View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Periodicals of Engineering and Natural Sciences (PEN - International University of...

Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol. 8, No. 3, August 2020, pp.1471-1481

Design and improving the work of a concave solar collector - CSC

Rusul Dawood Salim
Physics Department, College of Education for Pure Science, University of Basrah

ABSTRACT

The purpose of the project is to design and improve the work of a concave solar collector CSC to heat the water; it works by reflecting the solar radiation and the global warming, also it works in the cloudy and fractional cloudy ambience. Used materials available on the local market to build and improve design: The body of the design is concave, mirrors, copper tube, Clear glass panel, thermal insulating materials, Matte black pigment and devices were used to record the temperature of H_2O leaving the CSC. Tested CSC before and after the improvements during the period from Dec-2017 to Jan-2020, showed the test results stability in the work of CSC where the temperature of H_2o produced on sunny days is (58-97) C°, cloudy days are (49-70) C° and fractional cloudy days are (45-70) C° to take into account the ambience temperature on that day. Before the improvement, the flux velocity stabilized at 0.162 L/min but after the improvement, the flux velocity stabilized at 0.17 L/min where the productivity of the CSC per one day of hot H_2O is 112.2 L/m², it can be used in various fields far from other energy sources.

Keywords: Keywords: Solar Radiation, Solar energy, Industrial solar energy, Solar heating.

Corresponding Author:

Rusul Dawood Salim
Physics Department, College of Education for Pure Science,
University of Basrah, Iraq
E-mail: rusul.salim@uobasrah.edu.iq , rosalh7975@gmail.com

Nomenclature

CSC	A Concave Solar Collector.	H_T	Hot tank.
C°	Celsius.	L	Liter.
m	Meter.	L/min	Liter per minute.
m²	Square meter.	%	Percentage.
E_T	External Tank.	I.D.	Iraqi Dinar.
H_2O	Water.		

1. Introduction

Energy is an essential component of humanity and the progress of civilization. With the decrease in the quantities of oil, which is the main source of energy and is a non-renewable source. At the same time, the world suffers from climate change, air pollution, ozone layer recession and overheating, the challenge facing the world has become:

1- Finding an alternative to energy. 2- Environment cordial. 3- Reduces the drain of non-renewable energy. 4- It reaches all over the world. 5- At reasonable prices.

Solar energy is a permanent natural resource, available in nature, constantly renewable and without using pollution.

Motivated by these reasons, NGOS are working to expand the contribution of renewable energy sources to human consumption, therefore, reducing fossil fuel consumption, which contributes to reducing the aforementioned obstacles [1].

Also, the solar energy is a white liveliness and environment cordial in nature. The water also occurs naturally, so there is compatibility between white liveliness and raise the water temperature [2, 3].

De Saussure is a Swiss scientist; in 1767 he introduced a preliminary design for solar water heating and black painted with top glass cover (two Clear glass panels) [4]. It was called the Hot Box; it was designed for heating,

cooking and hot water production. But innovator Clarence M. Kemp was the first to manufacture a commercial solar heater (Climax) in 1891 and he obtained a patent from the United States of America [5].
At the beginning of the twentieth century, researchers interested in improving the water heating system by solar energy to be continuous and effective. William Bailey developed a solar water heating system that made it into two parts: Solar collector and thermal tank to collect the produced hot water, this tank is insulated to retain heat [6].
Became solar applications are widespread; currently, it contributes significantly to the domestic and industrial sectors in many countries. There are countries that control the international market in solar energy, such as China and European Union [7].
Despite the spread of solar applications such as collectors, stills and others; However, few expected uses have been achieved [8]. And to know the percentage of the use of solar heating system, see Table 1. Expected in 2030, increase the need for solar energy requirements by 0.6% of the lands [7].

