Interseasonal Accumulation of Solar Heat

Doğan Özdemir

Ishik University, Erbil, Iraq, Email: dogan.ozdemir@ishik.edu.iq

Received: October 5, 2014 Accepted: December 12, 2014 Online Published: December 25, 2014

Abstract: The sun has been a powerful source of energy for years. Solar energy is the solar radiation which reaches the surface of the earth. The energy coming from the sun is immense. The potential of Solar Energy is at least 100 times greater than any other renewable energy source. The solar energy can be converted in other forms of energy such as heat and electricity. This information made us to conclude that the way of receiving the thermal energy by converting it from the solar energy is a good and relatively cheap way. So, the basic purpose of our project is the developing of a construction for interseasonal accumulation of the solar heat and using it in the form of thermal energy.

Key Words: Interseason, Thermal Energy and Solar Radiation

The solar energy

The sun has been a powerful source of energy for billions of years. Solar energy is the solar radiation which reaches the surface of the earth. The energy coming from the sun is immense. The potential of Solar Energy is at least 100 times greater than any other renewable energy source. The solar energy can be converted in other forms of energy such as heat and electricity. In 1830s, the British astronomer John Herschel used a solar thermal collector box (a device that absorbs sunlight to collect heat) to cook food. Nowadays the solar energy is used by people for lots of things. The traditional resources used in producing the thermal energy like gas, are not renewable, they are limited. With approaching to this limit it's logically to suppose that the cost for these resources will grow. We've studied information about the solar radiation reached to the surface of the earth during the year, about the consumption of the thermal energy in our country, the information about the prices for the thermal heat produced by traditional methods and for the materials used in converting solar energy into thermal energy. All this information made us to conclude that the way of receiving the thermal energy by converting it from the solar energy is a good and relatively cheap way. So, the basic purpose of our project is the developing of a construction for interseasonal accumulation of the solar heat and using it in the form of thermal energy.

Problem

The basic problem in usage of the solar heat in purposes of a heat supply is that the solar heat is mostly received in warm seasons, but the basic need of it takes place during the winter period.

Hypothesis

This project is looked at the opportunity and expedience to create an interseasonal accumulation of the solar heat by using innovative technologies. The price for the thermal energy received with the help of the construction is expected to be lower than the price of the same energy received by traditional methods.

Materials and Methods

The basic way of getting the data and the results was the mathematical way, or in other words the virtual way. In this chapter you will see the tables with our results which we obtained during our research. Our construction is collecting the solar energy and accumulating it in the same time, so we named it like collector-accumulator. The temperature of water used in heating houses in the winter period is approximately 70 ^{0}C, so our research's basic purpose is to achieve this temperature of water in our reservoir.

The construction is composed of 3 main parts:

1) The field of solar collectors

2) Floating platform

3) Water reservoir

To show different possibilities to build our collector-accumulator, we have researched 4 different constructions for the field of solar collectors:

- I – Horizontal solar collector without a transparent protector. Maximum water temperature reached – 40 ^{0}C.

- II – Horizontal solar collector with a transparent protector. Maximum water temperature reached – 70 ^{0}C.

- III – Rows of collectors which have a constant angle of inclination (30 ^{0}) with a horizontal surface. Maximum water temperature reached - 70 ^{0}C.

- IV - Rows of collectors which have an adjustable angle of inclination with a horizontal surface. Maximum water temperature reached 70 ^{0}C.

Basic parameters of the construction's elements **Table 1**

No.	Name of the construction's element Value of the element's parameter	I	II	III	IV

1	Reservoir Diameter, m Depth, m Volume, m^3	 100 6.6 51800	 100 6.6 51800	 100 6.6 51800	 100 6.6 51800
2	Floating platform Area, m^2 Thickness of the platform, m	 7850 0,3	 7850 0,3	 7850 0,3	 7850 0,3
3	Field of solar collectors Area of the field, m^2 Number of rows	 7850 1	 7850 1	 5703 38	 7500 50
4	Heating-pump installation Power, kW	 160	 160	 -	 -

I – Horizontal solar collector without a transparent protector. Maximum water temperature reached – 40 ^{0}C (by using a heating-pump installation we increase the temperature to 70 ^{0}C).

