THERMAL DESALINATION DRIVEN BY AN INNOVATIVE SALINITY GRADIENT SOLAR POND LOCATED IN THE COASTAL WATERS OF OPEN SEAS

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Thermal Desalination (MSF/FBE) in Combination with Renewable Energy

In many earlier publications, the Multi-Stage Flash/Fluidized Bed Evaporator (MSF/FBE) has been described as a very interesting emerging thermal desalination technology for renewable energies like wind, solar and geothermal.

Main reasons are:

- Its robust design (no anti-scaling chemicals and no wire-mesh demisters needed and complete flash-off),
- low pumping power requirements,
- variable distillate production of excellent quality at a varying maximum operating temperature
- and the possibility to install many stages in a relatively short flash range, utilizing very small ΔT's, which allows for a design with a very low specific heat consumption.

In session 4 of these CWC Seminars, a presentation pays attention to the miracles of the MSF/FBE.

Salinity Gradient Solar Pond (SGSP) as Source for Renewable Energy -1

Description:

A solar pond is a thermal solar collector with integrated storage. It consists of three layers with different salt concentrations of which the storage layer at the bottom has the highest concentration and density.

About 15% of the total received solar energy by the pond, i.e. for the Arabian Gulf approx. 5.6 kWh/m^2/d, is absorbed by a blackened bottom. The water being trapped by its high density is heated to the desired temperature.

Depending on the thickness of the storage layer, vast amounts of thermal energy can be stored at temperatures up to 80^{0}C – 90^{0}C.

Salinity Gradient Solar Pond (SGSP) as Source for Renewable Energy -2

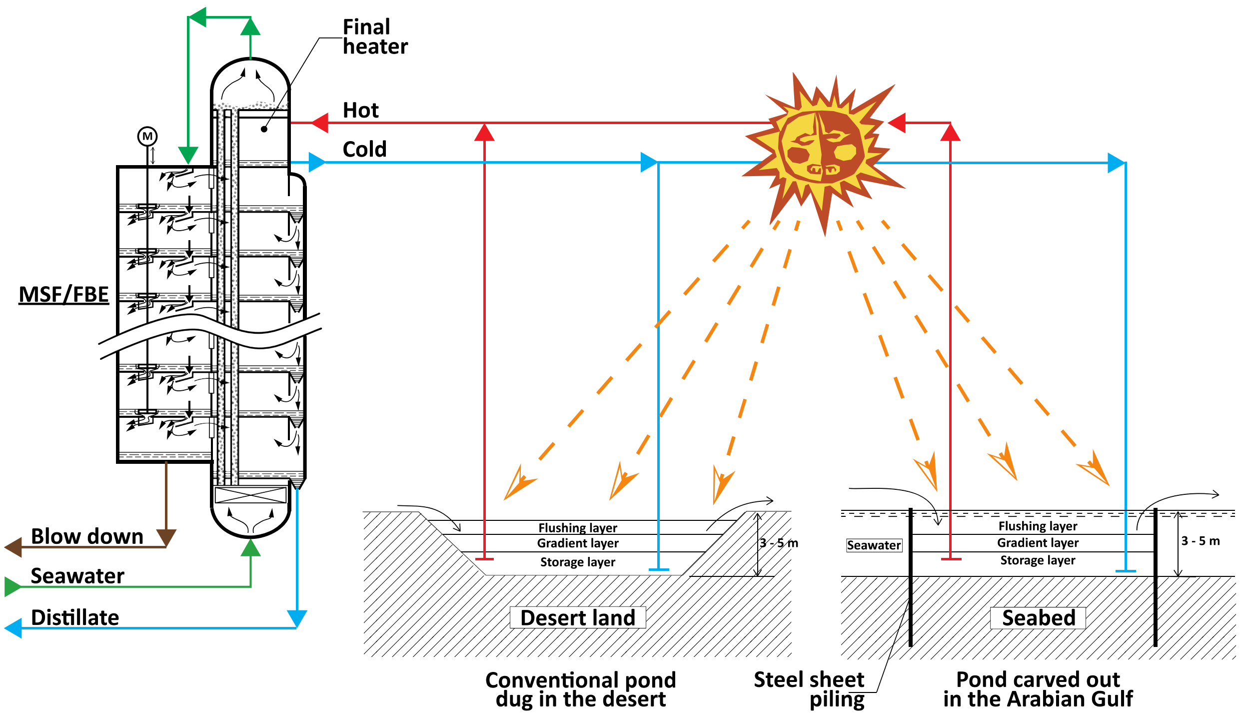
Advantages of the solar pond system:

- Low investment costs per installed collection area.
- Thermal storage is incorporated into the collector (solar radiation directly loads the storage) and is very inexpensive.
- Diffuse radiation (‘cloudy days’) is fully used, also at a high temperature of the storage zone.
- Expensive cleaning of large collector surfaces in dusty areas becomes unnecessary because the pond system is ‘self-cleaning’ (dust sinks to the bottom and surface pollution is washed away).

