ΚΑΠΕ
CRES

MARE Project

22 – 23 February 2016, Athens

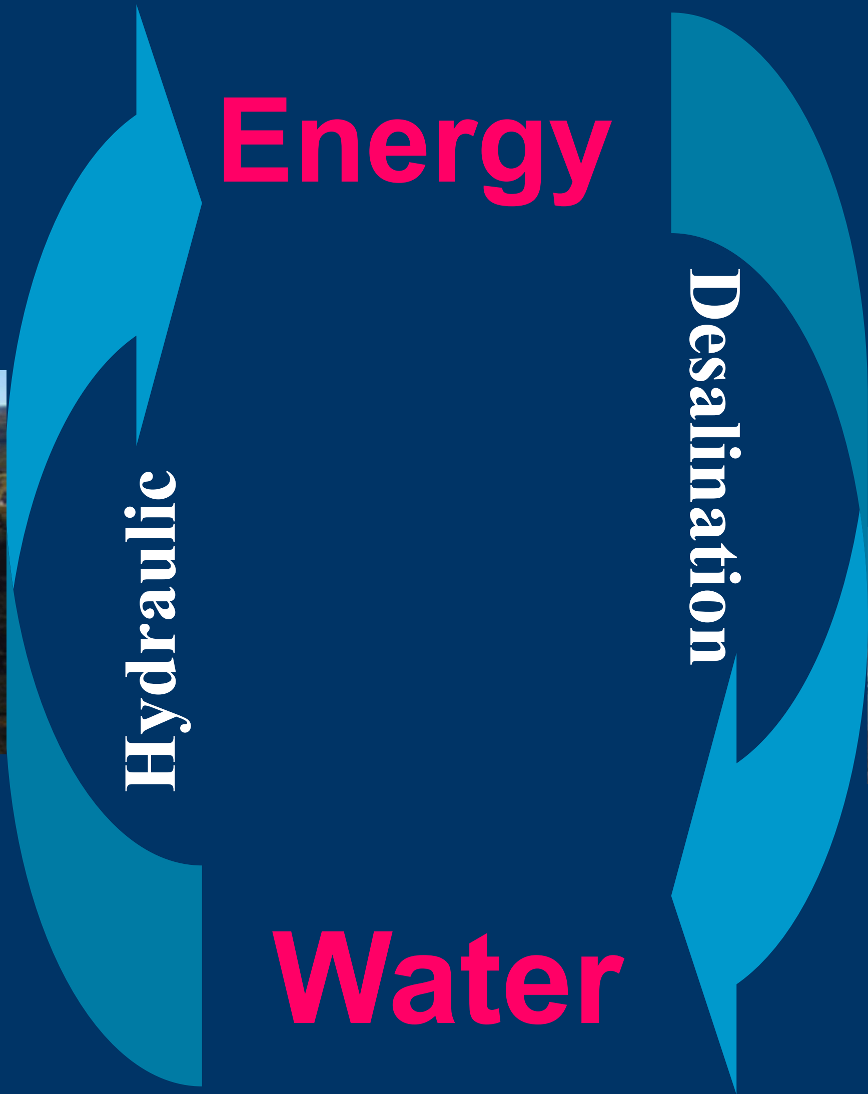
RES desalination trajectory in Morocco. Selected stations

Driss Zejli

-National School of Applied Sciences-
Kénitra

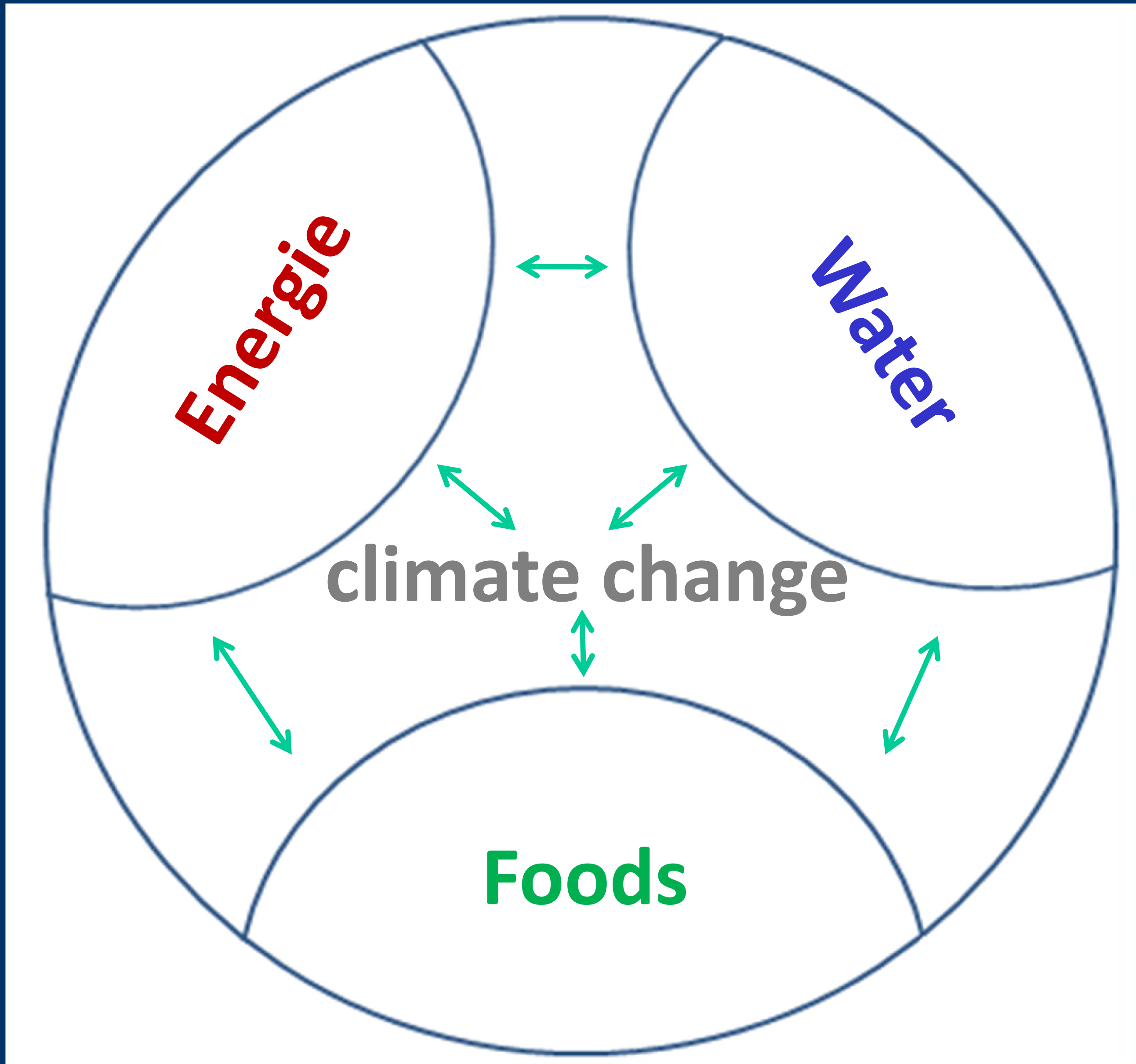
-Moroccan Society of Renewable Energy
Development (SMADER)

Energy – Water Nexus



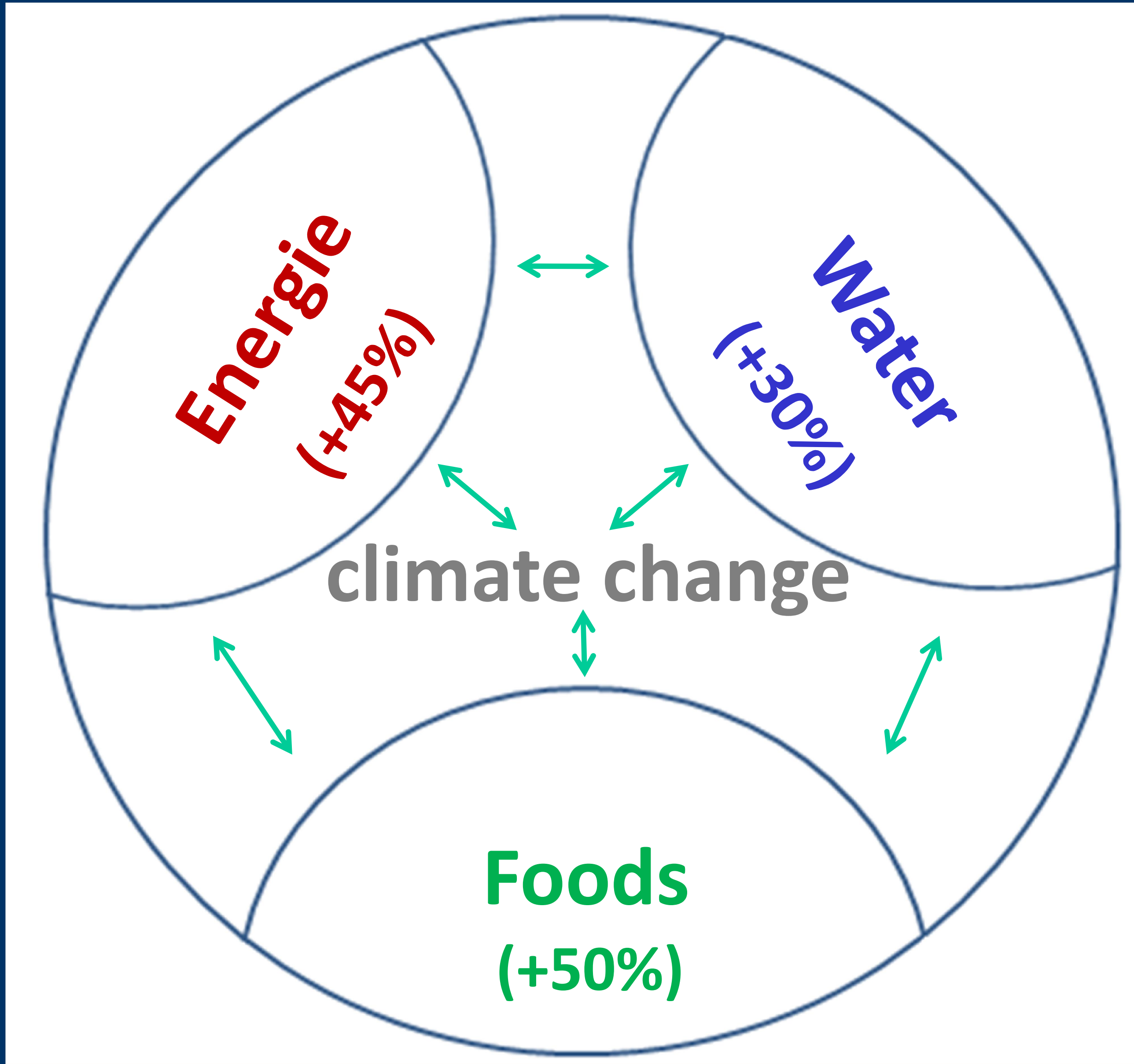
(B. Tardieu. GID Enjeux et défis de l'énergie, 22 Novembre 2007. Rabat, Maroc)