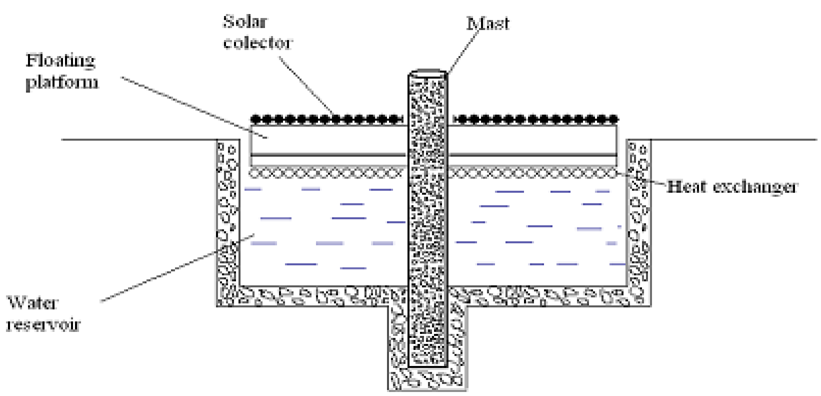

Fig. 1 Horizontal solar collector without a transparent protector.

II – Horizontal solar collector with a transparent protector. Maximum water temperature reached – 40 ^{0}C (by using a heating-pump installation we increase the temperature to 70 ^{0}C).

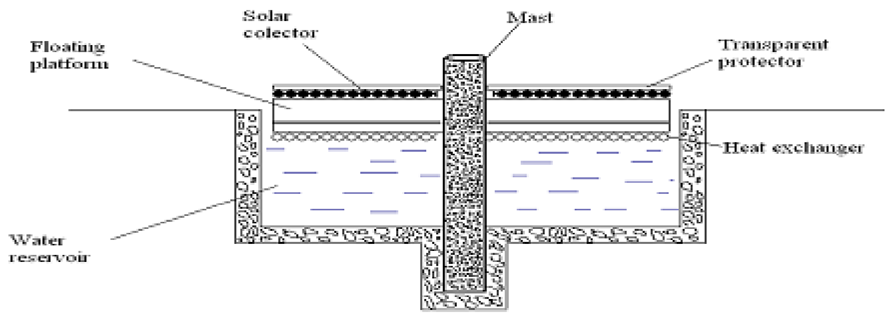

Fig. 2 Horizontal solar collector with a transparent protector.

III – Rows of collectors which have a constant angle of inclination (30 ^{0}) with a horizontal surface. Maximum water temperature reached - 70 ^{0}C.

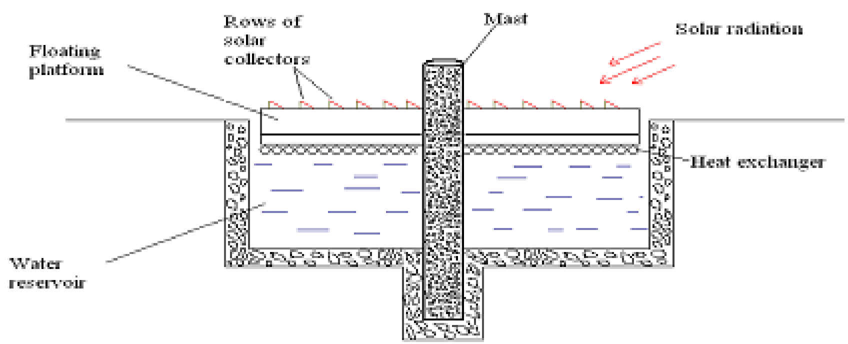

Fig.3 Rows of collectors which have a constant angle of inclination (30 ^{0}) with a horizontal surface.

IV - Rows of collectors which have an adjustable angle of inclination with a horizontal surface. Maximum water temperature reached 70 ^{0}C.