Table 1. Shows the percentage of the use of solar heating system

Country	China	European Union	Turkey	Japan	Palestine	Brazil	US	India	Australia	South Korea	Other
Percentage	70.5 %	12.3%	5%	2.8 %	1.7%	1.6 %	1.3 %	1.2%	0.9%	0.7%	2%

Solar energy research is of great importance, and solar heating is a real technology, which has the opportunity to improve its performance, and researchers are conducting more work and analysis on various aspects of solar energy applications to suit regional geographic conditions [9].
There are designs fit many of the environments or ambience conditions, duo to it depends on the idea aggregation solar radiation in a small area while providing global warming [10].
The intensity of solar radiation varies during daylight hours, whereas, the shortest path of solar radiation is at midday [11, 12, 13]. So, the sun must be traced continuously. Therefore, the angle of slope of the solar collector with Earth is changed (15º) in summer and (45º) in winter [10, 14], which it lies on the longitude (47º45´) and latitude (30º33´) [13].

2. Materials of CSC

a. The clear glass panel is (1.2 x 1.2) m² and its thickness is (0.004 m).
b. Strongthen clear glass panel is (1.2 x 1.2) m² and its thickness (0.003m).
c. Copper tube, diam (0.0115 m), extent (16 m).
d. Mirrors (0.085 x 0.085) m².
e. Matte black pigment.
f. Tank for supplying liquid (External Tank E_T).
g. Dish TV, diam (1.2 m) (dish1, dish2).
h. Valve.
i. Cohesive matter.
j. Holder of aluminium (girder intoxicated is (0.02-0.06) m).
k. Insulated hot tank H_T with a capacity of 25 L.
l. Thermally insulating materials (Glass wool).
m. Plastic hose.

3. Epistemology

3.1 Manufacturing of New CSC

The CSC is a concave solar collector, this design was chosen because it is suitable for many environments or ambience conditions, duo to it depends on the idea aggregation solar radiation in a small area. The facade of the concave shape is in a circle with a diam of 1.2 m. Mounted on the concave surface are mirrors, aluminum holders, and a copper tube, and then a glass cover. See Figure 1.

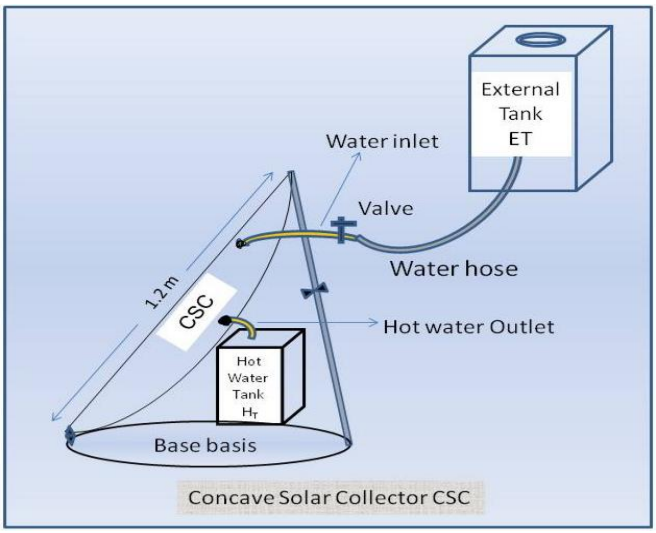


Figure 1. An illustration of the solar collector CSC

There are three sources to gain the heat in this design:

1) Sunlight fallen directly on CSC.
2) A reflection of sunlight from mirrors.
3) Global warming inside design CSC.

The aluminum holders are mounted on the concave surface, regularly, and equal dimensions, the purpose of the aluminum holder is to lift the copper tube from the surface from 0.02 m to 0.06 m in order to take advantage of the solar radiation reflected from the mirrors. The mirrors are mounted on the concave surface, synergistically, and the area of the mirror is (0.085×0.085) m², in order to reflect the sunlight falling on it towards the copper tube. The solar radiation reflected from the mirrors will fall along the pipeline, therefore, it will raise the H_2O temperature In the CSC. See Figure 2.

Figure 2. Shows The aluminum holders and mirrors are mounted on the concave surface

Used the copper tube for market availability and at a good price, easy to wrap in small workshops, good endothermic, relatively long life. The dimensions and capacity of the tube are as follows:

1- The diam of the tube is 0.0115 m.
2- The length of the tube is 16 m.
3- The capacity of the tube is 1.7 L.

