Economic Study of Solar Chimney Power-Water Distillation Plant (SCPWDP)

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Abstract: This work provides technical and economic feasibility of installing a solar chimney power-water distillation plant (SCPWDP) in the port of Aqaba in Jordan. A mathematical model for the SCPWDP has been developed and validated. A full year of weather conditions data has been processed, where water and electricity productions have been estimated. The results show that the SCPWDP can produce 481,440 kWh of electricity and 123,753 ton of distilled water yearly simultaneously. The economic analysis shows that the levelized cost of energy (LCOE) for the SCPWDP is $1.86/kWh. The cost estimate seems reasonable once compared with other studies. However, from economical point of view the LCOE of SCPWDP requires a further decrease in order to make it economically feasible. The sensitivity analysis shows that increasing the chimney height of the SCPWDP would increase the production of electricity, and hence, decreases the LCOE. However, increasing the chimney height would have a marginal improvement since it increases both capital and operation expenditures.

1. Introduction

Shortage of energy and excessive harmful emissions from greenhouse gases (GHG) have brought a lot of attention of the scientific community in the recent years. Although there are alternate energy resources available in the universe, however, to address this problem, it seems that solar energy has emerged as a good potential solution. This is primarily due to the accessibility of solar sources and the flexibility of means to convert the solar energy into a different type of energy [1–3]. Jordan has recognized this problem and in order to address this, a renewable energy strategy [4] has been established. In addition to the energy problems, the world is also facing a freshwater shortage problem too. The scarcity of the freshwater resources, global weather changes and continuous increase in demand for water are the primary reasons for water shortage in the world. This issue has been particularly challenging in the last ten years or so, and it will continue to be challenging in the years ahead due to the continued growth of populations and economies. Although water shortage is a world-wide problem, it has been reported that the availability of water has been declining, particularly, in the Middle East [5]. Having said that, it has been reported that solar chimney power plant (SCPP) can be a viable solution to address future demands for water and the need for clean renewable energy as an alternative for fossil-fuel energy resources [6,7]. The early concept of SCPP has been proposed by Schlaich [8], followed by a construction of a SCPP in Spain in 1980s. The structure of the SCPP

consists of a solar collector, turbine and chimney. The SCPP works on the principle of heating up the air underneath the collector due to solar radiation during the day. The heated air then gains energy and momentum to move towards the chimney. The SCPP utilizes the difference in the air densities at the top and bottom of the chimney. The air density difference creates a pressure difference that drives the hot air to move from the bottom of the chimney to the top and then escape out of the chimney. While the air flows up the chimney, it exchanges energy with the blades of a turbine—located at the bottom of the chimney—to generate electricity.

Several attempts [9–15] around the world have been made to introduce various modifications to the conventional solar chimney. The focus was to enhance its performance, expand its application, or develop a new simulation model as detailed in Table 1.

Table 1. Literature review of the solar chimney power plant.

Aim of the Study	Author(s)
Develop a new simulation models.	Chergui et al. [16], Bilgen and Rheault [17]
Introduce multi turbo generators and power electronics.	Fluri and Von Backstrom [18]
Induce ventilation system using roof solar chimney.	Mathur et al. [19], Afonso and Oliveira [20], Arce et al. [21], and Harris and Helwig [17], [22]
Improve modeling equations.	Jing et al. [23], Pretorious and Kroger [24], Sangi et al. [25]
Use different absorber materials and collector types.	Miqdam and Hussein [26], Ninic [27], Koonsrisuk [28] and Chantawong et al. [29]
Improve storing capabilities.	Ming et al. [30], Liu and Li [31]
The relation between the geometric parameters of solar chimney and the power generation.	Hamdan [32], Koonsrisuk et al. [33], Jing et al. [23], Saifi et al. [34], and Kasaeian et al. [35]
Numerical investigations.	Guo et al. [36], Ming et al. [37], Maia et al. [38], Fasel et al. [39], Pastohr et al. [40]

A number of researchers explored the performance and feasibility of SCPP across different countries and geographic places. Table 2 presents an overview of research contribution based on locations. Their focus was specifically on the plant evaluation and economic viability by performing computational and experimental studies.

Table 2. Research contribution on solar chimney performance based on geographic locations.

