Utilizing Solar Energy for Desalination to meet Local Growth on Agriculture Demand without Affecting the Environment

Towards CO2 Reductions

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Overview

- KACST History of engaging with Solar Projects
- Khafji Concentration Photovoltaic for water Desalination Research
- Crops Modeling and Simulation
- Saudi Desalination Initiative's Objectives
- Al-Khafji Solar Desalination Plant (2016 - 2018)
- Climate Challenges in Saudi Arabia
- Localization of Industries and Material
- PV & CPV Module Reliability Laboratory
- Energy Economical Assessment
- Conclusions

Technology Readiness Level (TRL)

TRL 1 TRL 2 TRL 3

Knowledge Development

TRL 4 TRL 5 TRL 6

Technology Development

TRL 7 TRL 8 TRL 9

Business Development

Solar History in KACST

1977

Soleras

- KSA and USA agreement

1981

Solar Village

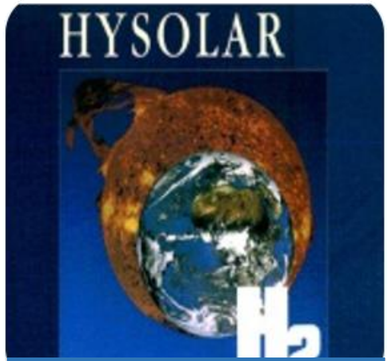
- 350 KW PV
- 1.5 MWh/day

1984

Yanbu Solar Desalination Plant

- Indirect contact freeze process
- 200 m^3/day
- 2.2 MWh/day

1986



Hysolar Program

- KSA and Germany agreement
- Hysolar MOU for Solar Hydrogen Production and Utilization

