

# CSP (Concentrated Solar Power) - Tower Solar Thermal Desalination Plant

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**Abstract:** The main goal of this paper is that achieve 1.48 US \$/m<sup>3</sup> for LCOW (Levelized Cost of Water) and 0.016 US \$/kWh<sub>th</sub> for LCOH (Levelized Cost of Heat). For this goal, the paper suggests an integrated CSP (Concentrated Solar Power)-Tower Solar thermal desalination facility with steam storage. The plant includes heliostat area, solar receiver, and thermal desalination unit and steam storage system. When sun shine, steam that is produced from the CSP heliostat field will be sent to steam storage system and the thermal desalination unit via steam reducer. Also, extra heat will be again used to charge the steam storage during the peak hours. The fresh water that is output of the desalination unit will be for public utilization. The brine (excessively salty water) that is output of the desalination unit will be processed for to obtain precious minerals with ZLD (Zero Liquid Discharge) technologies. Assumptions that is to calculate unit price are type of return schedule, type of interest rates for every year; and amortization and taxation are ignored. With these assumptions, the methodology achieves the goal with 1.48 US \$/m<sup>3</sup> and 0.016 US \$/kWh<sub>th</sub> for 12 years return time, %3 interest rate without subsidizing.

**Keywords:** LCOW, Levelized Cost of Water, LACW, Levelized Avoidable Cost of Water, LCOH, Levelized Cost of Heat, Discount Sensitivity, Payback Period

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## 1. Introduction

This paper introduces production of fresh water through solar thermal desalination. Most of the currently operational desalination plants use reverse osmosis, Delyannis [1], Khawaji et al. [2], Al-Shammiri and Safar [3], and Warsinger et al. [4]. Solar thermal desalination is superior to this and other methods of desalination for a number of reason, Crittenden et al. [5]. First, unlike these plants that burn fossil fuels and other un-renewable energy sources to run the plant, a solar thermal desalination plant runs entirely on solar energy; and the steam that it generates during the desalination process, Further, a solar thermal desalination plant can operate and produce water far more cheaply than the current technology, Panagopoulos [6], García-Rodríguez et al [7], Kalogirou [8] and Qiblawey and Banat [9]. Thus, a solar thermal desalination plant provides the environmental benefit of a reduced the carbon footprint, lessens the United States' dependence on foreign fossil fuels, and provides water to

the American public at lower costs.

Widespread commercialization of the solar thermal desalination process also addresses a critical, life-and-death issue namely, the scarcity of fresh water in various parts of the country. Indeed, the growth of the U.S. population, coupled with lengthy droughts, has created significant fresh water shortages in certain states. These shortages have not only threatened human life at the most basic level but also they have had significant socio-economic impacts. For instance, because of fresh water shortages, farming has had to be scaled back in certain U.S. states, which has led to job loss and shortages of farming products. Building thermal plants in these areas is a clean, cost-effective way to address provides immeasurable benefits to human health, safety, and prosperity.

The highlights of the paper are as follows:

- 1) Utilize CSP-Towers to operate desalination plants based on renewable sources;
- 2) Generate and store steam by using the lowest number of heliostats at high temperature and pressure;

- 3) Utilize steam generated by the solar thermal desalination plant to provide energy for the desalinization process during periods of no sunshine;
- 4) Achieve the lowest LCOW (Levelized Cost of Water) and LCOH (Levelized Cost of Heat) on the market today;
- 5) Utilize successful solar thermal desalination plant as a model for future use.

## 2. Technical Description

### 2.1. System Description

CSP field will be installed with 1500 heliostats; and during periods of sunshine, steam produced from the CSP heliostat field will be sent to steam storage system and thermal desalination unit via steam reducer. During periods of no sunshine, the steam storage system will discharge and thermal the desalination unit will continue to work. The brine that is output from the desalination unit will be processed to obtain precious minerals with ZLD (Zero Liquid Discharge) technologies. The fresh water output from the desalination unit will be for public consumption and utilization. The fresh water output from the desalination unit will be for public consumption and utilization.

### 2.2. Plant Components

Figure 1 represents a diagram for proposed CSP facility.

