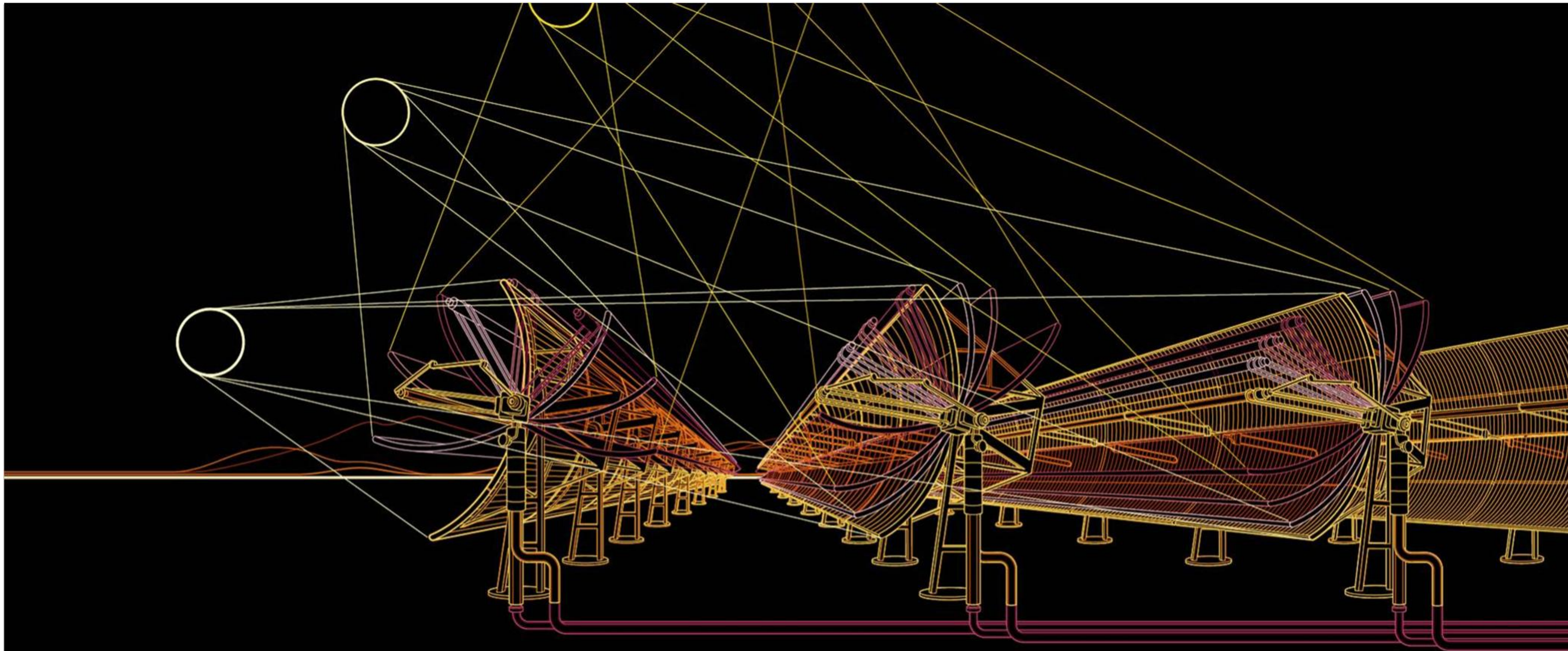
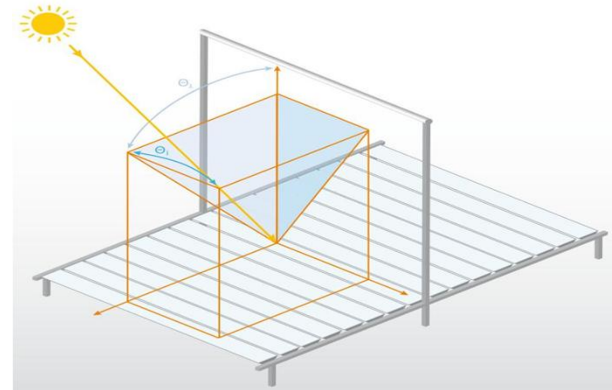