Location	Author(s)	Year	Contribution
Tunisia	Bouabidi et al. [41]	2018	Effect of the chimney configurations on the local flow characteristics.
Saudi Arabia	Abdelmohimen et al. [42]	2018	Numerical investigation of solar chimney power plants performance.
Nigeria	Okoye et al. [43]	2017	Performance analysis of SCPP using hourly weather data of seven selected regions. A theoretical model was established for power output, levelized cost of electricity (LCOE) and carbon emission predictions.
Egypt	El- Haroun [44]	2012	Performance evaluation of SCPP in some locations in Egypt theoretically to make an approximation of the quantity of the generated electrical energy.
Iran	Sangi [45], Asnaghi [46], Maghrebi et al. [47], Kasaeian et al. [35]	2012, 2012, 2017, 2014	Performance evaluation, simulation and optimization of different SCPP models in different locations across Iran.
Arabian Gulf region	Hamdan [32]	2011	Propose A simplified thermodynamics analytical model for steady airflow inside a solar chimney. Evaluate the effect of geometric parameters on the solar plant power generation.
Algeria	Larbi et al. [48], Larbi et al. [49], Rabehi et al. [50]	2010, 2015, 2017	Performance and CFD analysis of different SCPP Models across regions in Algeria.
Mediterranean region	Nizetic et al. [51]	2008	Analysis and feasibility of implementing solar chimney.
Cyprus	Okoye et al. [52]	2014	A parametric study on the feasibility of solar chimney.
China	Guo et al. [53], Cao et al. [54]	2014, 2013	Annual performance analysis of the solar chimney power plant in Sinkiang. Performance analysis of conventional and sloped solar chimney power plants in China.
Pacific Island Countries	Ahmed and Patel [55]	2017	Computational and experimental studies on solar chimney power plants for power generation in Pacific Island countries.
India	Akhtar and Rao [56]	2014	Study of economic viability of 200 MW solar chimney power plant.

A number of researchers have integrated a seawater desalination unit into a conventional solar chimney [57–60]. The idea is to install a layer of water stills on the base of the solar chimney to

produce distilled water and improve the efficiency. Most of the studies focus on numerical simulations, evaluating several possibilities to increase the overall performance and the utilization efficiency of solar energy. No single hybrid chimney-desalination configuration has yet shown itself to be the obvious choice. Numerous cost models are available in the research field for large-scale solar chimney power plants. Nevertheless, the studies published vary significantly, even when input parameters and models are closely similar. Fluri et al. [61] compared the newly developed cost models of solar chimney power plants with the previous ones. They have introduced a reference plant to make the analyzed results comparable. The impact of carbon credits on the leveled electricity cost was investigated. Results have showed that previous models underestimated the initial cost and leveled electricity cost of a large-scale solar chimney power plant. The results also showed that carbon credits significantly reduce the leveled electricity cost for such a plant. Despite Jordan having a low carbon footprint compared to other industrial countries, with a growing economy the projection of GHG would increase. Jordan is committed to reduce GHG for the short-term strategy 2013–2020 and for the long term beyond 2020. The application of SCPP would reduce 215 Mt CO_2 annually. This is based on US data that electrical production would contribute to 0.4483 kg CO_2 per kWh. Despite that this reduction is very little, installation of several SCPP in the country would help to further reduce the GHG and support the high demand for electricity in the country.

In this work, and for the first time, we validate the economics of solar chimney performance in Jordan. More specifically, we ran a modified version of the SCPP to simultaneously generate electricity and produce distilled water. The performance analysis of the proposed system is conducted and presented.