1994

12 Solar Radiation monitoring stations

- Radiations: Horizontal, Direct Normal, Diffuse
- Published Solar Atlas 1998

Solar History in KACST

1994

Sadoos PV Desalination

- PV systems
- 15 k liters/day
- 10.08 kWp
- 980 Wp

1996

Aseer Highway Lighting

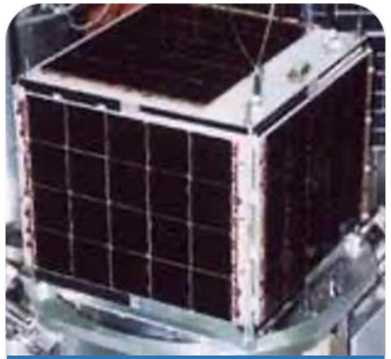
- 1.5 MWh /day

1996

Green House Application

- 14.4 kWp
- PV system and Batter storage

2000



Saudisat 1-a

- Satellite power

2016

King Abdullah Initiative for Solar Water Desalination

KACST Solar Initiatives Last 5 Years

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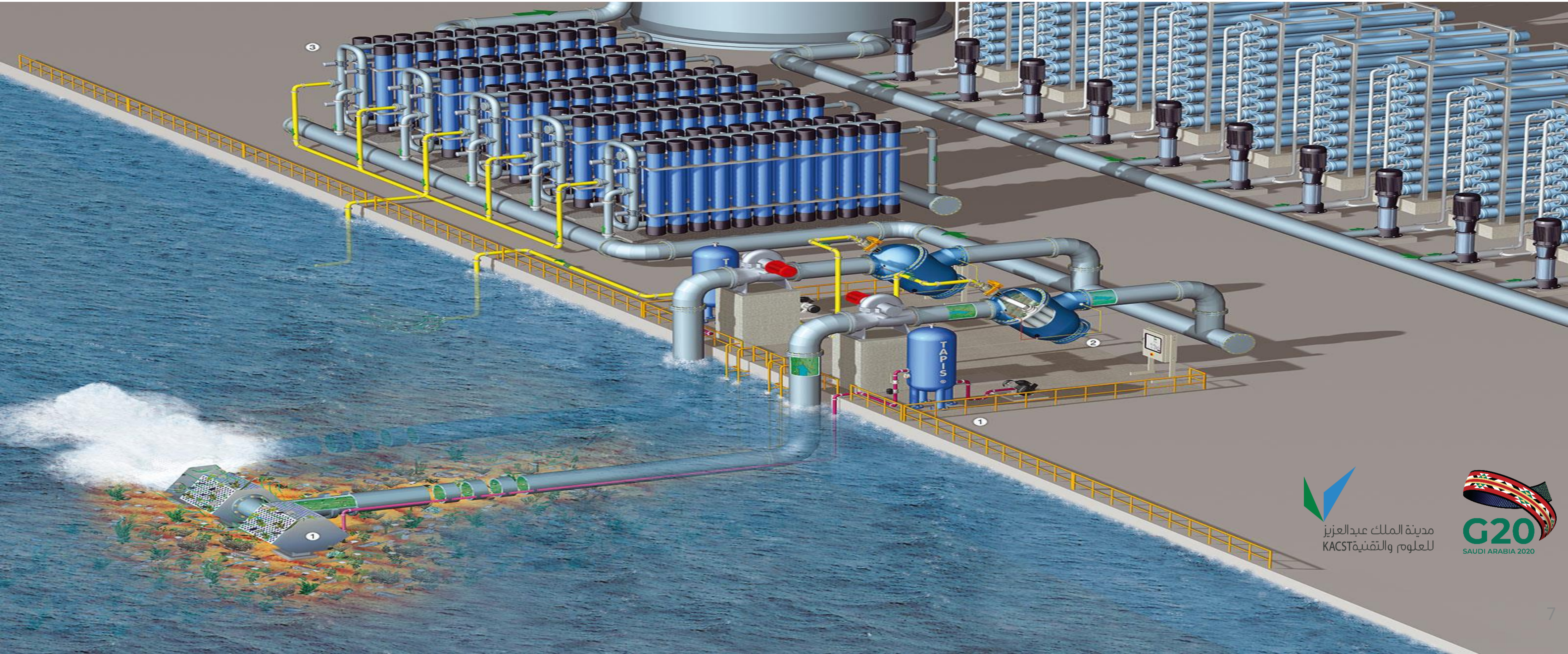
1. Residential 15KW
2. Gov. School 60 KW
3. Mosque 124 kW
4. Utility Scale Taif 1MW
5. Desalination 10MW
6. The initiative to Agriculture (0.14 $/m^3$)

A practical planning software program for desalination in agriculture - SPARE:WATER^{opt}

Goal : Reverse Osmosis sea water desalination plant in Khafjy with a daily water production of 60,000 m3 day−1

To achieve a maximum gross margin in relation to water supply by desalination considering irrigation technique, irrigation efficiency, water cost, and salinity level as well as crop producer prices