MSF/FBE Powered by SGSP -1

This figure gives an example of the MSF/FBE powered by two different SGSP's.

- Conventional pond excavated in the dessert.
- Pond located in the coastal waters of open seas using a steel sheet piling wall [1].



1) Steel sheet piles are long structural sections with a vertical interlocking system that creates continuous wall. The walls are most often used to retain soil or water.

MSF/FBE Powered by SGSP -2

Conventional pond compared to a new revolutionary pond located in the coastal waters of open seas.

- Conventional pond requires a massive excavation of soil to create the required depth and area. Moreover, the enormous area of the pond has to be made leak-proof by a sealed 'blackened' carpet or foil to prevent loss of water and contamination of the ground water.
- The pond located in the coastal waters of open seas has equal hydraulic pressures at both sides of the steel sheet piling wall. This means that there are no driving forces for leaking flows and, consequently, there is also no need for a sealed leak-proof 'blackened' rubber carpet or foil on the bottom.

Example -1

Specification 'once-through' MSF/FBE:

• Distillate production	: 90,000	m^3/d
• Total number of stages	: 30	-
• Average stage height	: 0.4	m
• Specific heat consumption	: 225	kJ/kg
• Maximum seawater temperature	: 82	^0C
• Seawater inlet temperature	: 35	^0C
• Total pumping power requirements	: 1.25	kWh/m^3 distillate
• Total investment cost MSF/FBE	: 125	million $

Example -2

Specification Salinity Gradient Solar Pond (SGSP):

• Daily average incoming solar radiation (solarity) in the Arabian Gulf and Red Sea	: 5.6 kW
• Maximum temperature solar pond	: 85 ^{0}C
• Thermal efficiency solar pond	: 15 %
• Required blackened bottom surface area to serve the 'once-through' MSF/FBE	: 6.82×10^{6} m^2
• Diameter of blackened bottom surface area	: 2.95×10^{3} m
• Average pond depth	: 5 m
• Steel sheet piling length	: 10 m
• Cost of installed high duty coated piling wall	: 125 $/$m^2$
• Total cost piling wall	: 11.5 million $
• Total cost solar pond (estimated at 3 x 11.5 million $)	: 34.5 million $

Cost Comparison Solar Ponds

The conventional pond requires massive excavation of soil whether or not in combination with an additional dike construction to assure 5 m water depth and water tight sealed ‘blackened’ bottom. In 1987, the costs for the conventional solar pond were approx. $ 8/m^2. For the price level in 2014 and assuming an average annual inflation of 2% over the past 27 years, these costs may have been increased to $ 13.7/m^2, or $ 93 million for the full size pond.

The pond for the coastal waters of the open seas, e.g. Arabian Gulf or Red Sea, we have already estimated the total cost at $ 34.50 million, based on $ 11,5 million for the piling wall only.

