy for water heating is little costly- have developed more in the gas and oil-producing countries of the Arab-Persian Gulf.

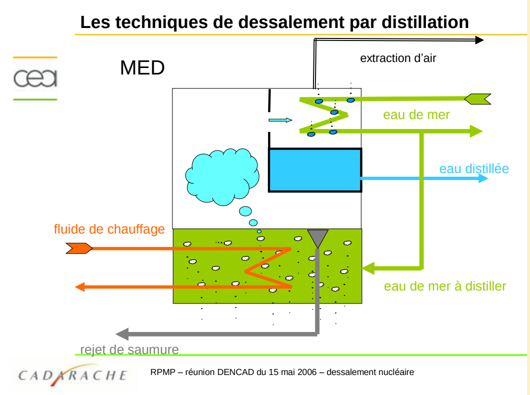
The reverse osmosis (RO) technique has reported a quite significant progress ever since its advent some time around 1960: modernized design, new materials, composite and dynamic membranes. Besides, performance, lifespan and cost have all improved. Four (4) types of membrane modules are marketed: *tubular, hollow, plane, spiral fibres.* Desalination plant constructors (in France: Degremont Suez, Sidem Entropie Véolia; in Spain: Acciona Agua; in Italy: Fisia Italimpianti, Impregilo group) are vying in performance and in size, and record achievements are regularly superseded (the desalination plant of Marafiq in Saudi Arabia has a capacity of 1 000 000 m^3/d in MED (Multi-Effect Distillation) technique).

Thus, reverse osmosis (RO) goes on gaining market shares and will become dominant in future. In 1990, RO accounted for 40% of installations in the world. Today this process accounts for approximately 55% of installations. In 2020, projections give the following breakdown: RO 70%, Distillation 20%, Other techniques 10% (data source IAEA-CEA (French Atomic Energy Commissionership)).

Box 1 Water desalination processes

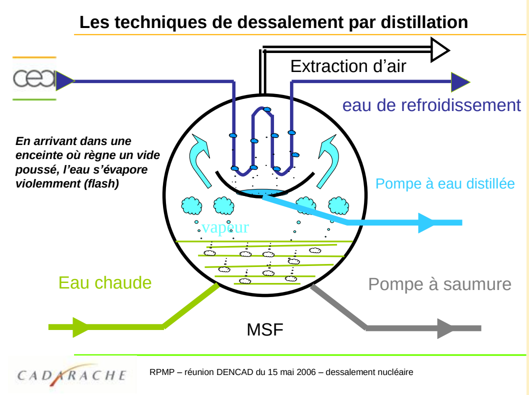
Water desalination processes may be classified into two broad categories: thermal processes and separation by membrane or reverse osmosis.

- The « thermal » processes by evaporation or distillation with stage change, known as MED (Multi Effect Distillation) and MSF (Multi Stage Flash), require energy under the form of heat. They operate based on the principle of sea water evaporation and vapour condensation, subsequently allowing for recovery of quasi-pure water.



Les techniques de dessalement par distillation

RPMP – réunion DENCAD du 15 mai 2006 – dessalement nucléaire

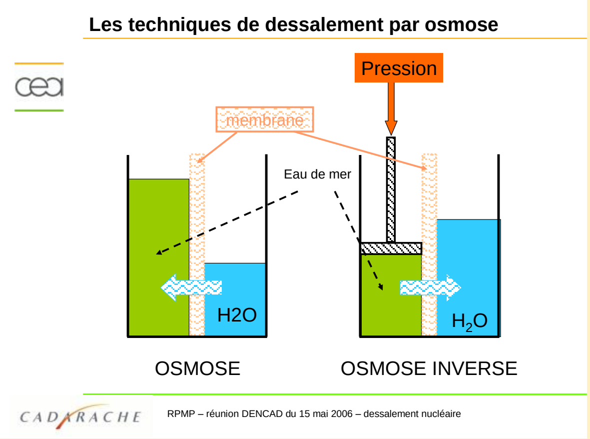


Les techniques de dessalement par distillation

En arrivant dans une enceinte où règne un vide poussé, l'eau s'évapore violemment (flash)

RPMP – réunion DENCAD du 15 mai 2006 – dessalement nucléaire

- The process of reverse osmosis (RO) requires energy under the form of electricity to supply high-pressure pumps which compress sea water to pass it through a filtration membrane.



Les techniques de dessalement par osmose

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The **membranes**—very fine filters—retain all impurities and salt. Salted water goes through one end under a pressure of 80 bars and, after passing through the membrane, comes out at the other end with 99% of its salt removed.

Electro-dialysis: a power current causes the ions to migrate to the electrodes. This being a quite profitable system for low salinity, the energy to be used depends on salt concentration (1kWh/kg of salt removed), but is prohibitive for sea water.

Temperatures of the main processes

MSF distillation: 110-130°C; MED: 60 à 100 °C, Reverse Osmosis: 15- 44°C

This recent market trend is due to two main factors. Energy consumption, a major component of desalination cost, has been significantly reduced for several years now with regard to RO. Besides, membrane cost has dropped quite considerably (20$/m^2 of module) and membrane performance has been improved. In Israel, the Ashkelon plant, of a 320 000 m^3/d capacity, consumes 3.7kWh/m^3 all in all; for best performance plants, with high energy recovery, consumption today is in the order of 3kWh/m3.

The penetration of the RO technique thus reflects its advantage in terms of a markedly lower cost of the desalinated m3 of water and of energy consumption than that related to thermal processes.

Research and innovation

The competition between the industry sectors and manufacturers has proven to be a progress factor. The breakthrough of reverse osmosis has spurred on the thermal techniques, which have achieved further progress translating into lower prices and higher performance. Thermal technology is mature, the specialists are in full control of its operating, and its costs have stabilised. Membrane based technology reports still significant progress; research is today focused, as a priority order, on the choice of materials and energy optimisation. Two research areas seem to be promising for the future: hybrid plants, on the one hand, and recovery of the energy of the brine disposed of by the desalination plants, on the other hand.

Hybrid power plants, with a joint power production and desalination, and new energy recovery systems are a large field of progress for the future. Indeed, a high-performance association of a thermal-electric plant and a desalination plant by inverse osmosis, installed on the same site on the coast, helps save much energy. For so doing, the flow of sea water for condenser cooling is used as raw material heated water for desalination, which constitutes a source of pressure and heat for desalination, with a sharing of the infrastructures of water intake from, and disposal into, the sea and reduction of the total costs and energy expenditure. Preheating the salted water up to 44°C induces greater viscosity and increases osmotic pressure, which represents two factors of reduction of energy consumption. In addition, the "hybrid" coupling of the two desalination techniques -thermal sector and inverse osmosis-, optimised according to the period and the load, allows a total economy (as in the desalination plant in Fujaïrah, in the United Arab Emirates).

Three solutions are today available to recover brine energy:

- **Integrated turbo-pumps**, recovering energy from brine in a water turbine,
- **Pelton turbines**,
- **Systems known as "pressure exchangers",** third generation, with higher output of over 95% (of which the energy recovery ERI system).[3]

Box 2 Technical constraints

Operators have to address in water desalination a variety of technical problems: furring up, fouling of exchange areas, deposits and clogging, corrosion, poisoning (contamination) of the membranes by certain chemical bodies.

The temperature and the degree of salinity differ according to the cases (Cf. further down), the degree of pollution (hydrocarbons, fibres, incompletely bio-degraded substances), as well as the proportion of plankton, may seriously affect the membranes, thus increasing their operation cost and reducing their useful life.

The efficiency and profitability of a reverse osmosis installation depend on the preliminary treatments applied to sea water. The manufacturers insist on the importance of modulating, according to the “difficulty” of the water tapped (elimination of suspended particulate and organic matter, single or double-layer filtration, high-speed floating, ultra-filtration membranes).

The choice of the conditions of operation, pressure, temperature, water velocity, type and size-measurement of pumps, cleaning, filtration, chemical treatment, de-scaling, is a complex process. All this requires skilled labour for operation, maintenance and replacement of membranes*.

Sea water and brackish water salinity

The salinity of seas open onto oceanic mass (Atlantic, the Channel, North Sea, Pacific) is in the range of 35 g/l, a value considered as standard sea water salinity. However, it may be quite different in the case of closed seas or those that are little open onto oceanic mass.

Mediterranean Sea	36 to 39 g/l
Red Sea	≈ 40 g/l
Dead Sea	270 g/l
Arab-Persian Gulf	40 to 70 g/l

Brackish water salinity: By brackish water, it is generally meant a salted, non potable water, with a salinity less than that of sea water. In fact, most brackish water has a salinity in the range of 1 to 10 g/l.

* There is significant complementarity between desalination techniques and those of water treatment, Cf. paragraph 3-3.

