الشركة الوطنية لاستغلال وتوزيع المياه
SOCIETE NATIONALE D'EXPLOITATION ET
DE DISTRIBUTION DES EAUX

Desalination in Tunisia - Solar power PV - Case Ben Guerdene desalination plant

Desalination Renewable Energy _ June 7th -2021

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Introduction

- ✓ Limited water resources mainly in the Center and South of Tunisia
- ✓ Non conventional water resources (desalination, water reuse) and Renewable energies are of utmost important for water supply either for domestic, industrial or agriculture sectors (high values crops)
- ✓ Tunisia has lunched an ambitious program of desalination still in progress
- ✓ Appropriate design of desalination units could be a solution for small communities and agriculture thrive

Water Resources in Tunisia

- ✓ Water resources in Tunisia are inventoried and well identified
- ✓ Tunisian Potential: 4840 Mm^3 (Surface water: 2700 Mm^3 – Groundwater: 2140 Mm^3).
- ✓ Resources available: 4640 Mm^3
- ✓ in 2014, Per capita/year water availability is 440 m^3 (the minimum considered by ONU is 1000 m^3).
- ✓ in 2014, about 93% of resources are mobilized.

Future Orientation

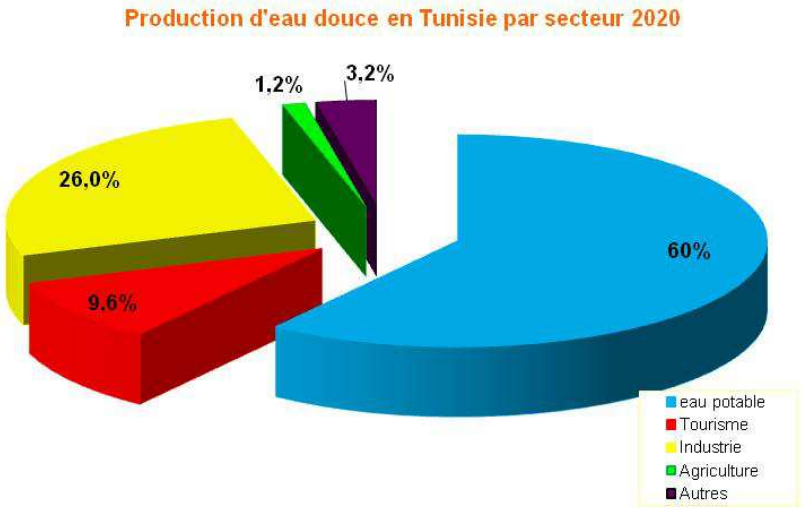
Development of non-conventional water resources

- ✓ Increase the rate of waste water reuse.
- ✓ Considering aquifer artificial recharge by treated waste water in some water aquifer
- ✓ Support wastewater recycling in industry sectors
- ✓ Development of brackish and sea water desalination program .

Current state of desalination sector

- ✓ Production capacity of desalination plants in June 2020 is about 250 000 m^3/ day
- ✓ The number of desalination plants , end of 2020, is 120.
- ✓ Desalination plants for domestic water supply are mainly present in the South of Tunisia.
- ✓ Drinking water alone accounts for 60% of production capacity

Analysis of water desalination sector Tunisia



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Analysis of water desalination process

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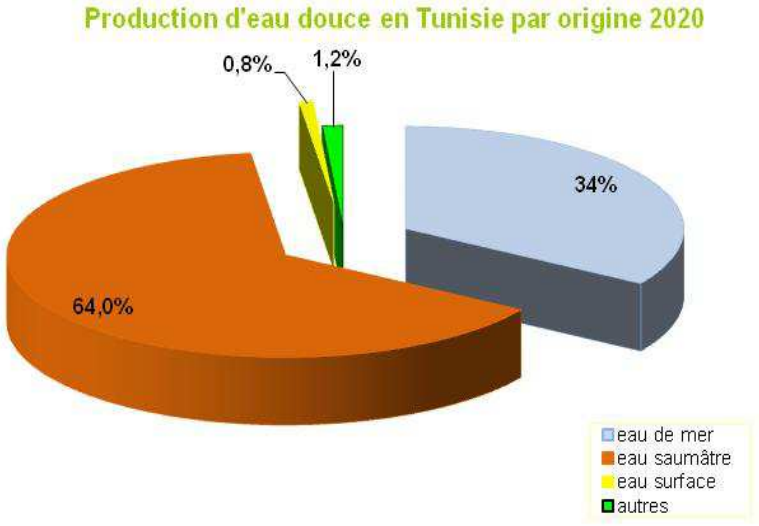
Analysis of water desalination resources



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Desalination plants operated by Sonede -I

Station	Gabès	Djerba	Zarzis	Kerkennah	Bengardène	Total
Nominal Capacity (m^3)	30 000	20 000	15 000	3300	1800	70 100
Maximal Capacity (m^3)	34 000	20 000	15 000	3300	2000	74 300
Conversion rate	74 %	75 %	75 %	75 %	70	75 %
Raw water salinity	3,2 g/l	6 g/l	6 g/l	3.7 g/l	14g/l	-
Osmosis water salinity	300 mg/l	300 mg/l	500 mg/l	300 mg/l	300mg/l	-
Lines number	04	05	03	4	3	16
Modules number	1584	756+162	756	144	100	3 502
Commencement of Operation Date	June 1995	August 99+08/07	January 00	En 1983	June 13	-