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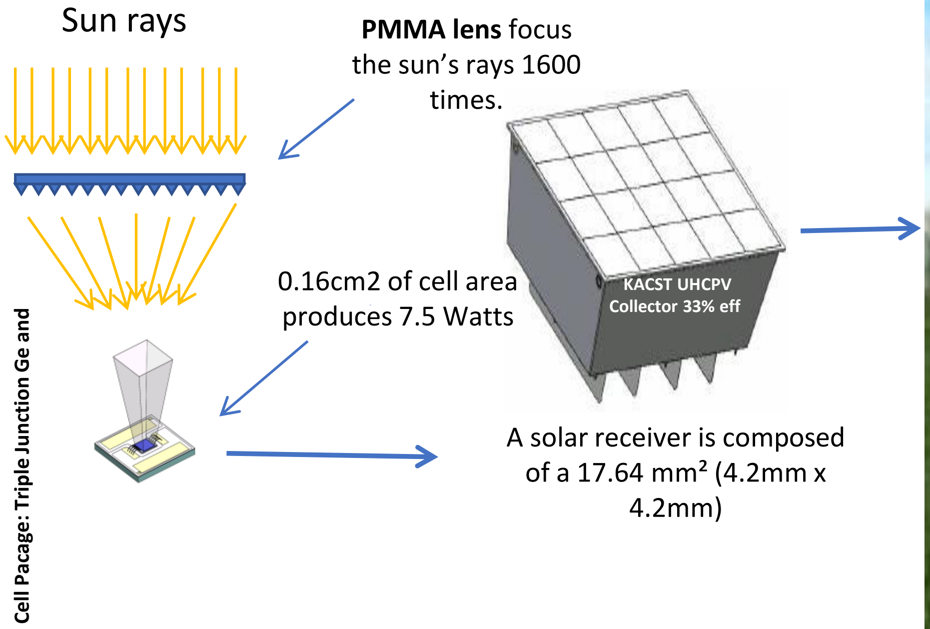
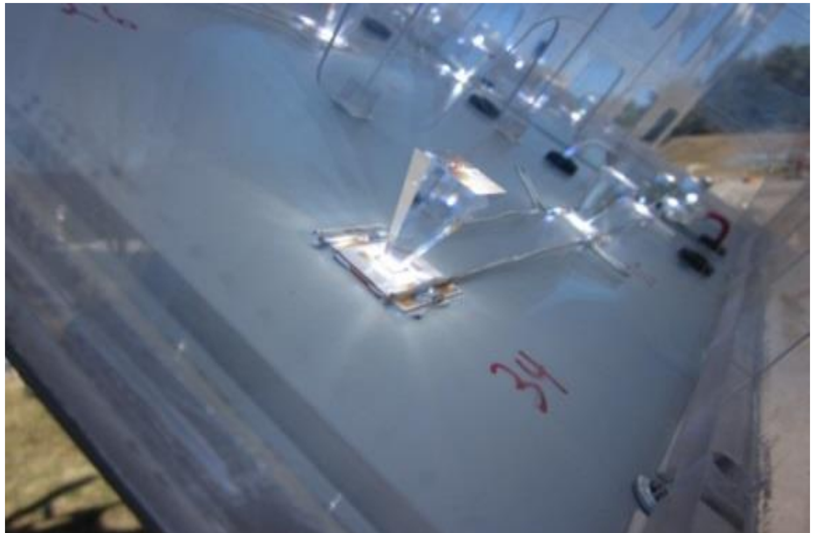
Ultra-High Concentration Photovoltaic (UHCPV) System



• **Cell type:**	**Triple Junction Ge and III/V**
• **Cell Size:**	**Square 0.375 cm**
• **Lens:**	**Stamped Acrylic Square15 cm**
• **Concentration:**	**1600 Suns**
• **# Cells per module:**	**20**
• **# Modules per tracker:**	**81**
• **Power per tracker:**	**9.75 kW**
• **Efficiency:**	**28-33 %**
• **Cooling:**	**Passive**



A case study

A case study was presented of a RO desalination plant in Al-Khafji, eastern of Saudi Arabia along the Arabian Gulf with a daily water production of 60,000 m3 day−1.

The irrigated fields sum to 84,753 ha, which is considered the total potential area for irrigation agriculture in this study.

The site-specific monthly crop water needs for 19 major crops grown in Saudi Arabia and their different sowing and cultivation dates were taken from a database calculated using SPARE:WATER in a previous study.

The desalination costs are fixed at 0.75 \$ m-3 and the daily production is 60,000 m3 day-1.

Additionally, costs for transport have been considered which have been derived from the vertical and horizontal pumping costs of water which are $0.5\ \$\ m^{-3}$ for 100 km horizontal and 100 m vertical pumping.

One crop (alfalfa)

The sole cultivation of alfalfa (500 ha) leads to a high-water demand throughout the year with a peak in the summer months.