Energy, Water, Foods, Climate change Nexus



Energy, Water, Foods, Climate change Nexus

2030



Water problematic

Population growth

recurring droughts

How to adapt the mobilisation of water resources to

the requirements of economic and social development

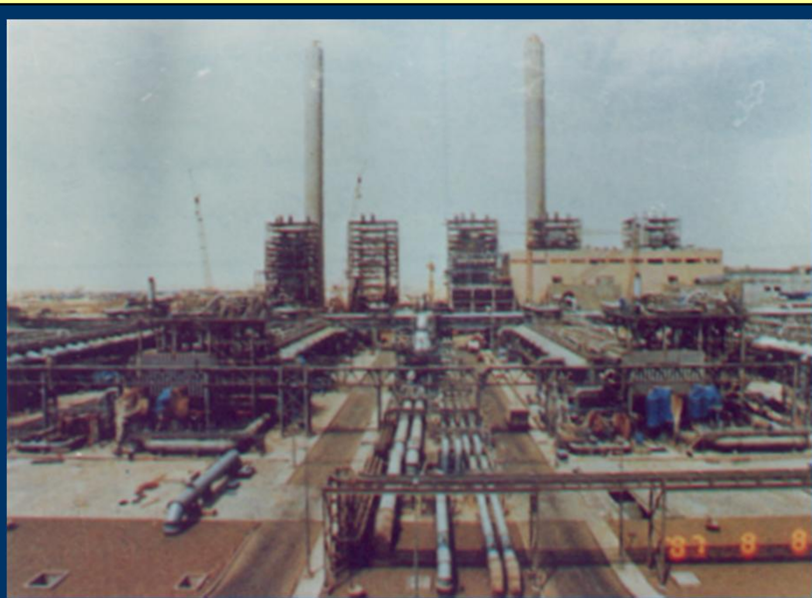
Urbanization, industrialisation

Growing needs of agriculture

Desalination technologies

Sea water desalination

Desalination technologies



High cost

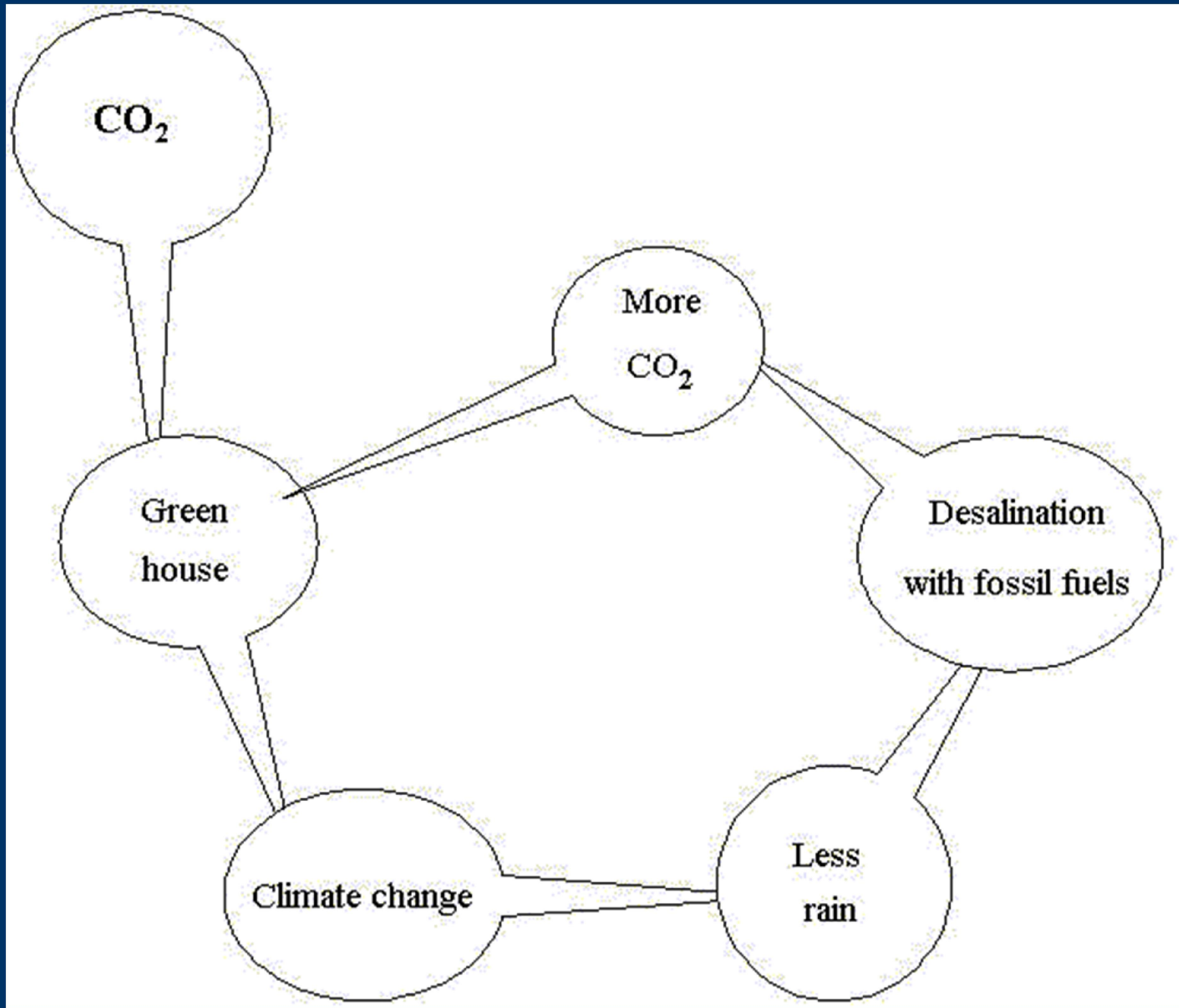
Sea water desalination

Desalination technologies

High cost

Incompatibility with the concept of sustainable development

The vicious circle of direct and indirect use of fossil fuels to power desalination



Which alternative for the current energy system?

The alternative should meet two necessary and sufficient conditions :

- The energy source should be inexhaustible

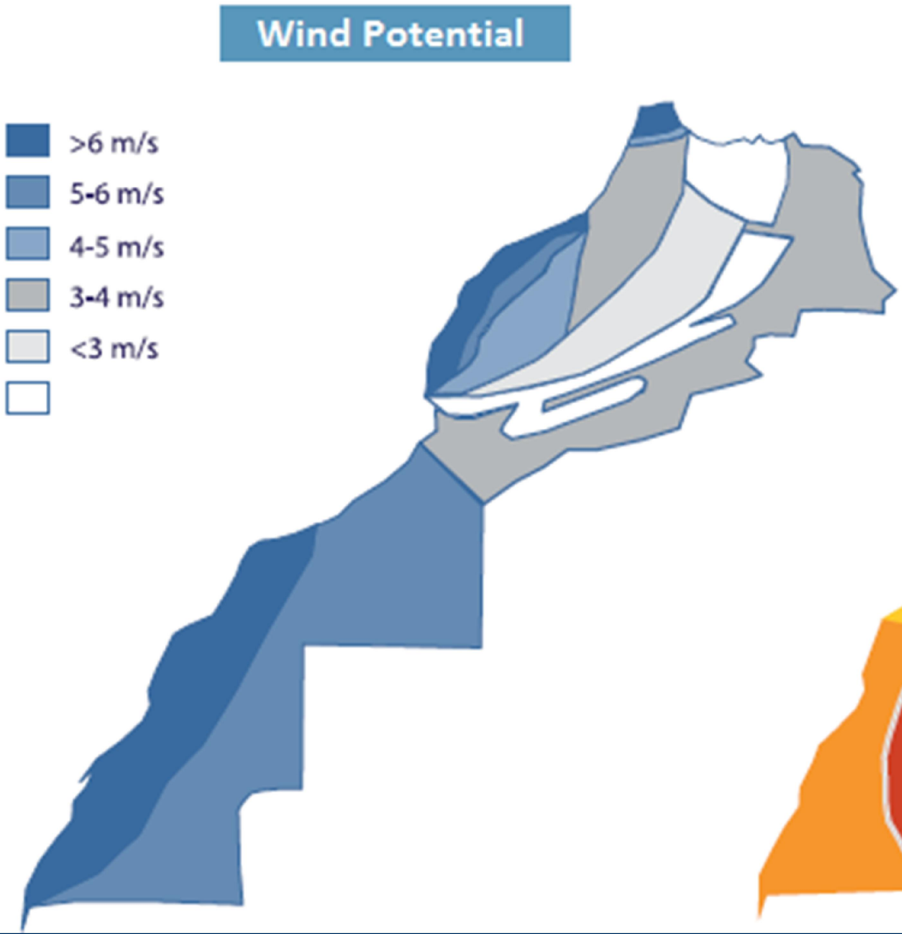
- The energy resource should be provided without support or with a recyclable support