Wraps copper tube began from the edge of the concave shape towards the centre. The end of the tube, close to the edge input of H_2O from E_T to CSC but The end of the tube in the centre is directed by hot H_2O from CSC to H_T. In order not to accumulate sediments in the watercourse, used a tube with a diam of 0.0115 m. The copper tube is painted in a matte black pigment, in order to increase the heat absorption, thus increasing the efficiency of the CSC, and obtaining water with a greater temperature. See Figure 3.

Figure 3. Shows the path of the tube, and its coating is Matte black pigment

Attached a clear glass cover on the front of the CSC for the following reasons:

1- Keep CSC clean.
2- Keep the copper tube from oxidation due to moisture in the air.
3- Providing global warming, which raises the temperature inside the solar collector CSC, thereby raising the temperature of the H_2O that passes through the copper tube.

3.2. Before the improvements

The area of clear glass cover is (1.2 x 1.2) m², and its thickness is (0.004 m). The solar collector CSC is equipped with water from an external tank E_T via a valve, and the velocity of the water flux was controlled by the same valve, the outer tank was attached to the solar collector by a plastic hose across the end of the tube at the edge, used the Insulated hot tank H_T with a capacity of 25 L, to collect hot water which comes out of the solar collector CSC. See Figure 4.

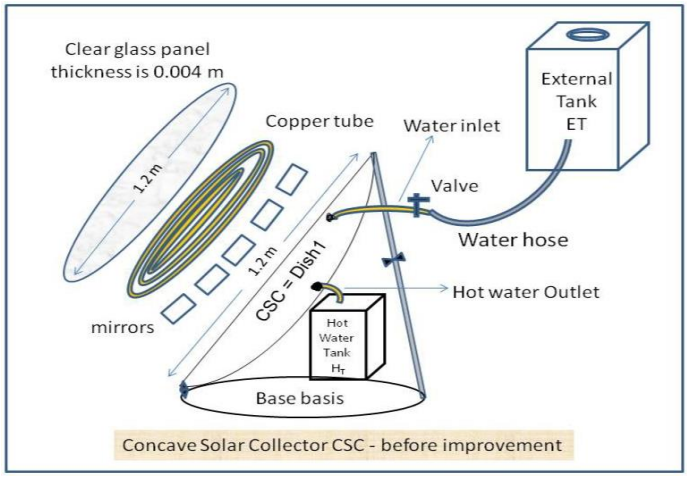


Figure 4. An illustration of the solar collector CSC before the improvement

According to the above, The CSC was tested during the period from Dec-2017 to Jan-2020, showed the test results stability in the work of CSC where the temperature of H_2O produced on sunny days is (58-97) C°, it turned out before improvements, the flux velocity stabilized at 0.162 L/min, means that the productivity of the CSC per 10 hours of hot H_2O is 97.2 L/m², and the H_2O temperature inside the tank H_T during the same period is (62-66) C°.

3.3. After the improvements

The aim of the improvement to the solar collector CSC is to reduce heat loss and the dispersing of reflected radiation, as there are reasons for heat loss in the design of the CSC:

1) Loss across the solar collector wall CSC, the surface of the solar collector is made of metal, and through the heat exchange pross between the mirrors and the wall there will be a heat loss. To prevent this loss, added a glass wool to the convex surface of the solar collector CSC, and then a metal cover (Dish2) over the glass wool. See Figure 5 & 6.

2) Heat loss due to the use of 0.004 m thickness clear glass cover, where has been replaced the glass panel thickness is 0.004 m with strongthen clear glass panel thickness is 0.003 m.
3) Heat loss and the dispersing of reflected radiation due to the dispersing of reflected radiation from mirrors.