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[3] In the ERI system, a revolving ceramics cylinder, with holes in it, recovers energy from the high pressure current of the inverse osmosis, with a very high output of up to 97%. This generates gradually rising performance, reaching 2.5 KWh/m3 of water in reverse osmosis alone (exclusive of preliminary treatment and annexes). Obviously, the investment, as well as the floor area, are a little higher, but the energy performance obtained is quite interesting, and thus contributes significantly to the progress of this desalination technology. (ENERGY RECOVERY INC. 1908 Doolittle Drive, San Leandro, CA 94577, USA; Tel.: 0015104837370, Fax: 0015104837371 sales@energy-recovery.com, www.energyrecovery.com)

The decision to use a sophisticated energy recovery system—improving the performance and specific energy consumption per m^3 of fresh water produced—depends on the economic conditions and, particularly, on the energy cost. These high performance, but investment intensive, systems are to be recommended particularly when energy prices are on the rise and that one wants to encourage the reduction of GHG emissions.

4. DESALINATION COST

Desalination cost has dropped by a half over the past ten years, with however a rise in price recently, as a result of the rise in prices of raw materials, of which stainless steel. On the economic level, the capital costs are in the range of 1000 to 1200€/m^3/d for MED thermal distillation, and 900 to 1000€/m^3/d for Reverse Osmosis (RO).

The cost of desalinated water is estimated based on the sum of the three following items: financial costs, energy cost, operation and maintenance cost.

The cost of desalinated brackish water is markedly lower than that of desalinated sea water. For major plants, it is reckoned as 0.2 to 0.3€/m^3 for brackish water as against 0.4 to 0.6 €/m^3 for sea water. (Source: Manufacturers; Costs Checked)

These figures are higher for smaller, lower performance, or old, plants, and –obviously- **very sensitive to the cost of electric energy** which differs according to the countries, and which is lower in oil and gas producing countries, such as Algeria and the Gulf countries.

The size effect brings down the cost of the fresh water obtained, hence the need to build large capacity installations, when this is matched by the demand and with due care as to environmental impacts.

It is also worth recalling that the cost of mobilization of one cubic meter of conventional water ranges between 0.1 and 0.3€/m3 and that the cost of reuse of treated wastewater ranges between 0.3 and 0.5 €/m3[4]. Desalinated costs -for large scale plants- are approximately twice (2) higher than conventional water and 1.5 times higher than reused water, though with significant differences, according to the situation on the ground. With identical capacity, the recycling of wastewater is definitely less expensive than sea water desalination (the energy spent is cut down at least by a half).

5. ENVIRONMENTAL IMPACTS AND RISKS

The environmental impact of a desalination project relates to the phases of construction of the structure and its operation, with the effluent and the impact on the natural medium.

As far as the construction aspect is concerned, the usual impacts of infrastructures on the coastline (total land requirement, concreting…) and on habitats are encountered. It is also necessary to take into account the vulnerability of these infrastructures to climate change, in view of extreme events and possible rise in sea level.

The site and the geographical location must be studied. It is interesting to join on the same site a power plant and a inverse osmosis desalination plant, which helps optimise water intakes, limit the total land requirement and the areas, as well as the environmental impact, while gaining in output. The quality of the water intakes is very important. Beach wells represent a quite useful preliminary filtration.

The environmental impacts due to the operation of desalination units are in particular related to brine disposal in the natural medium. The impacts of “brine” disposal into the sea on the ecological balance of the coastline are still rather insufficiently known. In particular, the disposal of

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4 Source: SHF Conference on “Social and Economic Water Management”, Paris (17 and 18 October 2007).

high-concentration and insufficiently diluted brine effluent can impoverish or destroy the water ecosystems and degrade water quality.[5]

Thus, an evaluation of the effect of effluents, taking into account the marine currents tidal effect, is necessary. An assessment and a monitoring of brine effluents and chemical products (volumes, temperature, depth, expanse and area of the zone of impact of the water intakes and water discharges after desalination) must, in addition, be accompanied by a monitoring of land, but above all, marine fauna and flora.

Lastly, **GHG emissions** are all the stronger if the desalination electric energy is produced by fossil fuels. Reverse osmosis, with lower energy consumption, is better in this regard than thermal energy. Reverse osmosis, on the other hand, disposes of more chemical products into the water (descaling, preliminary treatment).

IV. OVERVIEW OF THE STATUS AND PROJECTS OF WATER DESALINATION IN THE MEDITERRANEAN: WORK DONE AND CURRENT PROJECTS

This part provides an outline of the status of desalination in the Mediterranean, based on some ten active countries in the field (Table 1 gives an overview of the situation). This group of countries is regarded as representative of the regional situation. Three Northern Mediterranean Countries (NMC) are reviewed: Spain, leading Mediterranean country in desalination and reporting a strong growth in the field, Cyprus and Malta, two islands in water shortage. Seven Southern and Eastern Mediterranean Countries (SEMC) are analysed: Four energy-importing countries -Morocco, Jordan, Israel and Tunisia-, and four energy exporting countries -Algeria, Libya, Egypt and Syria.

For each country, the situation of current and projected desalination activity are presented, together with the main motivations having contributed in the development of desalination.

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[5] See the WWF report of June 2007: "Making Water, Desalination: Option or Distraction for a Thirsty World?", a report that is highly critical of desalination.

Table 1 Situation of desalination in the Mediterranean

Countries	Uses	Desalination capacity (m3/d)	Complementary information	Comments
Spain	Drinking water, tourism, irrigation	2 500 000	Balearic & Canary Islands Many projects	The only country to use desalinated water for agricultural purposes
Cyprus	Drinking water	10 000	10 000 m^3/d for the Greek part of Cyprus, extension in process	Water shortages due to recurrent droughts
Malta	Drinking water, tourism	150 000	3 units 93 000 m^3/d Desalination represents 60% of drinking water supply	Improvement of the energetic performances of the old desalination units
Algeria	Drinking water	800 000	Program of 33 new units, 2,5 million m^3/d Algiers El Hamma 200 000 m^3/d	Energy producing country, important water leaks, mass desalination projects planning
Libya	Drinking water	1 000 000	distillation	Energy producing country, transfer of fossil water, nuclear desalination project
Egypt	Drinking water		Isolated area in the Red Sea Region, aeolian projects	
Israel	Drinking water	800 000	320 000 m^3/d coming from the Ashkelon unit, the biggest reverse osmosis unit in the world	Technologic skills
Tunisia	Drinking water, tourism	100 000	Projects of 250 000 m^3/d (new units)	Desalination project via renewable energy in arid area (small units)
Morocco	Drinking water	20 000	Desalination in the Saharan area (20 000 m^3/d), project in process in Agadir (90 000 m^3/d)	Rational use of water and desalination
Jordania	Drinking water		Studies on aeolian and desalination	
Total		5 380 000		

Note: The data provided in the table above are derived from various publications and information available on desalination, as well as from the national press of the countries studied; this table does not seek to be exhaustive (certain uses or projects may not figure in it). Yet, it provides an overall picture of the current situation, which is its main objective.

1. NORTHERN RIM: SPAIN, CYPRUS AND MALTA

1.1. Spain: Desalination for tourism and agriculture

Spain, with over 2 500 000 m3/d of installed capacity and about 1500 operating plants (of which the majority being of small capacity), ranks 4th globally, after Saudi Arabia, the Gulf countries and the USA. The early plants were installed in the 1980s in the Canary islands, then in the Balearic islands, particularly to meet tourism related needs (Cf. Box 3)

Box 3 The Balearic Islands: Water for tourism

In Majorca, the water contained in the shallow aquifers has a salinity rate that is too high for it to be used as it is. This problem is all the more important as the water needs have been increased significantly by the inflows of tourists. Tourism accounts for 80% of the Community's GDP. "In the Balearic islands, desalination has become the only means to 'water the tourist flock'"*(Spanish press* and http://www.combat.infosplus.net). Palma de Majorca has installed 3 plants, with the major one providing 68 000 m^3/d, thus helping supply some ten million tourists and about twenty golf courses. Besides, 2 other plants have been constructed in Palma and in Ibiza. In the 1950s and 1960s, the islands were self-reliant and had practically no surface water regulation capacity. All rested on the tapping of springs and shallow aquifers. The decision to construct a desalination plant in Ibiza island was taken in 1989. It was commissioned in the summer of 1994, thus incepting the management of sea water desalination by the Balearic government. The population received the project favourably in spite of a slight increase in the rates. The water provided was perfectly potable.

Spain amended in 2004 its National Hydrological Plan which initially envisaged to divert part of the Ebre water towards the arid areas of the South-East, Valencia and Murcia. Instead of this water transfer, it is projected to construct up to fifteen new desalination plants (1.7 million m^3/d) under the AGUA programme, based on projects of desalination of sea water, reuse of treated wastewater (200 Mm^3/year) and water saving, to supply in drinking water the large coastal cities and also mitigate the water deficits observed in certain irrigated areas. The private sector, too, plays a significant role in the development and operation of sea water desalination projects.