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Desalination plant of Bengardène

- Photovoltaic-powered reverse osmosis desalination plant **(210 Kwc)** with a production capacity of 1800 m^3/day
- Associated with an evaporation pond of 11.9 ha

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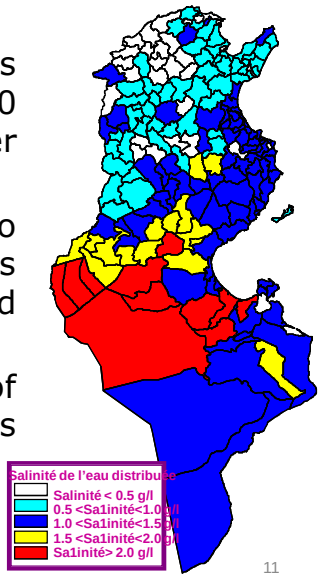
Programs for improving water quality

Carried out in 2 phases

- The first one refers to regions with population over than 4000 habitants and where water salinity is greater than 2.0g/l .
- The second phase refers to regions where water salinity is between 1.5 g/l et 2.0 g/l and population over 4000 habitants.
- Achieved study, preparation of tendering procedure in progress and some drilling startup works



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Programs for improving water quality

First phase projets (October 2017)

Governorate	Station	Capacity m³/day	Technology	Nombre lines	% progress rate
Tozeur	Tozeur	6000	OI	3*2000	100%
	Nafta	4000	OI	2*2000	100%
	Hezoua	800	OI	1*800	100%
Kébili	Kébili	6000	OI	3*2000	100%
	Souk Lahad	4000	OI	2*2000	100%
	Douz	4000	OI	2*2000	100%
Gabès	Matmata	4000	OI	2*2000	100%
	Mareth	5000	OI	2*2500	100%
Médenine	Béni Khédache	800	OI	1*800	100%
Gafsa	Belkhir	1600	EDR	2*800	100%
Total		36200			

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Desalination plant of Matmata 4000m^3/day

Evaporation Pond of the desalination plant of Matmata 4000m^3/d

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Desalination plant of Belkhir 1600m^3/day

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Programs for improving water quality

Second phase projets

Governorate	Station	Capacity m^3/day	Technology	Number lines
Tozeur	Dégueche	2000	OI	2*1000
Kébili	Kébili extension	2000	OI	2*1000
Sidi Bouzid	El Meknassi-Mazouna-Bouzian	3000	OI	2*1500
Médenine	Ben Guerdane	9000	OI	3*3000
Gafsa	Gafsa Mdhila-Gtar-Metlaoui Redayef-Moulares	9000 6000	OI OI	3*3000 2*3000
Total		31000		

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Sea water desalination program : Desalination plant of Djerba

- - Objective : strengthening capacity for water resources and improving water quality supply .
- - Contracting method : Turn-key.
- - Project description :
- * Seawater intake, desalination plant and brine discharge.
- * Desalination capacity of 50 000 m^3/day expandable to 75000 m^3/day using reverse osmosis technology
- * Storage of produced water after being mixed with brackish water
- * Deferrisation of the mixed water
- * Connection of the desalination plant to the distribution network
- - Work progress: in operation since 2018

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Desalination plant of Djerba

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Sea water desalination program : Desalination plant of Sousse

- Objective : strengthening capacity for water resources and improving water quality supply in Sahel region
- Capacity: 50 000 m^3/day expandable to 100 000 m^3/day to be achieved in two phases.
- Contracting method : Turn-key.
- Project description :
  - Seawater intake, desalination plant and brine discharge.
  - Desalination capacity of 100 000 m^3/day using reverse osmosis technology
  - Connection of the desalination plant to the Sahel distribution network
  - Budget : Government
  - Work start: 2022.

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Desalination plant of Sousse

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Sea water desalination program : Desalination plant of Zarat

- Objective : strengthening capacity for water resources and improving water quality supply for Gabes and Medenine regions until expiry of 2030
- Contracting method : EPC
- Project description:
  - Seawater intake, desalination plant and brine discharge.
  - Desalination capacity of 100 000 m^3/day using reverse osmosis technology
  - Connection of the desalination plant to the distribution network
- Budget: funded by KFW.
- Work progress: 65% in may 2021

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Desalination plant of Zarat

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Sea water desalination program : Desalination plant of sfax

- Objective: Strengthening capacity for water resources and improving water quality supply for Sfax region
- Capacity: 200 000 m^3/day to be achieved in two phases.
- Contracting method : Turn-key.
- Project description:
  - Seawater intake, desalination plant and brine discharge.
  - Desalination capacity of 200 000 m^3/day using reverse osmosis technology
  - Connection of the desalination plant to the distribution network of Sfax region
  - Budget: Funded by JICA
  - Work progress: start works in 2021

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Sea water desalination program : Desalination plant of Kerkennah