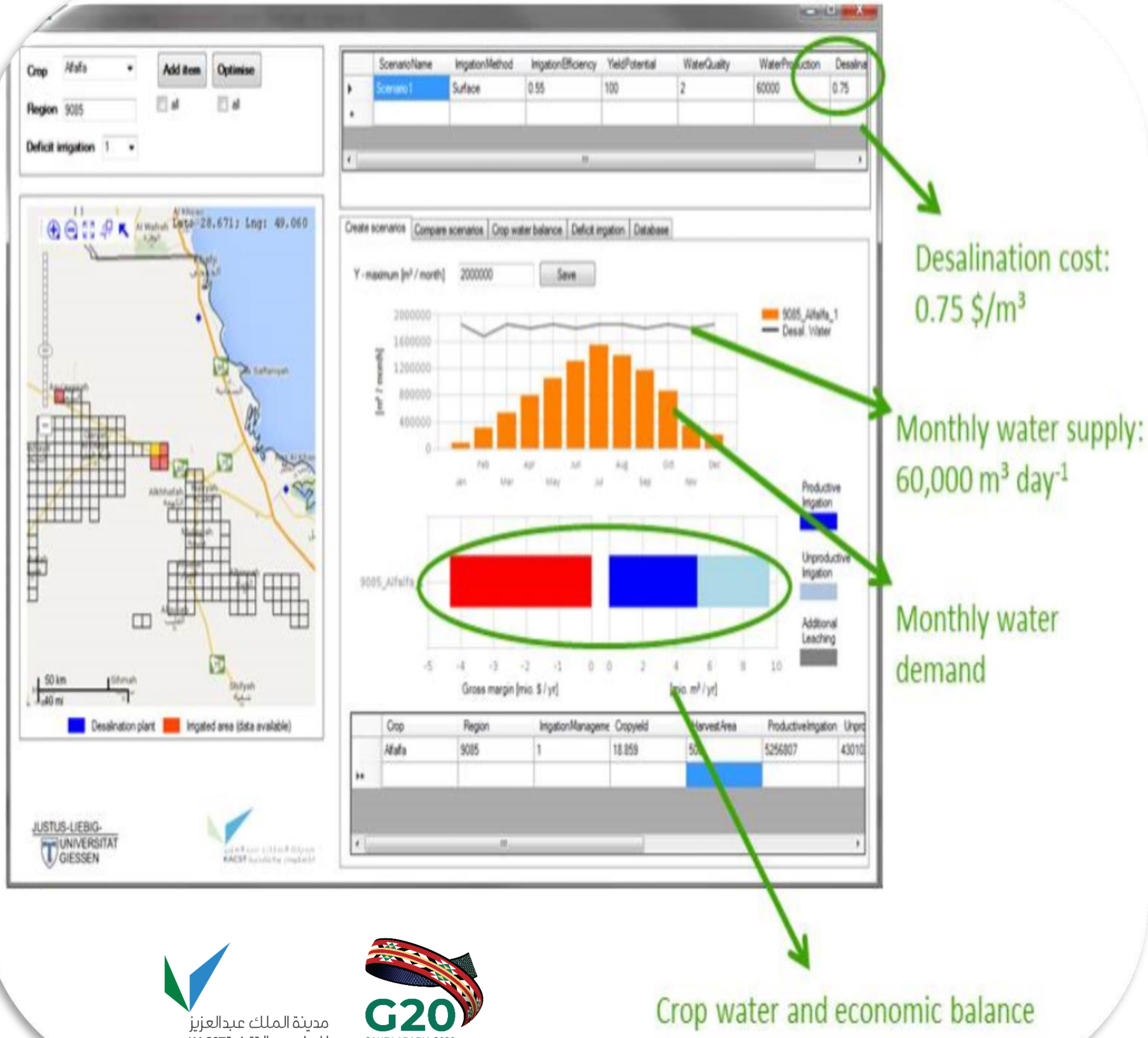
The gross margin is negative because of high-water demand and low producer price of alfalfa (300 $ t^{-1}).

Two crops (alfalfa & tomatoes)

When the cropping pattern is expanded by growing tomatoes (500 ha) a positive total gross margin can be gained, because tomatoes have a higher producer price (48 $ t-1) paired with high yields larger than 70 t ha-1 .

multiple crops (alfalfa, wheat, tomatoes & date palms)

A balanced cropping pattern with a fodder crop (alfalfa), a staple food crop (wheat) and two cash crops (tomatoes, dates) leads to more constant water demand throughout the year and an overall positive gross margin.