Under threat of water restrictions, Barcelona reports the construction in progress of Europe's largest desalination plant (200 000 m3/d), which will help supply, by 2009, not less than 1.3 million inhabitants.

Spain has the characteristic of allotting a significant portion of the desalinated water to agricultural needs, particularly for the production of greenhouse vegetables intended for "off-season" exports to the European market in order to compete with products grown under gas-heated greenhouse in the Netherlands. The Carboneras plant (121 000 m^3/d), in the arid province of Almeria, supplies both agriculture and tourism, but operates at only 15 % of its capacity, for lack of clients. Initially intended to supply the zone of Mojacar, it was also set to supply the vast greenhouse crop area in the region. However, the higher cost of desalinated water causes the farmers to continue to draw water, often illicitly, from the shallow aquifer. This is why a transfer of desalinated water from this plant of Carboneras to Barcelona is considered.

(cf. the article published in The Monde on the 25.04.08 by Cécile Chambraud)

1.2. Cyprus: Drought, water rationing and desalination

Cyprus, an island with a semi-arid climate in increasing water shortage**,** has also been faced with a mismatch between its water resources and its domestic and irrigation needs. The situation is set to worsen: in March 2008, the island was already at grips with a serious crisis, due to recurrent droughts, requiring water rationing. The authorities of the Greek part decided to import water from Greece. For the northern part of the island, the needs are already at 60 % covered by Turkey (transport by huge balloons of 30000 and 35000 m^3) and the construction of a pipeline of 110 km in length, of which a buried section of 78 km, between Turkey and Northern Cyprus, is under study.

Two desalination plants are operational and produce 94 000 m^3/d. The Larnaca plant, inaugurated in April 2001, has a theoretical production capacity of 54000m^3/d. It was constructed under a 10-year BOOT (Build, Own, Operate and Transfer) contract. Water is intended mainly to supply the conurbations of Larnaca and Nicosia, whose needs are increasing at a rate of 4% per year.

The Dhekalia plant has a capacity of 40 000 m^3/d. Constructed by the Spanish -Cypriot consortium, Catagua- Caramondani, under BOOT contract, it was commissioned in April 1997 with a capacity of 20.000 m^3/d, scaled up at 40.000 in 1998, and modernized and made much more efficient with a reduction in energy consumption. A third factory is envisaged in the region of Limassol for commissioning in 2008.

Significant efforts have been made to improve water resources and management:

- by an increase in storage capacity, as Cyprus currently has 106 dams and water retention structures, offering a storage capacity of 307.5 million m^3, and ranks first among European countries in terms of water storage, with a ratio of 50 major dams for 10.000 km^2. By 2010, the total water storage capacity will amount to nearly 400 million m^3;
- via the "Southern Conveyor Project" which provides an interregional transfer of water resources, with several dams, a main pipe extending over 110 km in length, the diversion tunnel of Dhiarizos (14.5 km), as well as the treatment plants of Limassol and Tersephanou. It allows the irrigation of about 14000 ha.

Several projects of urban sanitation and wastewater treatment for irrigation purposes have been implemented or are in progress in the main Cypriot conurbations. As of now, it is envisaged to develop municipal sanitation in rural environment. The recent political developments, after the elections of early 2008 and the resumption of dialogue between the Greek and Turkish communities are likely to pave the way for a more efficient, comprehensive water policy in Cyprus.

1.3. Malta: A tourism island pioneer of desalination in the Mediterranean

The Republic of Malta, located at the centre of the Mediterranean, 80 km to the south of Sicily, comprises the islands of Malta, Gozo, Comino and Filfola. Malta consists of a very arid, low-altitude karstic plateau (its highest point stands at 239 m). The climate, of a Mediterranean type, presents hot and dry summers and cold and wet winters. Annual rainfall is in the range of 560 mm. The population of the Maltese archipelago is estimated as 400 000 inhabitants, that is an average density of 1 250 inhabitants per km^2, one of highest in the world, and is set to reach 425 000 inhabitants within the next 15 years. The water resources of the island being very limited, this population density is a fundamental datum weighing on the country's development. The population is at 90% urban.

To meet the population needs, water is obtained in two ways: groundwater and desalination. Desalination installations were introduced in the 1980s. **Today, desalination contributes as much as 60 % to drinking water supply in Malta**, with 150 000 m^3/d installed capacity. There are three desalination plants, and many small installations, particularly in hotels. Malta vaunts one of the oldest sea water desalination experiences of the whole Mediterranean region. The 3 oldest reverse osmosis plants, dating back to 1982, 1989 and 1994, are:

Table 2 Desalination plants in Malta:

Ghar Lapsi	1982	20,000 m^3/j	10 × 2,000 m^3/j
Cirkewwa	1988/89	18,600 m^3/j	2 × 3,000 m^3/j 3 × 4,200 m^3/j
Pembroke	1991/94	54,000 m^3/j	6 × 4,400 m^3/j 6 × 4,600 m^3/j

Significant improvements **of the energy efficiency of desalination plants** have been undertaken. A modern energy recovery technology was introduced in the existing factories by the Water Service Corporation:

- **Pelton wheels** installed on 6 trains using pumps for reverse osmosis at Phase Pembroke II, replacing older equipment. This project has contributed towards a reduction of energy consumption from 4.5 kWh/m^3 to 3.6 kWh/m^3;
- **pressure exchangers** introduced in Lapsi, with complete change of the equipment, as well as replacement of high-pressure pump. The specific energy consumption was reduced from 4.8 kWh/m^3 to 3.2 kWh/m^3. This has contributed towards an annual power saving of about 13 million kWh.

At present, nearly 10% of the wastewater of Malta is treated and made available for reuse in the agricultural and industrial sectors that is a total annual volume of about 1.5 hm^3. As from 2008, the scheduled construction of three new treatment plants will allow the production of about 14 hm^3 of re-treated effluent per year.

Twenty five percent (25%) of Malta's hotel bed capacity depends on self-produced desalinated water; this figure is set to rise in the future owing to the fact that an increasing number of 4- and 5-star hotels located on the coast are installing their own reverse osmosis equipment (50% of 5-star hotels, and 20% of 4-star hotels consume self-produced desalinated water). However, very few hotels are interested in the treatment and reuse of wastewater (Cf. paragraph 3).

2. SOUTHERN RIM: ENERGY-PRODUCING COUNTRIES: ALGERIA, LIBYA, EGYPT

2.1. Algeria: Large-scale urban desalination

In Algiers, and for the west of the country, the drought requires a shortening of the distribution time period, for 70% of the population, from 16h/day to 8h/day.

A large-scale drillings programme, launched in the West of the country, involves Tiaret, Chlef, Mascara, Aïn Temouchent and Sidi Bel Abbès. The major project of water conveyance from Aïn-Salah to Tamanrasset over 70 km in length, will ensure by 2010 a drinking water supply of about 100 000 m^3/d, as part of the Greater South development plan.

Besides, to compensate the lack of drinking water in the country and to no longer depend on climatic risks, Algeria has decided to rely on desalination plants. Forty three (43) units will be operational by 2019, to supply the major urban centres, while keeping treated wastewater and dam water for agriculture and for industrial use (1000 000 m^3/d installed capacity, 2 000 000 m^3/d scheduled). Desalination is thus enlisted to meet the needs of over a fifth of the population. "Desalinated water, owing to its relatively high cost, can only be used for domestic consumption. The intention is to supply the major urban centres, such as Algiers, Oran and Skikda, with desalinated water and to keep treated wastewater and dam water for irrigation, agriculture and industrial use" *(Minister for Water, newspaper El-Watan (The Nation))*. Farmers are called upon to use drip irrigation. Several wastewater treatment plants are being constructed to meet agricultural needs. The public is sensitised as to the need to rationalize their consumption and to put an end to water losses which are in the order of 40% in Algiers. However, the government announced that, in spite of the development of the desalination plants, the price of water will remain unchanged for the Algerian consumers (thanks to the subsidies).

Ten plants are already in operation in the country, and 33 new ones are envisaged by 2019; the 12 major plants are being constructed under the BOO (Build, Own, Operate) formula, according to which the design, construction and operation are assumed by the foreign private investor during the time period of the concession granted by the State. Such is the case of El Hamma, 200 000 m^3/d, that is a third of the drinking water of Algiers. By late 2009, thirteen (13) new desalination plants should provide 2.3 million m^3/d to Tipasa, Skikda, Mostaganem, Beni-Saf (Tlemcen) and Arzew.