#### 2.2.1. The Heliostat Field

- 1) 1500 heliostats (each heliostat is 16 m<sup>2</sup>; total field is 24,000 m<sup>2</sup>).
- 2) Main goal is production cost of heliostat less than 100 US \$/m<sup>2</sup>, including simple site assembly and erections designs including.
- 3) Smart and independent heliostat system with wireless communications and autonomic calibrations.
- 4) Automated interactive heliostat field control management using auxiliary software.
- 5) An analysis is conducted based on solar conditions that are typical in areas in which the proposed solar thermal desalination plant would operate.
- 6) Figure 2 presents the design data for a heliostat field derived from an engineering analysis.
- 7) Figure 3 presents the calculation of production hours and power using the design data.
- 8) Figure 4 presents a graph of seasonal production times for identified performance points.
- 9) Figure 5 represents the seasonal average thermal energy production graph derived from the design data and seasonal working hours.

#### 2.2.2. The Thermal Desalination System

A "MEP (Multi-Effect Plate Evaporator)" is considered, and the MEP desalination process consists of a series of evaporation and condensation chambers known as effects. Each effect is fitted with heat transfer, and in the plate

channels of an effect, seawater or brackish water on one side is heated up and partially evaporated to distillate vapor, which is used in the next effect; on the other side, the distillate vapor from the previous effect is condensed, giving up its latent heat, into pure distillate. By maintaining a partial pressure difference across the effects, the process is able to yield maximum efficiency from available low-grade thermal energy sources. The performance and the capital cost of the system are proportional to the number of effects contained in a unit. The system flow diagram of a four effect MEP is shown by Figure 6.

#### 2.2.3. The Steam Storage System

The proposed methodology will be implementing the design and pilot scale application of the steam storage system to increase availability in concentrated solar energy systems. The sensible heat storage, steam production and heat loss rate will be measured. Additional improvements will also be made to optimize the steam storage system.

### 2.3. The Operating Principle of the System

- 1) Seawater or brackish water is pumped into the system via a seawater pump to a condenser. Here, the seawater acts as a coolant, removing the heat supplied to the system and thereby maintaining the proper energy balance.
- 2) In the condenser, the vapor produced in the last effect is condensed into pure distillate.
- 3) As distillate vapor is condensed, heat is transferred to the seawater.
- 4) The seawater or brackish water pump also transports preheated seawater or brackish water downstream of the condenser to the various effects of the unit for evaporation.
- 5) The seawater or brackish water is led towards the evaporation side of the plate stack, creating a uniform and controlled thin film on the plate.
- 6) To minimize scaling, the special design of the plate surfaces ensures a uniform flow without any dry areas. On the evaporation side of the plate stack, the seawater or brackish water is partially evaporated by the heat from the condensation side of the plate stack.
- 7) The vapor thus produced is passed through a demister to separate salt from the water droplets before the vapor enters the condensation side of the subsequent heat exchanger plates. Here, the vapor condenses into distilled water while transferring its latent heat through the plates to the evaporation side. The process is repeated in all effects.
- 8) Finally, distillate and brine are extracted from the last effect.
- 9) The evaporation takes place at sub-atmospheric conditions, and vacuum conditions are created and maintained by a venting system.
- 10) The venting system is a water-driven ejector, and as shown on the flow diagram. The venting system

removes air from the plant at start-up and extracts non-

condensable gases during operation of the plant.

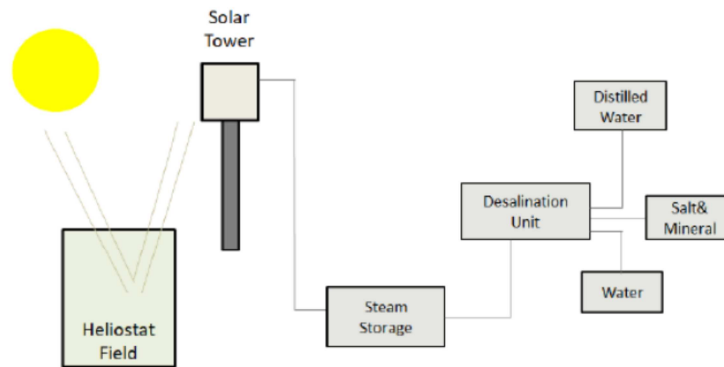


Figure 1. Process diagram.