The Initiative's Objectives

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The Initiative's Objectives

1. Desalinate seawater by solar energy at low cost to contribute to the Kingdom’s water security and support the national economy.
2. Applying nanotechnologies developed in the field of Photovoltaic and RO membrane systems.
3. Build advance industries advocated by the Industrial strategy of the Kingdom.
4. Design and installation of photovoltaic capacity of 10 megawatts.
5. The cost of energy production not to exceed 7 halalas (2 US Cent per kilowatt-hour).
6. Link solar station to the Grid.
7. Power the seawater desalination plant by PV.
8. Develop clean energy and protect the environment.

Water Desalination Initiatives

The Initiative will be implemented in four phases:

Phase 1 — Construction of a solar-powered desalination plant at Al-Khafji ($30,000\ m^3$/day).

Phase 2 — Construction of a solar-powered desalination plant. (300,000 m3/day).

Phase 3 — Apply the initiative throughout the Kingdom.

Phase 4 — Apply the initiative to Agriculture (0.14 $/m³)

SITE LOCATION:

The Solar photovoltaic power plant will be located 9km North of the Municipality of Khafji, in the Kingdom of Saudi Arabia

Latitude	28°29'26.00" N
Longitude	48°27'49.00" E
Altitude	2m above sea level

Al-Khafji Solar Desalination Plant (2016 - 2018)

Building a desalination plant with a capacity of 30,000m^3/day to meet the needs of one hundred thousand dweller of Al-Khafji City (Arabian Gulf) and construction of a solar energy station with a capacity of 10 Megawatts with Cost $ 0.26/ Cube Meter.

- Complete 10MW PV power plant
- Project Benefits: To demonstrate capability of KACST’s solar systems
- Built with KACST manufactured PV components (PV modules, PV inverters, mounting structures, In-plant service, monitoring). Energizing 60 cubic meter/day water desalination plant

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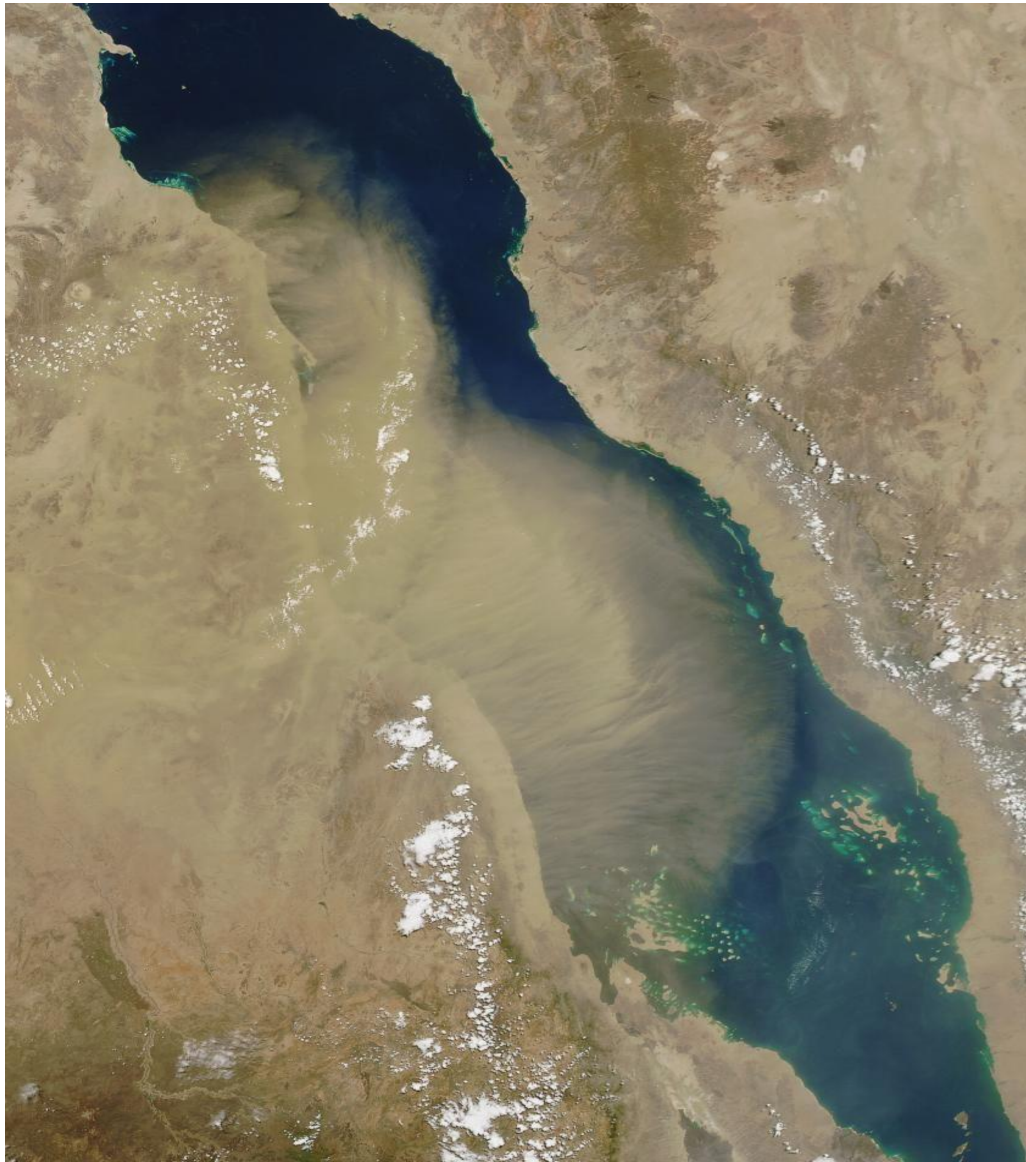
Successful Story: Desalination Plant (Video)