Open Seas Pond and Its Novelties

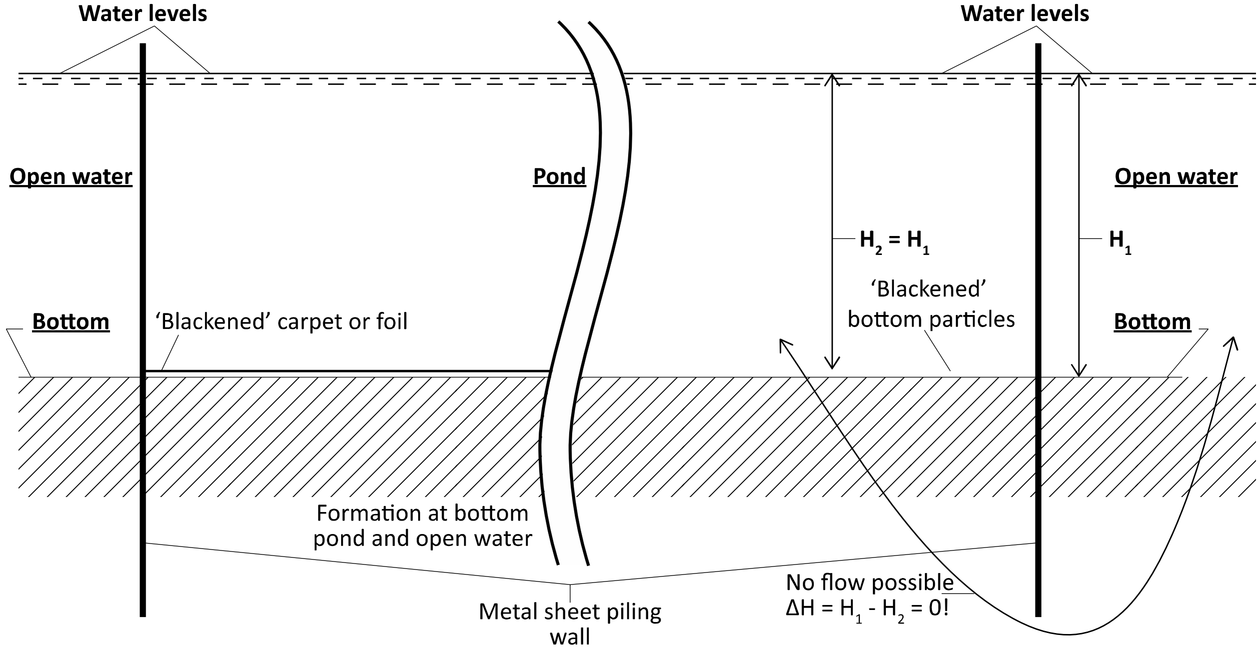
1. The pond is separated from the open water by the steel sheet piling wall which can be erected at relative low cost.
2. Because of almost equal hydraulic pressures, i.e. water levels, inside and outside the pond, there are no leak flows from outside the pond into the pond or vice versa. As a consequence a 'blackened' bottom consisting of a sealed leak-proof carpet or foil is not necessary and can be replaced by a much lower cost layer of a few centimetres of coal particles, gravel or similar material.
3. Tidal effects in the open water are used to flush the piling walls with relatively cold fresh water and prevent direct contact of these walls with the hot high salinity and very corrosive brine at the bottom of the pond.
4. Servicing tool for the construction of the pond and the 'blackened' bottom.

Some of these novelties require a more detailed explanation to be given in the following slides.

Novelty # 1

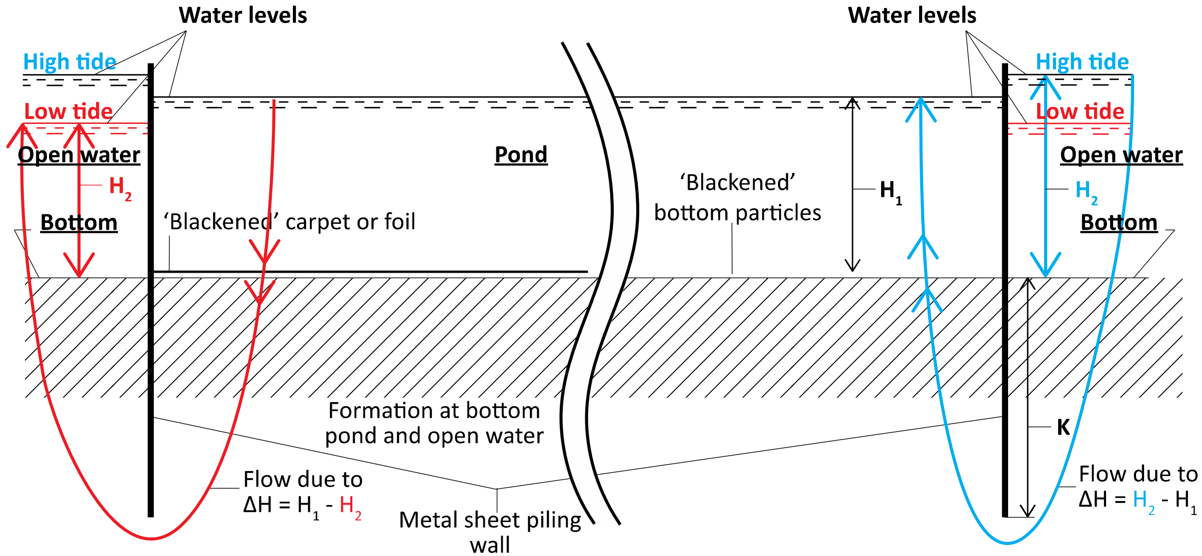
This novelty refers to the use of the steel sheet piling wall for the isolation of a pond in open waters, instead of a man-made pond on land requiring massive excavations of soil and/or heavy dike constructions.

