

Research Note

Solar Energy Application for Desalination of Caspian Sea Water

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Abstract

This paper studies and presents application of solar energy in the desalination process of the Caspian Sea to supply drinkable water in Absheron Peninsula. For this purpose three types of solar energy plants were developed and tested: parabolic, parabolic trough and flat-plate solar collector. The dependence on time of water temperature in solar energy was determined. The process was also appraised economically and ecologically. Economic benefits were determined after thorough calculations. It was observed that payback duration lets the project to be realized.

Keywords: *Desalination by solar energy, Discount factor, Parabolic, Parabolic trough and flat-plate solar collector*

1. Introduction

At present, the demand for drinkable water is increasing because of the high growth rate of population in the world. In Azerbaijan, for example, the population is about to reach 9150000. That is why, to stabilize a particular amount of both drinkable water for the population and the irrigation water for agriculture, it is necessary to desalinize the Caspian Sea water, which is the greatest water basin in the Country. In the Caspian Sea, the average annual water temperature increases by approximately 0.8 °C from the north to the south at each degree of parallel. In order to realize the process ecologically clean and economically cheap, only solar energy was used. In the literatures a great deal of scientific and practical results were given on the methods of sea water desalination (Abdullayev *et. al.* 2002, Agamaliyev, *et. al.* 2005). For this purpose three solar energy plants: parabolic trough (mirror square – 1 m²), parabolic (mirror square – 1.3 m²) and solar collector (absorber square – 0.9 m²) having azimuthal and zenithal sun tracking systems were built and tested in several technological processes (Mammadov 2008, 2011).

As it is seen in figure 1, in the northern part of Azerbaijan, water temperature varies between 22 and 24 °C, while in the southern part it is 28 °C. In Absheron peninsula, water temperature varies from 26-27 °C.

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2. Materials and Methods:

2.1 Study Area

Water samples were collected from the seaside region of the Caspian Sea basin at several distances and different depths. Physical and chemical properties of these samples were then determined in the laboratory. Generally, salinity level of water in the northern and southern parts of the Caspian Sea varies between 12.82 and 12.86 ‰, but in Absheron peninsula, the annual average is 12.6 ‰. Therefore, in order to determine comparative maximal temperature and productivity, experiments and testes on water motion by the means of the rmosiphon method were carried out at solar parabolic trough, parabolic energy plants and solar collectors. During the practice-taking into consideration economical and thermal-energy parameters- solar radiation falling on the surface of the mirror, heat absorbed by the plant, heat losses and efficiency of heat supply were determined and then proper calculations were carried out on them. Afterwards, under stable solar radiation, working regimes and technical characteristics of all three plants were studied and defined. It was revealed that parabolic mirror is 12-15% more effective in comparison with parabolic trough, but in congruence with solar collector, it is 25-30% more effective.

2.2. Methods

Building of solar plants may be realized in different enterprises. It is a fact that renewable energy sources are the need of the day due to the rapid depletion of fossil fuels and their hazardous impacts on the environment. Alternative or renewable energy sources are not only eco friendly but they may have varied economic benefits. Similarly, solar energy plants building can be a lucrative business project depending on expenditure on building and utilization.

Here, in this regard, the method of calculation to determine the economic efficiency of solar energy application in the process of desalination of Caspian Sea water is taken into account. Application and utilization of alternative energy resources is not something new and its usage is rapidly gaining popularity due to the fact that it is both economically and ecologically efficient. Therefore, investment in a project to desalinize water through the application of solar energy will be feasible both financially and socially for the investor. In order to estimate the economic efficiency of such a project, first of all the building and exploitation cost of the solar energy plant to be used in such a project is taken into consideration and then it is compared with the expected financial benefits from the investment, also taking into account the time frame or duration of the project. Hence the expenditure on building of solar energy plant for the project and the expected financial benefits are calculated at the same time.

While estimating the capital efficiency in advance, depending on time, discount coefficient is used (Mammadov 2006). Having determined discount coefficient index bank per cent norms, the benefit of the capital put by investor and so on, can be important.

Discount coefficient (D_c) is calculated according to the following formula (Mammadov 2006):

$$D_c = \frac{1}{(1+r)^n} \quad (1)$$

Here,

r – Discount norm is shown by relative unit.

n – Discount period is shown by years.

Several indexes are utilized while estimating economical efficiency of the investment projects and selecting them. The following indexes are concerned to them:

- Pure discount benefit or integral profit (PDB)
- Income norm or internal benefit norm (IBN)
- Benefit index or profitable index (BI)
- Payment duration (PD)

PDB showings are supplied to express in dollars the results of investment project realization. PDB is determined by the following method (Mammadov 2006):

$$PDB = EC - IC \quad (2)$$

Here, EC - is current discount cost of the included capital during the realization of investment project; IC - is the cost of investment spent for the realization of investment project.

While estimating investment project if PDB equals zero or negative marks then the realization of this project will never bring additional benefit to the investor.