The Oran plant will produce, in 2011, some 500000 m^3/d of drinking water [Source *El Watan* (The Nation), April 2008]. It is the Hyflux group of Singapore which was awarded this project, as a BOO contract, upon a tender, for a delivery price of 0,5577 dollar/m^3 of water and a total investment cost of approximately 468 million dollars. Hyflux has already been awarded, in consortium with the Malakoff group of Malaysia, the sea water desalination project of Souk Tlata, located in Tlemcen, with a capacity of 200 000 m^3/d.

Other plants will be located in Mostaganem, Zéralda (West of Algiers), Cap Djinet (East of Algiers), Sidna Ouchaa, Honaïne and Aïn Tourk in the Wilaya (regional administrative department) of Oran, Jijel and El Kala. Also, 20 other small plants will be constructed, by 2016 under State budget, and will be entrusted to ADE (Algérienne des Eaux)[6]. In addition, a cooperation agreement with France for nuclear desalination was signed in December 2007.

2.2. Libya: Oil, but too little water

Libya -a arid country- is lacking in water, but is quite rich in oil and gas. The water needs are increasingly quite significantly, with a fossil water resource and a desalination installed capacity of 900 000 m^3/d. Desalination, of a "non sustainable" nature, is made mainly by distillation, although some thirty small plants use reverse osmosis.

The main desalination competitor in Libya is **the *Great Man-Made River* (GMMR)**, considered as the greatest water transfer project worldwide, stretching over a distance of 1600 km, in 3 phases, for a flow of more than 5 million m^3/d. This major water transfer is not "sustainable", for this rests on the water of a large fossil aquifer in the South of Libya, lying at a depth in the range of 3000 to 6000 m, which dates back to 3000 years and which is not renewable. It is probable that, as from 2050, these fossil aquifer resources will shrink before utterly depleting. Libya will then end up in a situation of a highly acute water shortage and will, accordingly, have to resort to a very large-scale desalination. In the short term, it is envisaged to install desalination plants for an additional volume of 1 million m^3/d within the next 5 years.

For the coming years, a very rapid increase in electric energy demand is expected; **the water desalination plants** will constitute the main demand drivers. To meet such demand, various non CO2 emitting power sources are analysed: renewable energies and nuclear energy.

The power utility GECOL (General Electricity Company of Libya) is considering the installation of a pilot sea water desalination plant, based on renewable energy sources. Wind and photovoltaic energy will be used for the operation of a unit using inverse osmosis technology with energy recovery. The rated production will be of 300 m^3/d for the supply of a village in drinking water.

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[6] See in annex a general Table of desalination plants in Algeria.

Besides, a French-Libyan cooperation agreement was signed on 10 December 2007, for the development of peaceful use of nuclear energy and sea water desalination. The related text comprises, in particular, provisions relating to assistance in training, setting up a legislative, legal and administrative framework and the supply "of one or several reactors for sea water desalination". Training activities for Libyan engineers on aspects of nuclear energy dedicated to desalination are underway (CEA[7]-Libya Cooperation Agreement signed for a 3-year period in November 2006).

2.3. Egypt: Wind-energy based desalination in the Red Sea

Egypt's water resources come mainly from the Nile. In view of the needs of an increasing population and of irrigation, the desalination of sea water and brackish water is more and more considered as an option.

As of now, the projects seem to have been limited to isolated zones, remote from the Nile and water conveyances, and experiencing a great water shortage. Studies have already been conducted for the Provinces of Northern Sinai, Southern Sinai and Matrouh. The problem also arises concerning the Province of the Red Sea (20% of the country's area for a mere 0.2% of the population) which is particularly isolated and landlocked, and is not connected to the power supply network. Fortunately, certain sites are provided with an appreciable local wind potential, and stable throughout the year -in need of development- which would be suitable for mechanical vapour compression (MVC) desalination systems.

3. DESALINATION ACTIVITY IN THE ENERGY-IMPORTING SEMC

3.1. Israel: Towards water control

In Israel, a desalination capacity of more than 800 000 m^3/d is installed.

Average rainfall is of **250 mm/year** (700 mm/year in the North, as against 20 mm/year in the South), with short periods of rain and years of great drought. Other factors, such as low relief and scarcity of natural reservoirs, contribute in the acuteness of the water supply complexity. Two thirds (2/3) of the annual drinking water potential come from 3 main reservoirs: Lake Tabaria, the only surface reserve (1/4 of the resources), and the major two shallow aquifers: the coastal aquifer which extends over 120 kilometres from Carmel to the Gaza Strip, and the mountain aquifer to the east of the coastal plain which extends from the Carmel Mounts to the south of Beersheva (1/5 of the resources each). Natural springs, especially in the North of the country, are the third major drinking water resource. Besides its crucial problem of water shortage, Israel has to contend with a deterioration of the quality of the water resources.

The increasing total annual water **consumption** is about 2000 Mm^3.The breakdown goes as follows: 56% for agriculture, 38% for domestic use, and 6% for industry. Water supply by Israel to Jordan and the Palestinian Authority is provided within the framework of the peace agreements. Consumption is set to go on increasing because of the massive arrival of new immigrants, of natural population growth and of a rise in the standard of living.

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[7] CEA: French Atomic Energy Commissionership.

The national programme, initially designed to overcome, within 10 years, the future lack of resources, as well as to replenish the overexploited aquifers, has been readjusted to give priority in the immediate future to large-scale desalination plants, in Ashkelon and Hadera, by resorting in particular to private investment. Besides, the Israeli authorities are pursuing their incentive policy towards the development of new resources, such as the reuse of treated wastewater for irrigation, the use of brackish and salted water (though after desalination) in agriculture, and rainwater harvesting.

The public company **Mekorot** is the main producer of water resources. The major projects are the Red Sea - Dead Sea water transfer, as well as sea water and brackish water desalination. **The desalination plant of Ashkelon**, the largest reverse osmosis plant in the world, produces 320000 m^3/d, that is a sixth of the domestic consumption of the Hebrew State. The plant produces water not only of a very high quality but also at quite competitive prices, since the factory gate price of the cubic meter is a mere 0.5€/m^3. For Israel, the plant meets a twofold objective. First, the purpose is to mitigate the country's water dependence; second, beyond its own consumption, Israel also counts on this project to develop its know-how in the future market of water-related technologies.

3.2. Morocco: A judicious desalination

In Morocco, water resources are limited and, for the major part, already mobilized via the existing storage and transfer structures. Surface water runoffs are low. They originate from a few floods, often brief and intense. Rainfall presents significant regional disparities.

The basins of Bou Regreg, Oum Er Bia, Tensift and Souss-Massa, and Moulouya -which concentrate the major part of the country's water demand- report a significant water deficit. Out of the total water resources available, generated by effective rain, only 16 billion m^3 are mobilisable under acceptable technical and economic conditions. Indeed, rainfall ranges from about 2000 mm/year in the wettest Northern zones to as little as 100 mm, if not less, in the Southern arid zones of the country.

On the whole, Morocco has a natural water resources potential estimated, in average year, as about 20.7 billion m^3, that is an average per capita allocation of about 691 m^3/ year.

Besides these inherent characteristics, the water potential is highly prompted, with an overexploitation of the near-total of the country's aquifers. This potential is also threatened by the pollution induced by urban and industrial wastes, as well as by the use of chemical fertilisers and of pesticides in agriculture. This leads to a drop in piezometric levels, a reduction in flows, if not the drying up of springs, a disruption and decline of traditional irrigation and of oases.

The increase in this potential is mobilized for the large-scale development of irrigated farming over approximately 1.6 million hectares, which -though consuming considerably- is still far from achieving any impressive results. Water losses (unaccounted-for water) in irrigation and in drinking water distribution are estimated as 4790 million m^3 per year, of which 2300 million m^3 are considered as recoverable under acceptable technical and economic conditions.

To mitigate the problems of water shortage, the mobilization of non conventional water resources in Morocco, particularly the desalination of sea water and brackish water, is an option to be considered alongside with demand management actions.

Morocco has garnered a 30-year experience in the field of desalination of sea water and of salted water, which has provided it with a capacity installed of 20000 m^3/d, that is 2% of the national drinking water production capacity. The main plants are located in the Southern provinces

(Laâyoune, Boujdour, Tarfaya and Tan Tan), owing to almost non existent conventional water resources in these zones.

As over a half of the urban population lives on the coast or near the sea, the desalination of sea water or brackish water can, indeed, represent a solution that is suitable not only for the cities of the South, but also for large cities. In fact, projects have already been incepted in Agadir (44 000 m^3/d, within a first phase, to be followed by a second phase within 5 years), in Layoune (13 000 m^3/d) and in Tan Tan (90 000 m^3/d).

Desalination is, thus, called upon to play a key role in the future in this country. It could gather momentum with the gradual decrease in costs, which makes it competitive compared to conventional water. It is likely to represent the last resort to make up for the deficits observed in many basins and to resolve the conflicts between the various uses which have arisen in basins where desalination had never been considered as an option before (Tensift, Oum Er Bia and Bou Regreg).

