Article
JOURNAL OF UNIVERSITY OF BABYLON
For Pure and Applied Sciences (JUBPAS)
Vol.32; No.2.| 2024

Determining the Effectiveness of Solar Collectors Used In Low-Radiation Areas

Qasim Shakir Kadhim
College of Basic Education, University of Babylon, Babylon 51002, Iraq
basic.ausama.abed@uobabylon.edu.iq

تحديد مدى فعالية المجمعات الشمسية المستخدمة في المناطق الإشعاع منخفضة

قاسم شاكر كاظم
كلية التربية الاساسية, basic.qasim.shakir@uobabylon.edu.iq, 51022, بابل, العراق

Accepted: 29/3/2024 **Published:** 30/6/2024

ABSTRACT

Background:

In this paper considers the issues of using solar collectors as an alternative source of energy for territories remote from the power grids. One of the main criteria when choosing the solar collectors is the choice of the working fluid for heat transfer. Solar collectors according to the type of coolant are divided into a liquid and air.

Materials and Methods:

The solar collector works on the principle of energy transfer to a liquid from a source of radiant energy that is located a certain distance away, unlike conventional heat exchangers. In actual use, there are two types of solar collectors: one concentrates solar energy, the other doesn't.

Results:

It is possible to give air clusters in places with low air temperature and low solar activity, and we use energy equations and their balances. Moreover, we have determined the thermal properties of solar clusters and useful energies.

Conclusion:

Climate characteristics and structures are crucial to the results of a solar array's efficiency in covering ocean temperatures and the types of solar arrays to choose from with good results, heat fluxes and densities. In addition, we show that the solar collector is not considered a basic criterion in choosing the types of collectors.

Key words:

Solar energy, sustainable energy, low-radiation, solar collector, heat transfer

ISSN: 2312-8135 | Print ISSN: 1992-0652
info@journalofbabylon.com | jub@itnet.uobabylon.edu.iq | www.journalofbabylon.com

مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية

مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية

ISSN: 2312-8135 | Print ISSN: 1992-0652
info@journalofbabylon.com | jub@itnet.uobabylon.edu.iq | www.journalofbabylon.com

INTRODUCTION

There is an increasing interest in the use of renewable solar energies in the world due to the possibility of forming them, and they are considered clean and non-polluting energies in the environment [1-3]. can reduce energy use and achieve sustainable development, since the same intense demand does not require energy [4]. One crucial energy source for buildings is solar energy. The solar complex can be improved with the use of solar collectors [5-7]. To gather heat, a low- and medium-temperature sun collector is employed. One instance of this is the widespread usage of reflectors by scientists and researchers in their investigations to advance collectors' work [8]. A basin is used in solar energy gathering to warm water in cold climates [9]. Collaborate to develop a series of mathematical formulas that will be used to calculate the reflector's location and the energy collectors' dual sun exposure [10]. Building and enhancing simulation models to maximize system efficiency and increase solar energy [11]. It is common knowledge that using finite fossil fuels has a detrimental effect on the environment. In the global energy balance within the next years, energy from renewable sources will occupy a significant portion of the market.

Materials and Methods

The solar collector works on the principle of energy transfer to a liquid from a source of radiant energy that is located a certain distance away, unlike conventional heat exchangers. In actual use, there are two types of solar collectors: one concentrates solar energy, the other doesn't [12]. In Fig. 1, cross sections of the water and air heater are displayed.

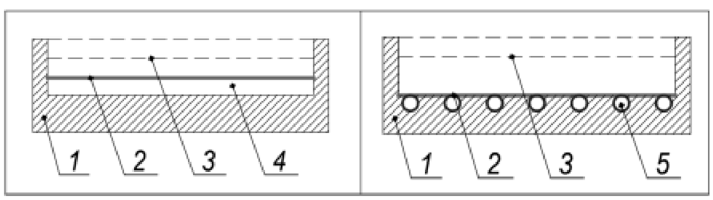

Fig. 1. Schemes of solar collectors with air and water coolants: 1 - thermal insulation; 2 - absorbing plate; 3 – transparent coatings; 4 - air channel; 5 - pipes connected to the plate.