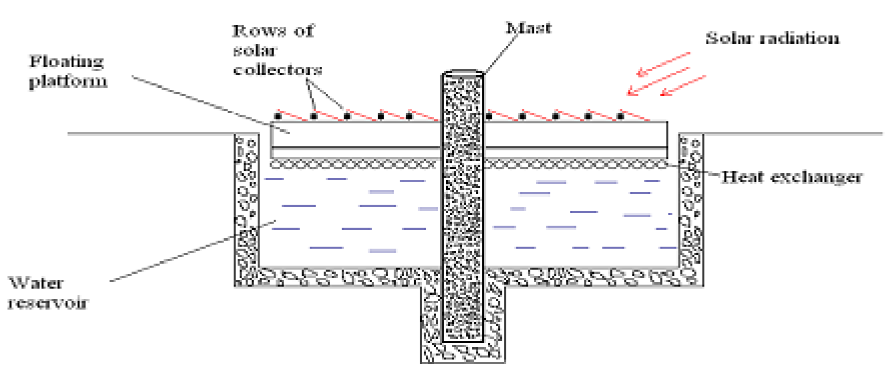

Fig.4 Rows of collectors which have an adjustable angle of inclination with a horizontal surface

Structure of the floating platform:

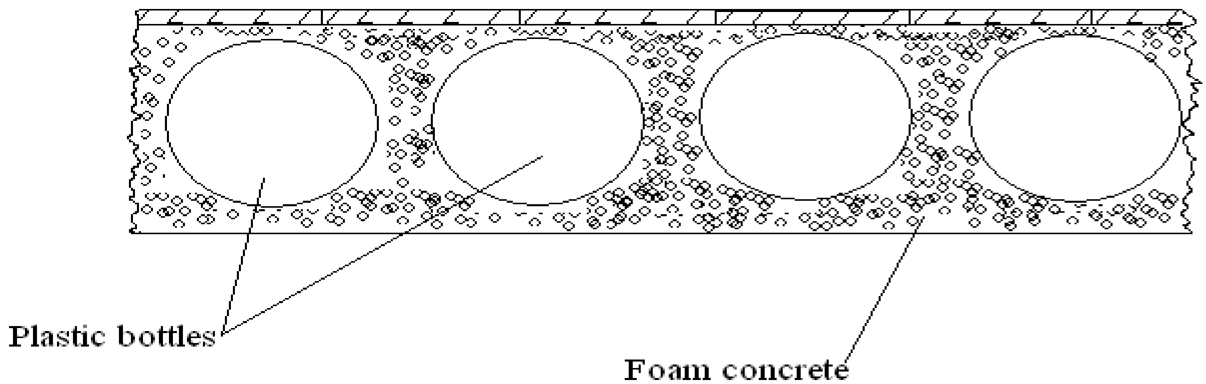

Fig.5 Structure of the floating platform

Collector's construction:

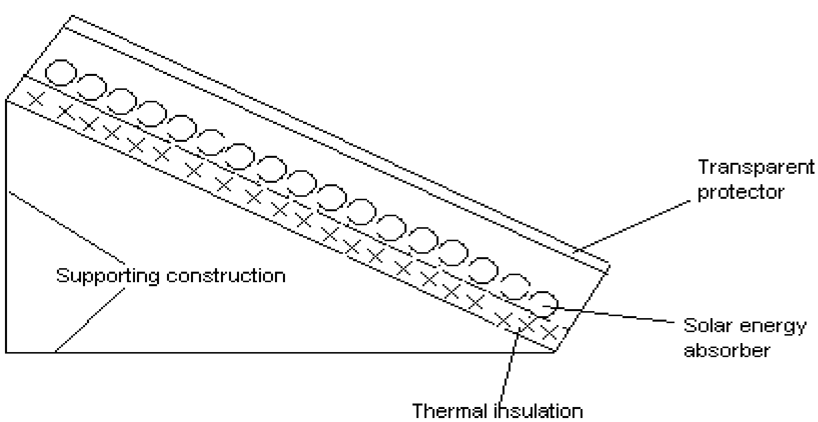

Fig.6 Collector's construction

Initial data for calculating the economical parameters of the collector-accumulator **Table 2**

Name	Value	Units
System lifetime	15	years
Present unit energy cost, c_q	0.12	$/kWh
Unit soil-excavation cost, c_e	3	$/m^3$
Polyethylene tube	0,27	$/m
Armature	660	$/t
Thermo-insulation	90	$/m^3$
Plastic bottles	0.01	$ per unit
Foam concrete	120	$/m^3$
Polycarbonate	18	$/m^2$
Concrete	90	$/m^3$
Water-resistant veneer	5	$/m^2$
Heating-pump installation	500	$/kW

Amount of materials and prices

Field of solar collectors

Length of the polyethylene tube spiral, D=20mm :