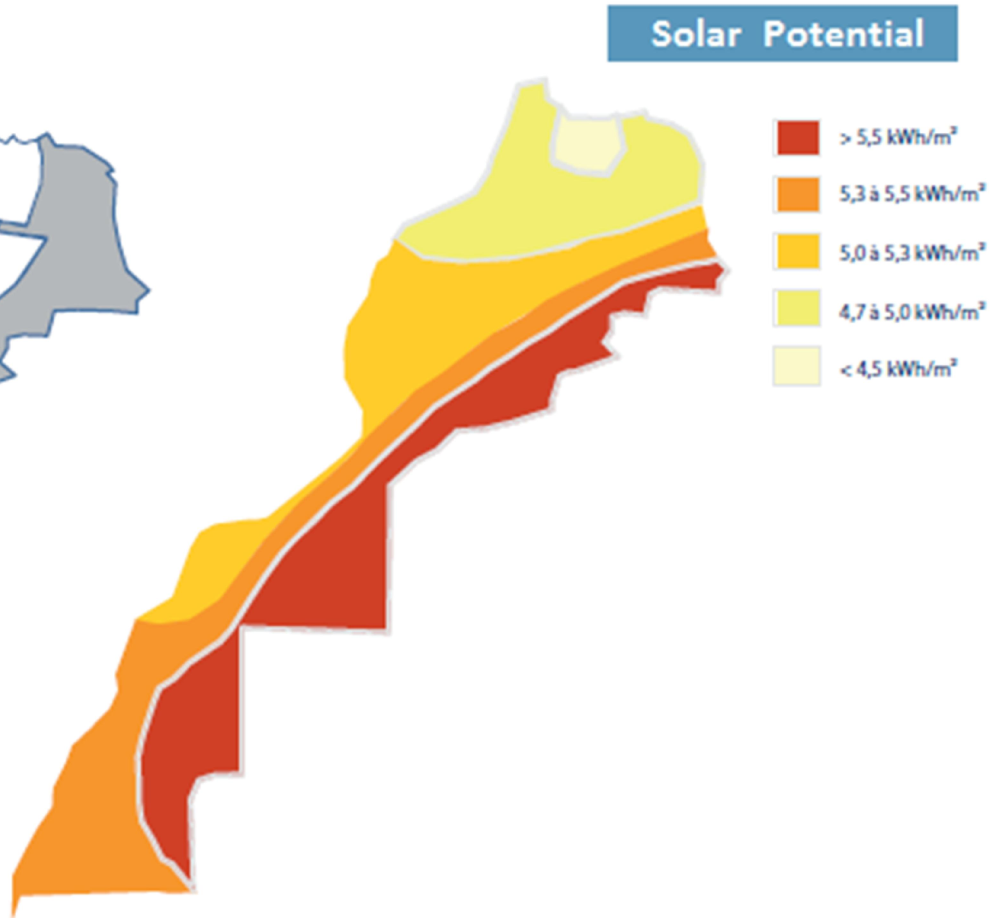
N O R T H A F R I C A

11,540 km
Coastline length

High Renewable Energy Potential

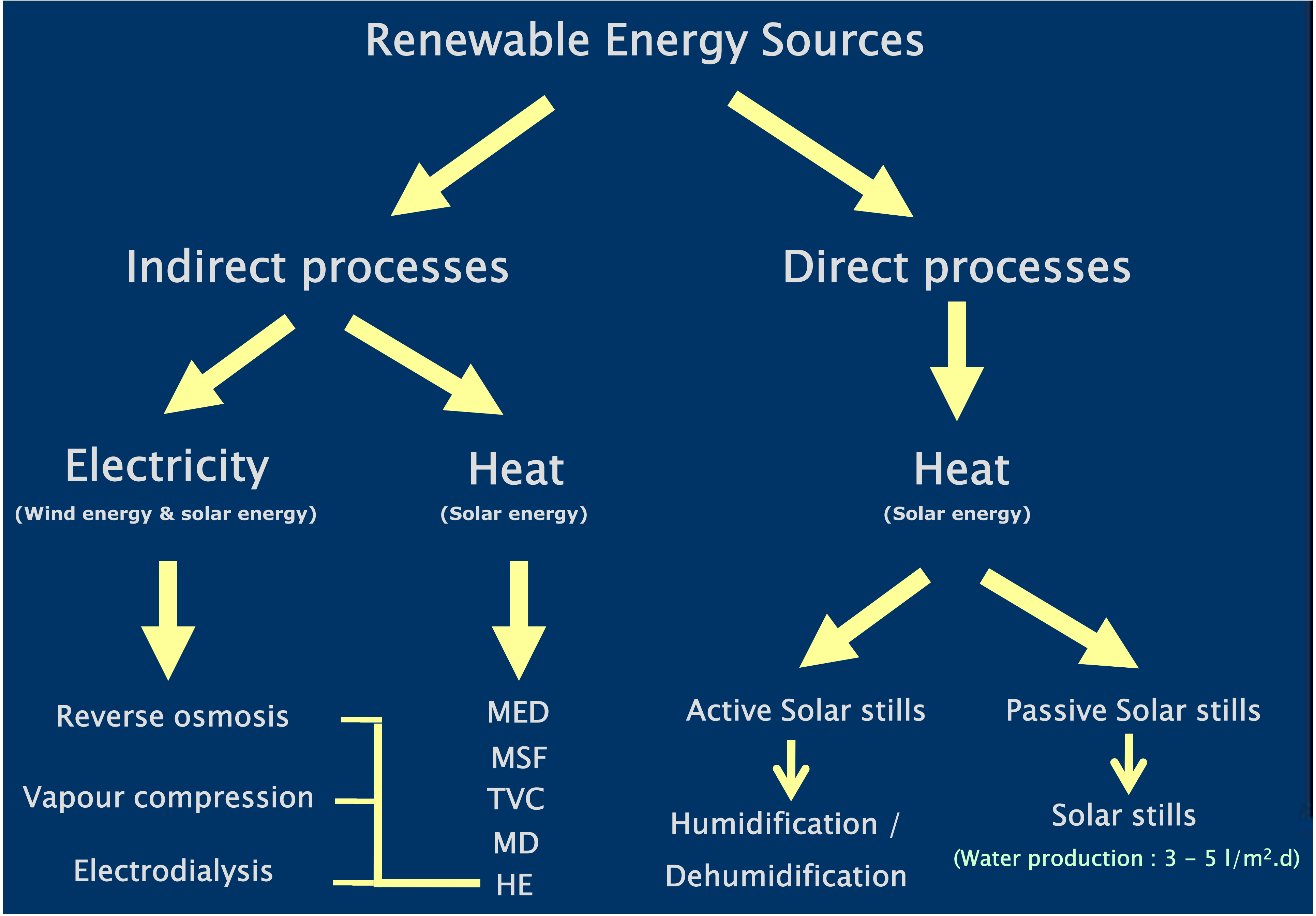
Neither water nor energy should be scare


Wind Potential
>6 m/s
5-6 m/s
4-5 m/s
3-4 m/s
<3 m/s


Solar Potential
> 5,5 kWh/m²
5,3 à 5,5 kWh/m²
5,0 à 5,3 kWh/m²
4,7 à 5,0 kWh/m²
< 4,5 kWh/m²

Urgent need to develop the renewable energy technologies

Renewable energy powered desalination



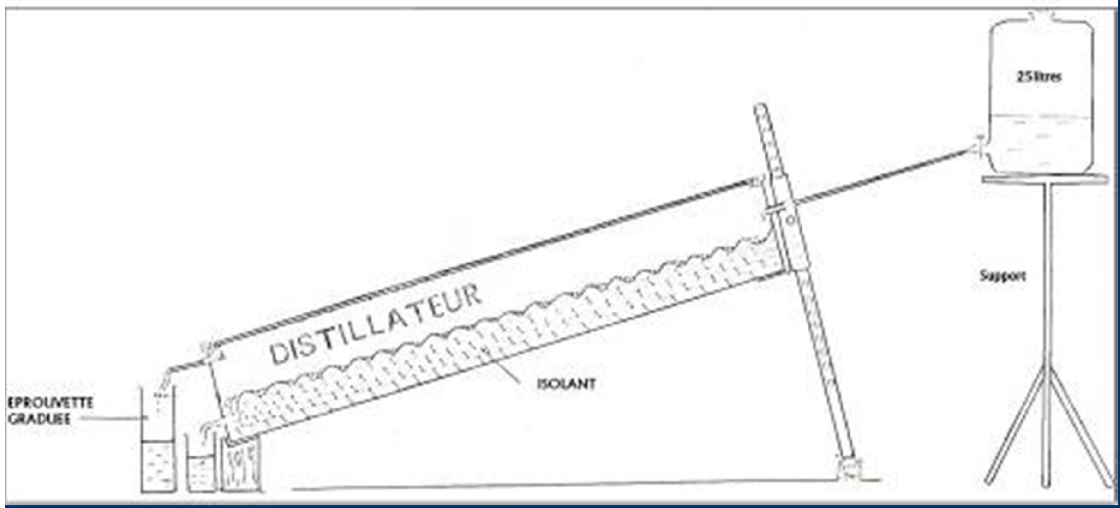
R&D IN THE FIELD OF RENEWABLE ENERGY DRIVEN DESALINATION SYSTEMS IN MOROCCO

Solar Thermal Desalination

Basic Solar Stills

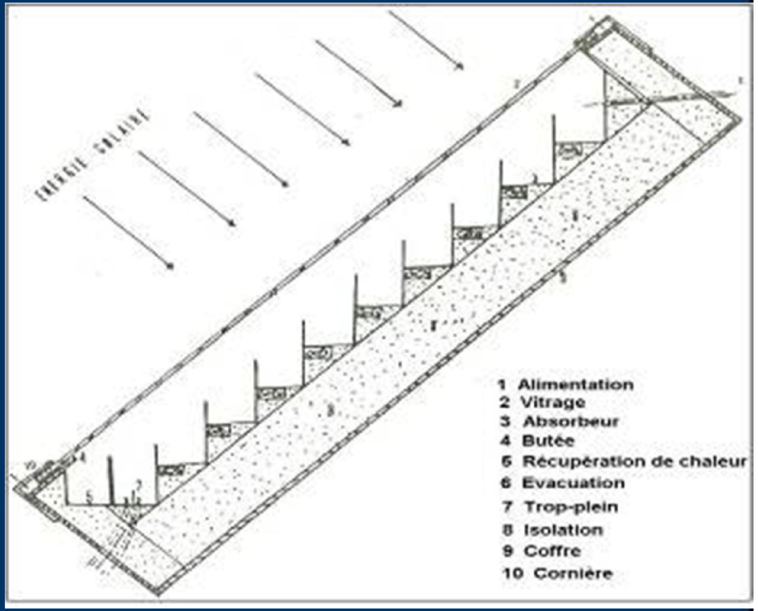
Hassan II Agronomic Institute

(1984 – 86)