## 2. Materials and Methods

2.1. SCPWDP Description

The structure of the solar chimney power-water distillation plant (SCPWDP) is shown in Figure 1. The SCPWDP is divided into three zones: air heating zone, water evaporation zone and chimney zone. The SCPWDP is similar to a conventional SCPP with the exception of adding a water pool at the base of the SCPWDP. The main components of the SCPWDP are the collector, base, water pool, turbine and chimney. The process in the SCPWDP is started when the air trapped between the collector and the base is heated due to solar radiation. As the air heats up it becomes lighter and start to move towards the chimney of the SCPWDP due to a slight elevation (tilting) of the collector. As the air moves towards the chimney, it passes over the water pool where it becomes moisturized. When the air reaches the base of the chimney—where the turbine is located—it hits the fans of the turbine transferring its energy to the turbine. Once, the turbine overcomes its initial cut-in speed, it starts to produce electricity. The amount of electricity produced is directly proportion to the velocity of the air at the inlet of the chimney. Once the air passes the turbine area, it continues to travel up the chimney to exit at the top of the chimney. However, as it travels the chimney up, the moist air condensates at the inner wall of the chimney. The condensated water then drops into the designated area (pool) at the bottom of the chimney where it gets collected. The collected water is then moved outside the SCPDWP for further processing, through water pipes located below the water pool. See Figure 1c. Having said that, the SCPDWP is expected to produce both electricity and distilled water. Water in the water pool is expected to be seawater drowned from the Aqaba seaport through water pipes as seen in Figure 1c. The remaining brine from the seawater can be transported back to the sea or to other destination for further processing.
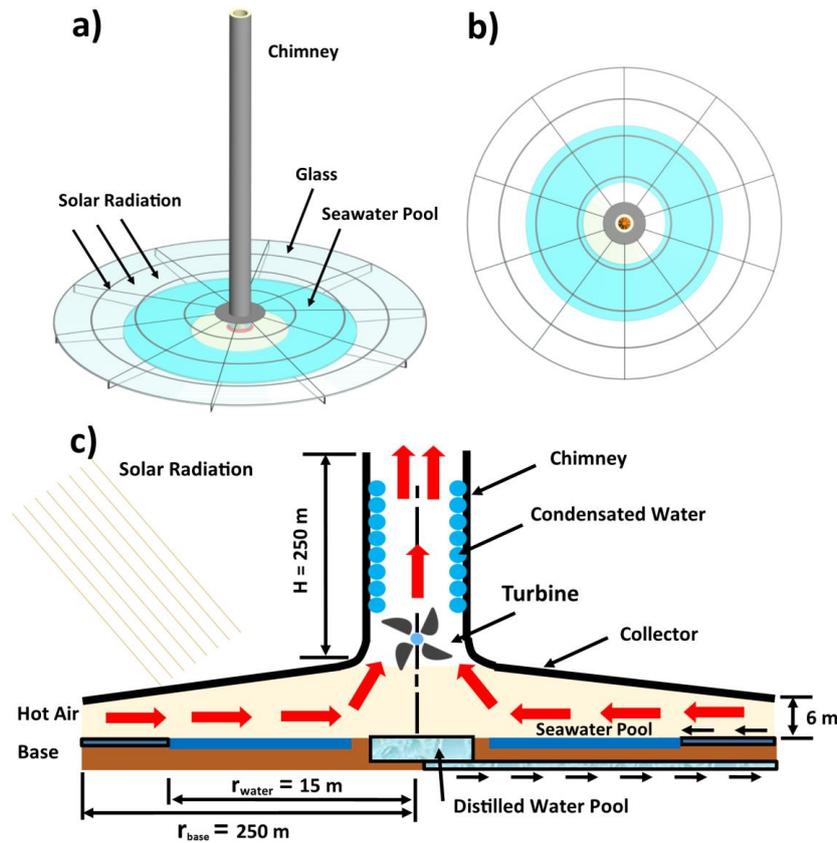
Figure 1. Schematic diagram of the proposed system: (**a**) 3d model view, (**b**) top view and (**c**) cross section.

2.2. Mathematical Model

The mathematical model of the SCPWDP system was developed based on Equations (1)–(12), see Figure 2. The energy balance equations for all three zones of the SCPWDP are presented, while the detailed derivations can be found in [62]. The equations were resolved numerically using finite difference method using MATLAB program. The program runs iteratively and terminates when the solution results do not change more than 1×10^{-6} (the difference between two consecutive results). MATLAB R2013a was used running on windows 7, 64-bit operating system, i5 CPU @ 1.8 GHz with 4.00 GB RAM. The dimensions of the SCPWDP and collector properties used in the model are shown in Tables 3 and 4 respectively.
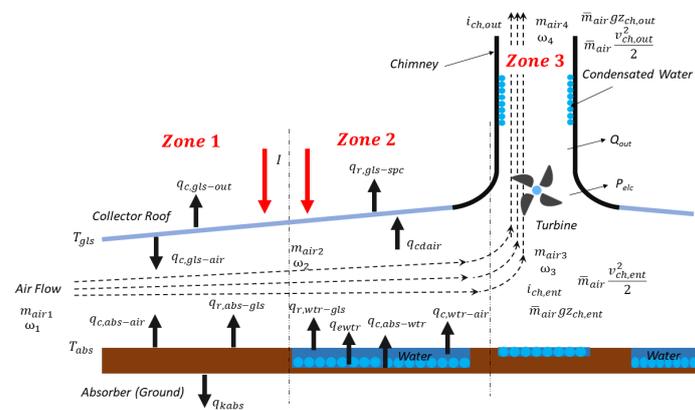
Figure 2. Energy balance diagram showing Zone 1 (Solar Air Heating), Zone 2 (Water Evaporation) and Zone 3 (Chimney) of the SCPWDP system.