IBN showings characterize the profitability level of the investment project realization. On the base of discount norm, benefit index showings are expressed as the follows:

$$IBN = \frac{PDB}{IC} \cdot 100 \quad (3)$$

IBN cost may be taken as discount norm. Then pure discount benefit will equal zero in the process of discounting.

Benefit index (BI) is expressed as the follows (Mammadov 2006):

$$BI = \frac{EC}{IC} \quad (4)$$

If PDB gets positive mark then $BI > 1$ must be. PD showings are the most important one in evaluation of the investment project efficiency. PD expresses the possibility of capital give back during any minimal time which was spent to the investment project realization. By other way payment duration reflects the additional benefit being gained at the exact time after investment done. PD is given as the follows (Mammadov 2006):

$$PD = \frac{IC}{EC(t)} \quad (5)$$

PD- is the payment duration of the capital for the investment project and expressed by years.

EC (t) - during t is the quantity reflecting yearly overage current cost of the capital included from the investment project.

For the investment project realization it is more important to take into consideration this factor in marketing.

The efficiency of the building and exploitation of solar plant is proposed on the base of ecological efficiency evolution, methods of investment project and showings mentioned above. The information according to the investment project proposed for this at the tables 1 and 2 may be used.

Using the first method, the additional information in table 1 and 2 and on the project of solar plant building, exploitation, pure discount benefit may be determined (Mammadov 2006):

$$PDB = EC - IC = 923517 - 500000 = \$ 423517 \text{ dollars} \quad (6)$$

So the pure discount benefit gained from the proposed investment project is \$ 423517. Thus, if company has invested about 500000 dollars in the project then after ten years investor will be able to get back both 500000 dollars spent on the project and 423517 dollars as the additional benefit.

Using the second method, the materials in the tables on the solar plant project internal profitability norm showings may be defined. In this case such discount norm must be determined that, while utilizing the current cost and the capital obtained during ten years should be equal to the amount of investment made in the project. The necessary discount norm can be determined as follows (Mammadov 2006):

$$IBN = \frac{PDB}{IC} \cdot 100 = \left(\frac{423517}{500000} \cdot 100 \right) = 84.70\% : 10 = 8.47\% \quad (7)$$

Hence, internal benefit norm of the project is high.

Using the third method and the materials in the tables, benefit index of the project can be calculated as the following:

$$BI = \frac{EC}{IC} \cdot 100 = \frac{923517}{500000} = 1.847 \quad (8)$$

In case benefit index showings are higher than one, then the realization of the investment project is economically efficient. So the capital gained 1.8 times more than the capital spent on the project.

Using the fourth method and the materials in the tables the payment duration of the capital being invested for the realization of the project is determined. That's why first yearly average of current benefit of the capital being gained during ten years after investment done must be calculated:

$$EC(t) = \frac{\sum_{t=1}^n EC^n}{t} = \frac{923517}{10} = 92351.7 \text{ dollars} \quad (9)$$

Payment duration of investment is determined as follows:

$$PD = \frac{IC}{EC(t)} = \frac{500000}{92351.7} = 5.4 \text{ years} \quad (10)$$

So investment resources of the solar plant's building and exploitation will be paid in 5.4 years.

According to the complex of showings calculated above, we may note that the realization of the investment projects proposed is efficient for the company. It must also be mentioned that the project is ecologically efficient as well, as economizing traditional fuels saves the atmosphere from hazardous gases.

So, Economical efficiency showings of investment project proposed above are characterized as follows:

- PDB=423517 dollars
- IBN=8.47%
- BI=1.84
- PD=5.4 year

All these are proofs of both ecological and economical benefits of the realization of the project proposed. Hence, giving the company the opportunity to make a decision considering the chances of favorable returns on investment made.