Mohammadia School of Engineers

(1984 – 86)



The production: less than 5 litres/m^2.d

Basic Solar Stills

Heat consumption in solar still

~1.5 kWh/litre

0.7 kWh/litre → **Evaporation heat**

0.8 kWh/litre → **Heat losses**

For a daily global irradiation of 5.5 - 8 kWh/m^2 on an horizontal surface (South of Morocco)

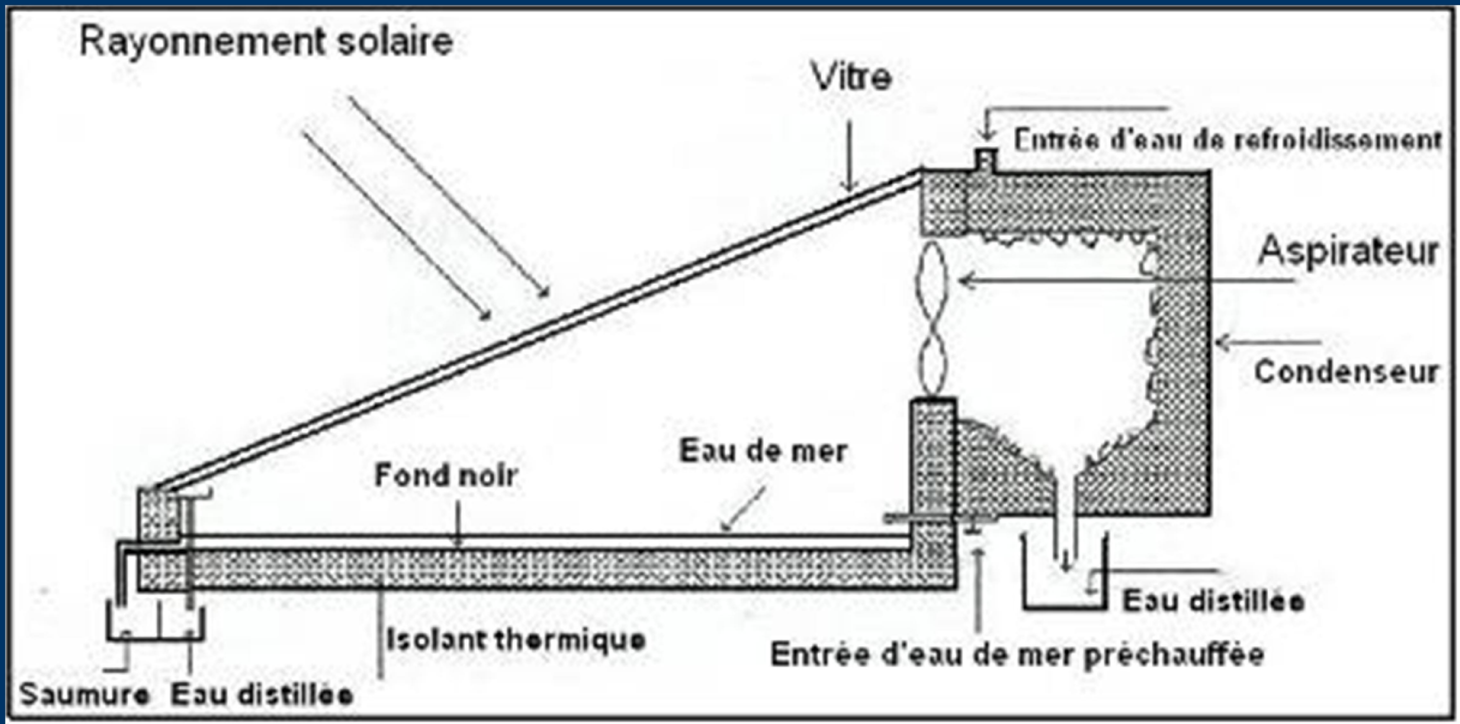
Production : 3 - 5 litres/m^2.d

Solar Stills Improvements

Examples of realization

University of Agadir

(2002 – 04)



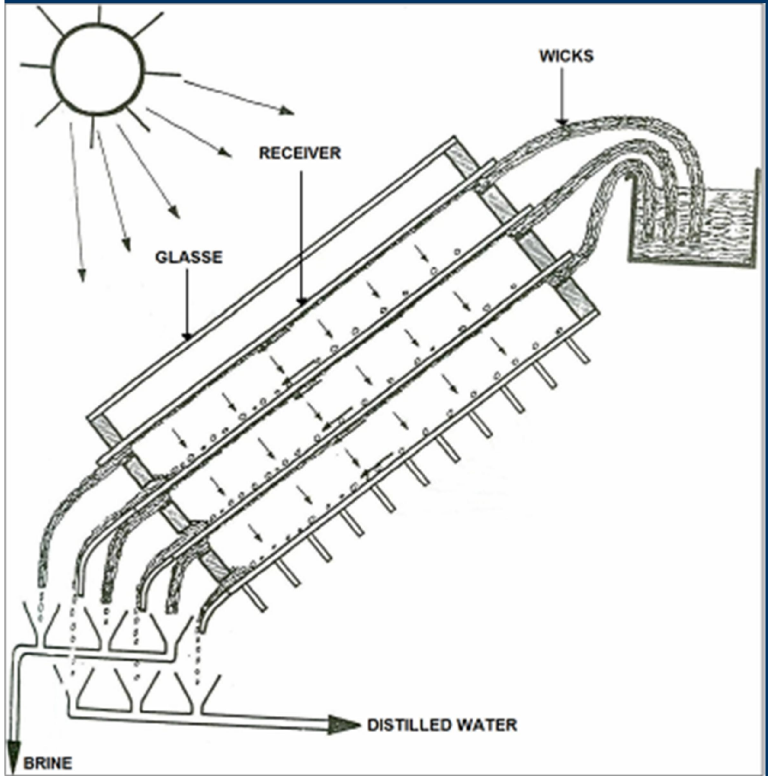
The production: less than 7 litres/m^2.d

Solar Stills Improvements

Solar stills with the recovery of the condensation latent heat into the water evaporation

Multi-Effect Solar Still

DIFICAP (ENCIC – Nancy)

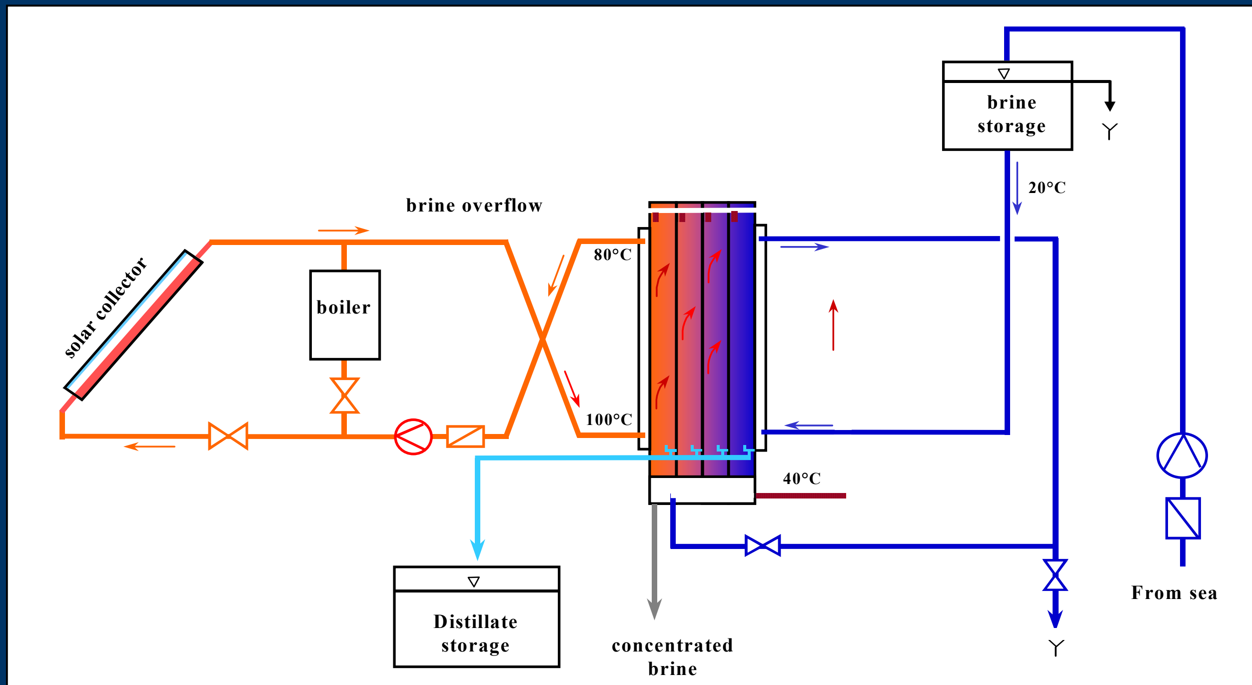


Un. Sc. Tech. Houari Boumediene (Algeria)	1986
Ecole Nationale d'Ingénieurs-Gabes (Tunisia)	1989
Ecole Supérieure de Technologie-Casablanca (Morocco)	1991
Research Centre on Solar Energy (Libya)	1991