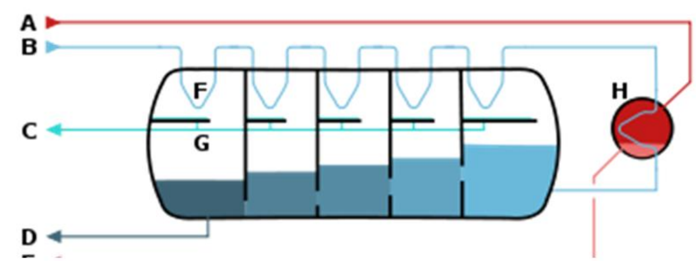
Dr. Senthilmurugan ABB 23, April, 2012

Solar Desalination
Important Technology Aspects

Solar Desalination
Talk content

- ABB in Water cycle
- Solar desalination – Introduction
  - Water scarcity vs. solar energy availability
  - Market analysis
  - Challenges and Importance of niche technology
- Technology selection criteria
  - Desalination technology
  - Solar technology
- Analysis of different possible combination of technology
  - Integration of solar and desalination technology
- Conclusion





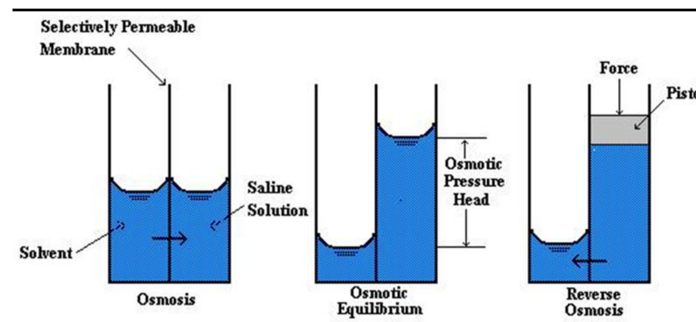
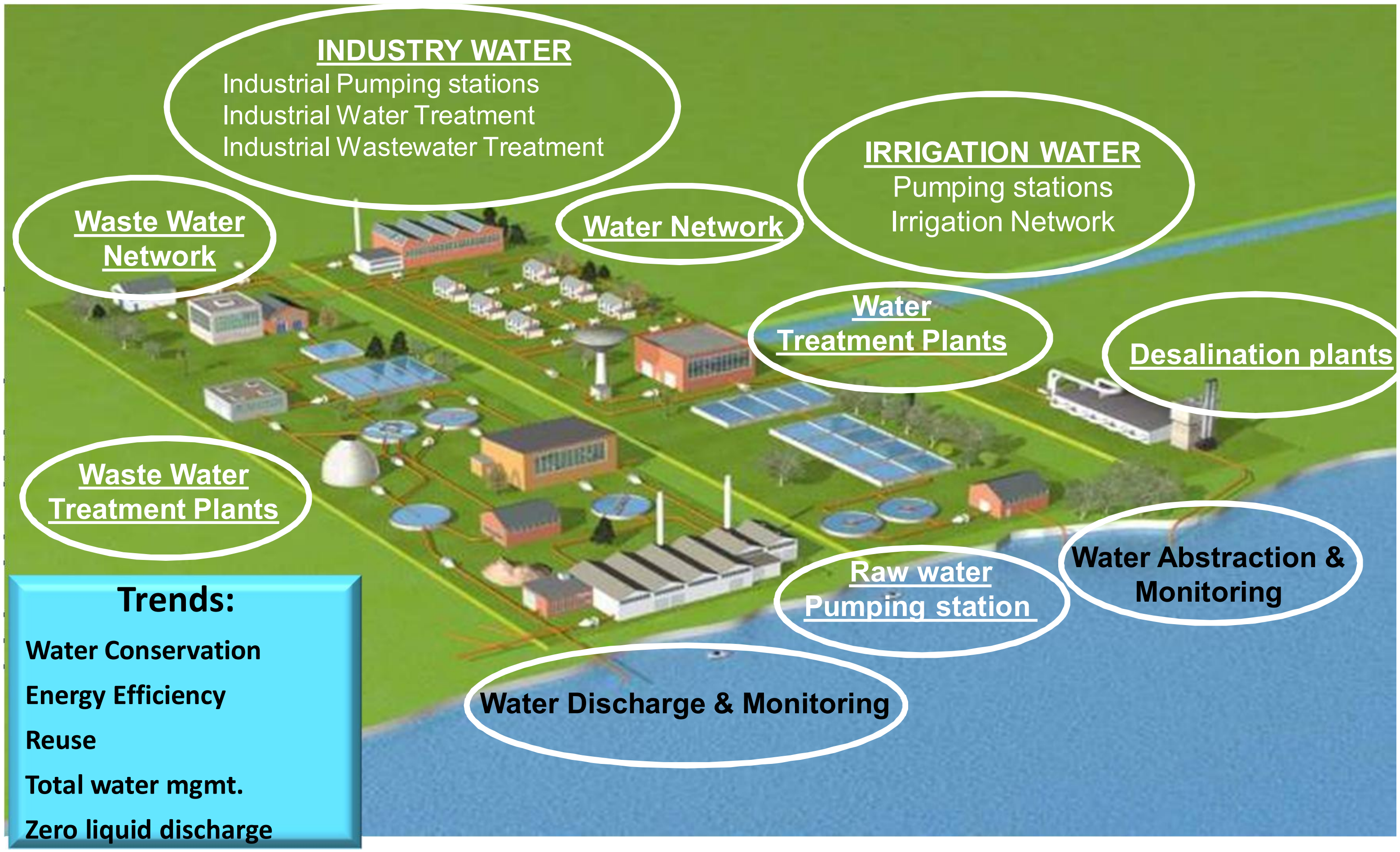