Table 3 Sea water or Brackish water desalination plants in operation or under construction in Morocco

Centre	**Process**	**Raw water and capacity (m^3/d)**	**Date of commissioning**	**Observations**
Tarfaya	Electrodialysis	Brackish water 75 m^3/d	1976	Out of order
Boujdour	MED-MCV distillation	Sea water 250 m^3/d	1977	Rehabilitated in 1997 and in 1998
Tarfaya	RO	Brackish water 120 m^3/d	1983	Rehabilitated in 1988 Out of order
Smara	RO	Brackish water 330 m^3/d	1986	Out of order since 1994
Boujdour	RO	Sea water 800 m^3/d		1se phase
Boujdour	RO	Sea water 2400 m^3/d		2nd phase
Laayoune	RO	Sea water 7000 m^3/d 6000 m^3/d	1995 2005	1st phase 2nd phase
Tarfaya	RO	Brackish water 800 m^3/d	2001	
Tan Tan	RO	Brackish water 1700 m^3/d	2003	
Total production in operation		20 000 m^3/d		
Projects				
Agadir	RO	Sea water 44000 m^3/d 2d phase 44000 m^3/d	1ste phase for 2010	In Tender phase
Laayoune	RO	Sea water 13000 m^3/d	Extension 2009	Consultation in progress
Tan Tan	RO	Sea water 90000 m^3/d		In the pipeline

Box 4 Desalination project of Agadir

Agadir is a big city with a current population of about 800000 inhabitants. The region reports a significant socio-economic development connected mainly with tourism. Several tourism facilities are either under construction or planned. The groundwater resource is steadily on the decrease (estimated as about 5%/year); the current flow is maintained based, every year, on new drillings. The annual volume regulated by the dams is set to report a fall during drought years. It is, therefore, proposed to resort to sea water desalination, with a concession of the BOT type (Build – Operate – Transfer). The concessionary will be responsible for the design, construction, operation and maintenance of the structures. It must ensure a specified water production in compliance with quality standards and a specified production cost of the m^3 produced. ONEP guarantees the purchase of the contractual water production.

Source: Meeting with ONEP (National Drinking Water Authority)

3.3. Tunisia: Brackish water and renewable energy

Tunisia is in a situation of water shortage, with increasing tensions. Several major drinking water transfers are in operation. An increasing portion of the water resource is brackish, with a deterioration of the country's aquifer reserves, as 50% of the mobilisable water resources have a salinity rate exceeding 1.5 g/l. The Tunisian government thus considered, as from the 1980s, the option of brackish water desalination. Four main plants were installed in the regions of Kerkennah, Gabès, Djerba and Zarzis and ensure the desalination of 60000 m^3/d, out of a total capacity of about 100000 m^3/d.

To continue to improve the quality -and the quantity- of drinking water, a national desalination programme was decided. Within a first phase, the objective set is to reduce the salinity of the water distributed throughout the country to 1.5 g/l in the regions where the latter exceeds 2 g/l. To this end, ten brackish water desalination plants will be installed, with a aggregate capacity of 40000 m^3/d, in the regions of Kébili, Douz, Souk El Ahad, Tozeur, Nefta, Matmata and Béni Khedache. Within a second phase, a programme of five plants will desalinate sea water in regions where the water reserves are limited. Thus, on the island of Djerba, it is provided to install a desalination plant of 50000 m^3/d.

To secure drinking water supply to the Southern regions, SONEDE (National Water Distribution Utility) projects to construct five sea water desalination plants for a total capacity of 250000 m^3/d and an investment of about 300 million dinars at current prices (180 million euros). According to Mr. Mohamed Zaara, Director of Desalination and the Environment, the resources mobilized for the island of Djerba will be short of meeting the consumers' needs by 2010. These will be followed by the plants of Zaarat (for Médenine and Gabès in 2011-2012) and those of Sfax (three plants in 2015, 2020 and 2025)."

To reduce the cost of desalination and to save energy, the State plans to resort to **renewable energies** for brackish water and sea water desalination, and this for three projects already identified:

- solar photovoltaic energy for the plant of Ksar Ghilane, 2 m^3/d;
- solar energy for 45 new desalination plants, due to be commissioned in 2011 in the Southern regions, of which Médenine, Tataouine and Kébili;
- by way of pilot experience, wind energy in one of the brackish water desalination plants of the Governorate of Kébili.

Tunisia already has on its territory several ongoing pilot projects, as well as show-case facilities, such as that of **Borj-Cédria**. (Cf. paragraph on "Training")

Besides, France and Tunisia signed on 28 April 2008 a partnership framework agreement in civil nuclear power for a 20-year time period. Among the fields involved in this partnership, mention is made of energy and sea water desalination.

3.4. Jordan: Wind energy under study for desalination

A wind-powered reverse osmosis desalination system is proposed, with a simulation study involving eight various sites in Jordan, according to the data on wind velocity and the salinity of the water intended for desalination. It has been found out that the sites of Hofa and RasMuneef are the most suitable for reverse osmosis desalination based on wind energy (they provide 57 % of the water volume of the whole eight sites). The second set of sites is "promising" but average (sites of Safawy, Twaneh and Tafila, providing 30 % of the total desalinated water of the 8 sites). The third set is poor (sites of Jurf AlDaraweesh, Aqaba and Shoubak, providing only 13 % of the total water volume).

Le chapitre qui suit a pour objectif d'analyser dans quelle mesure l'utilisation des énergies sans émissions de CO_2 est possible dans ce domaine.

The following chapter aims to analyze in which case the use of CO_2 emission free energies is possible in this area.

V. CO2 EMISSIONS-FREE DESALINATION: IS IT POSSIBLE?

Stock-taking in the Mediterranean countries reveals a high growth of current and future desalination. Indeed, desalination is already perceived as a possible measure of adaptation to the impacts of climate change on water resources.

However, the future challenge for these countries will be, on the one hand, not to foster CO_2 emissions via this high energy consuming adaptation option and, on the other hand, not to promote non sustainable energy and water production and consumption patterns.

A possible response requires the improvement of energy efficiency in this sector and the recourse to non CO_2-emitting energies (renewable and nuclear energy). The latter point is analysed in this part. Solar energy has already been tapped in thermal and photovoltaic facilities; wind energy is interesting in windy coastal areas (Gibraltar, Red Sea…), and nuclear energy is under study in some countries.

1. DESALINATION BASED ON RENEWABLE ENERGIES: A REAL POSSIBILITY TO BE TAPPED AND GENERALISED

1.1. Assets and constraints:

The large solar and wind energy potential of the Mediterranean countries can be harnessed to desalination, without carbon emission. However, the use of renewable energies for conventional desalination is hampered by two constraints: their high cost and the discontinuity of the production (regular day/night alternation, for solar energy, and climate risks, for wind energy).

- To circumvent the former constraint, the use of high energy performance desalination processes is imperative. The reverse osmosis process, using electric or mechanical power exclusively, presents the highest performance from a energy point of view (2.5 to 3 kWh/m^3 in the case of sea water).
- As to the latter constraint, there is a need for a energy storage or for a connection to the network.

On a global level, approximately a hundred desalination plants associated with renewable energies have been constructed over the past twenty years. The majority are small-size experimental or show-case installations (0.5 to 200 m^3/d). Several are located in the Mediterranean (Egypt, Algeria, Tunisia). They operate with a storage of energy by batteries, incurring high costs (limited lifetime, energy losses) and suffer from a lack of local skill, especially for maintenance.

However, experience shows that small capacity, solar and wind desalination plants, when they are well designed and operated, can help supply isolated sites in good quality water, at costs that are, henceforth, interesting. However, in order to avoid operation difficulties over time and to ensure good maintenance and sustainability, the installations must be as simple and as reliable as possible.

1.2. Two examples of wind energy harnessed to desalination:

In Australia, in Kwinana (near Perth), a new large-scale desalination plant of 200 000 m^3/d, commissioned in 2007, is combined with a wind power station which produces, in "green energy", the annual equivalent of the electric energy consumed. The desalination plant consumes a basic 20 MW of electricity, and 50 MW of wind power were installed (48 aero-generators, at the wind farm of Emu Downs, to the north of Perth). There is, therefore -in equivalent energy-, no additional carbon emission due to the sea water desalination of the Perth plant.

In Spain: **Grande Canarià Montana Pelada :** In Gáldar-Gran Canaria, the desalination plant (Agragua Ltd.), commissioned in 1990 and extended in 1998, has a capacity of 15000 m^3/d and an estimated annual consumption of 25000 MWh. The wind farm, studied and financed by IDAE, commissioned in March 2001, has a capacity of 4.62 MW, comprising 7 aero-generators of 660 kW and an operation equivalent to 2900 annual hours. The energy produced is mainly "self-consumed" for desalination purposes, with a balance supplied by the power network.