Table 3. Solar chimney power-water distillation plant (SCPWDP) physical dimensions.

Parameter	Dimension, m
Collector Diameter	250
Collector Entrance Height	6
Chimney Height	200
Chimney Diameter	10
Water Pool Depth	0.03

Table 4. SCPWDP collector materials' properties.

Material Characteristic	Value
Glass Transmissivity	0.90
Glass Emissivity	0.90
Glass Absorptivity	0.05
Water Transmissivity	0.90
Water Emissivity	0.95
Water Absorptivity	0.05
Base Absorptivity	0.95
Base Emissivity	0.95

Zone 1: Solar Air Heating

The energy balance equations for the absorber, collector roof and air flow in Zone 1 are as follows:

Absorber:

$$\alpha_{abs}\tau_{gls}I = q_{r,abs-gls} + q_{c,abs-air} + q_{kabs} \tag{1}$$

Collector:

$$\alpha_{gls}I + q_{r,abs-gls} = q_{c,gls-out} + q_{c,gls-air} + q_{r,gls-spc} \tag{2}$$

Air flow:

$$q_{c,gls-air} + q_{c,abs-air} = -\frac{c_{p,air}\overline{m}_{air}}{2\pi r}\frac{dT_{air}}{dr} \tag{3}$$

The above mass balance equation for air gives that $\omega_1 = \omega_2$.

Zone 2: Water Evaporation

The energy balance equations for the absorber, collector, air flow and water in Zone 2 are as follows:

Absorber:

$$\alpha_{gls}\tau_{wtr}\tau_{gls}I = q_{c,abs-wtr} + q_{kabs} \tag{4}$$

Collector roof:

$$q_{c,gls-air} + q_{r,wtr-gls} + \alpha_{gls}I = q_{r,gls-spc} + q_{c,gls-out} \tag{5}$$

Air flow:

$$q_{c,gls-air} + q_{c,wtr-air} = -\frac{c_{p,air}\overline{m}_{air}}{2\pi r}\frac{dT_{air}}{dr} \tag{6}$$

The energy balance for water is as follows:

$$q_{c,abs-wtr} + \alpha_{wtr}\tau_{gls}I = q_{ewtr} + q_{r,wtr-air} + q_{c,wtr-air} + c_{p,wtr}\overline{m}_{wtr}\frac{dT_{wtr}}{dt} \tag{7}$$

The output power [57] of the wind turbine is expressed as follows:

$$P_{elc} = \frac{1}{2}\rho_{en,ch}C_fA_{ch}V_{ch}^3 \tag{8}$$

Zone 3: Chimney

As the hot air moves from the collector (Zone 2) through the chimney it creates enough force to move the turbine blades, hence producing electricity. The hot air will continue to elevate through the chimney towards the chimney exit. However, the hot water will condensate at the inner walls of the chimney due to the temperature difference between the chimney wall and the outside temperature. The condensated water will eventually fall and be collected at the basin area below the chimney.

The energy balance equation at the inlet and outlet of the chimney:

$$\overline{m}_{air}\left(\frac{v^2_{ch,ent}}{2} + gz_{ch,ent} + i_{ch,ent}\right) - \overline{m}_{air}\left(\frac{v^2_{ch,out}}{2} + gz_{ch,out} + i_{ch,out}\right) = P_{elc} + Q_{out} \tag{9}$$

Furthermore, the energy balance for the air inside the chimney is given as:

$$Q_{out} = \overline{m}_{air}\left(i_{ch,ent} - i_{ch,out}\right) - \overline{m}_{air}(\omega_4 - \omega_3)i_{wtr} \tag{10}$$

The mass flow rate of water condensation is:

$$\overline{m}_{wtr} = \overline{m}_{air}(\omega_4 - \omega_3) \tag{11}$$

The enthalpy of the moist air entering the chimney ($i_{ch,ent}$) is calculated using [51]

$$i_{ch,ent} = T_{air} + \omega_3(2501.3 + 1.86T_{air}) \tag{12}$$

where, T_{air} is the temperature of the air entering the chimney in °C.