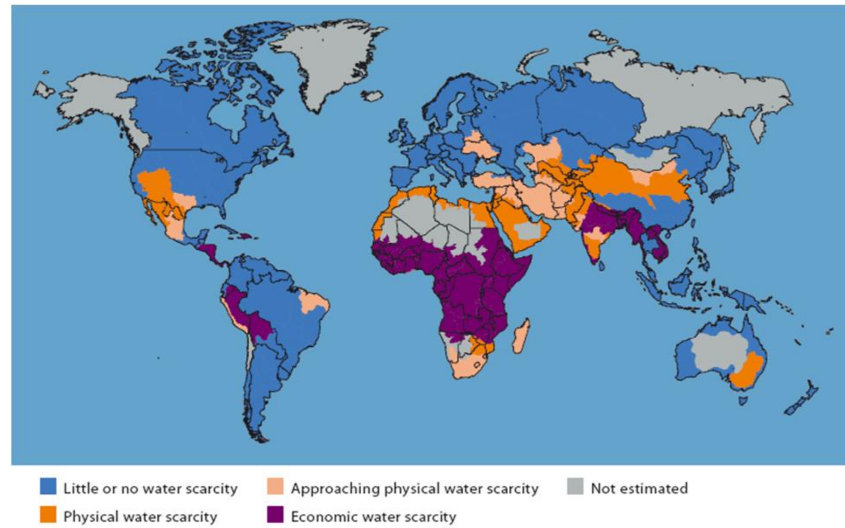
ABB in Water cycle
Where do we operate in Water market and applications?



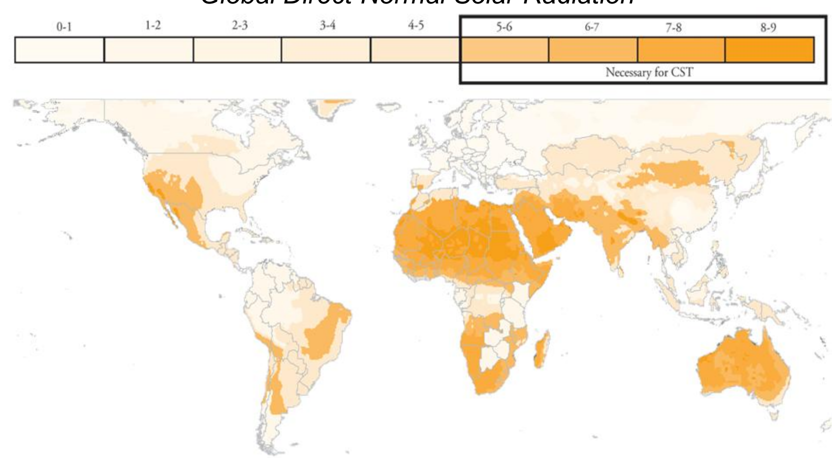
Solar desalination – Introduction
Water scarcity vs. solar energy availability