Various wind energy projects are under study for desalination purposes, in the Red Sea, in Jordan, in Tunisia (Governorate of Kébili).

1.3. Solar energy: Photovoltaic and thermal, a resource in need for further tapping

Association of solar energy with reverse osmosis

Solar photovoltaic energy has been quite widely used, and for a long time now, for water pumping. For instance, on the Site of El Hamrawin in Egypt, a facility was commissioned in 1981, using the mechanical energy of thermodynamic Sofretes solar pump, now replaced by a photovoltaic generator.

On the other hand, as regards desalination, few are the installations based on photovoltaic energy, no doubt owing to the high capital costs. It is, however, worth mentioning the Hassi-Khebi plant, in Algeria, based on reverse osmosis associated with a photovoltaic generator.

Solar thermal energy is economically more competitive, and there is already a significant number of installations in this regard.

Desalination by thermal solar distillation produces, from a few litres of water, up to 30m^3/d (a quantity allowing the supply of 60 l/d and per capita to a village of 500 inhabitants). There are solar distillers, especially of the greenhouse type, in the Mediterranean: in Greece, in Spain, in Tunisia. Tunisia envisages recourse to solar energy for 45 new desalination plants in the Southern regions, of which Médenine, Tataouine and Kébili. In Southern Tunisia, at the plant of Ksar Ghilane whose capacity is of 20m^3/d, a boiling-free water distillation technique seems to be quite suitable for solar energy or for the use of a low-temperature heat source.

The Technological and Scientific Pole of desalination by solar and wind energy **of Borj-Cédria (Tunisia)** is a platform for show-case, R&D and training actions, based on various technologies: greenhouse distillers by direct solar radiation, reverse osmosis, electro-dialysis, a 4 kW aero-generator for a wind velocity of 7 m/s, a 4 kWc photovoltaic generator with storage batteries. The objectives sought are various: training of Tunisian specialists in desalination, show-case actions on the ground, conducting R&D activities to resolve specific problems (scaling by silica, problems arising from hot water of over 70°C), socio-economic studies on desalination as alternative solution to the problem of drinking water, contribution in promoting a Tunisian industrial activity in desalination, with technology transfer.

Box 5 3MW Alambic

An interesting Alambic with high performances coefficient for the distillation of sea-water using low temperatures energy (such as solar, cogeneration…) has been developed by 3MW Society, (prototype of 2m^3/d under construction, around 20m^2 of surface plate in 250 liters volume, Optimum results at 85°C). This Alambic can distillate sea-water by using only low temperature heating (below 100°C).

Desalination and CSP: A promising potential

Concentrated Solar Power (CSP) would allow a large-scale use of solar energy for the production of electricity. The Concentrated Solar Power Desalination, MED-CSD project, BMU, German Aerospace Center, NERC Jordan, CNRST Morocco, NREA Egypt) belongs in this framework. A solar project is envisaged for Gaza, for the combine production of electricity and fresh water by desalination of sea water, a project that could be established in the coastal area on the Egyptian side of the Sinai peninsula.

The MED-CSP study sets to conduct a review of the technologies available and to select CSP and desalination configurations most suitable in technique for the Southern and Eastern Mediterranean Countries (SEMC) -while remaining cost-effective-, with a view to a transfer of know-how from

European partners to other Mediterranean partners. Feasibility studies will be conducted on hybrid water desalination combined with CSP, according to two technologies: in Egypt in Aqaba, CSP-distillation MED, and in Algeria, CSP-Reverse Osmosis, as reference plants for the design and feasibility studies in the participating countries.

2. DESALINATION AND NUCLEAR ENERGY: WHAT PROSPECTS ON THE MEDIUM TERM?

On the medium term, many experts hold that nuclear energy will have its place in the Mediterranean, by providing -without carbon emissions- a supply of kWh necessary for a very competitive and large-volume production both of water and electricity. There is a recurrent demand and there is an unquestionable political interest on the part of several countries from the Southern rim of the Mediterranean. In particular, Algeria, Libya and Morocco wish to have nuclear energy for desalination.

2.1. Mediterranean co-operation

Three nuclear cooperation agreements were signed, by late 2007, between France and i) Algeria and ii) Libya, and in April 2008, with iii) Tunisia.

CEA[8] is interested in the electricity -desalination linkage, and wishes to explore the possibilities for enhancing the output of reverse osmosis by reheating of the temperature of the input water, as well as the possibilities of dilution of the concentrates in the effluents from plants located on the coast. Cooperation work is conducted with North Africa (Libya, Morocco, Tunisia), with the hosting of engineer trainees in Cadarache and project studies.

2.2. Technique and costs

The distillation processes (MED and MSF) use primarily thermal energy; a coupling is necessary between the nuclear reactor and the desalination plant which needs heat. Reverse osmosis requires only electricity, without any particular coupling.[9]

In Kazakhstan, a desalination plant established in Chvetchenko (now Aktau), on the Caspian Sea, has operated thus since 1973 (fast, liquid sodium-cooled BN 350 reactor, 125 MW electric, 700 MW thermal). There are pilot installations in India, in Pakistan and in Japan (11 reactors) producing small quantities of water based on nuclear desalination, 110 000 m^3/d by distillation.

Plant designers have studied, in consideration of developing countries, multi-purpose reactors capable of electricity production and economical sea water desalination. Studies and seminars were

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[8] CEA: French Atomic Energy Commissionership.

[9] It is worth noting that the pre-heating of sea water before filtration in RO generates significant energy gains.

conducted, by IAEA, on "progress in nuclear desalination", by considering design, coupling, economy and safety of nuclear desalination plants.[10]

Energy needs: For the sake of information, in order to produce 300 000 m^3/d of desalinated water, the MED technique will require 520 MWth and 13 MWe, and the RO technique will require 40 to 50 MWe. It is, therefore, difficult to imagine a EPR reactor exclusively dedicated to sea water desalination. The assumption most commonly considered is to use between 5 and 10% of the reactor power to desalinate, with the remainder supplying the country's power and the Mediterranean power interconnection.

2.3. Competitiveness of nuclear desalination

Table 4 Cost in dollars of the m3 of desalinated water: Comparison between combine cycle gas turbine of 600 MWe and nuclear section PWR 900 (evaluated based on the DEEP software for Tunisia in 2005. (Source of data: IAEA-ECA).

Power installation	MED distillation	Reverse Osmosis (RO)
CC-600	1,64 $/$m^3$	0,89 $/$m^3$
PWR 900	0,89 $/$m^3$	0,61 $/$m^3$

(Source: IAEA-CEA)

Desalinated water in Reverse Osmosis mode is the most competitive in all cases, and even markedly less expensive based on nuclear energy, at 0.61 $/m3, that is about 0.4 €/m3. (The variance is, obviously, markedly greater in favour of the nuclear PWR, with an oil price in the range of 100 US$ per barril or more)[11]

Table 5 Advantages and drawbacks of nuclear energy

Advantages of nuclear energy	Drawbacks of nuclear energy
Economic competitiveness	High investment
Environment protection, no emissions of SO^2, NO^2; no CO^2 and GHG emissions	Public acceptance: nuclear waste, safety, psychological aspects …
Stability of kWh price over time	Need to set up an administrative and legal framework
Increased energy independence	Size-measurement problem, Need for a sufficient-capacity and well-interconnected network
High value added in the country using it	Long time-duration for choice of the sites, training of the staff, safety issues, construction

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[10] The DEEP (Desalination Economic Evaluation Programme) of IAEA analyses nuclear desalination and provides a preliminary estimate of the cost of nuclear desalination as compared with conventional desalination. DEEP: http://www.iaea.org/programmes/ne/nenp/nptds/ndesal/index.htm

[11] Il faut garder à l'esprit que toutes les simulations de prix du m^3 d'eau dessalé sont très sensible au coût de l'électricité, qui n'est pas homogène selon les pays, et moins cher dans certains pays pétroliers.

3. COLLECTION AND ADDITIONAL TREATMENT OF WASTEWATER IN THE MEDITERRANEAN: AN INSUFFICIENTLY TAPPED POTENTIAL, AND DESALINATION-KINDRED TECHNOLOGIES

As a complement to the desalination of sea water and brackish water, it was deemed relevant, among the future options for improving the management of water resources, to mention **secondary treatment of wastewater**, a sector that is still little developed in the Mediterranean. Thus, in Malta, only two of the major hotels to have been equipped with desalination have taken this option of secondary treatment. This issue seems to us to be worthy of further consideration; indeed, recovery and secondary treatment will cost less in energy than a desalination of new sea water quantities. However, membrane-based technologies, of reverse osmosis and treatment, are closely allied, and the necessary skills, uses, and training requirements are complementary.

Training and technology transfer are essential for all aspects of recovery and secondary treatment of wastewater, for which membrane-based technologies are quite appropriate.

