Masdar
A MUBADALA COMPANY

RENEWABLE ENERGY SEAWATER DESALINATION

WATER-ENERGY NEXUS AT THE HEART OF THE UNITED ARAB EMIRATES' HERITAGE AND FUTURE

Global water consumption doubles every twenty years, more than twice the rate of population growth. This is one of the world's most pressing issues, both economically and socially, and is especially critical in arid regions.

Listed by the UN as one most water-scarce countries due to its arid climate, water scarcity has been a primary concern for the United Arab Emirates since the nation's inception.

With a rapidly growing population and economy, the United Arab Emirates has emerged as a recognised, responsible leader in the water sector taking on the challenges of water conservation, management, and security.

The United Arab Emirates has put sustainability at the heart of its growth strategy and is actively promoting the adoption and expansion of the most advanced and innovative technologies to reduce water consumption, costs and waste using minimal resources and limiting environmental damage.

30%
GROWTH

Water demand in the United Arab Emirates is projected to grow 30% by 2030

THE UNITED ARAB EMIRATES HAS A HYPER ARID CLIMATE

- less than 100 mm/year rainfall
- groundwater recharge rate of less than 4% of the annual water used
- no reliable, perennial surface water resources

DESALINATION IN THE UNITED ARAB EMIRATES

Desalination is a critical component of the United Arab Emirates' sustainable growth

Representatives and CEO's of partner companies at the Inauguration of the Renewable Energy Desalination Pilot Plant in Ghantoot during the UAE's Innovation Week

Desalination has been the major source of potable water in arid regions for years, and a critical component of sustaining life and economic growth in the Gulf region.

The overall installed capacity in this region amounts to about 62% of the world's desalinated water capacity, and the United Arab Emirates stands as the second largest producer following the Kingdom of Saudi Arabia.

In the past, the desalination market in the Middle East was largely driven by robustness rather than efficiency, and water production was realised through costly and energy-intensive processes.

Today, the situation is quite different as the United Arab Emirates is committed to further advancing industrial-scale, sustainable desalination technologies capable of meeting the region's future demand for fresh drinking water. Recognising the link among energy, water, and food, the United Arab Emirates is investing heavily in cutting-edge technologies to improve the efficiency and reduce the environmental impact of the desalination process.

Abu Dhabi and Masdar, the renewable energy company based in the United Arab Emirates' capital, have made a commitment to decrease the use of traditional energy sources for desalination and in turn power desalination with the region's abundant renewable resources, such as solar or geothermal. This solution will improve water security, reduce the environmental impact of desalination, and reduce the cost of potable water.

By bridging the gap between research and development and commercialisation, the United Arab Emirates is providing an opportunity for scale-up of technologies that address water access, while also reaping economic, social and environmental benefits.

300%

In the United Arab Emirates, seawater desalination requires 10 times more energy than surface fresh water production, and its cost is projected to increase by 300%

THE UNITED ARAB EMIRATES' RENEWABLE ENERGY SEAWATER DESALINATION PROGRAMME

Transforming the desalination industry into a more sustainable model

The launch of the Renewable Energy Desalination Programme, November 2015

Masdar launched the Renewable Energy Desalination Programme in January 2013 following a mandate from Abu Dhabi's leadership.

This forward-thinking mandate directed Masdar to develop and demonstrate advanced and innovative technologies in desalination to both ensure water security and reduce energy consumption in the sector in order to meet the United Arab Emirates' energy reduction targets.

The goal of this programme is to identify industrial-scale and commercially viable desalination technologies that will address sustainable access to water both in the arid region and globally.

Specifying sustainability and energy efficiency as the primary focus represents a novel approach to an industry-wide challenge and is designed to create the right synergies between the academic and research worlds, industry and public institutions.

4 PILOT PLANTS, OPERATED FOR 18 MONTHS

Key benefits for the United Arab Emirates:

- Increased energy efficiency
- Diversification of energy supply
- Cost reduction of desalinated water
- Reduced environmental impact

The programme consists of two stages:

STAGE 1

(2013 – 2017): PILOTING PHASE

Demonstrate energy-efficient desalination systems at a small scale. The programme will include and operate four pilot plants, which will be located in Ghantoot, Abu Dhabi. The pilot plants are expected to be operated on a continuous basis for at least 18 months to demonstrate the reliable performance of the developed technologies.