Thermal energy is transferred in the collector using two different types of working fluid. Gases and liquids are these. The choice of coolant will depend on the circumstances in which the solar collector will be utilised, and is one of the key factors in selecting a product. Notably, the only gas that has achieved widespread use is air. The primary drawbacks of liquid solar collectors can be linked to liquid heat carriers' propensity to alter their properties in response to changes in ambient temperature, including freezing at low temperatures, expansion when heated, and metal corrosion in solar collectors. Solar air heaters have a lot of advantages over liquid collectors [13]. These include the absence of corrosion, which enables the use of less expensive materials in the building of the collectors themselves, and the absence of the danger of air freezing, which considerably lowers running costs. Conversely, there are a number of drawbacks to air solar heaters. Low

مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية

ISSN: 2312-8135 | Print ISSN: 1992-0652
info@journalofbabylon.com | jub@itnet.uobabylon.edu.iq | www.journalofbabylon.com

thermal conductivity, density, and air specific heat are a few of these [14]. Despite their low efficiency, solar air heaters are still more affordable than liquid heaters, according to the analysis above Fig. 2.

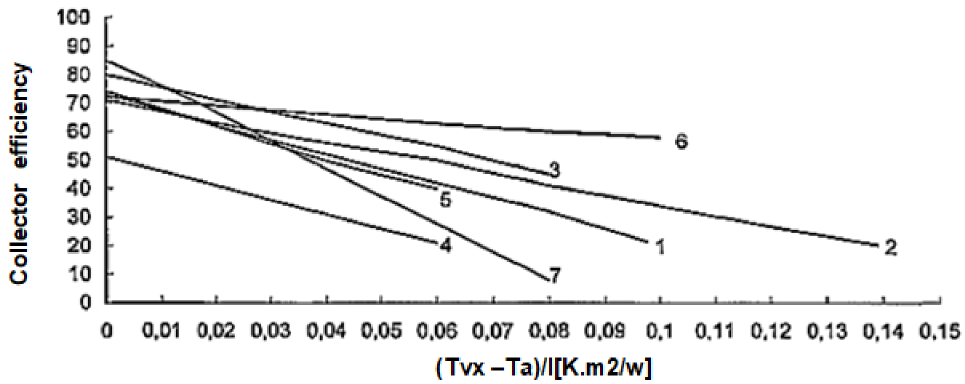

Fig. 2. Dependence of collector efficiency on climatic and design factors: 1 – water collector with double glazing; 2 - water collector with double glazing and selective surface; 3 – water manifold with single glazing and selective surface; 4 - air collector with double glazing; 5 – air collector with double glazing and selective surface; 6 - evacuated collector; 7 - collector with heat pipe

RESULTS AND DISCUSSION.

The advantage in using air collectors should be given in regions with lower air temperature and low solar radiation activity. Using the energy balance equation, you can determine the thermal characteristics of the solar collector and the useful energy of the coolant. For a flat collector whose area is A_c, the energy balance equation has the form

$$I_s A_c \tau\alpha = Q_u + Q_{loss} + \frac{de_c}{dt} \quad (1)$$

where $\frac{de_c}{dt}$ is the heat flux accumulated by the collector due to its internal energy dt; α is the absorption capacity of the surface of the absorbing plate of the solar collector; I_s is the flux density of solar radiation incident on the surface of the collector; Q_{loss} is the heat flow (or heat loss) from the absorbing collector plate to the environment; τ is the effective transmission capacity of the coating (coatings) of the solar collector. The thermal useful energy of the coolant flowing through the channels and pipes can be determined from the expression

مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية
ISSN: 2312-8135 | Print ISSN: 1992-0652
info@journalofbabylon.com | jub@itnet.uobabylon.edu.iq | www.journalofbabylon.com

$$Q_u = mc_p\left(T_{f,out} - T_{f,m}\right) \qquad (2)$$

Where m is the mass flow rate of liquid through the collector; $c_p$is the specific heat capacity of the coolant at constant pressure; $T_{f,out} - T_{f,m}$, , − is the temperature increase of the coolant when passing through the collector [15]. The ratio of useful energy to the energy of total solar radiation determines the efficiency of the instantaneous value:

$$\eta_c = \frac{Q_u}{A_c I_s} \qquad (3)$$

In constructive calculations of practical use, the efficiency must be determined for a specific period of time. Based on this, the average efficiency will be equal to

$$\eta_c = \frac{\int_0^t Q_u dt}{\int_0^t A_c I_s dt} \qquad (4)$$

In order to know the parameters that determine the thermal efficiency of a solar collector, it is necessary to determine the value of its total heat loss coefficient. At a given ambient temperature T_a and the local temperature of the collector plate is T_c , and the coefficient of heat loss of the collector U_c is given, then the heat flux from the absorbing collector plate to the environment can be written as

$$Q_{loss} = \int_{A_c} U_c \left(T_c + T_a\right) dA_c \qquad (5)$$

With two glass coatings, the solar collector circuit is shown in Fig. 3a. In order to combine the circuit elements into an equivalent heat loss coefficient (Fig. 3b), this circuit must be calculated

مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية
info@journalofbabylon.com | jub@itnet.uobabylon.edu.iq | www.journalofbabylon.com | ISSN: 2312-8135 | Print ISSN: 1992-0652

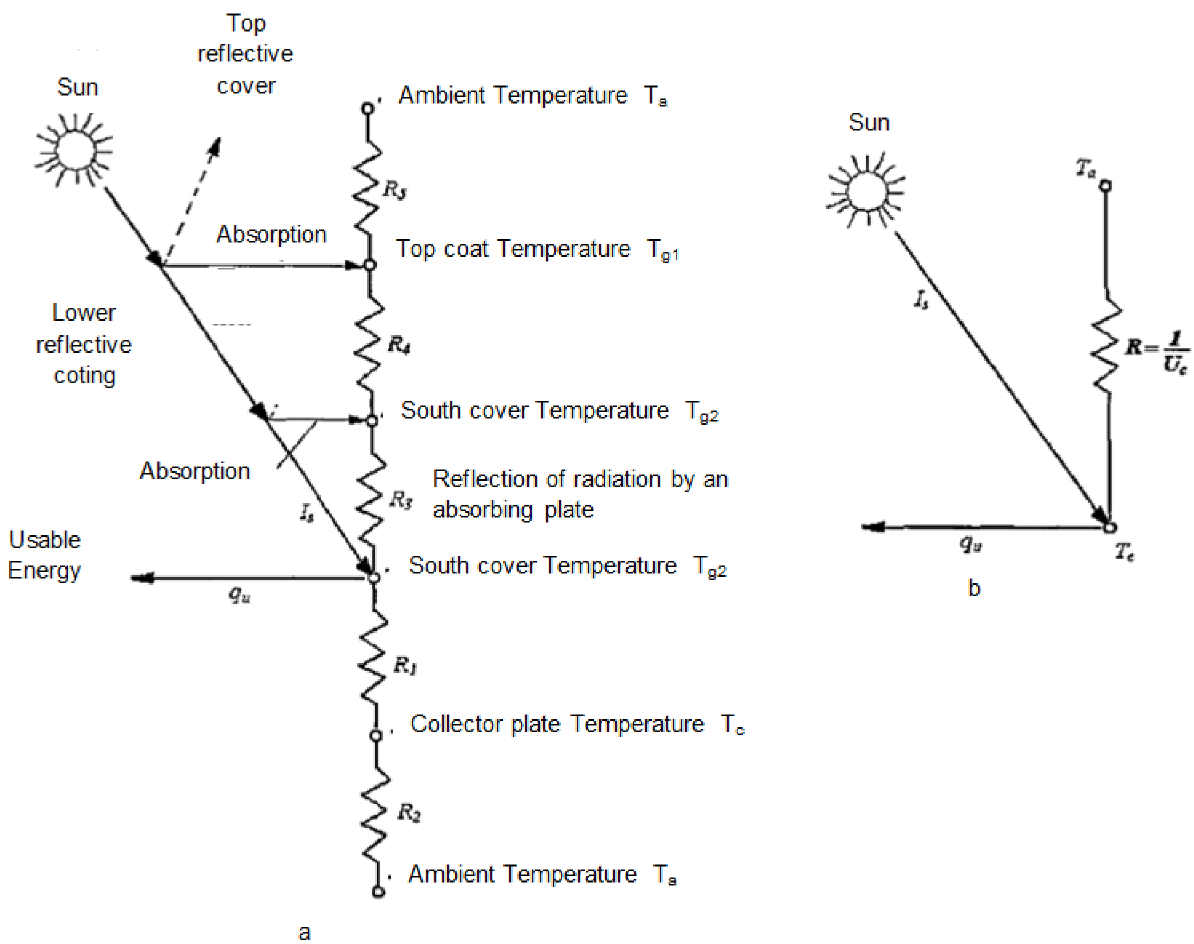

Fig. 3. Thermal circuits for a flat collector : a – detailed diagram; b - approximate scheme (equivalent to a scheme)[15].