- Objective: Strengthening capacity for water resources and improving water quality supply for kerkennah Island
- Contracting method : Turn-key.
- Project description :
  - well intake, desalination plant and brine discharge
  - Desalination capacity of 6 000 m^3/day using reverse osmosis technology
  - Connection of the desalination plant to the distribution network.
  - Budget : funded by Kuwait funds .
  - Work progress: tender preparation 2021

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Desalination Cost: Investment cost in $/m³/day depending on the capacity of the RO

Capacity m³/j	Sea Water	Brackish water
4000	2300	1000
8000	1600	800
15000 (Zarzis)	-	691
20000	1100	600
30000 (Gabès)	-	580
40000	1050	500
60000	1000	450

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Cost of produced water in $/m³

Capacity m³/day	Sea water	Brakish water
4000	1.500	0.700
8000	0.400	0.400
15 000 (Zarzis)	-	0.200
20000	1.300	0.250
30 000 (Gabès)	-	0.100
40000	1.100	0.220
60000	1.000	0.200

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Bengardene desalination plant

- Commissionning: June 2013
- Capacity : 1800 m^3/d
- Source raw water: brackish water of the Oligocene aquifer, salinity 14 g/l, rich in iron and temperature 45 ° C.
- The desalination process: Reverse osmosis
- Components :
  - a reverse osmosis unit capacity 1800 m^3/d
  - an evaporation basin brines 12 ha
  - a photovoltaic system of 210 kwc

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Bengarden plant: RO skids

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Photovoltaic system

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Photovoltaic system

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Cooling system

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Evaporation basin

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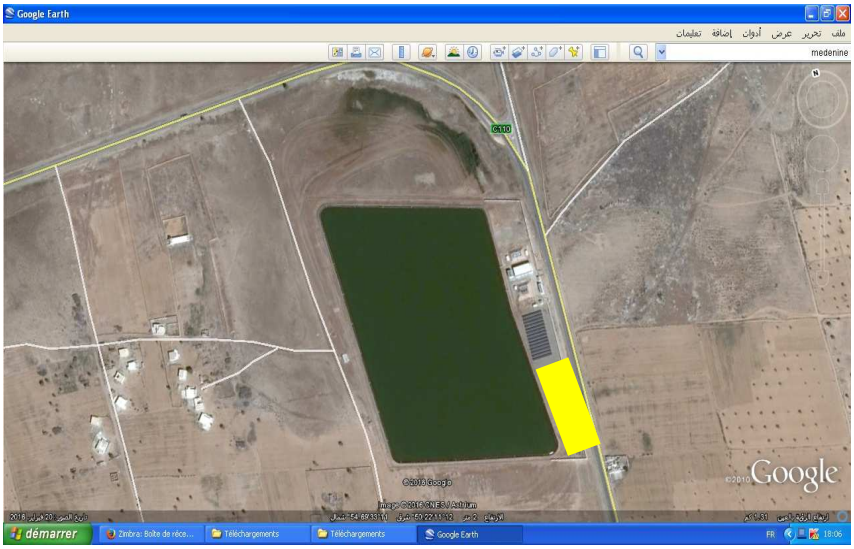
Extension 400 MWc under construction