2.3. Model Validation

In order to validate our model we compared our results with the results presented by Kiwan et al. [62]. We selected two data sets to compare. First, we compared our results obtained by looking at the air temperature profile starting at the entrance of the SCPWDP and ending at the start of the chimney. This was repeated for different diameters of the water pool. The results for both models are shown in Figures 3 and 4. We also studied and compared our data on the effect of the radius of the water pool on the produced amount of water and electrical power. As seen in the figures, the data trends from both models are almost identical proving that our model is accurate.
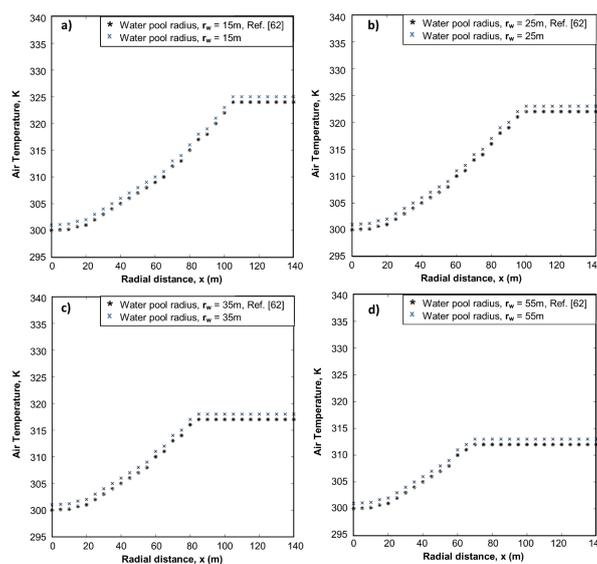
Figure 3. Current model validation compared to the reference model in [62]. Showing the results of air temperature variations across the radial distance at different water pool radius (rw), (**a**) rw = 15 m, (**b**) rw = 25 m, (**c**) rw = 35 m and (**d**) rw = 55 m.
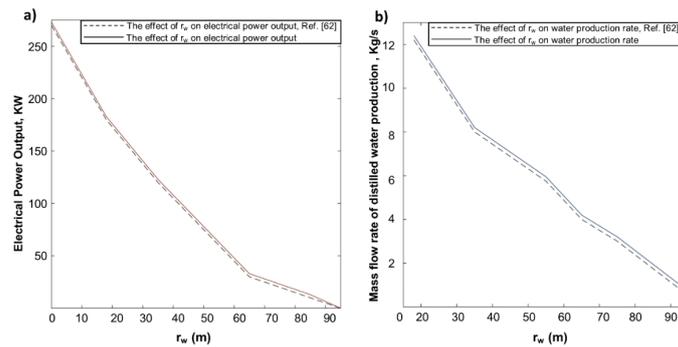
Figure 4. Current model validation compared to the reference model in [62]. Showing the results of: (**a**) electrical power produced and (**b**) the rate of distilled water produced versus different water pool radius.

3. Results and Discussion

The data was collected from the Aqaba port weather station, site (29°31′36.01″ N/35°00′28.01″ E), where it was sampled at an hourly rate. Table 5 shows a full day of weather information on June 21st. The data shows that the maximum solar irradiation (1000.20 W/m^2) occurs at about 11:00 AM. The data also shows that the minimum solar irradiations (0.71 W/m^2 and 8.90 W/m^2) occur at 4:00 AM and 18:00 respectively. A full year of weather data was processed using our optimized mathematical model. Hourly productions of water and electricity were added and totaled for each month. The results for the entire year are shown in Table 6. The table shows the production of electric power (kWh) and distilled water (ton) month-by-month starting from January and ending in December. The results show that the maximum production of electricity was 57,934.94 kWh and maximum production of distilled water was 14,975.27 ton.

Table 5. Data for a complete day on June 21 at Aqaba, Jordan.