The main heat loss occurs through the upper surface of the solar collector, since the lower part is insulated. Then the total heat loss coefficient of the collector U_c , can be represented as

$$U_c = \frac{1}{R_3 R_4 R_5} \qquad (6)$$

مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية

ISSN: 2312-8135 | Print ISSN: 1992-0652
info@journalofbabylon.com | jub@itnet.uobabylon.edu.iq | www.journalofbabylon.com

As can be seen from equation (6), in order to calculate the heat loss coefficient, it is necessary to calculate the thermal resistances $R_3R_4R_5$. Heat is transferred by convection and radiation between the second glass coating and absorbent plate. The relations for the heat flux between bodies with temperatures T_p *and* T_{g2} and between bodies with temperatures T_{g1} *and* T_{g2} are the same. The flux of solar radiation absorbed by the second glass coating is an exception. Then between the absorbing plate and the second glass coating it is possible to determine the heat flux density:

$$Q_{p-c} = A_c h_{c2}(T_p + T_{g2}) + \frac{\sigma(T_p^4 - T_{g2}^4)A_c}{\frac{1}{\varepsilon_g} + \frac{1}{\varepsilon_{g2}} - 1} \qquad (7)$$

Where h_{c2} is the heat transfer coefficient between the absorbing plate and the second glass coating. Equation (7), then can be represented as

$$Q_{p-c} = (h_{c2} + h_{r2}).A_c.(T_p - T_{g2}) + \frac{(T_p - T_{g2})}{R_3} \qquad (8)$$

$$h_{c2} = \frac{\sigma(T_p^2 + T_{g2}^2)(T_p + T_{g2})}{\frac{1}{\varepsilon_g} + \frac{1}{\varepsilon_{g2}} - 1} \qquad (9)$$

The expression for the heat flux between two glass coatings will have the form

$$Q_{p-c} = (h_{c1} + h_{r1}).A_c.(T_{g2} - T_{g1}) + \frac{(T_{g2} - T_{g1})}{R_4} \qquad (10)$$

$$h_{r1} = \frac{\sigma(T_{g1}^2 + T_{g2}^2)(T_{g1} + T_{g2})}{\frac{1}{\varepsilon_p} + \frac{1}{\varepsilon_{g1}} - 1} \qquad (11)$$

and h_{c1} is the heat transfer coefficient between the two transparent coatings. Radiation heat exchange takes place between the upper coating and the sky at the sky temperature T_{sky}. Conversely, convective heat transfer takes place between the top cover at T_{g1} and ambient air T_a. Consequently:

مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية

ISSN: 2312-8135 | Print ISSN: 1992-0652
info@journalofbabylon.com | jub@itnet.uobabylon.edu.iq | www.journalofbabylon.com

$$Q_{c-a} = (h_{c,\infty} + h_{r,\infty}).A_c.(T_{g1} - T_a) + \frac{(T_{g1} - T_a)}{R_5} \qquad (12)$$

$$h_{r,\infty} = \varepsilon_{g1}\,\sigma(T_{g1}^2 + T_{sky}^2)(T_{g1} + T_{sky}).\frac{(T_{g1} - T_{sky})}{(T_{g1} - T_a)} \qquad (13)$$

Using the dimensional relationship obtained by McAdams, one can determine the heat loss [16].

$$h_{r,\infty} = 5.7 + 3.8\,.\,u_w \qquad (14)$$

To determine the temperature of the sky, the following equations are recommended [17]:

$$T_{sky} = 0.0552T_a^{15}\ \ (°) \qquad (15)$$

Or

$$T_{sky} = T_a - 6(℃) \qquad (16)$$

The above calculations show us the ambiguity which of the expressions is more suitable for us. But, having analyzed all the expressions used in assessing the characteristics of the reservoir, we can conclude that in our case it is possible to use any. Specific radioactive conductivities, which are functions of the plate and temperatures, are not known to us. Therefore, the solution of equations (11), (12) and (13) is required to determine the heat loss coefficient of the solar collector (equation (6)). Agawam and Larson for solar collectors with uniform material coatings have proposed the most accurate empirical method for determiningU_c:

$$U_c = \left[\frac{N}{\left(\frac{C}{T_c}\right) + \left(\frac{T_c + T_a}{N + f}\right)^{33}} + \frac{1}{h_{c,\infty}}\right]^{-1} + \frac{\sigma(T_{g1}^2 + T_{g2}^2)(T_{g1} + T_{g2})}{[\varepsilon_p + 0.05N(1 - \varepsilon_p)]^{-1} + \left[\frac{2N + f - 1}{\varepsilon_g}\right] - N} \qquad (17)$$