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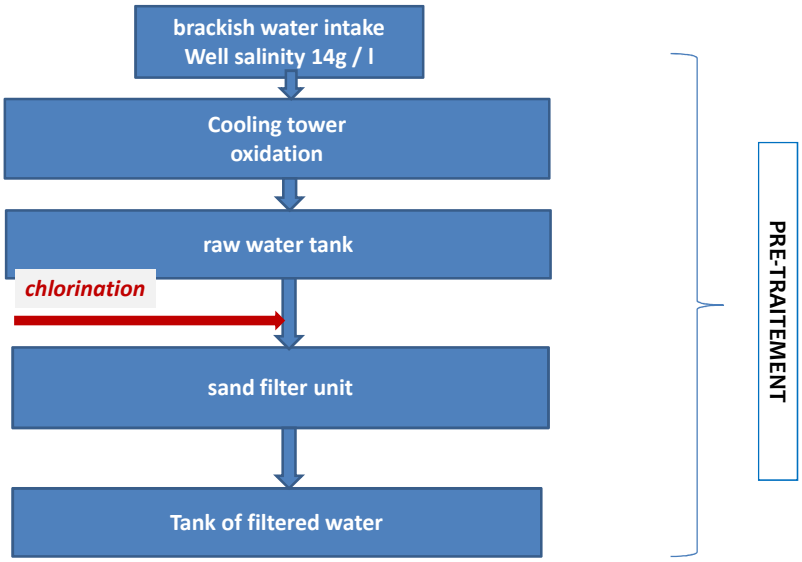
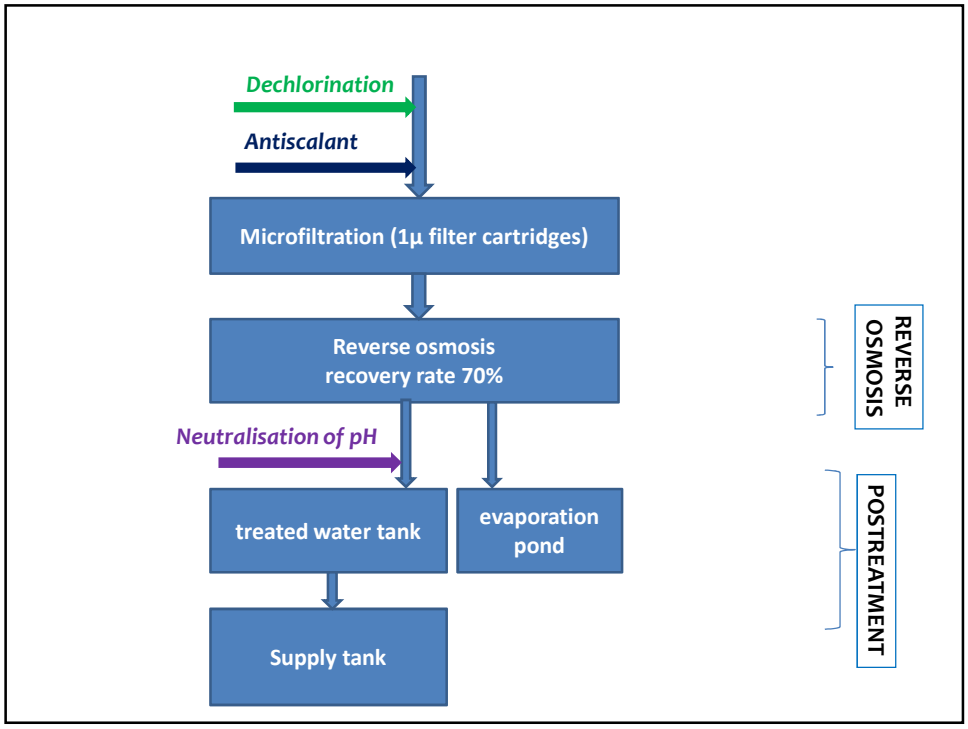
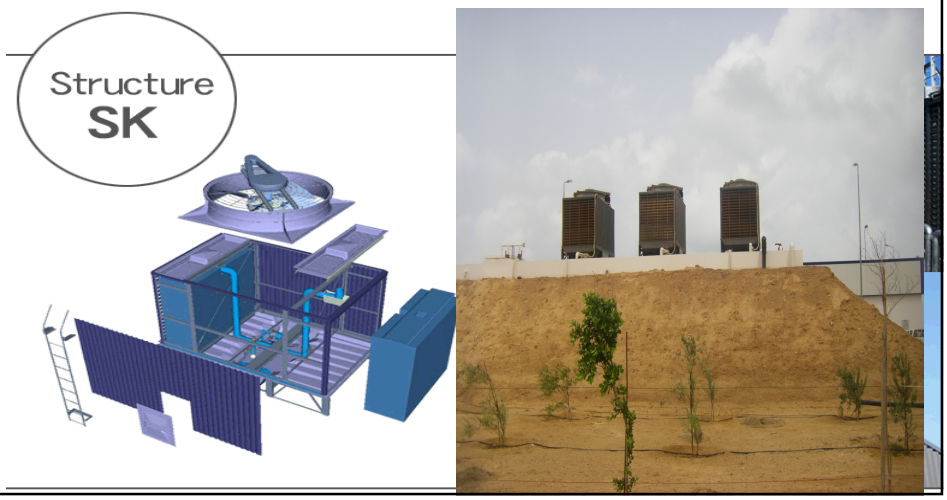
Stages of treatment





Cooling tower

- *The cooling tower (open type) is used to reduce the water temperature of 45 ° to 32 ° with forced ventilation, water falls freely in the basin at the bottom of the tower.*



Sand filters

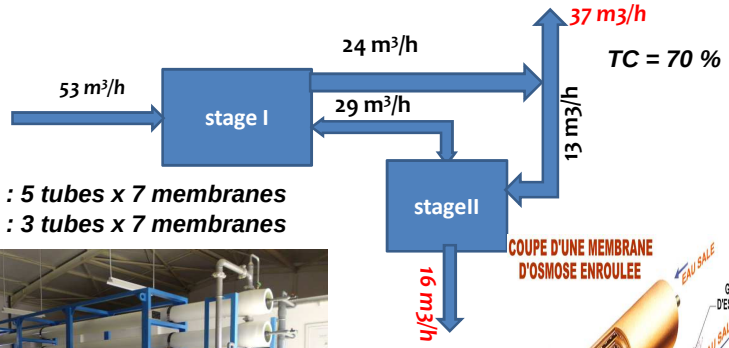
Microfiltration

After filtration over sand bed, the water goes through a microfiltration which ensures safety filtration and removes suspended solids which could not be retained by the sand filter. The cartridges used are polypropylene wound with a 1 micron filtration threshold nominal.