GREENWAY CSP POWER PLANT				
Engineering Analysis		Inputs	Outputs	
INPUT Calculation Summary		Value	Unit	
FIELD SIZE PARAMETER				
Number of Heliostat		1500	Piece(s)	matlab modelling
Single Heliostat Surface Area		16	m <sup>2</sup>	ref size
Total Mirror Surface Area		24000	m <sup>2</sup>	
WEATHER PARAMETERS				
DNI Threshold		400	Wh/m <sup>2</sup>	
Direct Normal Irradiation For Production limit		950	Wh/m <sup>2</sup>	
Wind Threshold		0	m/s	
PEAK EFFICIENCY PARAMETERS				Average Efficiency Parameters
Reflectivity Efficiency		92,0%		92,0%
Cosine Efficiency		79,7%		76,1%
Atmospheric Attenuation Efficiency		95,5%		94,1%
Blocking & Shadowing Efficiency		97,3%		93,2%
Total Field Efficiency		68,1%		61,4%
Mirror Cleanliness		95,0%		95,0%
Pipe & Thermal Efficiency		98,0%		98,0%
Boiler Efficiency		87,0%		87,0%
Thermal Efficiency		55,1%		49,7%

Figure 2. Engineering analysis.

CALCULATION OF OPERATING HOURS & ENERGY PRODUCTIC		Value	Unit					
Sample Year Production Hour		3029	Hour					
Hourly Thermal Energy (Without Losses)		22,80	MW					
Hourly Thermal Energy Production (peak)		12,57	MW					
Turbine Efficiency		22,0%						
Electricity Production (peak)		2,77	MWh					
Operating Hours For:		Summer	Spring & Autumn	Winter	Total annual operating hours	Unit		
Operational Capacity (% of total) 20%		30	44	51	125	h		
Operational Capacity (% of total) 40%		70	159	48	277	h		
Operational Capacity (% of total) 60%		196	300	95	591	h		
Operational Capacity (% of total) 80%		305	430	180	915	h		
Operational Capacity (% of total) 100%		334	575	212	1121	h		
Total operating hours (yearly)		935	1508	586	3029	h		
Thermal Power Production:		Summer	Spring & Autumn	Winter	Thermal Power produced	Unit	Total Thermal Energy produced	Unit
Operational Capacity (% of total) 20%		2,53	2,39	1,74	2,16	MW	0,27	GWh
Operational Capacity (% of total) 40%		5,44	5,32	5,06	5,31	MW	1,47	GWh
Operational Capacity (% of total) 60%		7,64	7,66	7,66	7,65	MW	4,52	GWh
Operational Capacity (% of total) 80%		10,13	10,16	10,09	10,14	MW	9,28	GWh
Operational Capacity (% of total) 100%		12,20	12,19	12,11	12,18	MW	13,65	GWh
Average Thermal Power Production		9,75	9,70	9,29	9,64	MW	29,19	GWh

Figure 3. Calculation of production hours and power.

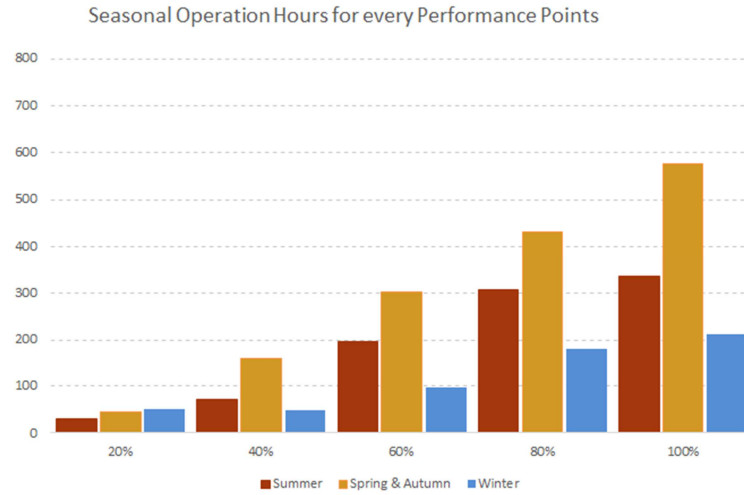


Figure 4. Seasonal operation hours for every performance points.