Number of turns Nt = D_p/D= 100/0.02=5000

Average length of the turn La=0.5πD= 157m

Length of the spiral Ls= LaNc=785000m

Table 3

Materials	I	II	III	IV
Polyethylene tube, m Cost, thousands $	785000 212	785000 212	142500 38	185250 49
Polycarbonate , m^2 Cost, thousands $	-	7860 141	5700 102	7500 133
Water-resistant veneer, m^2 Cost, thousands $	-	-	5700 29	7500 38
Thermo-insulation, m^3 Cost, thousands $	-	-	285 25	370 33

Additional equipment (supporting construction, hydro cylinders) Cost, thousands $	-	-	Supporting construction 1	Hydro cylinders 13
Total, thousands $	212	353	188	266

Floating platform **Table 4**

Materials	I	II	III	IV
Foam concrete, m^3 Cost, thousands $	943 113	943 113	943 113	943 113
Polyethylene tube of the heat exchanger, m Cost, thousands $	392000 11	392000 11	392000 11	392000 11
Armature, m Mass, kg (t) Cost, thousands $	78600 30654 (30,6) 20	78600 30654 (30,6) 20	78600 30654 (30,6) 20	78600 30654 (30,6) 20
Plastic bottles, pieces. Cost, thousands $	300000 3	300000 3	300000 3	300000 3
Total, thousands $	243	243	243	243

Reservoir

$$V = (2\pi R^2 + h2\pi R)\delta_w$$

δ_w =0.3 m, thickness of the reservoir's wall, h = 6, 6 m – reservoir's depth

$L_\Sigma = L_1 S_\Sigma$ L_1 =10m Armature's length on 1 m^2, S_Σ =17700м^2 area of the walls;

$m_\Sigma = m_1 L_\Sigma$ m_1 = 0,39kg/m, mass of 1m, 8mm armature;

L_Σ = 177000 m, total length of the armature

Reservoir, amounts and costs of the materials and the dredging **Table 5**

Materials	I	II	III	IV

Concrete, m^3 Cost, thousands $	5310 478	5310 478	5310 478	5310 478
Length of the armature, m	17,7*10^4	17,7*10^4	17,7*10^4	17,7*10^4
Weight of the armature, kg (t) Cost, thousands $	69000 (69) 45	69000 (69) 45	69000 (69) 45	69000 (69) 45
Dredging Cost, thousands $	155	155	155	155
Total, thousands $	**678**	**678**	**678**	**678**

Results

Energetic parameters of the collector-accumulator

Annual energetic parameters of the construction Table **6**

Construction and the operating mode	I	II	III	IV
Efficiency of the solar collector	0,4 (40 ^{0}C)	0,3 (40^{0}C)	0,35 (70 ^{0}C)	0,4 (70 ^{0}C)
Efficiency of the accumulator	0,8	0,8	0,8	0,8
S_{sc} , m^2 Area of the solar collectors' field	7850	7850	5703	7500
E_1 Energy received by 1 m^2 of the solar collectors, GJ/ m^2 (MWh/ m^2)	**2.5** **(0.7)**	**2,5** **(0.7)**	**5.4** **(1261*1,2= 1.5)**	**5.8** **(1261*1,3= 1.6)**
$E_g = S_{sc} * E_1$ Energy received by the of the solar collectors, TJ (GWh)	**5.6** **(1.5)**	**5.6** **(1.5)**	**19** **(5.2)**	**21** **(5.8)**
$E_{us} = E_g * \eta_{sc}$ Useful energy of the solar collectors' field, TJ (GWh)	**2.2** **(0.6)**	**1.6 TJ** **(0.4)**	**6.6** **(1.8)**	**8.4** **(2.3)**

$E_a = E_{us} * \eta_a$ Useful energy of the accumulator, TJ (GWh)	**1,7 (0,48)**	**1,2 (0,32)**	**5,3 (1,4)**	**6,7 (1,8)**

Calculation of annual parameters of the collector-accumulator with the heating-pump installation.

Heating period: November-March (τ ≈ 5*30*24=3600h)

Cost of electrical power: $C_{EP} = E_p P_p$ P_p - the tariff for the electric power;

$E_p = E_a/K_P$ - the electric power consumed per year.