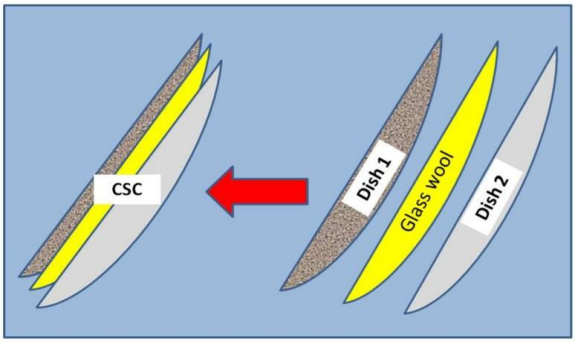


Figure 5. An illustration to adding glass wool and dish2 to dish1

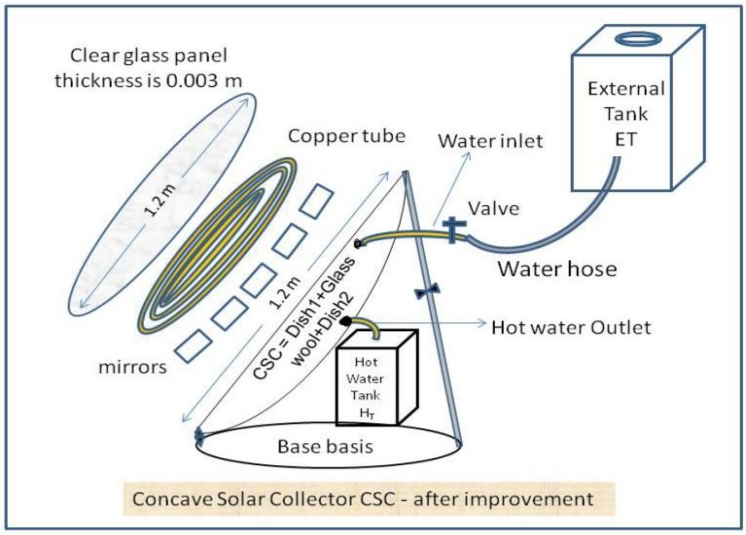


Figure 6. An illustration of the solar collector CSC after the improvement

After the improvements, the solar collector CSC was tested during the same period from Dec-2017 to Jan-2020, showed the test results stability in the work of CSC whereas the temperature of H_2O produced did not differ much except that the flux velocity was stabilized at 0.17 L/min, means that the productivity of the CSC per 10 hours of hot H_2O is 112.2 L/m², and the H_2O temperature inside the tank H_T during the same period is (63-71) Cº.

According to the above, the improvements have affected the functioning and efficiency of the solar collector CSC.

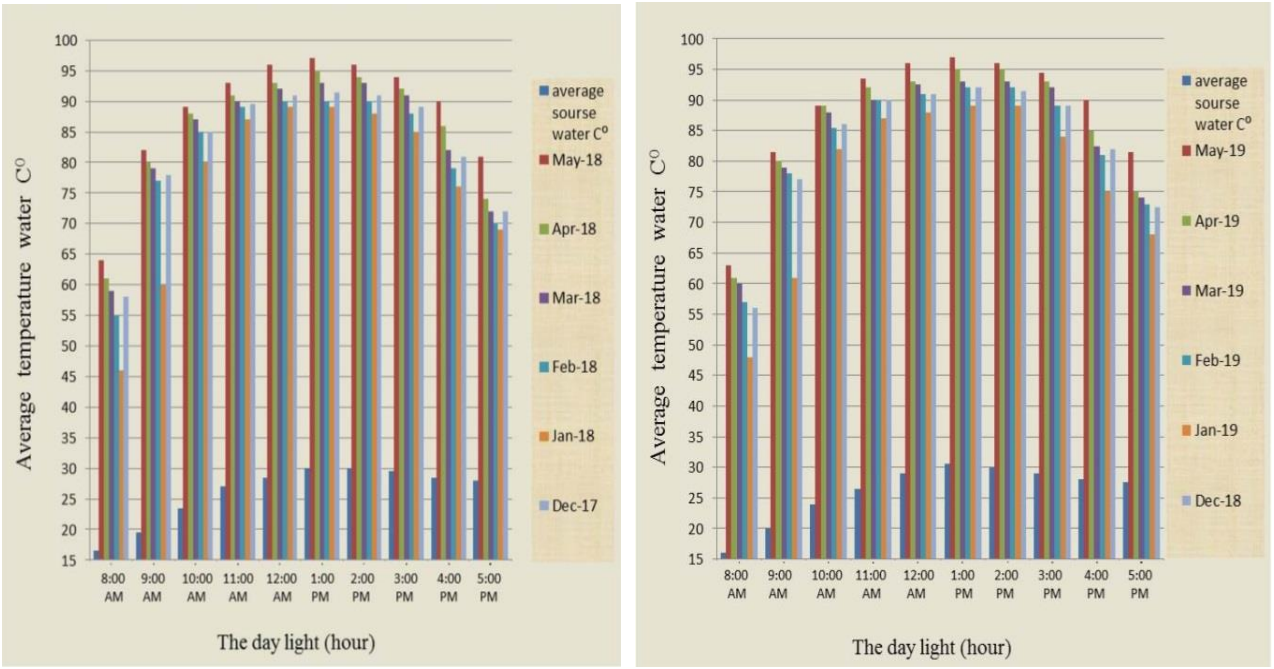
Conducted tests other on the design CSC in the cloudy and fractional cloudy ambience, taking into account the temperature of that day, and the results are as follows:

1. Cloudy ambience; CSC checkup in cloudy ambience on 10\3\2019 and the temperature ambience was (32 C°), and the following results were recorded:
    a. The temperature of outlet H_2O from CSC is (49-70) C°.
    b. The temperature of H_2O in (H_T) is (42-64) Cº.
2. Fractional cloudy ambience; CSC checkup in cloudy ambience on 10\1\2020 and the temperature ambience was (20 C°), and the following results were recorded:
    a. The temperature of outlet H_2O from CSC is (45-70) C°.
    b. The temperature of H_2O in (H_T) is (42-63) Cº.

4. Results and communicating

The CSC design was checked before and after the improvements in summer and winter seasons, during the period from Dec-2017 to Jan-2020, the results showed the stability of the work of the solar collector CSC during that period, with efficiency in work and production, also, the solar collector CSC does not need maintenance during all of this period, the design shape makes it easy to clean, and it can be moved easily.
Figure 7 shows a graph of a work of the solar collector CSC during the period:

a) For months (From Dec-2017 to May-2018).
b) For months (From Dec-2018 to May-2019).



(a) (b)

Figure 7. Shows working CSC per month:
(a) (From Dec-2017 to May-2018); (b) (From Dec-2018 to May-2019)

Where the temperature of H_2O produced on sunny days is (58-97) C°, it turned out before improvements, the flux velocity stabilized at 0.162 L/min, means that the productivity of the CSC during daylight hours from 8:00 a.m. to 5:00 p.m. of hot H_2O is 97.2 L/m², and the H_2O temperature inside the tank H_T during the same period is (62-66) Cº. See Table 2.

Table 2. Shows the affected items for CSC before and after improvements

Affected items	Before the improvements	After the improvements
The temperature of water produced C°	(58-97) C°	(58-97) C°
The flux velocity L/min	0.162 L/min	0.17 L/min
CSC productivity of hot water L/m²	97.2 L/ m²	112.2 L/ m²
The temperature of the tank H_T Cº	(62-66) Cº	(63-71) Cº

During the study and examination of the design it was found that there is heat loss and dispersion of solar radiation:

1) Loss across the solar collector wall CSC due to the heat exchange pross between the mirrors and the wall.
2) Heat loss and the dispersing of reflected radiation due to the use of 0.004 m thickness clear glass cover.

3) Heat loss and the dispersing of reflected radiation due to the dispersing of reflected radiation from mirrors.

Has been added improvements to address the heat loss and dispersion in each of paragraphs numbers 1 and 2. After the improvements, the solar collector CSC was tested during the same period, showed the test results stability in the work of CSC whereas the temperature of H_2O produced did not differ much except that the flux velocity was stabilized at 0.17 L/min, means that the productivity of the CSC during daylight hours from 8:00 a.m. to 5:00 p.m. of hot H_2O is 112.2 L/m², and the H_2O temperature inside the tank H_T during the same period is (63-71) Cº. See Table 2.
To know the behaviour of the monthly solar collector CSC during the examination period, the average H_2O temperature was taken for every month (from Jan-2018 to May-2019). See the graph in Figure 8.