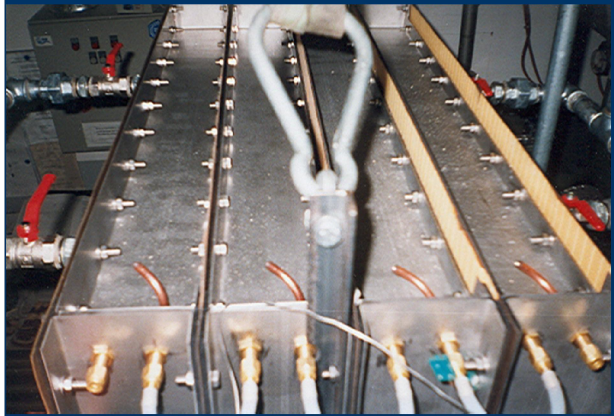
The production: less than 20 litres/m^2.d

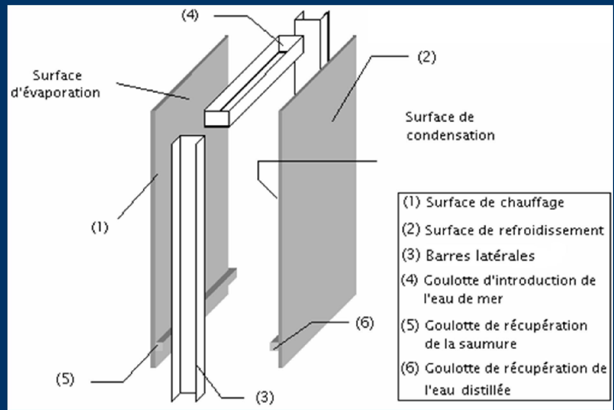
Solar Stills Improvements

Hybrid Fossil/Solar Heated Multi-Effect-Still in colaboration with the Centre for Solar Energy and Hydrogen Research (ZSW Germany) and the support of the Middle East Desalination Research Centre (MEDRC) (1999 - 2001)



The production: less than 20 litres/m².d



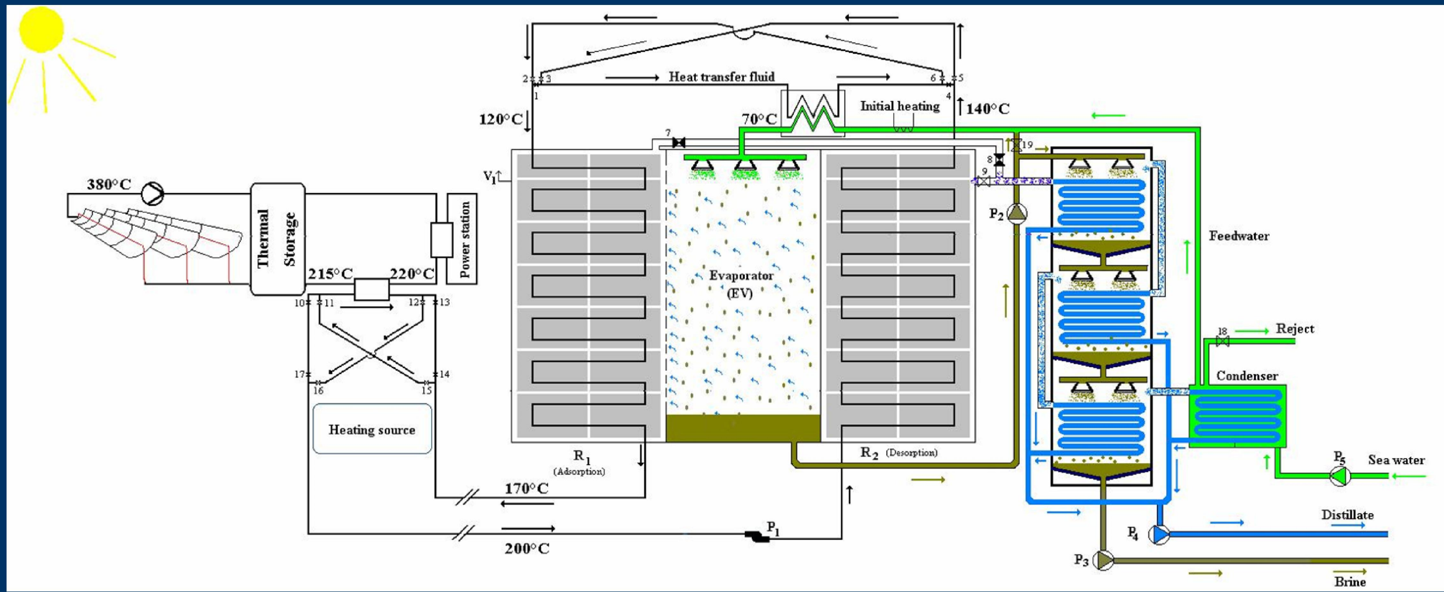

(4)
Surface d'évaporation
(2)
Surface de condensation
(1)
(5)
(3)
(6)
(1) Surface de chauffage
(2) Surface de refroidissement
(3) Barres latérales
(4) Goulotte d'introduction de l'eau de mer
(5) Goulotte de récupération de la saumure
(6) Goulotte de récupération de l'eau distillée

(1999)

Adsorption desalination

Design by TEER of an adsorption desalination system

(2000)



Total distillate water production per cycle	0.4 l/kg zeolite
Energy consumption	50 – 60 $kWh_{(th)}/m^3$

ELSEVIER

Desalination 168 (2004) 127–135

DESALINATION

www.elsevier.com/locate/desal

A solar adsorption desalination device: first simulation results

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[a]*National Centre of Scientific and Technical Research, 52, Ave. Omar Ibn Khattab, Agdal, BP 8027, Rabat, Maroc Tel. +212 (37) 77 40 99; Fax: +212 (37) 77 12 88; email: zejli@cnr.ac.ma*

[b]*Ecole Nationale de l'Industrie Minérale, Rabat, Maroc*

Received 12 February 2004; accepted 20 February 2004

Abstract

This paper describes a multi-effect desalination system operating with an adsorption heat pump with an open cycle and using zeolite as the solid vapor adsorbent. The water production and energy consumption of the system were studied using a theoretical model.

Keywords: Desalination; Solar energy; Heat pump; Adsorption; Zeolite; Heat regeneration

1. Introduction

For several decades desalination has been a solution to water shortages in numerous areas of the world, but desalination costs are too high and clearly beyond what developing countries can afford. In Morocco, the oil bill is a heavy burden for the economy of the country. On the other hand, the use of fossil fuels for energy for desalination procedures is incompatible with the goal of environmental protection and the fight against climate changes.

The abundance of renewable energies in Morocco is an excellent reason for one to be interested in the development of desalination technologies working with renewable energies. These can undoubtedly offer benefits in terms of environmental protection.

2. Description of the desalination-plant and its principle

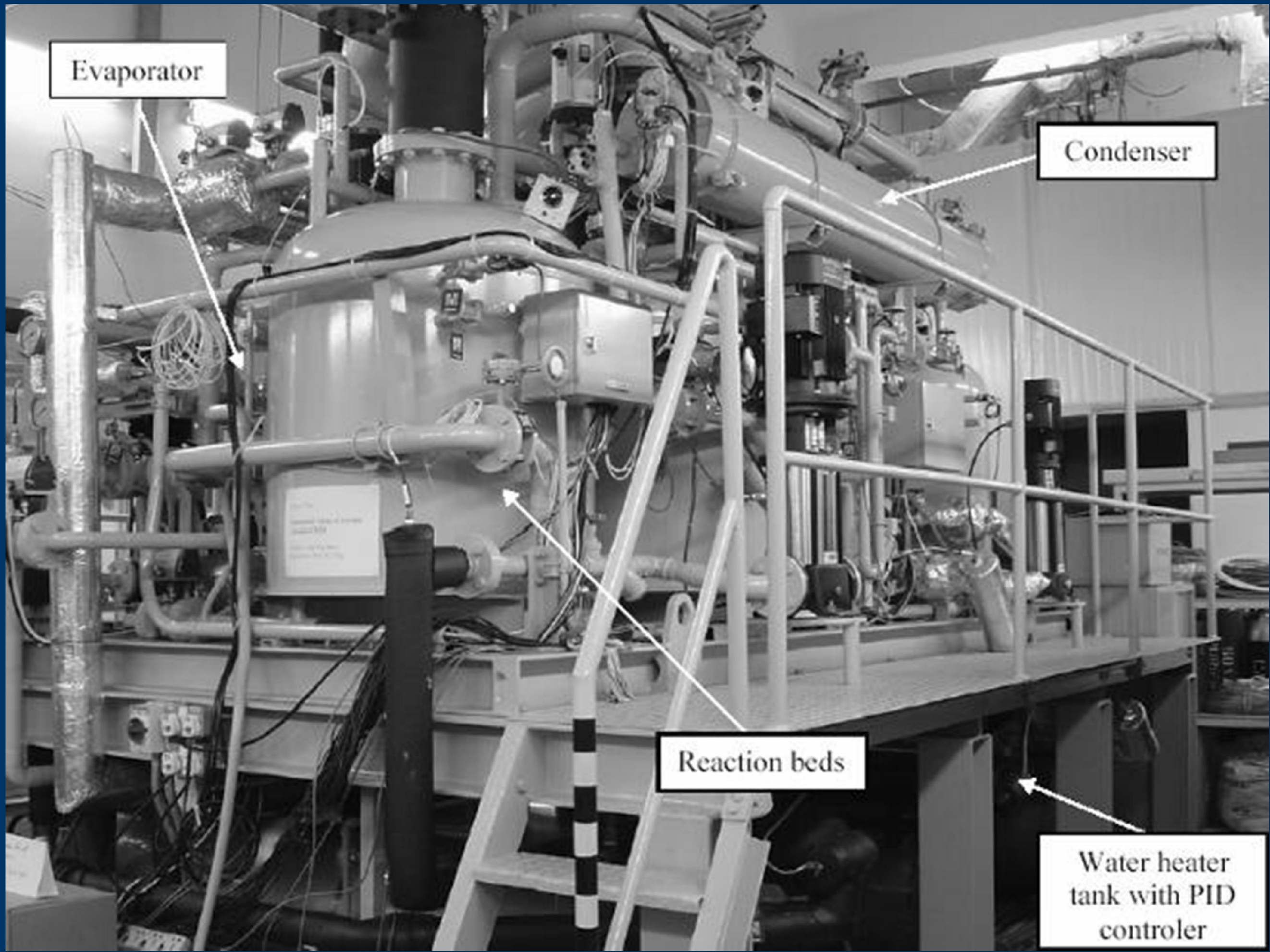
The desalination plant under study is a combination of a multiple-effect distillation system (MED) with an open cycle adsorptive heat pump using internal heat recovery, operating as a flash