- Solar desalination offers the most promising option for use of solar energy
  - High drinkable water scarcity zones correspond to usually high DNI areas
- Important applications
  - Municipal sectors: both urban and rural,
  - Industrial sectors: waste water treatment for mining, oil and gas, etc.
- Amongst these, important growth is seen in municipal sectors.
- Application for industrial sectors will largely be driven by
  - Economics of solar desalination vs. affordability of associated sectors such as reuse/disposal
  - Environmental regulations and social acceptance for use of the treated water

Physical and Economic Water Scarcity



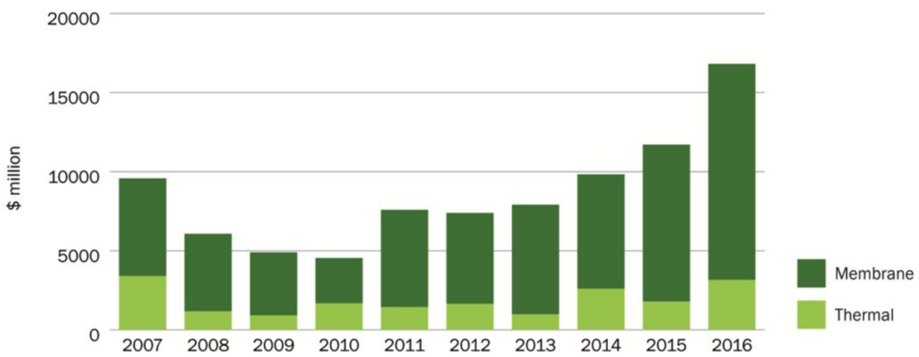
Global Direct Normal Solar Radiation



Source: World Resources Institute

Solar desalination – Introduction
Market analysis

- Use of desalinated water for
  - Municipal purposes
  - Industrial purposes
    - Mining industry: standard wastewater requirement
    - Oil & Gas, e.g. frac water treatment, recycling produced water where disposal options are limited
- Trend is towards membrane technologies with new technologies entering the arena (e.g. NanoH2O)
- Majority of investments is happening on the municipal side



Around 12.200 desalination plants under construction or in operation globally (out of around 16.000)

- Technology
  - Thermal (MSF, MED): around 1.250
  - Membrane (RO, NF): around 10.000
  - Hybrid; around 50
  - Other: around 900 (e.g. ED, EDI)
- Capacity
  - Small scale : around 11.000 plants
  - Medium scale: around 950 plants
  - Large scale: around 250 plants
- Geography
  - Americas: around 2.800 plants
  - Asia Pacific: around 3.150 plants
  - Europe: around 2.250 plant
  - Middle East, Africa: around 4.000 plants

Solar Desalination
Challenges and Importance of niche technology

Efficiency

- High efficiency solution i.e. high kw/m^2
- low cost (CapEx and OpEx) solar desalination

Power & water

- Integration of the solar technologies with the existing power plants
- Robust design for small to large water capacity