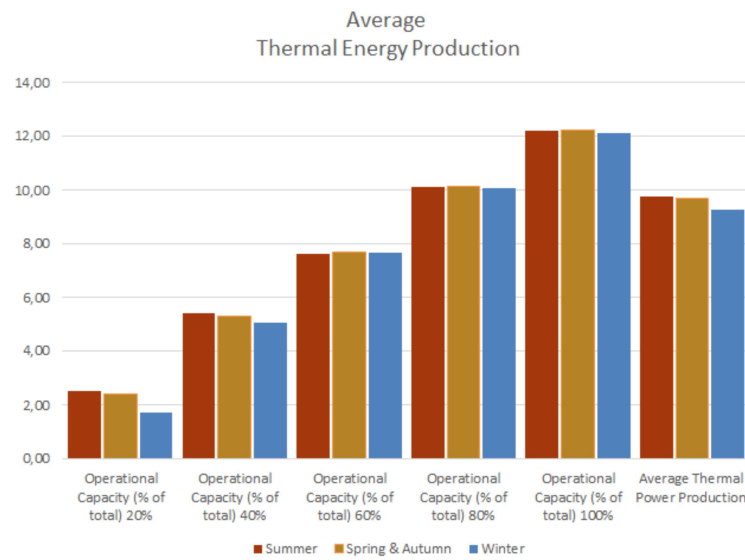


Figure 5. Average thermal energy production.

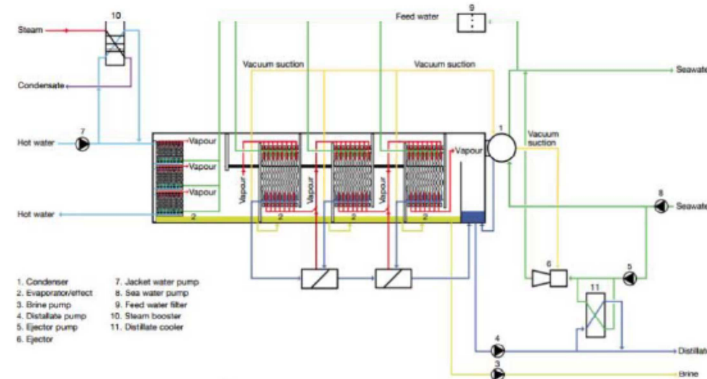


Figure 6. Multi-Effect plate evaporation diagram.

#### 2.4. Feasibility

We performed detailed feasibility studies for the proposed CSP-Tower Desalination facility within the scope of the paper. As a sample, we selected an area that would have

conditions typical of the conditions in which the proposed solar thermal desalination plant would operate. The "Nevada Area" was selected for a feasibility analysis. In this area, there will be 3142 available solar hours per year. The number

of heliostats to be used for the corresponding CSP-Tower field is 1500 when looking at the DNI data in the relevant area. This will correspond to 24,000 m<sup>2</sup>. Also the height of the tower is 50 m. In the desalination unit, 37.5 m<sup>3</sup> per hour fresh water will be generated. Because of the steam storage system, water production will continue for 24 hours in a day.

This design can be used in similar sunny areas like California or other states.

When all this design data and field design are taken into account, the conditions for reaching the target cost are created. All details for the scenarios are taken into consideration. The way to follow the scenario is as follows:

- 1) The cost of equipments and other components (cabling, electrical components, piping, etc.) to be used for the installation of the CSP plant has been calculated. For Levelized Cost of Water and Thermal Power, CAPEX (Capital expenditures) and estimated OPEX (annual expenses) are taken into consideration.
- 2) The generated amount of water and heat is calculated.
- 3) While the plant was is constructed, 80% of the cost is bank loans and the rest (20%) is organizations equity.
- 4) It was accepted that the credit will have a return time of 5, 10, 12 or 20 years.
- 5) At each return time, 3 different interest rates were settled. These ratios are: 0.03, 0.04 and 0.05.
- 6) For each return time and the interest rate within it, a unit price of 0.5 to 1.5 US \$/ m<sup>3</sup> was given.
- 7) Income is calculated for each payback time, interest rate and unit price.
- 8) OPEX cost was assumed to be similar to an equivalent plant's field data.
- 9) For the accepted 4 years and 3 different interest rates, the interest and principal payment was determined based on the relevant return time. Also, equal equity payments are calculated for equity.
- 10) Amortization and taxation are ignored in all

calculations made. In addition, no subsidizing has been considered when calculating the lowest cost. The assumptions can be changed according to agreements between banks and the organization's management.

The information used for the scenarios is shown by Table 1. Scenarios with 3 different interest rates for 5-year, 10-year, 12-year, and 20-year return times are shown in Tables 2-5, respectively. As demonstrated below, based on these assumptions, it is possible to reach the target price based on a 12-year payback period. If loan conditions change, it may be possible to achieve the target based on shorter return times. A form of LCOE (Levelized Cost of Electricity) and its advanced form of MLCOE (Modified Levelized Cost of Electricity) are used in calculations; and these calculations are extended as LCOW (Levelized Cost of Water), MLCOW (Modified Levelized Cost of Water), LACW (Levelized Avoidable Cost Of Water) and MLACW (Modified Levelized Avoidable Cost Of Water). The metrics LCOH (Levelized Cost of Heat) and MLCOH (Modified Levelized Cost of Heat) are also considered in the analyses, Bronski [10], Spark [11], Burenstam-Linder [12], Manzhos [13] and Cekirge and Erturan [14].

**Table 1.** Data for scenarios.

DATA	
Heliostat Numbers	1,500
Production Hours (h/year)	3,000
Capacity of Desalination Plants (m <sup>3</sup> /hour)	37.5
Number of Desalination Plants, Coefficient * 3	1
Water Production (m <sup>3</sup> /hour), from Desalination Unit	113
Desalination Unit Daily Working Hours	24
Water Production (m <sup>3</sup> /day), from Desalination Unit	2,700
Water Production (m <sup>3</sup> /year) from Desalination Unit	810,000
Total Cost (US \$)	8,220,000
OPEX (US \$/year)	405,000
Loan Share by the Owner	0.80

**Table 2.** Scenarios for 5-year return time.

Expenses									
Return Time (years)	Interest Rate	Unit Price (US \$/m <sup>3</sup> )	Income (US \$)	OPEX (US \$)	Interest (US \$)	Principle (US \$)	Equity Payment (US \$)	Total (US \$)	Decision
5	0.03	0.5	2,025,000	2,025,000	591,840	6,576,000	1,644,000	-8,811,840	NOT POSSIBLE
		0.7	2,835,000	2,025,000	591,840	6,576,000	1,644,000	-8,001,840	NOT POSSIBLE
		0.9	3,645,000	2,025,000	591,840	6,576,000	1,644,000	-7,191,840	NOT POSSIBLE
		1.1	4,455,000	2,025,000	591,840	6,576,000	1,644,000	-6,381,840	NOT POSSIBLE
		1.3	5,265,000	2,025,000	591,840	6,576,000	1,644,000	-5,571,840	NOT POSSIBLE
		1.5	6,075,000	2,025,000	591,840	6,576,000	1,644,000	-4,761,840	NOT POSSIBLE
	0.04	0.5	2,025,000	2,025,000	789,120	6,576,000	1,644,000	-9,009,120	NOT POSSIBLE
		0.7	2,835,000	2,025,000	789,120	6,576,000	1,644,000	-8,199,120	NOT POSSIBLE
		0.9	3,645,000	2,025,000	789,120	6,576,000	1,644,000	-7,389,120	NOT POSSIBLE
		1.1	4,455,000	2,025,000	789,120	6,576,000	1,644,000	-6,579,120	NOT POSSIBLE
		1.3	5,265,000	2,025,000	789,120	6,576,000	1,644,000	-5,769,120	NOT POSSIBLE
		1.5	6,075,000	2,025,000	789,120	6,576,000	1,644,000	-4,959,120	NOT POSSIBLE
	0.05	0.5	2,025,000	2,025,000	986,400	6,576,000	1,644,000	-9,206,400	NOT POSSIBLE
		0.7	2,835,000	2,025,000	986,400	6,576,000	1,644,000	-8,396,400	NOT POSSIBLE
		0.9	3,645,000	2,025,000	986,400	6,576,000	1,644,000	-7,586,400	NOT POSSIBLE
		1.1	4,455,000	2,025,000	986,400	6,576,000	1,644,000	-6,776,400	NOT POSSIBLE
		1.3	5,265,000	2,025,000	986,400	6,576,000	1,644,000	-5,966,400	NOT POSSIBLE
		1.5	6,075,000	2,025,000	986,400	6,576,000	1,644,000	-5,156,400	NOT POSSIBLE