STAGE 2

(2018 - 2020): IMPLEMENTATION

Implementation of the developed energy-efficient desalination technologies on a large-scale in the United Arab Emirates and the wider MENA region through seawater desalination plants completely powered by renewable energy. Operate a commercial scale facility by 2020.

DESALINATION TECHNOLOGIES

Bridging the gap between research & development and commercialisation

The Renewable Energy Seawater Desalination Programme foresees the demonstration of two different technologies:

TYPE ONE

Advanced technologies - defined as technologies that are based on commercially proven systems - are expected to have the potential to lower the specific energy consumption to reach the following target values:

- *Reverse osmosis plants: less than 3.6 kWh/m³ of electric energy* (see footnote)*
- *Thermal desalination plants: less than 1.0 kWh/m³ of electric energy and a specific thermal energy consumption varying in accordance to the temperature of the inlet energy stream as per Figure 1.*

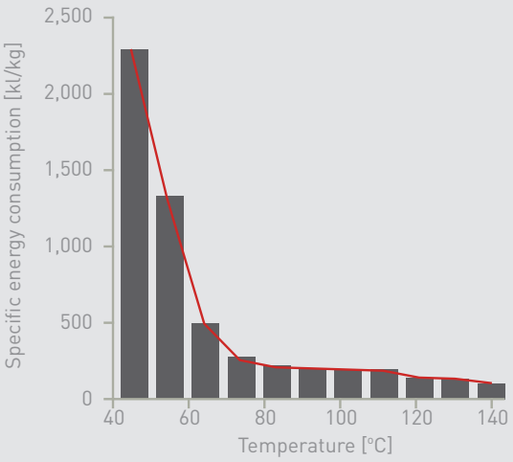


Figure 1 - Target specific thermal energy consumption of thermal desalination plants using advanced desalination technologies in dependence of the temperature of the energy supply

TYPE TWO

Innovative desalination technologies - defined as technologies that are based on novel concepts for seawater desalination - have the potential to lower the specific energy consumption to reach the following target values:

- *Membrane based processes: less than 3.1 kWh/m³ of electric energy* (see footnote)*
- *Thermal desalination processes: less than 1.0 kWh/m³ of electric energy and a specific thermal energy consumption varying in accordance to the temperature of the inlet energy stream as per Figure 2.*

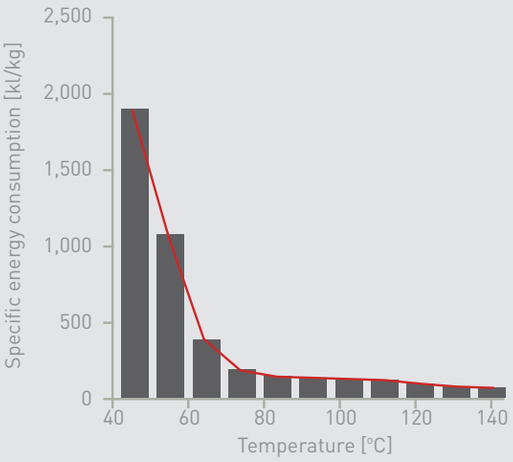


Figure 2 - Target specific thermal energy consumption of thermal desalination plants using innovative desalination technologies in dependence of the temperature of the energy supply

The target values are based on seawater with a concentration of total dissolved solids of 42,000 mg/L and a temperature of 30˚C.

Concurrently with the pilot projects in Ghantoot, Masdar Institute of Science and Technology is collaborating to support the programme through a series of research projects including:

- *A study and evaluation of membrane scaling and fouling in membrane distillation modules to mitigate problems and develop appropriate cleaning protocols*
- *Developing an optimised design of a full-scale solar energy powered seawater reverse osmosis (SWRO) plant using the most practical and economical PV and solar thermal energy technologies*
- *Capacitive de-ionization for treatment of permeates from the first-pass Reverse Osmosis to demonstrate the cost and energy savings potential in SWRO*
- *The development and testing of high-temperature forward osmosis membranes and manufacturing techniques.*

FORGING PARTNERSHIPS FOR SUSTAINABLE ADVANTAGE

The first stage of the programme concentrates on demonstrating energy-efficient desalination systems on a small scale.

The site of a decommissioned desalination plant in Ghantoot was selected as project site due to accessibility to deep seawater, availability of electricity and natural gas.

The four desalination pilot plants will be built on the same site, and auxiliary facilities will be shared among the four plants as shown in Figure 3.