The initial data for calculations of technical and economical parameters of the CA

Price of natural gas ....360$/thousand m^3

Inflation in the country...10%

Rate in rising of the natural gas' prices...12%

The period of the analysis of technical and economical parameters.......................... 30 years.

Service life of the solar collectors..15 years

Heating-pump installation's resource…..60 th. h

Based on our procedures and methods, the period of the investments recovery can be found from the next formula : $\tau_r = I_0 / (VEN_b - C_a)$, where I_0 are the first investments; VEN_b - annual amount of saved natural gas due to the usage of the CA; C_a - annual costs for CA exploitation. The cost price of the solar heat we found with the next formula: $C_{sh} = (I_0 / \tau_l + C_a) / E_a$ where τ_l - settlement term of CA operation (the technical life of solar collectors); E_a - useful energy of the CA. The saved volume of natural gas we can find with the formula $V = E_a / q\eta$ where $q\eta$ is the efficiency of the natural gas. In our calculations we took η =0.8 and q = 32 MJ/m^3. The annual prevented emission of the CO_2 we calculate by proceeding from the annual volume of saved gas and also the dioxide of carbon formed at burning of 1m^3 of natural gas.

Table 7

Initial investments	**thousands. USA$**	1470	1680	1430	1650
Annual costs	**thousands. USA$**	12.7	12.7	-	-
Volume of saved natural gas	**thousands. USA$**	215	333	266	412
Annual cost of the natural gas	**thousands. USA$**	77	120	96	148
Cost price of the energy received	**$/KWh** **Lei/Gcal** **Euro/MWh**	**0.23** **2700** **300**	**0.39** **4500** **500**	**0.08** **900** **110**	**0.06** **600** **80**
Recovery of the investments	**$\tau_{ок}$, Years**	**22**	**16**	**17**	**12**
Prevented emissions of CO_2,	t/**year**	**120**	**186**	**150**	**231**
Prevented emissions CO_2 for 30 years	thousands t.	**3.6**	**5.6**	**4.5**	**6.9**

Technical data of the first generation CSHPSS systems in Germany **Table 8**

Units	Friedrichshafen	Neckarsulm Phase I (Phase II)
Housing area	Planning: eight multi-family houses with 570 apartments	Six multi-family houses, commercial centre, school, etc.
Heated living area, m^2	39,500	20,000
Total heat demand, MWh per annum	4106	1663
Solar collector area, m^2	5600	2700 (5000)
Heat storage volume, m^3	12,000 (hot-water)	20,000 (duct) (63,400)
Heat delivery of the solar system [a], MWh per annum	1915	832
Solar fraction [a], %	47	50
Cost of the solar system (excluding subsides), Million Euro	3.2	1.5
Solar heat cost [a] (excluding VAT and subsides), Euro/MWh	158	172

[a] Calculated values for long-time operation.

After comparing the values from the Table 8, we can say that our energy is cheaper that the thermal energy obtained by the CSHPSS systems in Germany.

Conclusion

The considered technical and technological decisions of the problem of interseasonal accumulation of solar heat showed us, that there is a good possibility to build a construction which can be a good opponent to the centralized heating systems which are using natural gas, and also is cheaper than the large combined solar-fuel systems used in Europe. The further work should be directed on the searching of ways of depreciation of received solar heat, and also reduction of losses of energy to the environment.

References

1.John A. Duffie, William A. Beckman Solar Engineering of Thermal Processes, NY 2006.

2.У. Бекман, С. Клейн, Дж. Даффи - “Расчёт систем солнечного теплоснабжения”, М. Энергоиздат 1982 г.

3.T. Schmidt , D. Mangold, H. Muller-Steinhaen, “2004” – Central solar heating plants with seasonal storage in Germany, Solar Energy v.76 , 165-174

4. И. Б. Крепис Солнце-Людям, Кишинёв Штиинца 1989 г.

5.В.В.Ермуратский «3Э-Энергетика, Экономика, Энергосбережение». Кишинёв, 2005.

6.Ambros T. s.a. Surse regenerabile de energie. Manual, Chisinau: Editura «Tehnica-info», 1999.

7.Necesitati tehnologice si prioritati de dezvoltare, PNUD Moldova, Chisinau 2002.

8.Petru Tudos si altii, Energia regenerabila strudiu de fezabilitate, PNUD Moldova, Chisinau 2002.