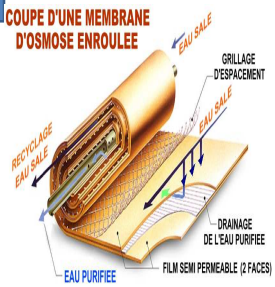
filter cartridge

The RO

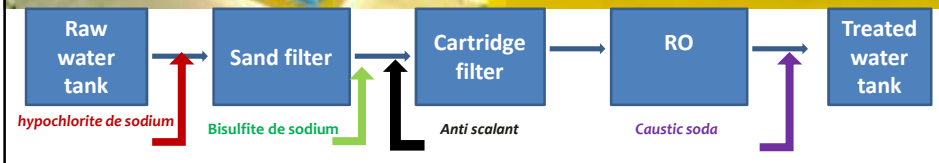
The plant is composed of two lines, each is as follows :



stage 1 : 5 tubes x 7 membranes
stage 2 : 3 tubes x 7 membranes



Chemicals



The PV system

The photovoltaic system installed at the Ben Guerdane desalination plant is a combined nominal output of 210 kWp. This system consists of 14 lines, each line contains 63 brand modules Conergy power plus 240 P

Assuming full production of the plant, the total energy consumption would be close to 12,000 kwh
If the photovoltaic system works in full power of 210 kilowatts and with 10 hours of sunshine, the total energy produced would be of the order of 2100kwh/day corresponding to approximately 17.5% of the needs of the station.

Well pump	92 kW
Raw water pump	18,5kw
Filtered water pump	18,5 kW
HP pump	132kw
Booster pump	30 kW
Transfert pump	22kw

Solar energy

✓ The photovoltaic effect is the phenomenon whereby light is used to generate electricity. This transformation is achieved through photovoltaic cells, which grouped together constitute photovoltaic modules (also called photovoltaic panels).

✓More specifically, the photovoltaic effect is obtained by absorption of the photons in a semiconductor material such as silicon (Si) which then generates an electric voltage.

✓Photovoltaics uses solar radiation to produce electricity

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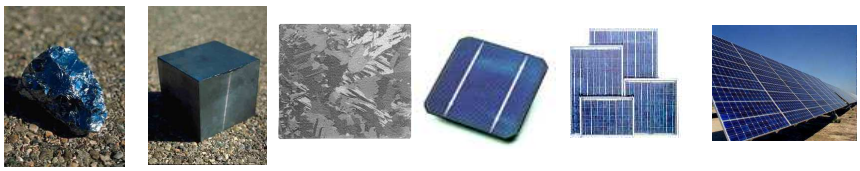
Photovoltaïc energy



purified silicon → Lingo → Wafer → Cell → Module → System

chemical process purification | Molding Sawing | Treatment Of surface | Lamination

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Solar masks

The steps for determining the mask of a solar installation:

- Tracking the presence of obstacles limiting sunshine
- Identification of key points to represent the whole of the obstacle (envelope curve)
- measuring angles (azimuth angle and height) of each of these points
- Report measures in the solar chart corresponding to the place.
- visual estimate of the risk of decreased plant performance
- Report measurements in sizing software

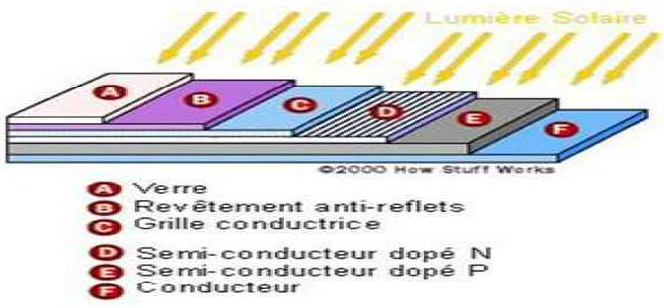
Availability of solar energy

sunlight extremely variable following:

- The site's latitude
- Season: sunshine duration, altitude of the sun, diffuse proportion / direct
- Weather conditions: cloud, dust, humidity, ...
- Altitude: fog plains and valleys
- The time of day: height / azimuth of the sun

Basic structure of a cell

The photovoltaic cell is the component of the system will actually be responsible for producing electricity. The most common cells are made of silicon (Si) which is a semiconductor that absorbs light energy and converts it directly to direct current electricity. Silicon is the most abundant element on earth after oxygen.



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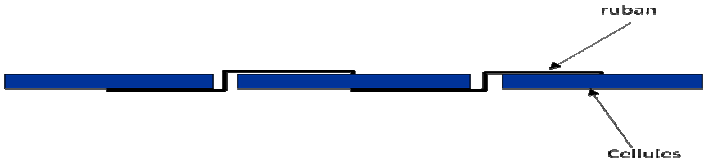
Module Specifications

- Each module comprises 36 polycrystalline cell type
- The cells are connected together by thin metal strips (tinned copper), the contact of the panel (-) in contact on the rear (+)



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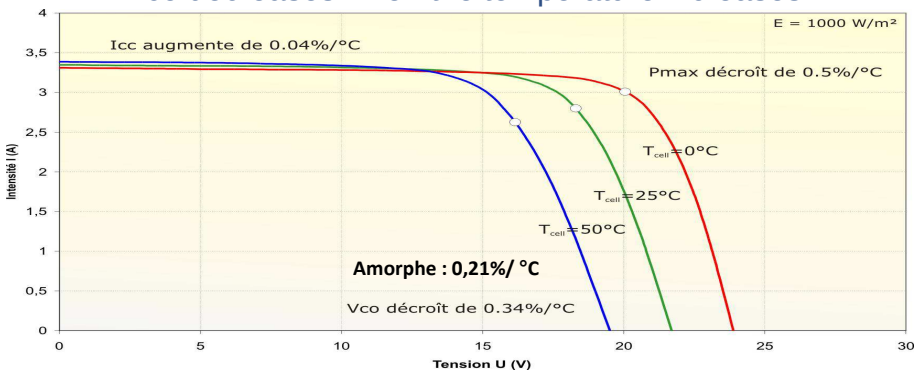
Characteristics of a photovoltaic module, crystalline silicon according to the temperature