Time	Global Horizontal Solar Irradiation (W/m^2)	Ambient Temperature (°C)	Wind Speed (m/s)	Time	Global Horizontal Solar Irradiation (W/m^2)	Ambient Temperature (°C)	Wind Speed (m/s)
0:00	0.00	30.86	7.10	12:00	985.60	41.05	5.00
1:00	0.00	29.91	6.80	13:00	909.40	41.63	4.70
2:00	0.00	29.41	6.20	14:00	772.79	41.84	3.40
3:00	0.00	29.06	4.70	15:00	589.90	41.62	3.90
4:00	0.71	29.02	3.70	16:00	380.11	40.85	4.10
5:00	103.40	30.03	4.30	17:00	174.31	39.67	3.30
6:00	295.21	31.66	3.40	18:00	8.90	38.24	2.90
7:00	507.10	33.55	4.10	19:00	0.00	36.90	3.40
8:00	701.90	35.47	5.00	20:00	0.00	35.55	4.70
9:00	854.79	37.26	5.90	21:00	0.00	34.20	3.90
10:00	957.60	38.83	5.90	22:00	0.00	32.86	2.80
11:00	1000.20	40.1	5.40	23:00	0.00	31.51	3.40

Table 6. Monthly values of power and water production for the SCPWDP at Aqaba, Jordan.

Month	Average Monthly Global Solar Irradiation (kWh/m^2)	Electric Power (kWh)	Distilled Water (ton)
January	112.06	21,846.24	4662.90
February	126.61	26,542.74	6066.50
March	186.81	42,384.30	10,054.61
April	206.22	47,485.61	12,041.33
May	233.99	53,760.64	14,072.61
June	248.17	57,934.94	14,975.27
July	248.90	57,222.29	14,700.75
August	232.43	52,992.54	14,778.50
September	192.43	42,322.52	11,846.42
October	160.64	33,813.33	9511.02
November	122.69	24,201.08	6185.75
December	108.23	20,934.28	4857.83
Sum	2179	481,440	123,753

3.1. Economic Analysis

SCPP is unmatured technology and the technical readiness level still beyond the commercial application. There are studies that investigated the economic aspect of SCPP revealing the current needs and future challenges. The main purpose of the economic analysis is to establish the current need, challenges and the main expectation of SCPP in Jordan.

The baseline for the economic assessment of SCPP is comparing cash payment for equipment fabrication and installation with the maximum power output [61]. Therefore, the decision of installing a SCPP must be economically feasible or solve electricity supply in remote areas that are far away from the electricity grid [8,63]. The cost contribution of a SCPP mainly comes from: the chimney, the collector and the turbine units. Our finding agrees with other economic analysis performed by [40,42,44,60]. SCPPs are not commercially available yet due to high capital cost versus the annual revenues. Despite the simplified design of the SCPP versus the other power production facility, the capital investment is one of the major issues due to its height as well as lower energy output. In this work, economic analysis of the developed design was conducted to calculate the capital expenditures (CAPEX) and the operation expenditures (OPEX). The main chimney tower component is specified in Table 7 with their corresponding cost. Several reports detailed the cost analysis of the SCPP [8,63,64]. The cost calculation was based on an assumption of the materials cost combined with fabrication cost using cost relative formulas. For calculating the CAPEX, each equipment cost was calculated individually based on correlation data for similar well-established equipment [65]. The cost of each component was calculated using a generic cost related algebraic Equation (13) presented by Gavin and Towler [65].

$$Cost, i = a + S^n \tag{13}$$

Table 7. Capital expenditures (cost) of main components of the SCPWDP.

CAPEX	Cost, $US	Reference
Chimney column	346,611	Equation (13)
Glass Base	35,000	$200/m^2
Concert basin	50,000	$300/m^2
Turbine	403,453	Equation (13)
Installation cost	417,532	Installation cost factor for Jordan assumed 0.039
Total	1,252,596	

The *Cost, i* represents the individual component cost chimney column, glass bass and concrete basin. The total CAPEX cost presented in Table 7 is the sum of all individual component cost, *Cost, i*. The *S* represents the component sizing parameters, *a* represents a tabulated factor and *n* is the exponent factors for the equipment type. The collector is basically the combination of glass base with the concrete basin. The cost calculations were based on initial costs of construction that are specific for Jordan. The cost of glass base was based on vendor tabulated cost data retrieved from commercial site, while the cost of concert basin was based on local Jordanian average cost of construction per meter square.