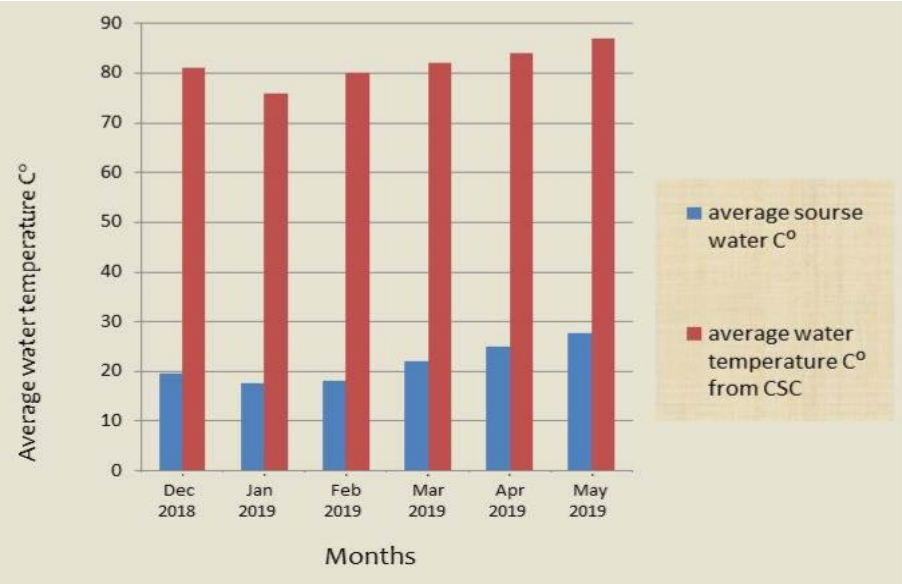


Figure 8. The behavior of the monthly solar collector CSC during the examination period

The CSC checkup in cloudy ambience on 10\3\2019 and the temperature ambience was (32 C°). The temperature of outlet H_2O from CSC is (49-70) C° and the temperature of H_2O in H_T is (42-64) Cº, these results indicate the efficiency of the solar collector CSC to operate during different ambience conditions. See the graph in Figure 9 and Table 3.

Figure 9. Graph of the work of CSC in a cloudy ambience on 10-3-2019

Table 3. Shows CSC in cloudy and fractional cloudy through daylight

Cloudy ambience			Fractional cloudy ambience		
(10/3/2019) -32 C^{O}			(10/1/2020) - 20 C^{O}		
Time	T_{ow} C^{O}	T-Tank C^{O}	Time	T_{ow} C^{O}	T-Tank C^{O}
08:00	49	42	08:00	45	42
09:00	61.5	56	09:00	53	51
10:00	65.5	58	10:00	62	53.5
11:00	67.5	61	11:00	68.5	59.5
12:00	70	63	12:00	69.5	63
01:00	70	63.5	01:00	70	63
02:00	70	64	02:00	70	63
03:00	69.5	63.5	03:00	70	62
04:00	66.5	63	04:00	67.5	62
05:00	61.5	62	05:00	60	61.5

The CSC retested in fractional cloudy ambience on 10\1\2020 and the temperature ambience was (20 C°). The temperature of outlet H_2O from CSC is (45-70) C° and the temperature of H_2O in H_T is (42-63) C°, these results confirm the efficiency of the solar collector CSC to operate during different ambience conditions and its work continues. See the graph in Figure 10 and Table 3.