Vco decreases when the temperature increases



The photovoltaic modules are connected in series. Series are called branches ("string"). Three fibers will be connected to a junction box and each junction box is connected to an inverter Conrgy IPG 15T

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Side direct current (DC)

- The modules are divided into fields and branches ("string")
- A photovoltaic branch is a set of modules connected together in series: the electrical potential generated by the branches is equal to the sum of the voltages provided by the individual modules which make up the branch or string.
- In this photovoltaic plant branches are composed of 21 photovoltaic modules.
- A module typically contains several cells connected in series, that is to say that the positive terminal of a cell is connected to the negative terminal of the next and so on, only the first and the last cell being connected across the module

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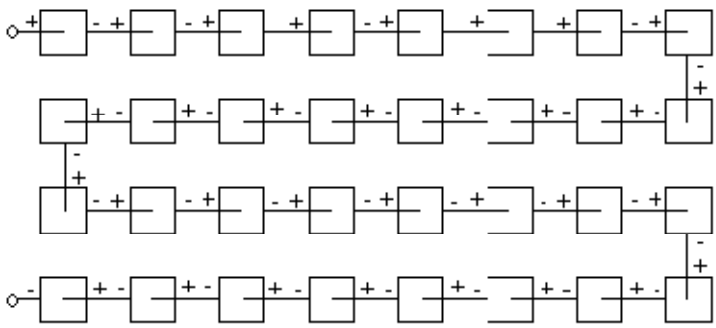
Series connection



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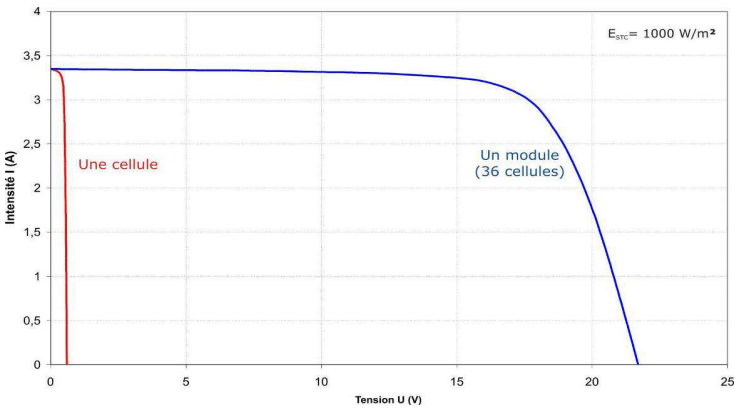
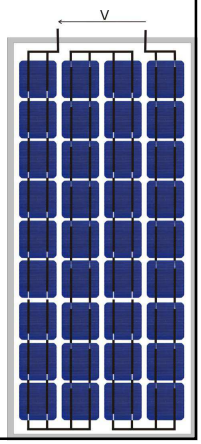
Series connection

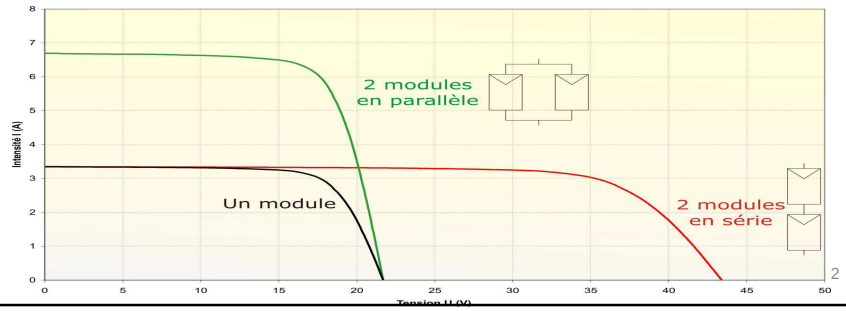
- The cells placed in series increases the voltage while maintaining the power of a cell
- Series connection of photovoltaic cells





Parallel connection

- A PV array is a collection of several branches connected in parallel: The current issue of the field is the sum of the currents flowing in each string.
- Three branches are connected in the junction box. Inside of it, there is a DC MCB and a special terminal box. Each DC output cable from the junction box will be connected to the input of the inverter. The inverter converts the DC power into AC power.



junction box

- Junction boxes are installed in the photovoltaic field to connect the group of branches at the inverter. These small DC electrical panels have the following functions:
- disconnection of parallel branches, using the DC circuit breaker and 1.000Vdc protection of overload and a short-circuit on the cables of each individual leg by fuses 12A 1.000Vdc.
- Protection device against surges with the SPD type II (for double protection on the DC side, on the other - type III-installed inside each IGBT inverter).