*Corresponding author.

Presented at the EuroMed 2004 conference on Desalination Strategies in South Mediterranean Countries: Cooperation between Mediterranean Countries of Europe and the Southern Rim of the Mediterranean. Sponsored by the European Desalination Society and Office National de l'Eau Potable, Marrakech, Morocco, 30 May–2 June, 2004.

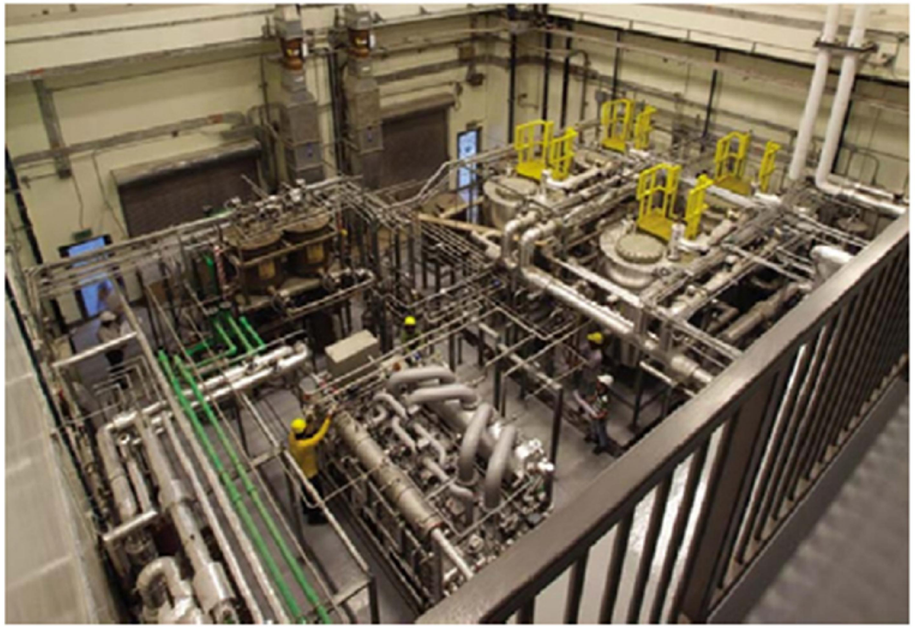
doi:10.1016/j.desal.2004.06.178

Adsorption desalination



Daily Production : 3.5 – 4 litres/kg Silica gel

(Source: Xiaolin Wang, Kim Choon Ng, Applied Thermal Engineering 25 (2005) 2780–2789)

485 m^2 of flat-plate thermal collectors	The AD plant is on the left-side and the hot water tanks are on the right side. The de-aeration and water collection tanks are situated on the top of the picture.
	

Pictorial views of the solar-powered adsorption desalination cum chiller plant at the King Abdullah University of Science & Technology (KAUST). A nominal water production capacity of 12.5 m3 per tonne of silica gel per day (85 °C for the heat source, 30 °C for the cooling water and 7 °C for the chilled water)

(Kim Choon Ng and al. Adsorption desalination: An emerging low-cost thermal desalination method. Desalination 308 (2013) 161–179)

PV Driven Electric Desalination Systems

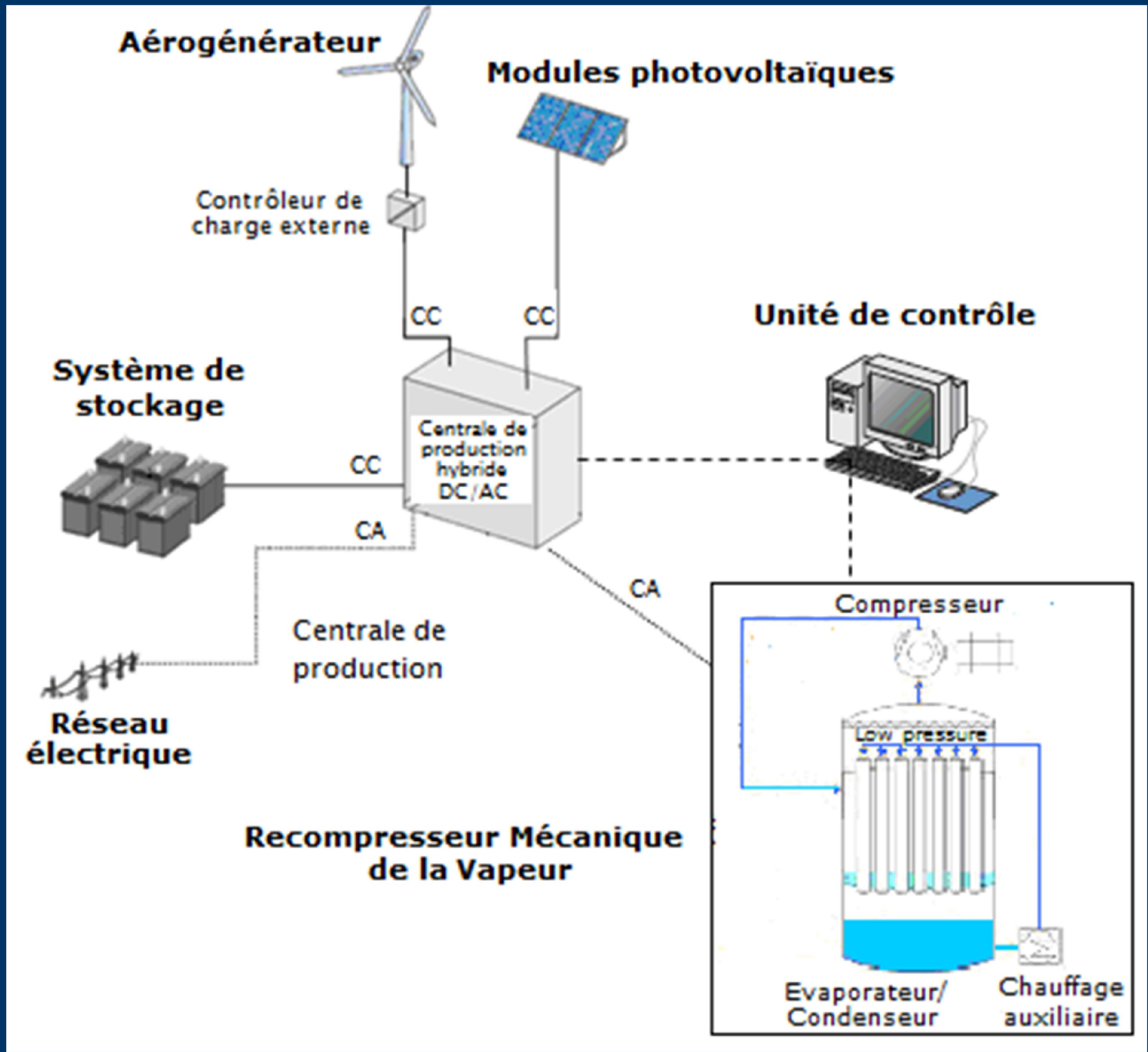
ADIRA Project in Morocco

	Ait Bensaine	Ouelad Elboukhari Ounzar
RO unit (l/h)	600	1000
PV Generator (W_c)	4800	2700
Batteries (Ah)	610	375

(Source : A. Outzourhit, 2009)

Wind/PV hybrid desalination system

An optimization model for a mechanical vapor compression desalination plant driven by a wind/PV hybrid system



Applied Energy 88 (2011) 4042–4054

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journal homepage: www.elsevier.com/locate/apenergy

An optimization model for a mechanical vapor compression desalination plant driven by a wind/PV hybrid system

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Optimization

ABSTRACT

A renewable hybrid system to produce domestic water is presented. It consists of a photovoltaic module, a wind turbine, a mechanical vapor compression desalination plant and a storage unit. An optimization model based on a mathematical programming is developed to control the energy flows exchanged among the system components in order to satisfy the domestic water demand. The model has been solved for three specific case studies in Morocco, where two of them are located in Rabat which aim to satisfy the hourly and monthly water demand of 20 households, whereas the last one is in Essaouira, which aims to ensure the monthly water demand of 40 households. The main motivations behind selecting these specific case studies are the evaluation of the efficiency and feasibility of such system in two coastal sites having different characteristics of renewable energy sources. The obtained results show that the domestic water demands are satisfied in each time interval at a reasonable economic cost comparable to the current average cost of water in Morocco which is about 0.7 € m^{-3}.