Novelty # 2



Pond in open water with equal water levels, no tidal influences

Novelty # 3 -1



Pond in open water with different water levels caused by tidal influences

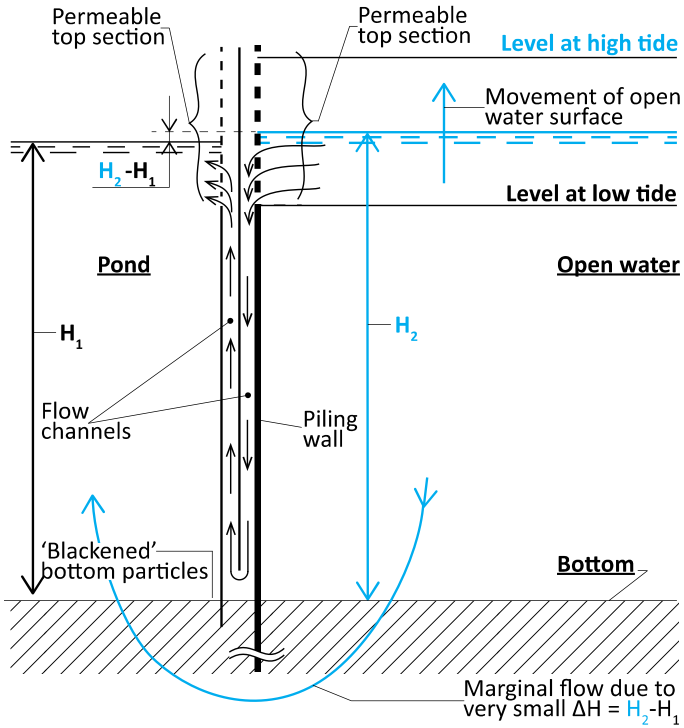
Novelty # 3 -2

Consequently, the third novelty is based on the idea that we use the tidal effects in the open water to allow in- and out flows between pond and open water. These flows through the channels mounted along the steel sheet piling wall should prevent direct contact of the metal sheet piling wall with the hot and very corrosive high salinity brine at the bottom of the pond. The materials used for these channels do not require the strength of the piling wall, but should be able to withstand the corrosive brine.

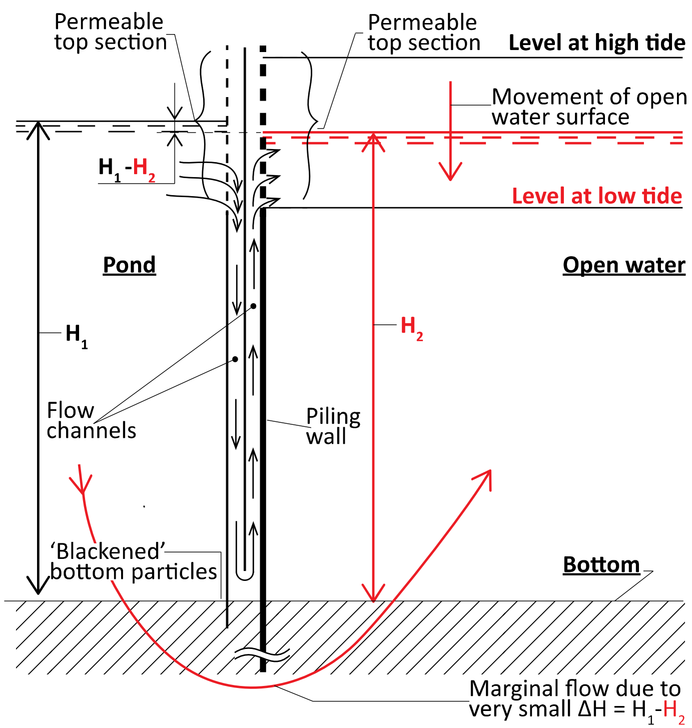
The channels allowing for this in- and out flow between pond and open water can be designed for a very low pressure drop of the water flow, or very small differences in water height between the open water and the pond which minimizes the flow through the formation at the bottom of the pond and allows for a low cost ‘blackened’ bottom.