**Table 3.** Scenarios for 10-year return time.

Expenses									
Return Time (years)	Interest Rate	Unit Price (US \$/m <sup>3</sup> )	Income (US \$)	OPEX (US \$)	Interest (US \$)	Principle (US \$)	Equity Payment (US \$)	Total (US \$)	Decision
10	0.03	0.5	4,050,000	4,050,000	1,085,040	6,576,000	1,644,000	-9,305,040	NOT POSSIBLE
		0.7	5,670,000	4,050,000	1,085,040	6,576,000	1,644,000	-7,685,040	NOT POSSIBLE
		0.9	7,290,000	4,050,000	1,085,040	6,576,000	1,644,000	-6,065,040	NOT POSSIBLE
		1.1	8,910,000	4,050,000	1,085,040	6,576,000	1,644,000	-4,445,040	NOT POSSIBLE
		1.3	10,530,000	4,050,000	1,085,040	6,576,000	1,644,000	-2,825,040	NOT POSSIBLE
		1.5	12,150,000	4,050,000	1,085,040	6,576,000	1,644,000	-1,205,040	NOT POSSIBLE
	0.04	0.5	4,050,000	4,050,000	1,446,720	6,576,000	1,644,000	-9,666,720	NOT POSSIBLE
		0.7	5,670,000	4,050,000	1,446,720	6,576,000	1,644,000	-8,046,720	NOT POSSIBLE
		0.9	7,290,000	4,050,000	1,446,720	6,576,000	1,644,000	-6,426,720	NOT POSSIBLE
		1.1	8,910,000	4,050,000	1,446,720	6,576,000	1,644,000	-4,806,720	NOT POSSIBLE
		1.3	10,530,000	4,050,000	1,446,720	6,576,000	1,644,000	-3,186,720	NOT POSSIBLE
		1.5	12,150,000	4,050,000	1,446,720	6,576,000	1,644,000	-1,566,720	NOT POSSIBLE
	0.05	0.5	4,050,000	4,050,000	1,808,400	6,576,000	1,644,000	-10,028,400	NOT POSSIBLE
		0.7	5,670,000	4,050,000	1,808,400	6,576,000	1,644,000	-8,408,400	NOT POSSIBLE
		0.9	7,290,000	4,050,000	1,808,400	6,576,000	1,644,000	-6,788,400	NOT POSSIBLE
		1.1	8,910,000	4,050,000	1,808,400	6,576,000	1,644,000	-5,168,400	NOT POSSIBLE
		1.3	10,530,000	4,050,000	1,808,400	6,576,000	1,644,000	-3,548,400	NOT POSSIBLE
		1.5	12,150,000	4,050,000	1,808,400	6,576,000	1,644,000	-1,928,400	NOT POSSIBLE