1. Introduction

The progress of human societies can be explained by the increasing control of man on energy and water. While both of these two inseparable commodities are increasingly becoming scarce, their overuse during the last two centuries has led to cumulative environmental degradation that cannot be easily reversed. So, the energy and water challenges of the next decades seem to be much more difficult to tackle than most people realize.

In the last few years, the implementation of renewable energy and desalination plants has increased on a large scale. Renewable energy driven desalination systems have been extensively discussed as an innovative approach to desalinate water economically and in an environmentally friendly manner, with specific interest in remote and arid regions where the use of conventional energy is costly or unavailable. Desalination has been practiced on a large scale for more than 50 years and has emerged as the primary response to water scarcity in several member countries. The six world leading countries by desalination capacity are Saudi Arabia (17%), the United Arab Emirates (14%), USA (14%), Spain (9%), China (4%) and Kuwait (4%). Globally, the total installed capacity of desalination plants was 61 million m^3/d in 2008. Seawater desalination accounts for 67% of production, followed by brackish water, at 19%; river water at 8%; and wastewater, at 6% [1]. Desalination is taken into account as an effective method of meeting some of the world's growing fresh water needs due to the abundance of seawater and brackish waters [2]. Desalination can be achieved by a number of techniques. These may be classified into two categories: phase change or thermal process, and membrane or single-phase process [3].

The inception of the commercial mechanical vapor compression (MVC) units dates back to the early 1970s [4,5]. MVC units have been evolved to become a mature technology over the past decades. However, it is not applied as widely as it should or could be. Initial costs, system design and energy consumption remain to be challenging problems. Efficient use of energy in such energy-intensive operations is crucial to reduce the net energy consumption and to compete with reverse osmosis (RO) technology.

Renewable energy sources (RES) are essential to deal with the population needs, especially those in the remote areas. RES can contribute significantly to ensure sustainable solution like water desalination plants. RES powering desalination processes can be taken as a very promising option especially in remote and arid regions where the use of conventional energy is costly or unavailable.

The MVC process remains to be attractive and competitive for production capacities less than 5000 m^3/d [6]. The minimum theoretical energy required for separating the salts-desalination, to produce freshwater is 0.7 kW h/m^3 [7]. In practice, much higher energy is required by the currently available desalination technologies.

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0306-2619/$ - see front matter
doi:10.1016/j.apenergy.2011.04.031

Avec le soutien de

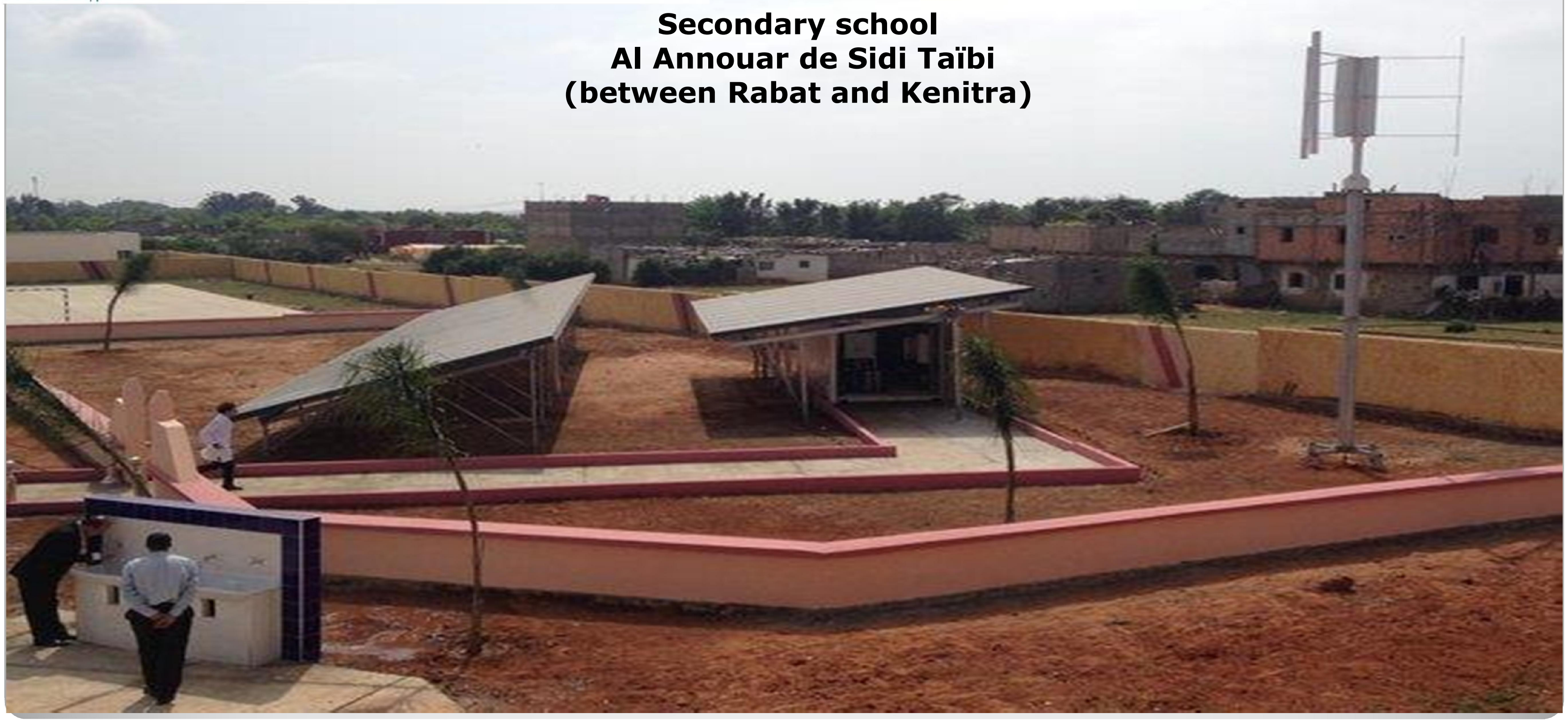
Water production: 3 m^3 water/day

Vertical axix Wind turbine: 2.2 kW

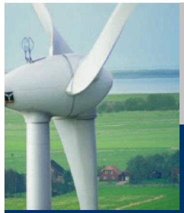
Photovoltaic system: 23.22 kWc

Storage capacity: 48 kWh

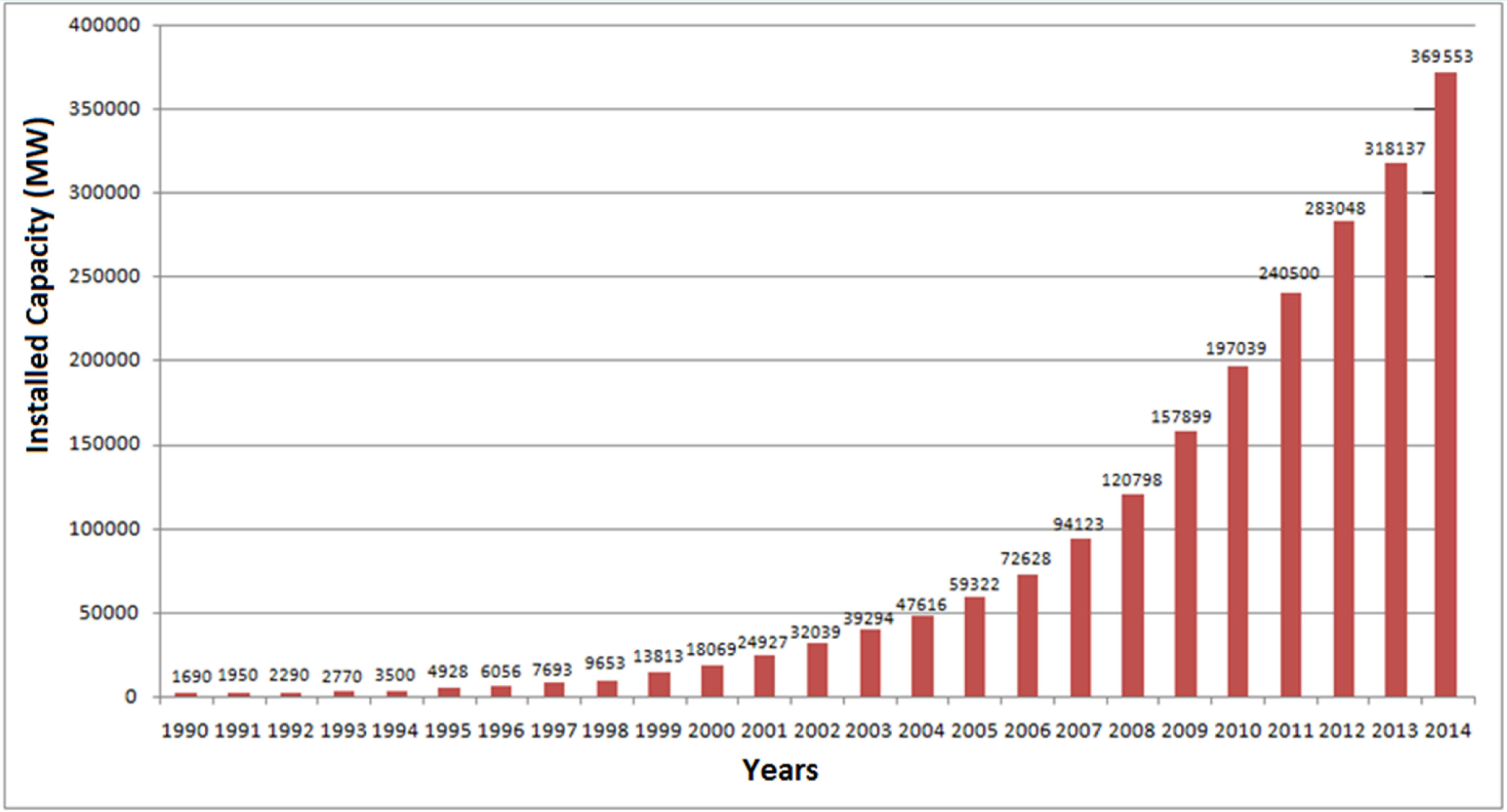
Secondary school
Al Annouar de Sidi Taïbi
(between Rabat and Kenitra)