The in-and out flows between the surface of the pond and the surface of the open water caused by the tidal effects are water flows with approximately the same temperature. Consequently, this exchange of flows has little consequences on the thermal efficiency of the solar pond.

Novelty # 3 -3



Flows and water levels at high tide



Flows and water levels at low tide

Flows through channels and water levels (heights') at different tides

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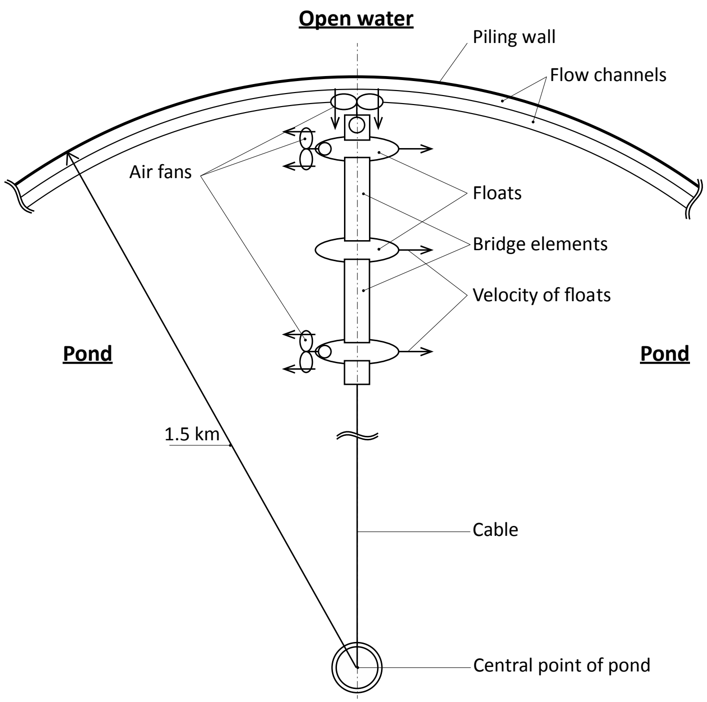
Novelty # 4 -1

This novelty refers to the tool used for completing the functionality of the pond and servicing the 'blackened' bottom. This tool consists of bridge elements carried by a large number of floats which can be rotated around the central point of this cylindrical pond using air fans installed on some of the floats.

With auxiliary equipment installed on this construction, we can reach any position in the pond and evenly distribute and put in place on the bottom 'blackened' carpet, foil or particles and maintain the bottom in excellent condition, clean the bottom when necessary, and also add the large quantities of salt (preferably NaCl) to establish the required salinity gradient in the pond.

Novelty # 4 -2

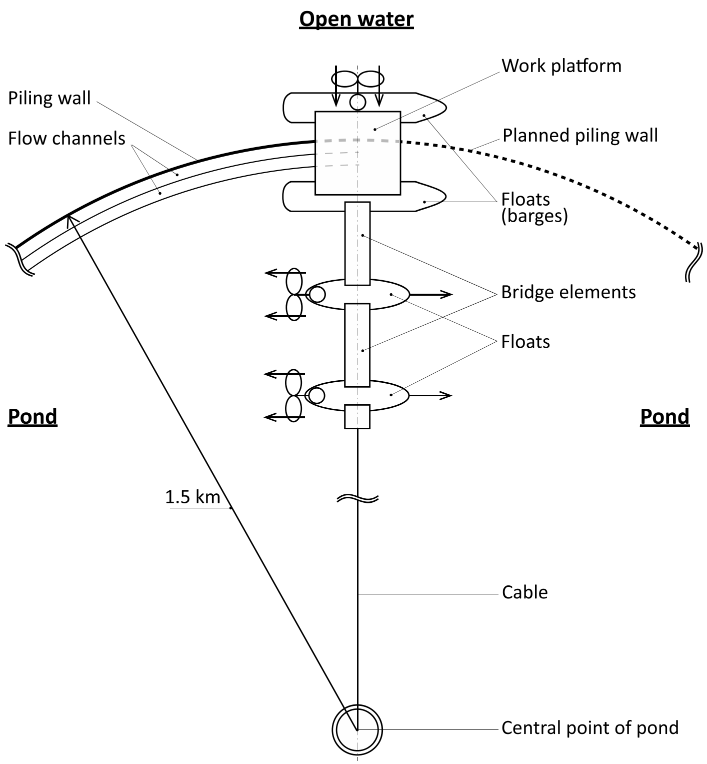
A cable with variable length is used for radial positioning. One fan is keeping the cable under tension. Two fans are responsible for the rotation.