Challenges

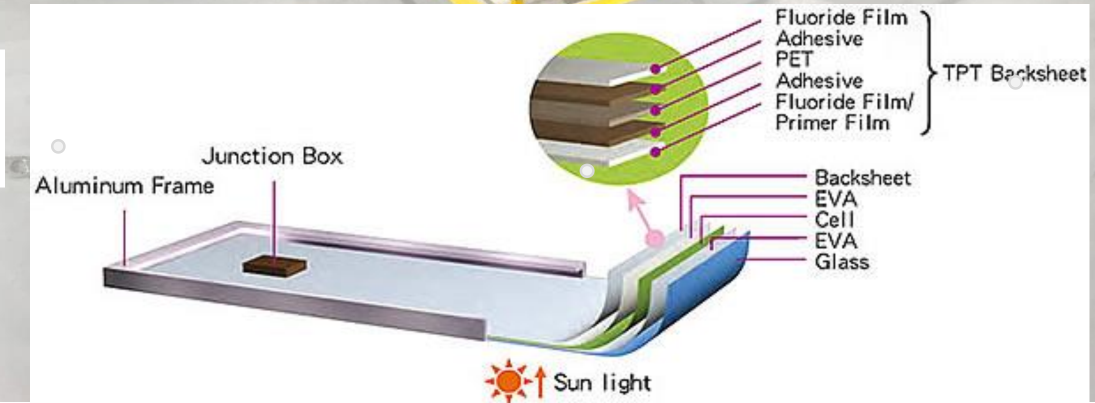
- **Temperatures:**
  - +10 ˚C higher temperatures
  - Peak temperature ~50 ˚C
- UV radiation (×2 higher)

- **Environment:**
  - Dusty
  - Aggressive Sandstorms

- **25. February 2012:**
  - PV power = ZERO



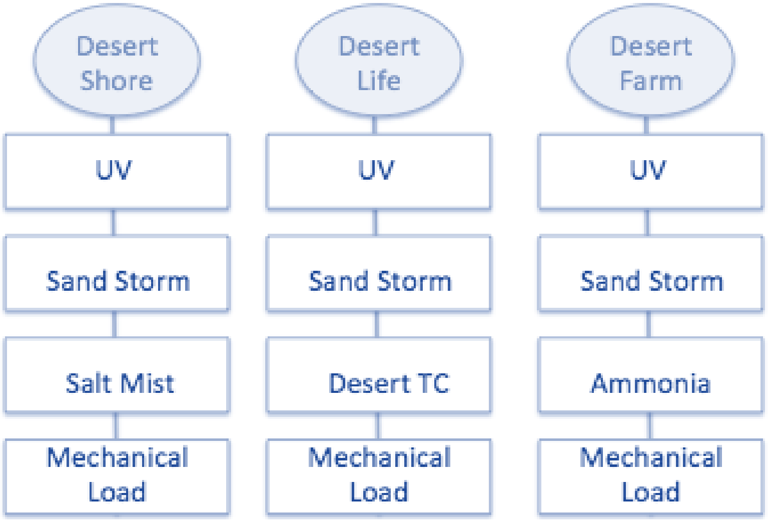
Industry: PV system Manufacturing & Localization of Industries and Material