The electricity consumed by the pilot plants will be supplied by the national grid. The heat for the desalination pilot plants will be provided by a central boiler unit, fired by natural gas and solar thermal collectors.

Each desalination plant will be designed, engineered, constructed and operated by a selected technology provider. In February 2013, Masdar invited 180 different companies and organisations in the water desalination industry to participate in this unique programme.

Masdar partnered with four key players of the desalination industry:

- Abengoa - Spain
- Suez Environnement/Degremont - France
- Veolia/SIDEM - France
- Trevi Systems - USA

The technologies used in these programmes have passed research, lab testing, modelling and prototyping. However the technologies have not been commercialised nor used on a utility scale anywhere else in the world.

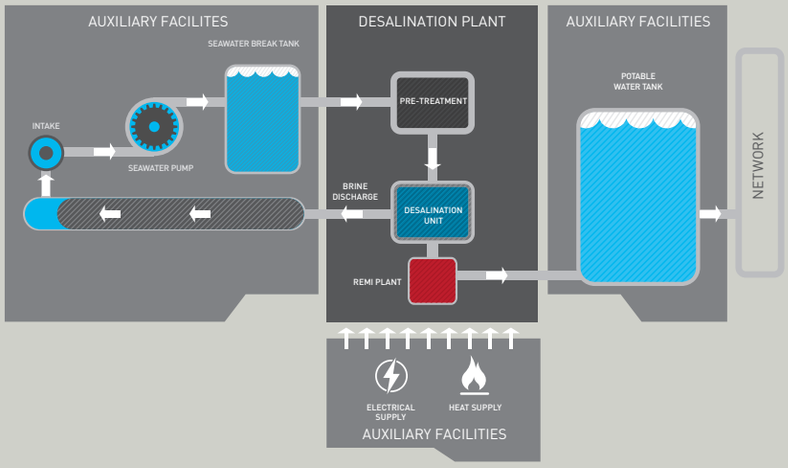


Figure 4 - Schematic layout of a pilot plant

Each desalination pilot plant will deliver potable water in accordance with Abu Dhabi's potable water quality standards as released by the Abu Dhabi Regulatory & Supervision Bureau.

Desalination technologies used in the pilot plants:

- Reverse osmosis + membrane distillation
- Reverse osmosis + ion exchanger
- Reverse osmosis
- Forward osmosis

The second stage of the programme will concentrate on one or more large-scale seawater desalination plants using the highly energy-efficient desalination technologies developed in stage one.

The desalination plants will be powered by renewable energy, mainly PV and CSP.

Masdar
A MUBADALA COMPANY

ABENGOA

suez

Pioneering Next Generation Desalination

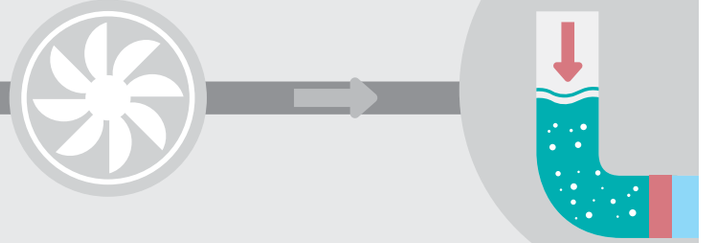
RENEWA
POWERE
SEAWAT
DESALINA

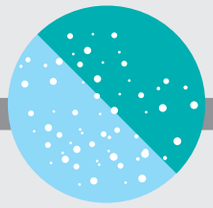
1/3
UAE greenhouse gas emissions from desalination