Rotating tool for maintenance services of the pond

Novelty # 4 -3

Impression about the working platform used for the erection of the piling wall and attached flow channels. Because we are still working in open water we can use submerged screws or propellers’ for positioning.



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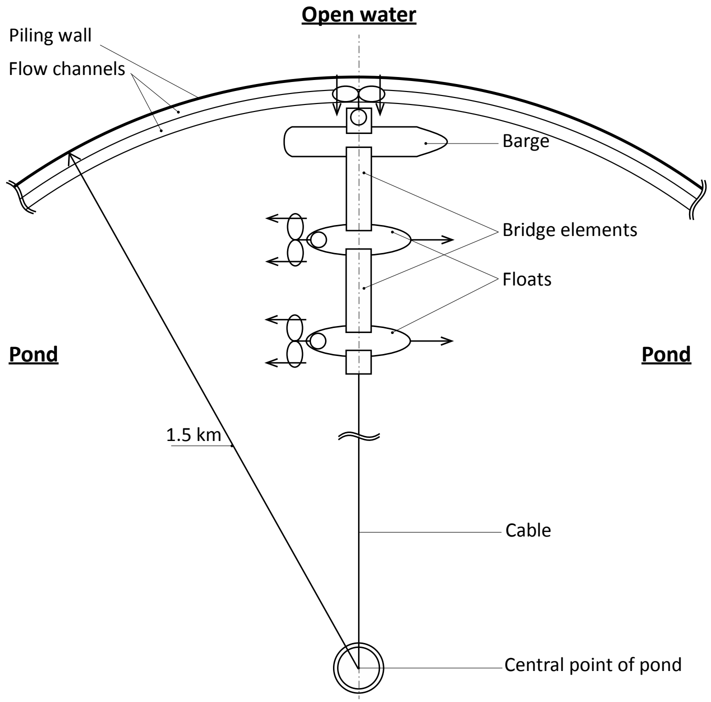
Novelty # 4 -4

One of the barges for the erection of the piling wall as the rotating tool is used for maintenance services of the pond, although now equipped with air fans.



Remarks about the Required Basic Raw Materials

We do not know yet how fast the pond would build up the required salinity gradient by itself due to evaporation at the water surface. Sometimes, this might take considerable time, and in that case it is an advantage that we depend on NaCl, the most preferred salt for solar ponds, and abundantly available. When we need more salt to accelerate the start-up of the desalination plant, large quantities of NaCl can be made in salt ponds on nearby shores requiring a minimum of transportation cost.

A layer of 1 cm of ‘blackened’ brown coal particles on the bottom of the pond with a porosity of 40% (i.e. packed bed) and a dry density of approx. 1,200 kg/m^3 would require a total quantity of approx. 50,000 tons brown coal of the poorest quality (i.e. a high moisture content, high ash content and high concentration of impurities) at an estimated price of $ 50/ton, and total cost of $ 5.0 million, including packaging in big bags and transportation cost. For a rather even distribution of the brown coal in the big bags over the bottom of the pond, we again rely on GPS positioning in combination with an additional fine-tuning and equalization of this layer using the tool for servicing the bottom of the pond presented in the previous slides.

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Conclusions

This presentation has paid attention to:

- *An emerging thermal desalination process*, for which we refer to the MSF/FBE technology, a vertical 'once-through' MSF evaporator equipped with fluidized bed condensers, for a production of 90,000 m^3/d, a specific heat consumption of 232 kJ/kg and a maximum (chemically untreated) seawater temperature of 83^0C,

  driven by

- *renewable energy,* for which we refer to the use of solar energy in Salinity Gradient Solar Ponds. For the construction of the solar pond which also includes the possibility for thermal storage, we have introduced new revolutionary ideas. As a consequence, we plan to build the pond in open water, e.g. the water near the coast of the Arabian Gulf or Red Sea with a total area of 6.8 km^2.

Finally resulting in distillate cost less than $ 0.60 / m^3.

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Thank You!

Any Questions?