Accredited PV Reliability Laboratory

Desert Protocols:

- Dedicated Equipment to simulate harsh local environment
- Unique Protocols developed to suit different environmental challenges




Sand Spray Chamber

Environmental Chambers
Physical Stress Tests
Electrical Performance Tests
Outdoor Tests

Real Value of AlKhafji Project

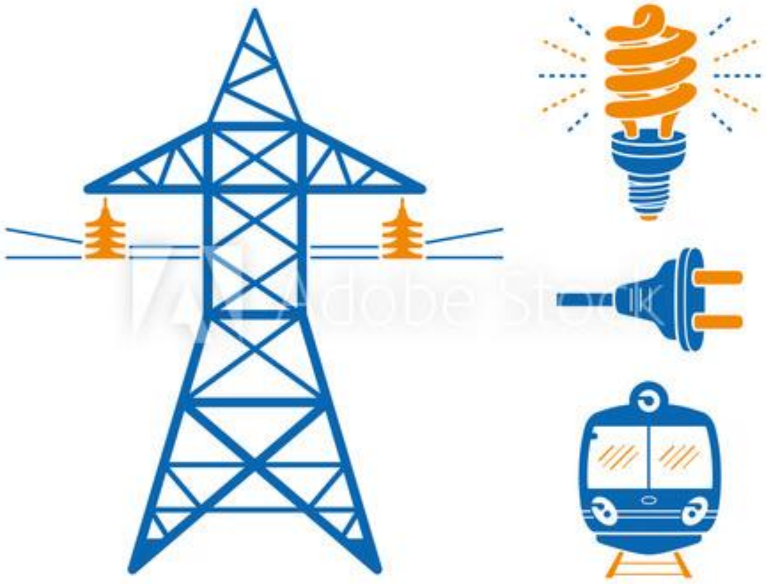
Electricity generated over 25 years: 508,165,500 kWh

Savings:
40,653,240 USD into the commercial electricity bill
43,346,517 USD into the governmental electricity bill
24,391,944 USD into the industrial, private educational facilities, private medical facilities electricity bill

364,355 tCO2 emissions

135,908 t of wood

318,969 barrel of oil



Saudi Tariff ECRA : Commercial ($ 0.08 / kwh)
Governmental ($ 0.0853 / kwh)
Industrial, Private educational facilities, private medical facilities ($ 0.048 / kwh)

Conclusions

- Desalinate seawater by solar energy at low cost to contribute to the Kingdom's
  - Water security,
  - Food security,
  - Support the national industry and Localization
  - Support the national economy
  - Creating Job Opportunity
- Targeting a cost-benefit analysis of desalinated seawater use for agriculture.
- Optimal cropping pattern can be determined by using an economic optimization algorithm which maximizes the gross margin under limited water supply and land availability.
- The economic feasibility of desalinated seawater use is driven by the related cropping pattern which is irrigated.
- The crop specific boron tolerance needs to be considered when the quality of desalinated seawater is analysed. Some crops are rather sensitive such as wheat, sesame and barley which tolerate concentrations between 0.75 and 1.0 mg L^{-1} .
- Other crops are rather tolerant, such as alfalfa, sorghum and tomatoes which tolerate large boron concentrations between 4.0 and 6.0 mg L^{-1}.
- The desalination with only one RO cycle leads to a boron concentration of 2.33 mg L^{-1} which is suitable for tolerant crops

THANK YOU

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