The operating cost, Table 8, was estimated based on daily expenses that were associated with the operating of the chimney tower. The tower configuration works only on the water supply and requires no chemical additions, except the chemicals that are used to prevent the corrosion effect inside the pumping pipes. The OPEX is extremely low due to no fuel cost, no daily usage of chemicals and no labor work that are required for daily operation. The OPEX cost emerges from the power required for the water pumps, quarterly maintenances and minor labor work. This is greatly advantageous compared to the power plant and the other hybrid energy system, which were fuel that were required as part of their daily operation.

Table 8. Annual operating cost of the SCPWDP.

OPEX	Cost, $US/Day	Cost, $US/Annual	Reference
Anti-corrosion chemicals	10	3500	
Pumps	10	3500	
Maintenance	10	3500	
Labors	20	7000	
Credit value produced electricity	−6.211	−2173.97	$93/MWh cost in Jordan
Total	44	15,326	

The levelized cost of energy (LCOE) is a critical performance parameter that determines the economic feasibility of the proposed design. The LCOE will be compared with other energy technology providers in the country, Table 9. The LCOE include capital costs, fuel costs, fixed and variable operations and maintenance (O&M) costs, financing costs and an assumed utilization rate for each plant type. The LCOE was calculated using the below Equation (14):

$$LCOE = \frac{\sum_{t=1}^{n}\left(\frac{It+Mt+Ft}{(1+dr)^t}\right)}{\sum_{t=1}^{n}\left(\frac{Et}{(1+dr)^t}\right)} \tag{14}$$

Table 9. Annual operating cost of the SCPWDP compared to other technologies.

| Technology in Aqaba/Jordan	LCOE ($/kWh)
SCPWDP	1.86
Power Plant	0.1, Ref [66]
PV	0.15, Ref [67]
Wind	0.162, Ref [68]

The LCOE for SCPWDP calculation using Equation (14) was found to be $1.86/kWh. The cost estimate seems reasonable once compared with other studies and power producing technologies. However, from an economical point of view the LCOE of SCPWDP requires a further decrease in order to improve the process economy. Schlaich [8], Schlaich et al. [63] and Bernardes [64] calculated the LCOE for SCPP to be 0.1045, 0.1000 and 0.0370 Euro/kWh respectively. Their values are lower than the value calculated in our present study. This is likely due to high CAPEX since this technology is not mature yet and the fabrication parts do not exist in the market and require a customized part that would cost more. However, utilization of water as an added value was not included in the LCOE calculation due to a lack of standardized information about water cost in Jordan. The proposed SCPP in Jordan does not compete with other energy production technologies rather it acts as a complementary energy supply system. Water generation from SCPP contributes to the energy mix strategy and reduces the burden of energy providers. In particular, underground water pumping from in Jordan consumes 10% of the total electricity supply. Jordan has a limited natural resource and suffers significant water shortages mainly during summertime. The SCPP system would be a future game player with respect to the c-water energy supply system once the process is economically justified.

The economic analysis proposed a further reduction in CAPEX and OPEX by adopting a new design configuration that maximizes both power water outputs. Improving the CAPEX could be achieved by exploring new materials that cost less but function the same. For example, replacing the main steel tower by enhanced plastic materials that provide thermal and chemical stability. This topic will be further investigated in a new study that will focus on the materials aspect of the SCPP. Another example, the glass surface could be replaced by Plexiglas materials that has the same physical and mechanical properties of the glass. The OPEX values already but could be further reduced by adopting a new

automation system that regulates the power water production according to the demands of the market. In future work, we will simulate the technical and economic performance of SCPP as a hybrid system in specialized software such as HOMER [2] for further development.