Box 6 Wastewater and direct or indirect drinking water production

As an example, it would be worth mentioning a plant for the reuse of wastewater in large-scale agricultural irrigation in Kuwait City, of 375 000 m^3/d capacity.

The scheme seeks to develop the recycling of “grey water” in buildings (treated by a membrane-based “bio-reactor”) and the recycling of wastewater in industry (for the development of paper mills, for instance). In certain cases, the recycled water may account for as much as 85 % of the total consumption.

Indirect production of drinking water based on treated wastewater requires intermediate storage in shallow aquifers, lakes or other natural reservoirs. This is a large-scale operational reality in the USA, particularly in California, where shallow aquifer recharge helps avoid their pollution by sea water intrusion. Such a practice is worth further study in the Mediterranean to protect the overexploited shallow aquifers, which tend to become brackish in coastal zones (Morocco, Tunisia, Libya).

An example of direct production of drinking water is that of the Windhoek plant, in Namibia, commissioned in 2002 and with a production of 20000 m^3/d. The process involves: preliminary ozonisation, coagulation-flocculation, sand and active charcoal filtration, and membrane-based ultra-filtration (Veolia Water Systems).

This potabilisation is less costly in energy and less GHG emitting than sheer desalination of sea or brackish water. It is, therefore, worth promoting.

However, **there are impediments** to the introduction of wastewater recycling for the direct production of drinking water; these are of three types:

- **technical**: physiochemical treatment of wastewater for purification and hygiene (bacterial or viral pollution) in order to secure the obtaining of the quality and safety standards desired; such impediments are nowadays easy to overcome without major difficulty;
- **economic**: the coupling of water treatments and physiochemical processes incurs capital costs and operating expenses, and requires the use of a skilled labour;
- **psychological and cultural**: often the most significant! Indeed, the population is not willing, at the outset, to use its wastewater, be it perfectly regenerated, for its consumption needs. This major aspect requires awareness-raising and information.

Indeed, many information and training actions are necessary.

VI. PROSPECTS OF DESALINATION-RELATED INDUSTRIAL AND ECONOMIC DEVELOPMENT

In the field of desalination and water treatment, which are interrelated, a significant industrial development is possible in the SEMC, subject to technology transfer, training and cooperation. Emphasis could be placed on decentralized Renewable Energies (RE).

To date, this has not been the case: the investments which are made are nothing more than a mere "turn-key" procurement of imported technologies, using a fossil type of energy.

1. ECONOMIC AND INDUSTRIAL FRINGE BENEFITS

The development of desalination in the Mediterranean can generate significant fringe benefits for the region, in terms of employment, development of industrial sectors, creation of services enterprises. These fringe benefits can vary appreciably according to the options selected for desalination (size of the infrastructures, type of energy).

Large-scale Inverse Osmosis desalination plants are today constructed under a "turn-key" arrangement, with little local manufacture. Technology hails from the developed countries of the North, hence the still relatively little transfer of technology and know-how from the European partners to the Mediterranean partners. The energy recovery systems are protected by sophisticated patents. The membranes are not manufactured in the Southern and Eastern Mediterranean Countries (SEMC), except for Israel, which develops significantly water-related technologies and where Israeli companies are competitive today for new exportation markets. Mediterranean cooperation remains limited, however, often for political reasons.

Besides, the institutional model of concession of desalination to a private operator, as investor - builder - operator under BOO arrangement, selected after international tender and often a non national, is often based on the only criterion of the lowest cost of the m^3 and does not prioritise technology transfer and the development of an industrial sector in the SEMC.

For all future investments in desalination and in water treatment in the SEMC, the guidance proposed should be to promote the development, in the SEMC and particularly in the arid countries for which proper management of water is crucial, of a true industrial fabric and water-related services.

The industrial development policies of the main operators serving in the field of desalination should be geared towards the use of water techniques on national level with the acquisition of know-how, if not exportation abroad.

There is an economic and strategic interest in sustaining the development, in the Southern and eastern Mediterranean Countries (SEMC), of a technological sector resting on sustainable production methods, in particular for small size desalination facilities in arid areas, not using state-of-the-art technology. This is especially the case of decentralized RE projects, using thermal solar energy. For example, the low-temperature thermal distiller of the 3MW company could be manufactured in Mediterranean countries with rustic and adapted materials (plastic film, local assembly). (Cf. paragraph 3-1-3-2 on Solar Thermal, further down)

The needs of the SEMC in terms of research & development, investments and training, related to desalination, are considerable, particularly in the field of water management, and in matter of training in membrane technology and secondary treatment of water. To this end, schools of engineers, universities and training centres must be put to service. Tunisia, Morocco and Israel are keen in this regard.

A true industrial strategy, thus, needs to be deployed in the field of water treatment, (for example: membrane-based technologies, energy efficiency, solar thermal distillers…).

Herein lies a very important stake, and a long and exacting task needs to be undertaken in partnership with the SEMC, facilitating technology transfer and training for job creation.

One of the possible further actions issuing from this study could be to pursue work on desalination and reuse of wastewater, in a spirit of industrial development in the field of water in the Mediterranean.

An inventory of the know-how and needs in the SEMC, in terms of equipment and maintenance services, for the technologies, and of the professions related to water treatment, pumping, abstractions and irrigation, must be conducted with a view to a true industrial project, for which there will be complementarity between the two rims of the Mediterranean. (Cf. Chapter 7, criterion n° 5, further down).

2. EMPLOYMENT, TRAINING AND HUMAN RESOURCES, FOR WATER-RELATED PROFESSIONS

The management of fresh water is a very important sector in the Mediterranean, but technicians, managers and operators are still often too few. The initial training of technicians and administrative staff is often more theoretical than really practical, and that of farmers and irrigation operators needs to be developed. Vocational training remains to be organized. It is, therefore, necessary to train a skilled labour in the SEMC, in proper water use, membrane technologies, preliminary treatment and physiochemical treatments for problems of furring up, fouling of exchange areas, deposits and clogging, and corrosion, as well as operating conditions, pressure, temperature, water velocity, type of pump and size measurements, cleaning, filtration…

Show-case platforms, such as that of Borj-Cédria, technological pole in Tunisia, must be used for these training and awareness-raising actions, particularly in scattered and semi-arid rural areas for decentralised solutions based on renewable energies.

Training and information can help overcome resistance of a **psychological and cultural** nature, which often represent impediments to a sustainable use of recycled water. Such aspects must be mainstreamed in training, including for purposes of sensitising the public at large, or in school curricula.

VII. DESALINATION AND ADAPTATION TO CLIMATE CHANGE: CONCLUSIONS AND RECOMMENDATIONS

In conclusion, it seems worthwhile to underscore the fact that certain options in matter of desalination may lead to “vicious circle” scenarios. By way of recommendations, we have elected to put forward a certain number of criteria for consideration when taking investment decision in the field.

1. A DISASTER SCENARIO?

In view of the water shortage looming ahead for the Southern and Eastern Mediterranean Countries (SEMC), is desalination an easy way out, a costly and short-term solution, to provide fresh water for the richest, but at the risk of a potentially “disaster” scenario, or rather a solution likely to exceptionally be described as sustainable?

A water energy scenario in the Mediterranean that needs to be absolutely avoided would be of the following type: a country invests massively, via international donors, in desalination plants; the energy consumption ensuing therefore soars, and so do CO_2 emissions. The desalinated water -in order to be optimised on the international market- is used massively for off-season crops, on the one hand, and for bio-fuel dedicated crops, on the other hand. The country, having not developed an industrial strategy related to desalination, finds itself obliged to always import more equipment and maintenance services. Moreover, it is dependent on the fluctuations of the international prices of this equipment (itself being partially dependent on the prices of raw materials, as well as on demand). Owing to the energy requirements of the desalination plants, its energy bill grows heavier; and the country, if it is an importer, increases its trade deficit, and, if it is an exporter, increases its loss of earnings… The whole range of these liabilities is not fully compensated by the development of bio-fuels, land for traditional farming grows scarce, and imports of foodstuffs soar… Internal tensions between the users increase…

That was a loser-loser scenario, but which is by no means improbable, if one were to accumulate the implementation of short-term easy solutions… The consequences for climate change are quite bad: increase in GHG emissions, depletion of hydrocarbon resources, shrinkage of land resources, etc.

Thus, desalination is not in itself an option compatible with the objectives of sustainable development; it is an alternative of adaptation to climate change when all other "sustainable" possibilities have been exhausted.

It should be limited to the production of drinking water for human consumption, and could use low-consumption technologies, supplied by non CO_2 transmitting renewable energies. It is worth highlighting, as a non desirable example, the construction of two desalination plants in Spain, of over 100000 m^3/d for the irrigation of off-season greenhouse crops.