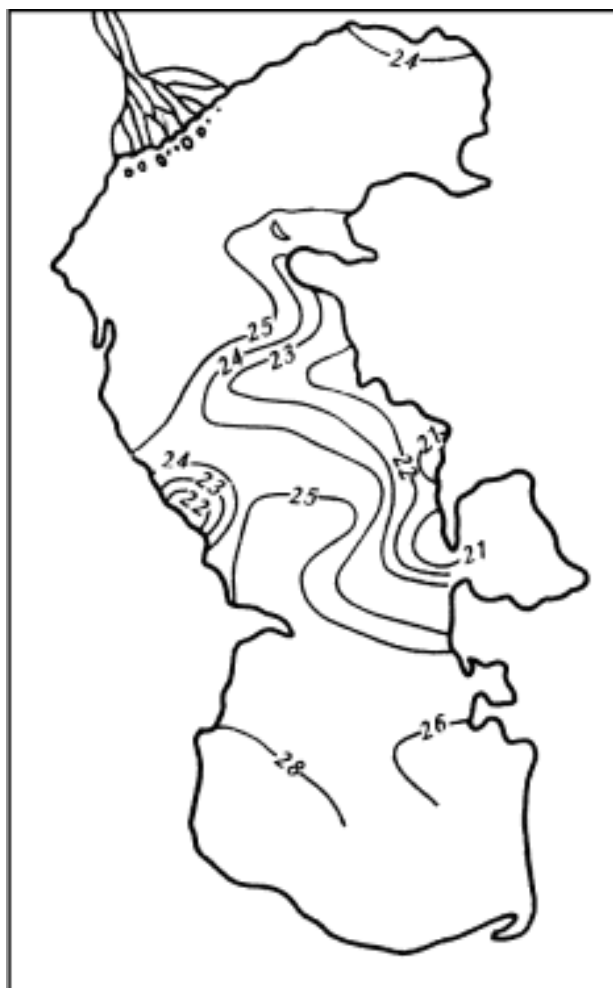
4. Results

After conducting the desalination of water through solar energy project, and in view of the results obtained from the study, it can be proposed that investment in desalination of water through the application of renewable sources of energy; especially solar energy can be beneficial both ecologically and economically, thus bringing in both financial and social viability for the investors. Hence it will not only be feasible but widely beneficial for investors especially water companies to invest in and take up projects to desalinize water from Caspian Sea through the application of solar energy.

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Appendix



Scale 1:15 000 000

Figure 1. Distribution of water temperature ($^{\circ}\text{C}$) on the surface of the Caspian Sea in summer season.



Figure 2. General view of flat-plate, parabolic and parabolic trough solar energy collectors.

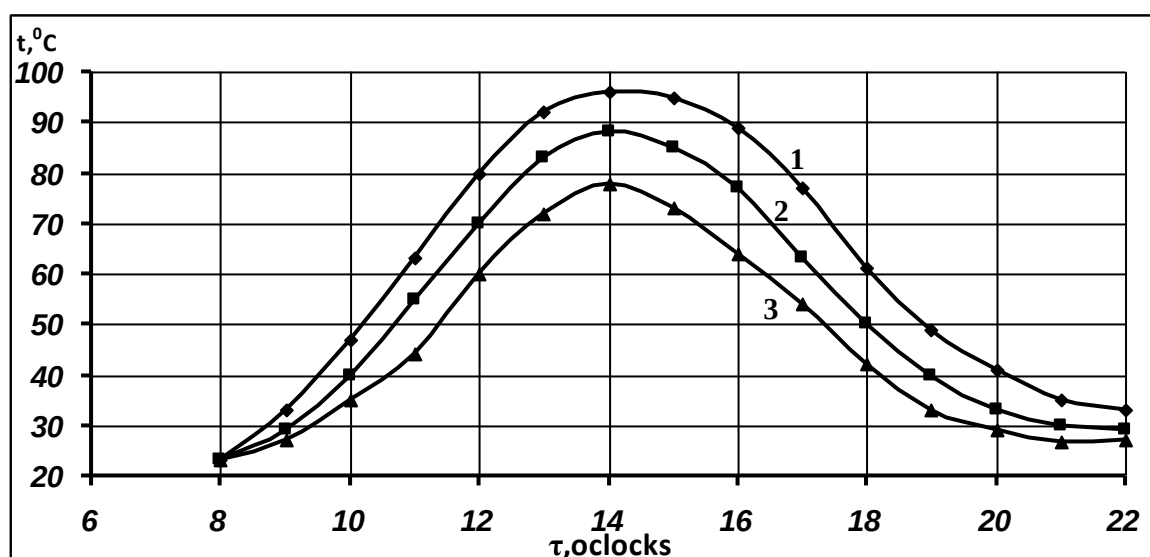


Figure 3. Dependence of water temperature in solar energy plants on time (at different time intervals:
1. Parabolic, 2. Parabolic trough and 3. Flat-plate Solar Collector)

Table 1. The annual information being used for determining economic efficiency estimate of
investment in solar plant building and exploitation project

Nº	Showings	Measurement unite	Indexes of showings
1	Volume of investment being spent on the project:	US dollar	500000
2	Considered exploitation duration of investment project:	Year	10
3	As a result of project realization volume of capital economized:	US dollar	1503000
4	Also in years: 1st year..... 2nd year..... 3rd year..... 4th year..... 5th year..... 6th year..... 7th year..... 8th year..... 9th year..... 10th year..... Total:	— — — — — — — — — — —	150300 150300 150300 150300 150300 150300 150300 150300 150300 150300 1503000
5	The discount norm being used in estimating the capital cost depending on the time:	%	10

Table 2: Calculation of current discount cost of expenses on the investment project

Years(t)	Current cost of capital (CCC)	Discount coefficient calculated by 10% discount norm (DC)	Discount cost of capital (EC) EC^t=CCC^t·DC	Calculation of discount coefficient $D_c = \frac{1}{(1+r)^n}$
1st year	150300	0.9091	136637	0.9091
2nd year	150300	0.8264	124208	0.8264
3rd year	150300	0.7513	112920	0.7513
4th year	150300	0.6830	102655	0.6830
5th year	150300	0.6209	93321	0.6209
6th year	150300	0.5645	84844	0.5645
7th year	150300	0.5132	77134	0.5132
8th year	150300	0.4665	70115	0.4665
9th year	150300	0.4241	63742	0.4241
10th year	150300	0.3855	57941	0.3855
Total	1503000		923517	