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junction box

These boxes are Located in the direct current of the electrical circuit between the solar panels and the inverter, string junction boxes are used to protect and to parallel the different chains of the photovoltaic field.

- **Converting the DC current into AC current occurs in the inverter cabinet,**

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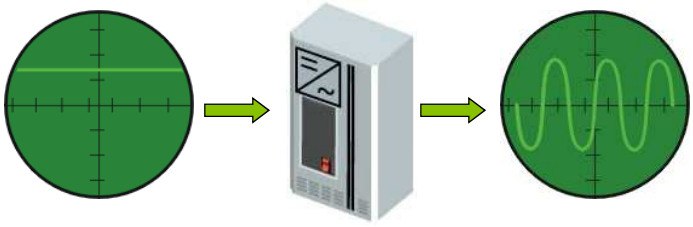
inverters

- functions:
- Converts direct current into conventional alternating current in phase with the network
- Operates the PV sensors at maximum power (MPPT) whatever sunshine and temperature
- Disconnects in the absence of mains voltage
- Protection of people by isolating the control circuit continues



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inverters

- The system uses a total of 14 inverters (1 inverter for each line).
- The inverters are brand Conergy IPG 15T.
- It is an energy receiver produced by the photovoltaic generator

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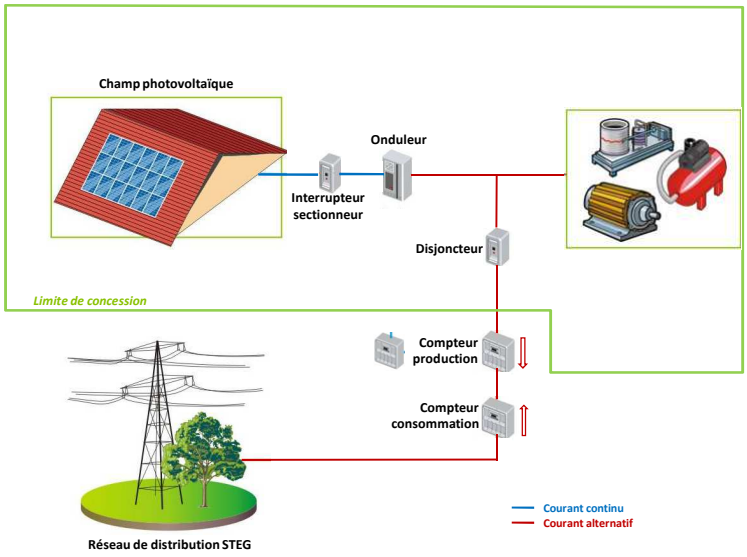
Connecting the PV system



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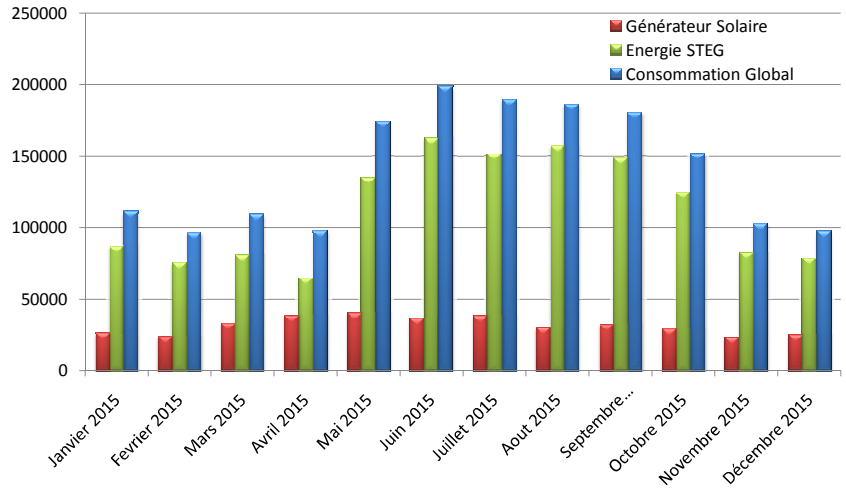
2015 Energy Balance



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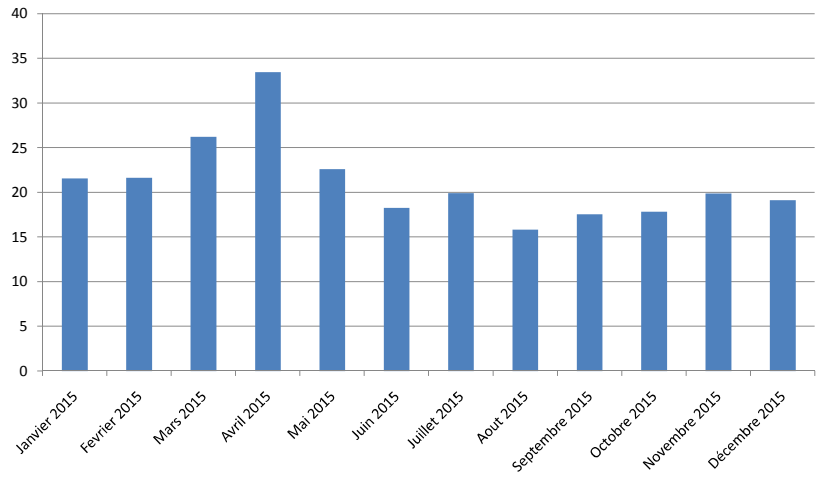
2015 Energy Balance