Where f *and* C are the parameters determined from the equations

$$f = (1 - 0.04h_{c,\infty} + 0.05h_{c,\infty}^2)(1 + 0.091N), c = 250[1 - o.oo44(s - 90)]$$

مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية

ISSN: 2312-8135 | Print ISSN: 1992-0652
info@journalofbabylon.com | jub@itnet.uobabylon.edu.iq | www.journalofbabylon.com

N is the number of coatings, *s* is the angle of inclination of the collector [18].In order to calculate the efficiency of a solar collector, it is necessary to determine the heat flux to the coolant in the cross section of the collector and determine the useful energy:

$$q_u = [\tau_g \alpha_p I_s - U_c(T_p + T_a)] \qquad (18)$$

Due to the fact that the thermal resistance of the wall is very small, the energy u q which is transferred in the form of heat is equal to

$$q_u = h_p(T_p + T_f) \qquad (19)$$

To determine the relationship between useful energy and ambient temperature and physical parameters, it is necessary to remove the dependence on the plate temperature in expressions (18) and (19). To do this, we solve equation (19) for T_p and substitute the results obtained into expression (18):

$$q_u(x) = F'[\tau_g \alpha_p I_s - U_c(T_f(x) + T_a)] \qquad (20)$$

Where F′ is the collector efficiency factor, determined by the formula:

$$F' = \frac{\frac{1}{U_c}}{\frac{1}{U_c} + \frac{1}{h_p}} \qquad (21)$$

The ratio of the actual heat flux to the heat carrier and the heat flux at the maximum temperature difference between the environment and the absorbing plate determines the heat removal coefficient F_R . This coefficient will allow you to compare the optimal thermodynamic characteristics with the characteristics of a solar collector and a real collector. The same coolant temperature at the inlet and outlet is a condition for limiting thermodynamic resistance [19]. Then F_R can be expressed as

$$F_R = \frac{G_c c_f(T_{f,out} + T_{f,m})}{\tau_g \alpha_p I_s - U_c(T_{f,m} + T_a)} \qquad (22)$$

Where $G_c = m/A_c$ is the liquid flow rate per unit area of the collector surface. Based on the fact that the right side of expression (22) is equal to u q , now the useful heat flux can be presented in the following form:

$$q_u = F_R[\tau_g \alpha_p I_s - U_c(T_{f,m} + T_a)] \qquad (23)$$

Using the formula, we determine the relationship between F_R *and* F' [20,21]:

$$F_R = \frac{G_c c_f}{U_c}\left[1 - exp\left(\frac{U_c F'}{G_c c_f}\right)\right] \qquad (24)$$

Dividing both sides of equation (23) by I_s , we obtain the following reservoir efficiency expression:

$$\eta = F_R(\tau_g \alpha_p) - \frac{F_R U_c (T_{f,m} + T_a)}{I_s} \qquad (25)$$

CONCLUSION

Structural and climatic factors are decisive in the results of calculating the efficiency of a solar collector. These include the ambient temperature, the type of solar collector chosen, and the intensity of the heat flux. It can also be concluded that the efficiency of solar collectors is not the main criterion for choosing the type of collector. Together, system design, operating conditions, efficiency, etc., must be taken into account.

Conflict of interests.

The authors declare no conflicts of interest.

References

[1] A. Zamzamian, M. KeyanpourRad, M. KianiNeyestani, and M.T. Jamal-Abad, “An experimental study on the effect of Cu-synthesized/EG nanofluid on the efficiency of flat-plate solar collectors”. Renewable Energy 71(2014): pp.658-664. doi.org/10.1016/j.renene.2014.06.003.

[2] A. Sözen, T. Menlik, M. Gürü, K. Boran, F. Kılıç, M. Aktaş, and M.T. Çakır, "A comparative investigation on the effect of fly-ash and alumina nanofluids on the thermal performance of two-phase closed thermo-syphon heat pipes". Applied Thermal Engineering, 96(2016): pp.330-337. doi.org/10.1016/j.applthermaleng.2015.11.038.