Energy Inputs

Seawater

Osmos





%30
increase in demand for water by 2030

1,50
m³/da
potable w
in 15 mor

1 Increased energy efficiency

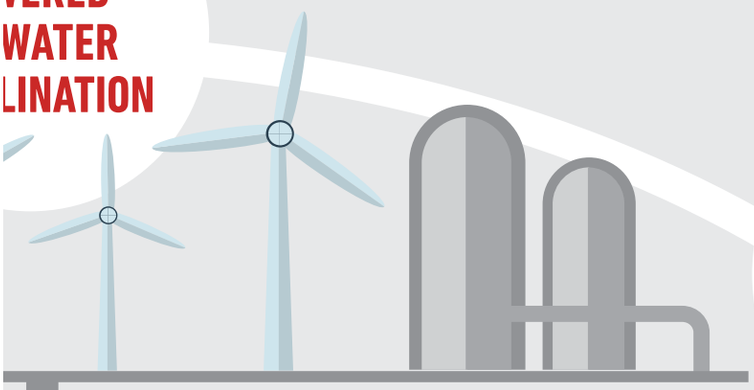
2 Reduced cost of desalination

SIDEM VEOLIA

TREVI SYSTEMS

Masdar INSTITUTE

EWABLE
VERED
WATER
LINATION



Energy Inputs

Potential
%40
reduction in
energy intensity

mosis

Drinking
Water

$94
Million in potential
annual savings

500
/day
le water
months

3 Decreased environmental impact

4 Diversification of energy supply

RENEWABLE ENERGY SEAWATER DESALINATION PROGRAMME

A key step to achieving water security and reducing energy consumption

1960

The construction of the **First Desalination Plant** in the UAE.

1971

The founding of the **United Arab Emirates**, a federation consisting of seven emirates.

1992

هيئة كهرباء ومياه دبي
Dubai Electricity & Water Authority

DEWA

Dubai Water and Electricity Authority was established.

هيئة مياه وكهرباء أبوظبي
Abu Dhabi Water & Electricity Authority

ADWEA

Abu Dhabi Water and Electricity Authority was established.

1998

الهيئة الاتحادية للكهرباء و الماء
Federal Electricity & Water Authority

FEWA

Establishment of the **Federal Electricity and Water Authority**.

1999

The launch of **Masdar**, Abu Dhabi's Renewable Energy Company.

Ministry of Environment and Water was established.

Masdar
A MUBADALA COMPANY

2006

Masdar launched renewable powered desalination pilot aiming to test and develop advanced energy-efficient seawater desalination technologies suitable to be powered by renewable energy sources.

The completion of the construction and the inauguration of Masdar's 4 pilot programmes in Ghantoot, Abu Dhabi.

Water Conservation Strategy was launched.

The establishment of **M-station, the UAE's Largest Power and Desalination Plant.**

The launch of the **Abu Dhabi Sustainability Week** (ADSW).

The completion of Abu Dhabi's **Strategic Tunnel Enhancement Programme**

STEP

2008

Construction began in Masdar city, The World's First Low Carbon City.

Inaugural **World Future Energy Summit** held.

2010

2012

International Water Summit announced

2013

During the Abu Dhabi Ascent in May, Masdar partnered with four global industry leaders to start the construction of the desalination plant.

The launch of the UAE Water Strategy.

The UAE's **Regulation & Supervision Bureau** (RSB), in collaboration with **Abu Dhabi Distribution Company** (ADDC) and **Al Ain Distribution Company** (AADC), announced a revision to water and electricity tariffs.

2014

2015

suez

TREVI SYSTEMS

SIDEM VEOLIA

ABENGOA

PROJECT COMPLETION SCHEDULE

Completing the project	100%	100%	0%	Phase 4 Wide range implementation (Commercial)
Phases	Phase 1 Assessment	Phase 2 Partnerships	Phase 3 The Testing	
Actions Taken	• Asses the best desalination techniques • Determine the elements of success in the pilot project • Determine proper sites for the pilot projects • Prepare work offer requests	• Analyse offers • Discuss agreements • Analyse commercial projects and select the best and low-priced techniques • Sign contracts for four pilot projects in Abu Dhabi	• Design and engineering • Manufacture • Shipment • Installation • Trial operation	
Established Points	• Determine work sites • Request pricing and labour offers	• Sign cooperation agreements • Overall design for experimental projects	• Work plan and financial models • Funding channels for commercial projects	
Time Line	Start January 2013 — 6 Months — End July 2013	Start August 2013 — 10 Months — End May 2014	Start June 2014 — 39 Months — End August 2017	2018 — 2020

Masdar
A MUBADALA COMPANY

TREVI SYSTEMS

suez environnement

SIDEM VEOLIA


Kuwait
ARABIAN GULF
Bahrain
Qatar
GULF OF OMAN
Abu Dhabi
United Arab Emirates
Kingdom of Saudi Arabia
Oman
Yemen

"Water is more important than oil for the United Arab Emirates. We have to come up with ways to meet future demand and preserve natural resources for coming generations"

His Highness Sheikh Mohamed Bin Zayed Al Nahyan
Crown Prince of Abu Dhabi and Deputy Supreme Commander of the United Arab Emirates Armed Forces.

Masdar
A MUBADALA COMPANY

PO Box 54115, Abu Dhabi, United Arab Emirates
T +971 2 653 5026
E SP-info@masdar.ae

www.masdar.ae