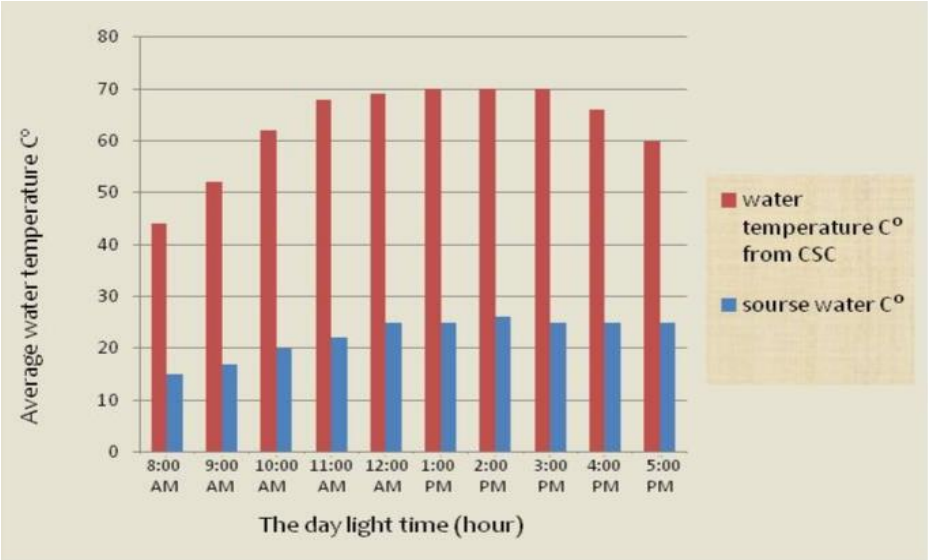


Figure 10. Graph of the work of CSC in a fractional cloudy ambience on 10-1-2020

It is noted that the solar collector CSC continued to operate during the period from Dec-2017 to Jan-2020, indicates that the operating life of the solar collector CSC is more than 3 years.

5. Economic cost

The CSC design possesses practical qualities such as ease of manufacture and cleaning, also, damaged and consumed materials were used as raw materials in its construction (Recycling of materials), This contributes to supporting the economy of countries, operating manpower, reducing unemployment, ridding countries of some

solid waste, and preserving the environment. Where a damaged dish TV was used with broken mirrors, and the cost of assembling these materials with the current price of the materials (1 U.S. $ = 1200 I.D.) is shown in Table 4.

Table 4. Shows the cost of manufacturing the CSC design from recycling materials

Materials	The number	The cost I.D.	
		CSC before the improvement	CSC after the improvement
Clear glass panel thickness is (0.004 m)	(1.2 x 1.2) m²	3000	-
Strongthen clear glass panel thickness is (0.003 m)	(1.2 x 1.2) m²	-	6000
A plastic hose	3 m	750	750
Copper tube, diam (0.0115 m)	16 m	16000	16000
Mirrors thickness is (0.003 m)	(1.2 x 1.2) m²	0	0
Glass wool	(1.2 x 1.2) m²	-	1200
Matte black pigment	1	500	500
Dish1 diam (1.2 m)	1	0	0
Dish2 diam (1.2 m)	1	-	0
Valve	1	250	250
Cohesive matter	2	1500	1500
Holder of aluminium	-	0	0
Insulated hot tank (HT)	1	3000	3000
Total		**25000**	**29200**

Either if new raw materials are used, and they are available in the local market, as the cost of manufacturing the solar collector CSC according to the current price of the materials (1 U.S. $ = 1200 I.D.) is shown in Table 5.

Table 5. Shows the cost of manufacturing the CSC design of new raw materials

Materials	The number	The cost I.D.	
		CSC before the improvement	CSC after the improvement
Clear glass panel thickness is (0.004 m)	(1.2 x 1.2) m²	3000	-
Strongthen clear glass panel thickness is (0.003 m)	(1.2 x 1.2) m²	-	6000
A plastic hose	3 m	750	750
Copper tube, diam (0.0115 m)	16 m	16000	16000
Mirrors thickness is (0.003 m)	(1.2 x 1.2) m²	6000	6000
Glass wool	(1.2 x 1.2) m²	-	1200
Matte black pigment	1	500	500
Dish1 diam (1.2 m)	1	8000	8000
Dish2 diam (1.2 m)	1	-	8000
Valve	1	250	250
Cohesive matter	2	1500	1500
Holder of aluminium	-	250	250
Insulated hot tank (HT)	1	3000	3000
Total		**39250**	**51450**

From Table 5 it was found that the cost of manufacturing the collector CSC is appropriate with the amount of hot H_2O production, as in Table 2, its operating life, ease of manufacture, maintenance and transportation also. From Tables 4 and 5, it is observed that there is a significant difference in the manufacturing cost, which is almost double, in addition to rid the countries of some solid waste, maintain the environment, Employment of many segments of society, which is a contribution to reducing unemployment, engcouraging and exporting the local product and providing difficult currencies for countries, especially developing countries.
And if they are produced in factories or workshops, the cost will be much less because the raw materials are at wholesale prices.