**Table 4.** Scenarios for 12-year return time.

Expenses									
Return Time (years)	Interest Rate	Unit Price (US \$/m <sup>3</sup> )	Income (US \$)	OPEX (US \$)	Interest (US \$)	Principle (US \$)	Equity Payment (US \$)	Total (US \$)	Decision
12	0.03	0.5	4,860,000	4,860,000	1,282,320	6,576,000	1,644,000	-9,502,320	NOT POSSIBLE
		0.7	6,804,000	4,860,000	1,282,320	6,576,000	1,644,000	-7,558,320	NOT POSSIBLE
		0.9	8,748,000	4,860,000	1,282,320	6,576,000	1,644,000	-5,614,320	NOT POSSIBLE
		1.1	10,692,000	4,860,000	1,282,320	6,576,000	1,644,000	-3,670,320	NOT POSSIBLE
		1.3	12,636,000	4,860,000	1,282,320	6,576,000	1,644,000	-1,726,320	NOT POSSIBLE
		1.48	14,385,600	4,860,000	1,282,320	6,576,000	1,644,000	23,280	POSSIBLE
	0.04	0.5	4,860,000	4,860,000	1,709,760	6,576,000	1,644,000	-9,929,760	NOT POSSIBLE
		0.7	6,804,000	4,860,000	1,709,760	6,576,000	1,644,000	-7,985,760	NOT POSSIBLE
		0.9	8,748,000	4,860,000	1,709,760	6,576,000	1,644,000	-6,041,760	NOT POSSIBLE
		1.1	10,692,000	4,860,000	1,709,760	6,576,000	1,644,000	-4,097,760	NOT POSSIBLE
		1.3	12,636,000	4,860,000	1,709,760	6,576,000	1,644,000	-2,153,760	NOT POSSIBLE
		1.5	14,580,000	4,860,000	1,709,760	6,576,000	1,644,000	-209,760	NOT POSSIBLE
	0.05	0.5	4,860,000	4,860,000	2,137,200	6,576,000	1,644,000	-10,357,200	NOT POSSIBLE
		0.7	6,804,000	4,860,000	2,137,200	6,576,000	1,644,000	-8,413,200	NOT POSSIBLE
		0.9	8,748,000	4,860,000	2,137,200	6,576,000	1,644,000	-6,469,200	NOT POSSIBLE
		1.1	10,692,000	4,860,000	2,137,200	6,576,000	1,644,000	-4,525,200	NOT POSSIBLE
		1.3	12,636,000	4,860,000	2,137,200	6,576,000	1,644,000	-2,581,200	NOT POSSIBLE
		1.5	14,580,000	4,860,000	2,137,200	6,576,000	1,644,000	-637,200	NOT POSSIBLE

**Table 5.** Scenarios for 20-year return time.

Expenses									
Return Time (years)	Interest Rate	Unit Price (US \$/m <sup>3</sup> )	Income (US \$)	OPEX (US \$)	Interest (US \$)	Principle (US \$)	Equity Payment (US \$)	Total (US \$)	Decision
20	0.03	0.5	8,100,000	8,100,000	2,071,440	6,576,000	1,644,000	-10,291,440	NOT POSSIBLE
		0.7	11,340,000	8,100,000	2,071,440	6,576,000	1,644,000	-7,051,440	NOT POSSIBLE
		0.9	14,580,000	8,100,000	2,071,440	6,576,000	1,644,000	-3,811,440	NOT POSSIBLE
		1.1	17,820,000	8,100,000	2,071,440	6,576,000	1,644,000	-571,440	NOT POSSIBLE
		1.14	18,468,000	8,100,000	2,071,440	6,576,000	1,644,000	76,560	POSSIBLE
		1.49	24,138,000	8,100,000	2,071,440	6,576,000	1,644,000	5,746,560	POSSIBLE
	0.04	0.5	8,100,000	8,100,000	2,761,920	6,576,000	1,644,000	-10,981,920	NOT POSSIBLE
		0.54	8,748,000	8,100,000	2,761,920	6,576,000	1,644,000	-10,333,920	NOT POSSIBLE
		0.9	14,580,000	8,100,000	2,761,920	6,576,000	1,644,000	-4,501,920	NOT POSSIBLE
		1.1	17,820,000	8,100,000	2,761,920	6,576,000	1,644,000	-1,261,920	NOT POSSIBLE
		1.18	19,116,000	8,100,000	2,761,920	6,576,000	1,644,000	34,080	POSSIBLE
		1.5	24,300,000	8,100,000	2,761,920	6,576,000	1,644,000	5,218,080	POSSIBLE
	0.05	0.5	8,100,000	8,100,000	3,452,400	6,576,000	1,644,000	-11,672,400	NOT POSSIBLE