It often seems easier for decision makers to act on the water supply side, by increasing the production, than to act on the demand side. The deployment of policies of rational water use (including incentive pricing), liable to reduce losses and curb misuse, constitutes the first response vis-à-vis the underlying (trend-based) increase in water demand and the aggravation of shortages.

The progress made with regard to inverse osmosis is a real promise for water-scarce countries, for desalination but also for all wastewater treatments using membrane-based technologies. However, whatever the technique selected, it is investment intensive and costly both in terms of maintenance and of environmental impacts.

Accordingly, the sea water desalination technique should be considered on a case by case basis, as a component of a diversified mix of water resources, according to each situation and according to a comprehensive approach encompassing the combined needs in water and electricity, in order to minimize the costs, energy expenditure and environmental and climate impacts. To this end, there is a pressing need for training in "good management of water resources", as well as for technology transfer in all Southern Mediterranean countries.

Euro-Mediterranean co-operation could play a significant role in this context, in information, promotion and transfer of best desalination technologies and of criteria of excellence in energy and environment, in training and preparation for the future for water related employment and professions, in assistance with the establishment of partnerships for the development of a true industrial project, for which there is complementarity between the two rims of the Mediterranean.

It could also participate in the dissemination and discussion of the criteria proposed to enlighten investment decision making, as outlined hereinafter.

2. WHAT REFERENCE CRITERIA TO AVOID A DISASTER SCENARIO VIA SEA WATER DESALINATION?

This part aims at putting forward a set of criteria that seem to be the most important in avoiding the "infernal spiral" scenario described above.

The environmental guidelines proposed seek to clarify, for the water sector, a set of environmental assessment criteria for large-scale projects which investors are called upon to finance. In a manner analogous to the procedure commonly used for dams, they identify the main factors of environmental impacts of a given project and identify criteria into several categories: Reference Criteria, Recommended Criteria and Best Practices Criteria.

When these criteria are fully observed, the project is regarded as acceptable on the environmental level. Failing that, its acceptability is appreciated on a case by case basis, according to the specificities of the project. If need be, the operation envisaged can be subject to the implementation of mitigation and/or compensation measures.

Best Practices Criteria specify the use, in a project, of the best technologies available, or of practices particularly worth promoting.

The environmental impacts are taken in the broad sense, including the GHG emissions due to electric or thermal power use, with its potential impacts on the climate.

They are supplemented by ***indicators*** which make it possible to compare projects in technical and energy performance, and their potential impacts on the environment (the relevance of these indicators can vary, however, from one project to another).

Criterion n°1: Justify the need for and the opportunity of a desalination project

Justification and appreciation of water needs in each case, demonstrate that a project of new desalination plant is actually the best solution.

Desalination plants must be constructed only when they have been proven to be the most efficient and least harmful solution to supplement fresh water supply, following an in-depth and transparent process of evaluation of alternative solutions and of their environmental, economic and social impacts.

There must be justified, for each project in its local and regional context, that there are not any less costly, better or complementary means to provide water, nor any that are less risky for the environment. Each project must be validated by **a technical-economic and environmental study**, integrating water uses for agriculture, irrigation, industry, domestic and drinking water needs, secondary treatment and recovery of wastewater, cutting down leaks and wastages, appropriate and water-saving incentive pricing. Accordingly, the adverse impacts of a water desalination plant may prove to be less than those which would be induced by another non sustainable water supply method (irreversible depletion of fossil groundwater resources).

The cost-benefit balance must be studied in each specific case. It is recommended to consider the analysis of alternatives, other water resources, and the use of renewable energies.

Criterion n°2: Choice of an operation method maximising avoidance of the negative impacts

This criterion seeks to ensure that the project meet an optimal energy and environment objective and actually belong in best practices.

To this end, it is useful to develop indicators in order to compare the various options, in particular:

- **Consumption of primary energy and electric energy per m^3 of water produced:** The indicator can also present the quantity of carbon emitted per m^3 of desalinated water, in CO^2 and GHG equivalent;
- **Promotion of excellence in energy use**, and of most energy saving technologies (inverse osmosis with energy recovery or production combined with optimised cogeneration). Ratios of $3kWh/m^3$ of desalinated sea water, and markedly better ratios for desalinated brackish water, are usually obtained today in best performance installations. Significant improvements have already taken place in old desalination plants;[12]
- **Promotion and optimisation of carbon imprint-free energies:** renewable energies (wind, solar thermal), even nuclear and low-temperature energy recovery.

Criterion n°3: Implementation of a plan of environmental management of effluents, allowing best prevention of impacts and their minimisation to an acceptable level.

A preliminary analysis of the existing situation and of the sensitivity of the ecosystem downstream of the effluents is required for large-scale projects, within the framework of the environmental impact assessment study. For projects with potentially significant impacts, the implementation of an environmental management plan is necessary: Monitoring water quality downstream (temperature, oxygen and toxic pollutants content) and implementation of the measures likely to minimize the direct impact on the ecosystems due to brine disposal.

Criterion n°4: Appropriate compensation of the impacts that can neither be avoided nor minimized

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[12] In Malta in particular, to be advanced as an example of best practices.

For very large-scale structures, special care must be granted to the more or less great reversibility of the major negative impacts. Insofar as the choice of the site and of the operation method is likely to generate significant impacts which can neither be prevented nor minimized, it is necessary to provide for an appropriate compensation of these impacts. Due care must be granted to the mediums and sensitive natural zones likely to be destroyed or degraded by the project.

Criterion n°5: Human and social aspect, job creation, training & human resources, technology transfer, awareness-raising among and information of the populations

Desalination projects must, inasmuch as possible, integrate significant fringe benefits in terms of employment, development of industrial sectors, creation of services enterprises and of new exportation markets.

It is important to prepare for the future, based on actions of training, transfer of expertise and technologies (membrane-related techniques, secondary water treatment, high energy performance technology) in order to train, in Mediterranean countries, a skilled labour force. Herein also lies a factor of integration and acceptance of projects, for good management and maintenance over the long term.

Sensitise and build awareness as to the fact that not only desalination, but also water pumping, abstractions and treatment are increasingly costly in fossil energy, with GHG emissions that must be optimised and reduced. It is necessary to exert pressure as to the need to improve the existing installations, including via an environmental awareness of the populations and of public opinion.

VIII. ANNEXE

Table 6 Large-scale desalination plants in Algeria

N°	Location	Capacity m^3/d	Population to be serviced	Forecast schedule
01	Kahrama (Arzew)	90 000	540 000	In operation
02	Hamma (Algiers)	200 000	1 333 320	In operation
03	Skikda	100 000	666 660	2009
04	BeniSaf (A.Temouchent)	200 000	1 333 320	2007
05	Mostaganem	200 000	1 333 320	2007
06	Douaouda (West of Algiers)	120 000	666 660	2008
07	Cap Djenet (East of Algiers)	100 000	666 660	2008
08	Souk Tleta (Tlemcen)	200 000	1 333 320	2008
09	Honaine (Tlemcen)	200 000	1 333 320	2008
10	Mactaa (Oran)	500 000	1 333 320	2011
11	El Tarf	50 000	333 330	2009
12	Tenes	200 000	999 990	2009
13	Oued Sebt (Tipaza)	100 000	666 660	-

Total Plants: **13**
Capacity m^3/d: **2 260 000**
Population : **11 873 220 inh.**

Table 7 Small-scale, single piece desalination plants in Algeria

Wilaya	Site	Municipality	Capacity m^3/d	Population to be serviced
Algiers	Champ de tir	Zéralda	5000	33 300
Algiers	Palm Beach	Staoueli	2 500	16 660
Algiers	La Fontaine	Ain Benian	5 000	33 330
Tlemcen	Ghazaouet	Ghazaouet	5 000	33 330
Tipasa	Bou Ismail	Bou Ismail	5 000	33 330
Skikda	L.BenMhidi	L.BenMhidi	7 000	47 000

Wilaya	Site	Municipality	Capacity m^3/d	Population to be serviced
Algiers	Champ de tir	Zéralda	5 000	33 330
Algiers	Palm Beach	Staoueli	2 500	16 660
Algiers	La Fontaine	Ain Benian	5 000	33 330
Tlemcen	Ghazaouet	Ghazaouet	5 000	33 330
Tipasa	Bou Ismail	Bou Ismail	5 000	33 330
Skikda	L.BenMhidi	L.BenMhidi	7 000	47 000
Tizi Ouzou	Tigzirt	Tigzirt	2 500	16 660
Oran	Bou Sfer	Bou Sfer	5 500	33 330
OranOran	Les Dunes	Ain Turk	2X2 500	33 330
A.Temouchent	Bou Zdjer	Bou Zdjer	5 000	33 330
A.Temouchent	Chatt el Ward	Bou Zdjer	5 000	33 330

IX. TABLE OF ILLUSTRATIONS