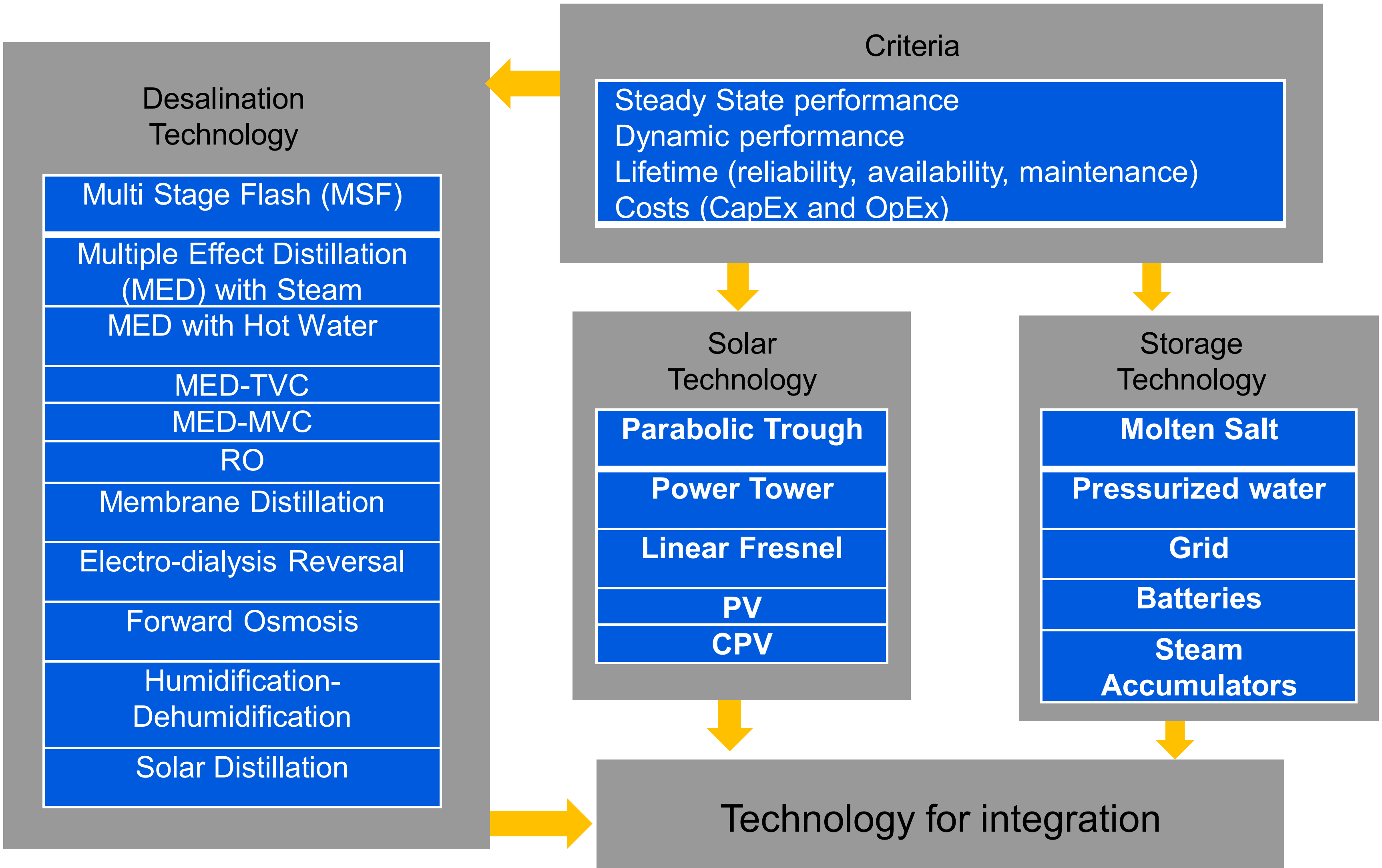
Robustness

- Robust desalination technologies with capabilities to operated at variable loads and feed quality

Storage

- Storage technology for continuous operation
- Low cost storage solution for desalination

Technology Section criteria
Desalination and solar technology



Technology Section criteria for larger capacity
Solar Desalination

Steady State Performance	Dynamic performance	Life time	Costs
$\frac{\partial p_{out}}{\partial t} = 0$ $\frac{\partial p_{in}}{\partial t} = f(in)$	$\frac{\partial p_{out}}{\partial t} = f(in, \tau)$ $\tau = \text{low}$	$\frac{\partial^2 life}{\partial t^2} < 0$ $life = f(in)$	$\frac{\partial^2 cost}{\partial t^2} > 0$ cost = CapEx +OpEx
Capacity of the plant (urban/rural) Geographical location of solar desalination system, Energy Dispatchability	Adaptability to dynamic operation Capability of decentralization Utilization of waste heat,	Ease of operation and maintenance Reliability availability, commercial maturity Scaling/fouling	CAPEX, OpEx,

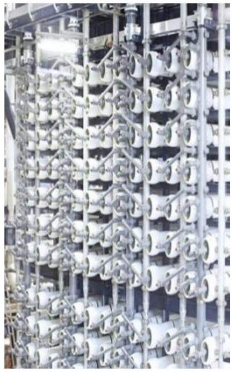
ABB

Analysis of Solar desalination
Steady State Performance

- Capacity of the plant (urban/rural)
  - Desalination technologies are: Multi-Stage Flash (MSF), Multiple Effect Distillation (MED) (with and without thermal vapor compression), Reverse Osmosis (RO) for seawater as well as Electro-Dialysis (ED) for brackish water most favorable for higher capacity
  - For smaller capacity : solar distillation, multiple effect dehumidification, membrane distillation, RO
- Geographical location of solar desalination system,
  - The factors related to geographical location are: cost of land, environmental factor i.e. corrosion, humidity, DNI
  - It will decide applicability of solar desalination technology selection for given geographical location.
- Energy Dispatchability
  - This is one of the important factors that influences the design of storage as well as integration with the existing conventional power plant.
  - CSP technologies will have clear advantage in terms of their suitability for thermal storage as well as integration with the existing power plants.
  - In this regard, the sizing and economics of storage as well as grid connectivity will influence the selection of appropriate technology for a given location.