3.2. Sensitivity Analysis

The sensitivity analysis reveals the relation between the acceptable LCOE and the maximum power output. The LCOE is influenced by the main design parameters such as the chimney diameter and height. The diameter and height of the chimney influence the capital cost and thus change the LCOE value, Figure 5. However, increasing the chimney height would have a marginal improvement due to increasing the LCOE. Thus, reducing the capital investment and operating cost by 50% would reduce the LCOE from $1.86/kWh down to $1/kWh. Decreasing the LCOE further down by 0.038 could further increase the power out by 20%. However, this would increase the simplified monthly operating cost on the nutshell due to an increase in the tower height. This would increase the overall capital cost making the overall process economy a main challenge.
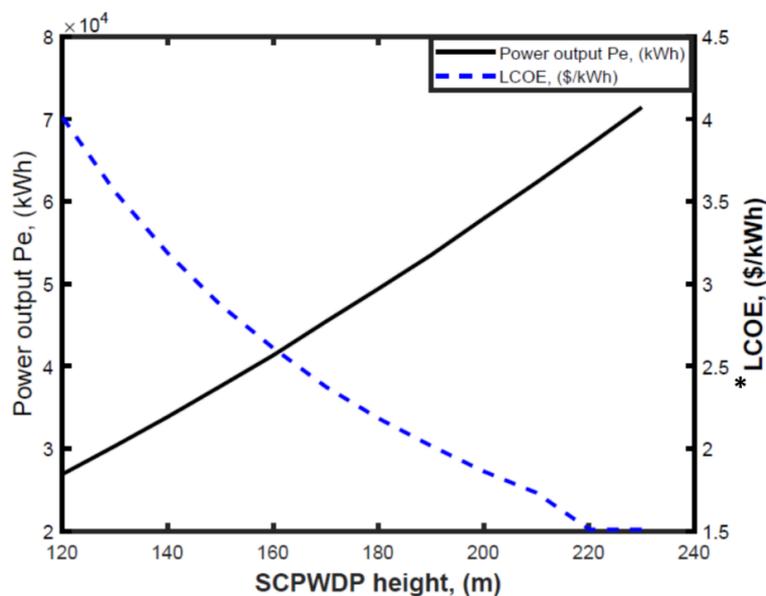
Figure 5. Sensitivity analysis for the calculated levelized cost of energy (LCOE) and produced electrical power when varying chimney height. *—The LCOE in the sensitivity analysis was based only for monthly production. We selected the monthly operating cost related to the maximum production in June.

4. Conclusions

The results show that developing a SCPWDP in the port of Aqaba is feasible. The SCPWDP will be capable of producing about 481,440 kWh of electricity and 123,753 tons of distilled water yearly. The results also show the LCOE for SCPWDP was found to be $1.86/kWh. Which was within reasonable expectations when compared to other studies and other power generating technologies. However, from an economical point of view the LCOE of SCPWDP requires further decreases in order to make it economically more feasible. Installing SCPWDP would be feasible for the decentralized energy supply system. If SCPWDP was combined with a system for vegetation leading to a win–win situation of power production combined with water and vegetation production. The SCPWDP could be improved further by unique design, finding cheap fabrication materials, maximizing the power output, and combining SCPWDP with other renewable energy production technologies. For the future recommendation, studies should focus on a detailed economic study and find an optimal way to decrease the LCOE.

Nomenclature

A	Area: (m^2)
H	Height, (m)
c_P	Specific heat capacity, (J/kg.K)
D	Diameter, (m)
I	Solar irradiation intensity, (W/m^2)
$Pelc$	Electrical Out Power, (W)
T	Temperature, (K)
Q_{out}	The heat transfer between the chimney and the ambient, (W)
h	Heat transfer coefficient, (W/m^2. K)
hfg	Latent heat of water evaporation, (W/m^2. K)
$\overline{m}$	Mass flow rate, (kg/sec)
g	Acceleration of gravity, (m/s^2)
q	Heat transfer rate, (W/m^2)
i	Enthalpy
r	Radius, (m)
k	Air thermal conductivity
dh	Hydraulic diameter, (m)
f	Friction factor
PV	Photo Voltaic
CPU	Central Processing Unit
RAM	Random Access Memory
GH	Giga Hertz
GB	Giga Byte
rw	Water Pool Radius
It	Yearly Investment Expenditures (Including Financing)
t	One Year Time
Mt	Yearly Operating and Maintenance Expenditures
Ft	Yearly fuel expenditures
Et	Yearly Electricity Production
dr	Discount Rate
n	System Life

Greek Symbols

T	Transmissivity
A	Absorptivity
P	Density, kg/m^3
ω	Humidity ratio
T	Transmissivity

Subscripts

air	Airflow
gls	Glass cover or convective heat transfer
abs	Absorber plate
ch	Chimney

cd	Condensated water
col	Collector roof
e	Evaporation
rad	Radiation heat transfer
out	Outside
ent	Entrance
wtr	Water
sky	Sky
c	Convective heat transfer
r	Radiative heat transfer

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