Expenses									
Return Time (years)	Interest Rate	Unit Price (US \$/m <sup>3</sup> )	Income (US \$)	OPEX (US \$)	Interest (US \$)	Principle (US \$)	Equity Payment (US \$)	Total (US \$)	Decision
		0.57	9,234,000	8,100,000	3,452,400	6,576,000	1,644,000	-10,538,400	NOT POSSIBLE
		0.9	14,580,000	8,100,000	3,452,400	6,576,000	1,644,000	-5,192,400	NOT POSSIBLE
		1.1	17,820,000	8,100,000	3,452,400	6,576,000	1,644,000	-1,952,400	NOT POSSIBLE
		1.23	19,926,000	8,100,000	3,452,400	6,576,000	1,644,000	153,600	POSSIBLE
		1.5	24,300,000	8,100,000	3,452,400	6,576,000	1,644,000	4,527,600	POSSIBLE

## 2.5. Innovations and Impacts

This paper has multiple unique strengths. First, the cost of the heliostats, which is one of the thermal facility's major components, is reduced by virtue of the optimum and experimental design. Second, the steam storage system, another critical component, is developed at low cost and enables the desalination plant to function 24 hours/day, including in no sunlight conditions. The goal of this paper is to prove CSP-Tower plants using steam storage as a feasible desalination method.

## 3. An Installation Plan

### 3.1. Objectives of the Plan

The goal of this paper is to use develop a method for delivering fresh water using a method that uses renewable energy. This serves the dual process of solving water shortage problems while avoiding the environmental harm that plants that rely on fossil fuels or other non-renewable sources create.

Specific objectives for the paper are:

- 1) To supply fresh water from sea water or brackish water;
- 2) To provide fresh water when the sun does not shine;
- 3) To use renewable energy sources to minimize carbon emissions;
- 4) To deal with solar intermittency via steam storage;
- 5) To obtain precious minerals and salt from brine with brine recovery;
- 6) To minimize negative impact on marine life with no discharge of brine to the sea or ocean;
- 7) To low cost and maintains free steam storage system design;
- 8) To reduce CAPEX (Capital Expenditures) and OPEX (Operating Expenses);
- 9) To increase solar beam emissivity and lightweight design criteria; and
- 10) To achieve the lowest LCOW and LCOH.

### 3.2. Technical Scope Summary

Phase 1. Initiate Phase Activities: The legal obligation and other all related documents are investigated and necessary actions are taken.

Phase 2. CSP System Design and Engineering Phase Activities: The most appropriate design, system details, all purchases and transportation are investigated.

Phase 3. Installation Phase Activities: Installation will be completed using the data of the selected location and design, and the requirements of the site of plant area are provided. The problems of mobilization can create Difficulties in terms of efficiency. Successfully mobilization of the field must be chosen as a milestone, since it will affect the future activities of the plant. At the end, the CSP and desalination plant will be ready for operation.

## 4. Conclusions

The total production cost of desalinating brackish groundwater ranged from US \$ 0.29 to US \$ 0.66 per m<sup>3</sup>, Arroyo and Shirazi [15]. In SWRO (Seawater Reverse Osmosis) projects, this cost has been flattened since 2005 in a wide the range of US \$ 0.79 to US \$ 2.38 per m<sup>3</sup>, Kim, et al. [16, 17] and Ghaffour, et al. [18].

The expected results of this studies are:

- 1) Providing 1.48 \$/m<sup>3</sup> for LCOW with Integrated CSP-Tower Solar Thermal Desalination Plant and most likely less,
- 2) Distributing the distillate water which meets standards to water grid system for public utilization; and
- 3) Adding value to existing conventional power generating equipments.

According to the market conditions, using lower or zero interest rates, the values of LCOW or MLCOW will be lower; and the payback period will be shorter. After CAPEX payback, there will be no fuel and energy cost that is the cost of production of water for m<sup>3</sup> will be far under one US dollar, MLCOW is the apparent and definite metric for these calculations.

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