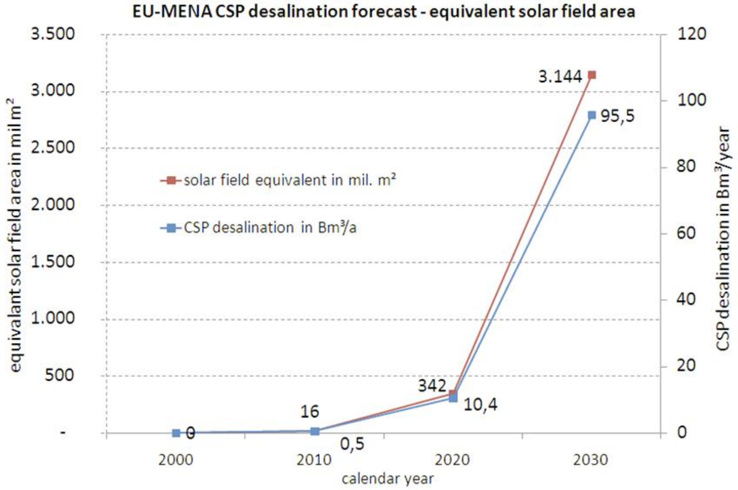
Analysis of Solar desalination
Dynamic performance

- Adaptability to dynamic operation
  - As far as solar system dynamics is concerned, PV operation is very dynamic with huge power ramp rates, whereas CSP has much smaller dynamics due to thermal inertia of the system.
  - However, in the cloudy weather, there is only reduction in power output of the PV while there is no/negligible power output for the CSP.
  - On the other hand, in specific areas with high DNI and negligible cloud cover (where the abovementioned drawback does not exist), CSP technologies will have clear advantage in terms of their suitability for thermal storage as well as integration with the existing power plants
  - As far as desalination is considered, a technology option that can easily adapt to varying capacity will be a favored choice.
- Capability of decentralization
  - The seawater desalination plants need to be located close to the coast, the DNI usually is not favorable in such locations.
  - This will favor solar installations at inland locations with grid connectivity.
- Utilization of waste heat
  - As far as thermal desalination technologies are concerned, the capability of utilization of waste heat from power plants plays a major role in the overall economics of the solar desalination integrated systems.
  - In this regard, the economic benefits associated with the utilization of such waste heat as well as its effect on the power generation will affect the choice of technologies.



Analysis of Solar desalination
Life time & cost

- The most important factors affecting overall economics are the CapEx and OpEx of the integrated system
- which is influenced by sharing of various components as well as overall increased efficiency of the integrated system.
- In additional to this, parameters like the ease of operation, reliability, availability, commercial maturity and lifetime of the integrated system will play a vital role in coming up with the best possible combination.
- Optimal selection of desalination and solar technology may lead to compromise on some of the least weighted parameters to achieve the final goal.



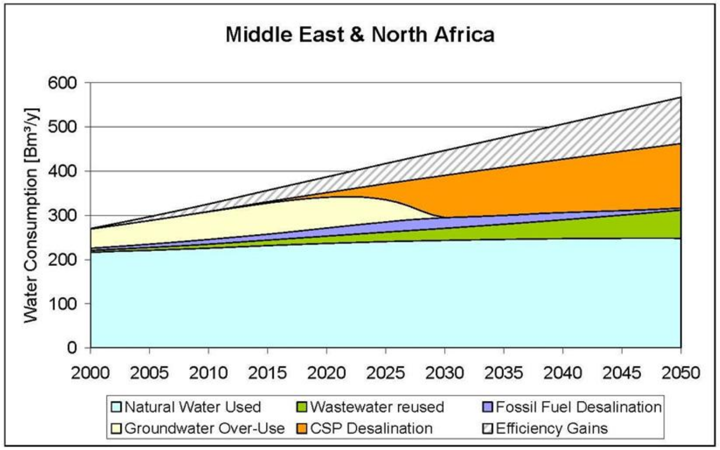
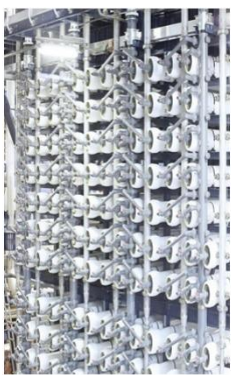