Wind Driven Desalination systems

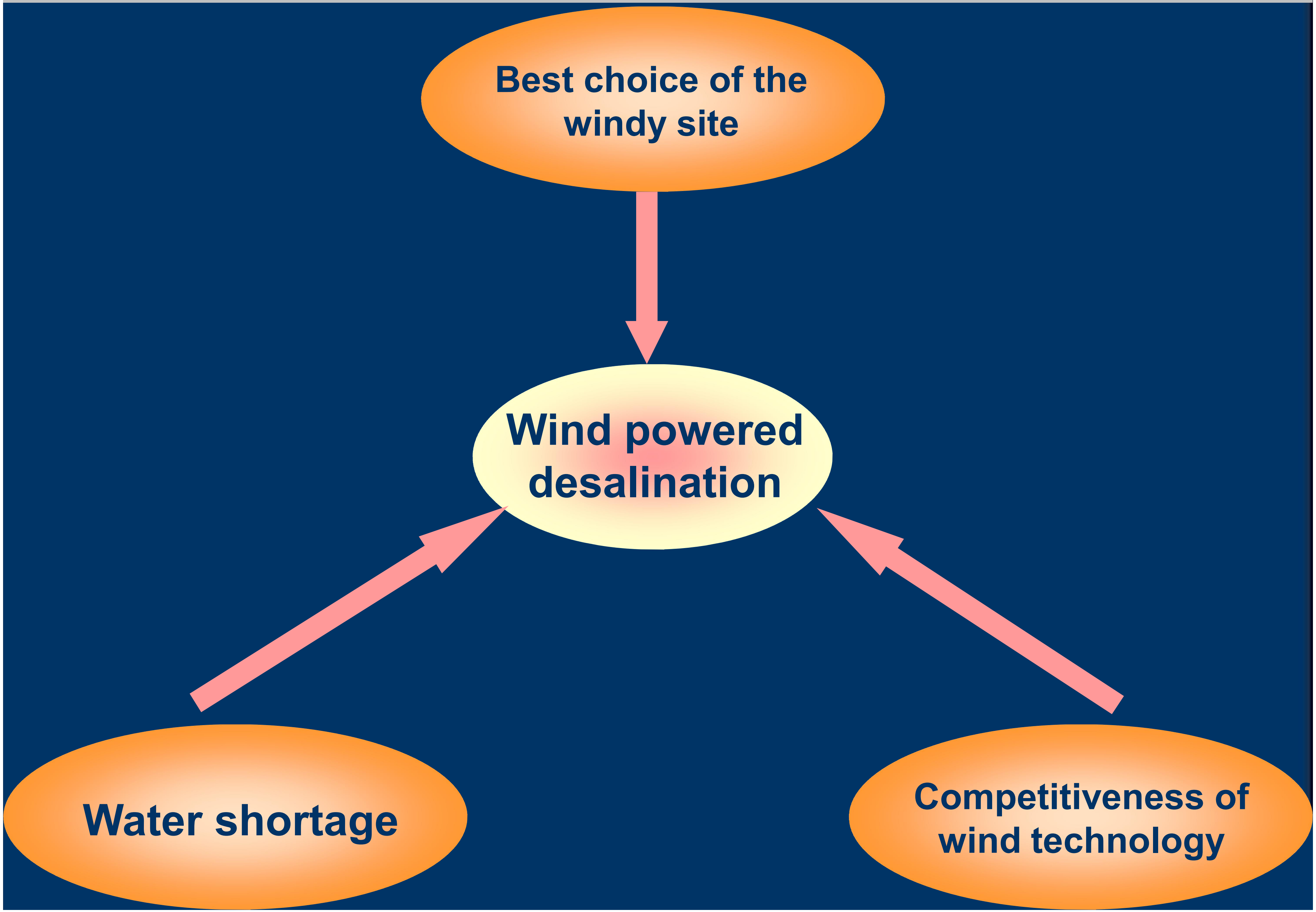


Wind energy

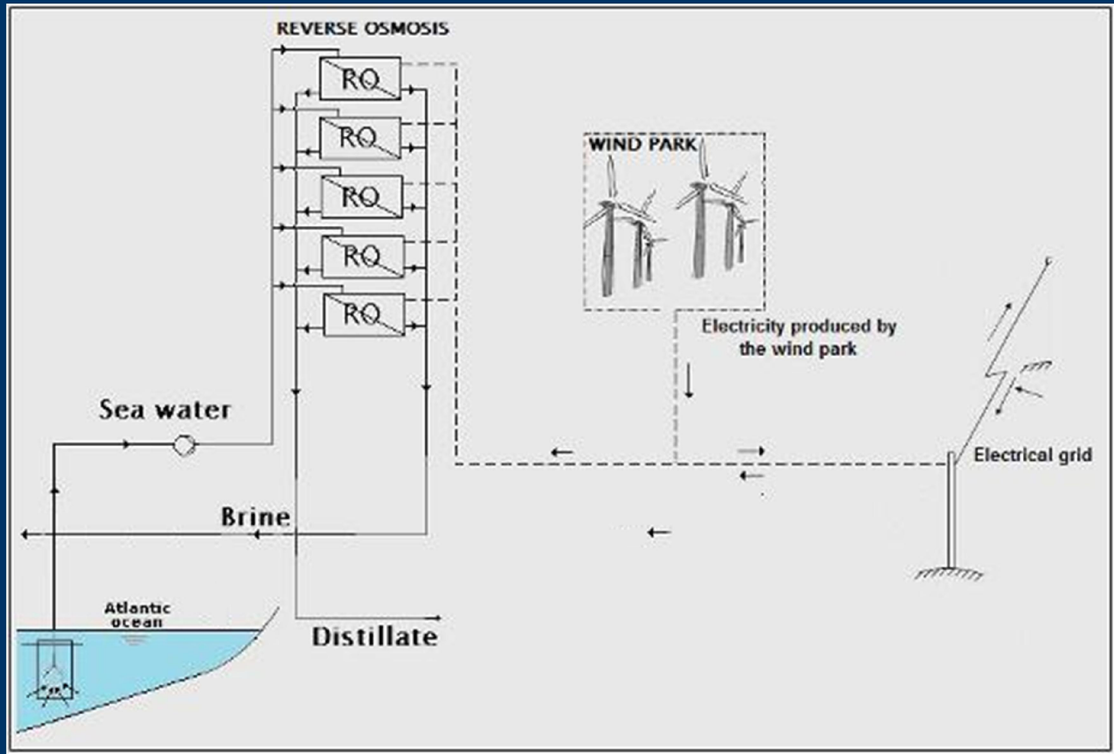


- 21,7 GW of new installations in the first half of 2015, after 17 GW in 2014
– Worldwide wind capacity has reached 392 GW, 428 GW expected for full year
– China close to 125 GW of installed capacity
– Newcomer Brazil: fourth largest market for new wind turbines

Wind powered desalination



Wind powered desalination configuration of the Tan-Tan plant project



	2008	2010	2015	
Technical caracteristics				
Wind parc				
Installed capacity (MW)	5,6000	3,2000	2,4000	11,2000
Desalination process				
Daily water production (m^3/day)	6048	3454	1730	11232

(Data source: M. Enzili (2008))

wind-grid configuration

LWC=0.84

grid-only configuration

LWC=0.82

Desalination and Water Treatment
www.deswater.com

18 (2010) 1–11
June

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Economic feasibility of a 11-MW wind powered reverse osmosis desalination system in Morocco

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Received 10 December 2009; Accepted 12 January 2010

ABSTRACT

In Morocco, the wind is an abundant resource in nearly all the coastal regions. In this context, an 11 MW Wind Powered Reverse Osmosis connected to the grid was planned in the Tan-Tan town. The purpose of this work is to investigate whether the wind powered reverse osmosis desalination system is economically feasible in this town. In this study, assessments of the wind power potential in Tan-Tan using Weibull functions were made. The Weibull parameters were calculated using the Standard Deviation method from the measured data. For the assessment of the Levelized Water Cost, an Excel calculation tool was developed. The research finds that the wind powered reverse osmosis desalination system is not economically feasible in Tan-Tan due to its low wind potential. The mean annual wind speed of this town was calculated to be 5.19 m/s at a height of 9 m above the ground.

Keywords: Desalination; Reverse osmosis; Wind energy; Cost; Morocco

1. Introduction

It is well known that the three major problems that mankind should face during this century are climatic change, fossil fuel depletion and growing water shortage. All these problems are threatening the future security and prosperity of Mankind [1,2].

In the Mediterranean region, the increasing scarcity of fresh water is becoming the most severe problem that one should face. The situation is becoming more complicated by increased pressure on water resources caused by population growth, urbanization, industrialization and growing needs of agriculture.

For several decades, desalination has been increasingly used worldwide to meet water needs in many scare areas.

Reverse osmosis is now a well-established technology for the desalination of brackish and sea water [3]. It gains acceptance around the world and plays a larger and more important role in the desalination market for small-, medium- and large- scale applications [4].

Furthermore, with regard to thermal processes, Reverse Osmosis is gaining increased acceptance as a viable technique, mainly because of its low energy consumption and design flexibility [5].

It is characterized by a high energy efficiency achieving specific energy consumptions as low as 3 kWh/m³ of desalinated water [6].

*Corresponding author.

Conclusion

To move from pilot plant level to viable commercial renewable desalination projects, these should benefit at least from the same incentives provided to encourage the renewable power sector

Thank to all of you