6. Conclusion

1- The CSC is a recent system and simple manufacturing, transporting and clean up.
2- The CSC is soaring efficiency and steadiness according to taped results.
3- The copper tube can be replaced with aluminium tube to reduce cost.
4- The temperature of H_2O produced on sunny days is (58-97) C^o, and the constant flux is (0.17 L\min) after improving the CSC.
5- The productivity of the CSC during daylight hours of hot H_2O is (112.2 L/m^2) after improving.
6- The hot H_2O keeps in the insulated hot tank H_T, the temperature of the H_2O in the H_T is (63-71) C^o.
7- The CSC is effective in a fraction cloudy ambience where the temperature of production H_2O is (45-70) C^o, the temperature of H_2O in H_T is (42-63) C^o.
8- The CSC is working in cloudy ambience where the H_2o temperature of the product is (49-70) C° and the temperature of H_2O in H_T is (42-64) C^o
9- the operating life of the solar collector CSC is more than 3 years.

References

[1] O. R. S. Rodrígueza, R. N. N. Koury and A. A. T. Maia "Design, fabrication and experimental study of a flat plate collector simulator", Engenharia Térmica (Thermal Engineering), Vol. 15, No. 1, p. 50-56, June 2016.
[2] S. Al-Kharabsheh and D.Y. Goswami "Analysis of an innovative water desalination system using low-grade solar heat", Desalination 156, pp. 323-332, 2003.
[3] M. Olalekan and Taiwo "Improving the performance of solar stills using sun track in", Mechanical Engineering, PP. 13-14, 2010.
[4] The Encyclopedia of Earth. http://www.eoearth.org/article/De_Saussure,_ Horace_B%C3%A9n%C3%A9dict.
[5] Butti K, Perlin J. A golden thread. London, UK: Marion Boyars Publishers Ltd; 1981.
[6] Butti K, Perlin J. Early solar water heaters, A Golden Thread. New York: Van Nostrand Reinhold Company; p. 117-127, 1979.
[7] Renewable Energy 2010: Key Facts and Figures for Decision Makers. Global status report. http://www.ren21.net/gsr.
[8] Renewable Energy Technologies, World Energy Assessment (WEA) Report 2001. www.undp.org/seed/eap/activities/wea/drafts-frame.html.
[9] M. Raisul Islam, K. Sumathy, Samee Ullah Khan, "Solar water heating systems and their market trends", Renewable and Sustainable Energy Reviews 17, pp1–25, 2013.
[10] Rusul D. Salim "Manufacturing Procedure of a Hybrid Design of Solar Collector (Sterilization and Water Heating) By Solar and Electrical Energy", International Conference on Advanced Science and Engineering (ICOASE), Kurdistan Region, Iraq, 2018.

[11] Asaad Rehman Saeed Al-Hilphy ″ A theoretical and practical study for the incident solar radiation intensity in the Basrah province (south of Iraq) ″, IOSR Journal of Engineering, Vol.3, p. 25, Issue9 (September. 2013).

[12] P. J. Lunde. Solar Thermal engineering. Willey, New York, 1980.

[13] Rusel D. Salem, Aqeel Y. Hashim, Jassim M. AL-Asadi ″Comparison between different designs of solar colector in basrah city″, IOSR Journal of Applied Physics (IOSR-JAP). Volume 7, PP 26-32, Issue 2 Ver. II,Mar. - Apr. 2015.

[14] Rusul Dawood Salim AL-Khafaji, Jassim Mahdi AL- Asadi, Aqeel Yousif Hashim ″ Construction and study the performance of water desalination and heating systems using solar energy ″, Ph.D., Solar Energy, College of education for pure Sciences, Basrah University, PP. 39, 2015.