Figure 4-5: Water demand scenario for MENA until 2050 and coverage of demand by sustainable sources, by unsustainable sources and by solar desalination. (shaded: efficiency gains with respect to business as usual)

Solar Desalination- Rural Municipal Water Applications
Analysis



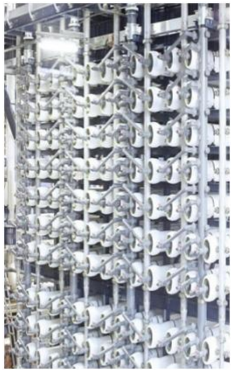
- For rural municipal water applications, the emphasis will be on solar desalination technologies such as solar distillation, multiple effect dehumidification, membrane distillation, RO etc., and will require smaller CapEx investments.
- Although such units can be operational only during daytime, simple storage options such as hot water storage and/or batteries can ensure continued production when Sunlight is not available.
- These technologies have advantages such as variable capacity operation, capability to use waste heat, lower operation and maintenance cost, ease of operation, etc.
- In addition to this, the poor infrastructure, lack of grid connectivity, non-availability of high skilled labor, etc., in a rural environment further favors application of these technologies at the desired small scale capacities.

Solar Desalination for industries
Analysis

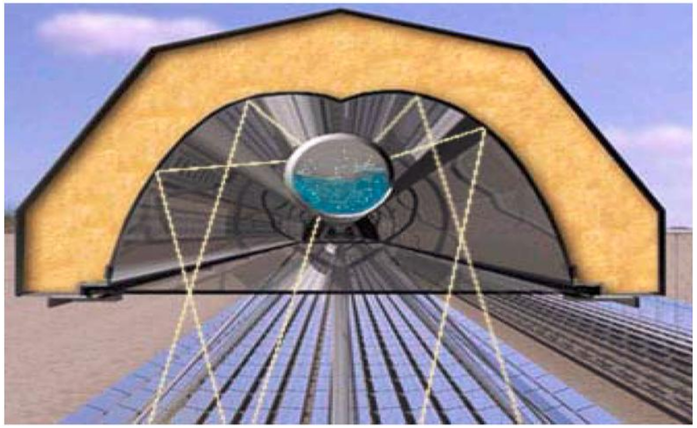
- As far as application for solar desalination for industries is considered, the technological advances achieved for the municipal water applications can be evaluated economically considering the overall economics of the water treatment process.
- Accordingly, the solutions can as extended for industrial application.
- In such cases, quality of the waste water, environmental regulations, availability of fresh water, integration with the existing power plant, along with the aforementioned criteria will play a crucial role.

ABB

Conclusion
Solar desalination technology Analysis



- The selection of optimal solar-desalination-storage technology combination will require evaluation of each criteria as well as assignment of suitable weight for each of them to arrive at the preferred choice.
- The weight assigned to each criterion will be governed by the priorities of the decision maker as well as external influencing factors such as local grid pricing, land pricing, environmental regulations, local laws, etc.



Conclusion
Solar desalination technology Analysis

- PV *vs* CSP Solar Desalination
  - PV plant located inland and providing electrical energy to the RO based-Grid connected desalination, will be a preferred option (due to higher DNI at the inland areas).
  - However, for CSP-MED combination, while less DNI and high land costs (at coast) are unfavorable, there are reduced costs due to waste heat utilization and use of the common power block. In addition to this, suitability of CSP based options for cheaper thermal storage over expensive battery storage will also be a favoring factor.
- As far as operability of 24 hrs/day is considered, higher CapEx investment in desalination for urban municipal water applications, will require that these plants be operated at full load. This makes CSP options, with capability of thermal storage and integration with the conventional power plants, a preferred choice.
- For low capacity rural applications, a standalone solar desalination system with relatively low CapEx will be suitable for the "day time only" operation. Cheaper hot water storage can be favorable for extending operational hours.
- Long term and high volume storage of water has limitations due to hygiene issues. In this case, thermal storage applications, although expensive, may offer possibilities of reduced water costs by ensuring full load operation (with/without conventional power plant connectivity).

Power and productivity
for a better world™

ABB