Participation en % de la production photovoltaïque dans la consommation globale de l'installation



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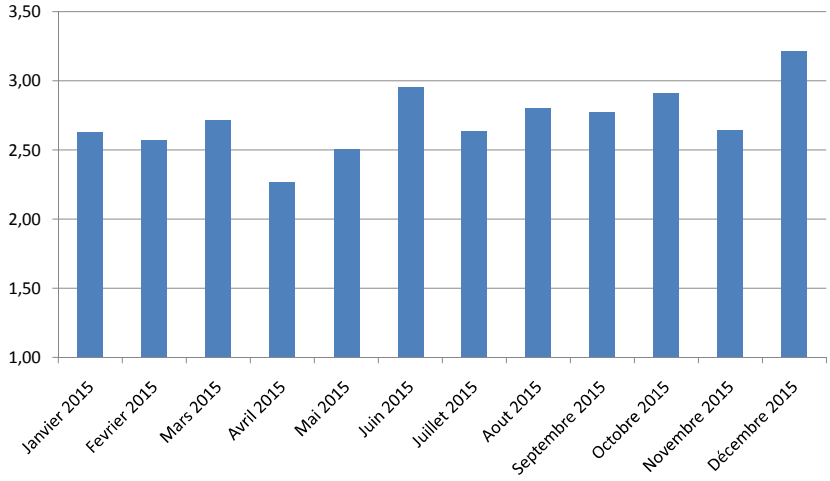
2015 Energy Balance

Consommation spécifique de la station de dessalement en kwh/m³



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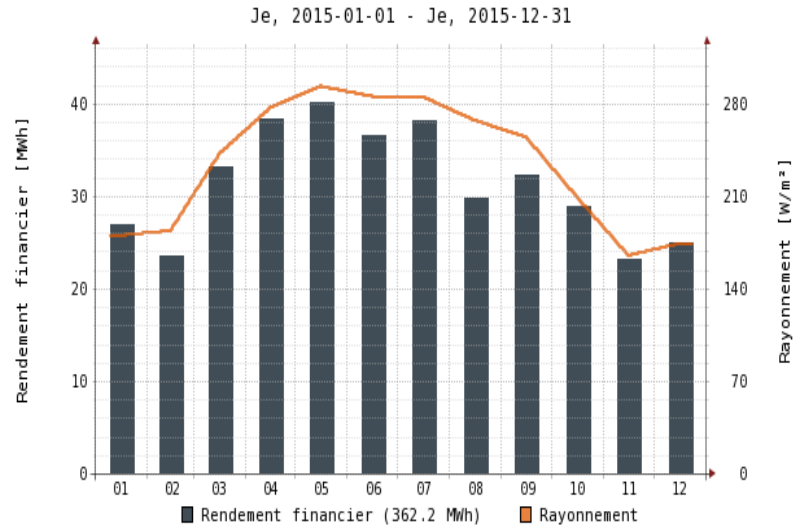
Yield curve radiation-2015



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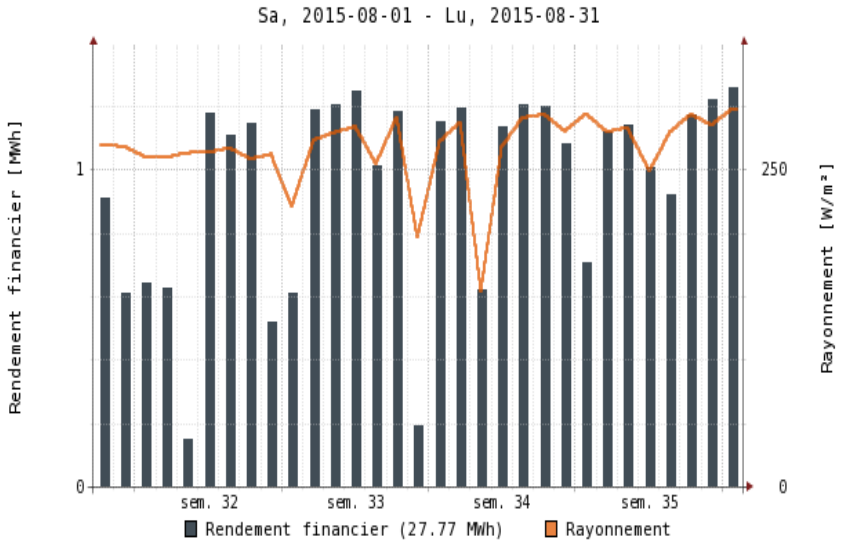
Yield curve radiation-August 2015



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Conclusions

- ✓ Priority is going towards:
  - Water mobilization management
  - Promote water saving
  - Intensify water demand management
- ✓ Seawater and brackish water desalination is an important option to mobilize additional water resources, particularly in the Central and Southern Tunisia.
- ✓ The desalination process is relatively costly and therefore the use of renewable energy is very important

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thank you for your attention