[3] O. Mahian, A. Kianifar, S.A. Kalogirou, I. Pop, and S. Wongwises, "A review of the applications of nanofluids in solar energy". International Journal of Heat and Mass Transfer, 57(2)(2013): pp.582-594. doi.org/10.1016/j.ijheatmasstransfer.2012.10.037.

مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية
ISSN: 2312-8135 | Print ISSN: 1992-0652
info@journalofbabylon.com | jub@itnet.uobabylon.edu.iq | www.journalofbabylon.com

[4] Z. Liu, Y. Liu, B.-J. He, W. Xu, G. Jin, X. Zhang, Application and suitability analysis of the key technologies in nearly zero energy buildings in China, *Renewable and Sustainable Energy Reviews*. (2019):pp329-345. doi.org/10.1016/j.rser.2018.11.023.

[5] G. Qiu, J. Sun, L. Nie, Y. Ma, W. Cai, C. Shen, Theoretical study on heat transfer characteristics of a finned tube used in the collector/evaporator under solar radiation, *Applied thermal engineering*. 165(2020):pp114564. doi.org/10.1016/j.applthermaleng.2019.114564.

[6] H. Jamali, Investigation and review of mirrors reflectance in parabolic trough solar collectors (PTSCs), Energy Rep. 5 (2019): pp.145-158. doi.org/10.1016/j.egyr.2019.01.00.

[7] F. Zhou, J. Ji, X. Zhao, W. Yuan, S. Huang, Study on the PCM flat-plate solar collector system with antifreeze characteristics. International journal of heat and mass transfer, 129 (2019) : pp.357-366. doi.org/10.1016/j.ijheatmasstransfer.2018.09.114.

[8] B. Zou, J. Dong, Y. Yao, Y. Jiang, An experimental investigation on a small-sized parabolic trough solar collector for water heating in cold areas. Applied Energy 163 (2016) :pp396-407.doi.org/10.1016/j.apenergy.2015.10.186.

[9] R. Winston, Principles of solar concentrators of a novel design, Sol. Energy 16 (2) (1974):pp89-95.doi.org/10.1016/0038-092X(74)90004-8.

[10] R. Baccoli, A. Frattolillo, C. Mastino, S. Curreli, E. Ghiani, A comprehensive optimization model for flat solar collector coupled with a flat booster bottom reflector based on an exact finite length simulation model, Energy Convers. Manag. 164 (5) (2018):pp482e507. doi.org/10.1016/j.enconman.2018.02.091.

[11] L.T. Kostic, T.M. Pavlovic, Z.T. Pavlovic, Influence of reflectance from flat aluminum concentrators on energy efficiency of PV/Thermal collector, Applied Energy 87 (2) (2010):pp410-416. doi.org/10.1016/j.apenergy.2009.05.038.

[12] R. Conceicao, J. Gonzalez-Aguilar, A.A. Merrouni, and M. Romero, Soiling effect in solar energy conversion systems: A review. Renewable and Sustainable Energy Reviews, 162(2022.):pp112434. doi.org/10.1016/j.rser.2022.112434.

[13] W. Ajbar, A. Parrales, A. Huicochea, and J.A. Hernández, Different ways to improve parabolic trough solar collectors' performance over the last four decades and their applications: A comprehensive review. Renewable and Sustainable Energy Reviews, 156(2022): pp111947. doi.org/10.1016/j.rser.2021.111947 .

[14] Z. Wu, S. Yan, Z. Wang, T. Ming, X. Zhao, R. Ma, and Y. Wu, Y.,. The effect of dust accumulation on the cleanliness factor of a parabolic trough solar concentrator. Renewable Energy, 152(2020):pp.529-539.

[15] A. Einav, Solar energy research and development achievements in Israel and their practical significance. J. Sol. Energy Eng., 126(3)(2004): pp.921-928.doi.org/10.1115/1.1758246.

[16] M. Hayek, J. Assaf, and W. Lteif, Experimental investigation of the performance of evacuated-tube solar collectors under eastern Mediterranean climatic conditions. Energy procedia, 6(2011):pp.618-626.doi.org/10.1016/j.egypro.2011.05.071.

مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية
info@journalofbabylon.com | jub@itnet.uobabylon.edu.iq | www.journalofbabylon.com ISSN: 2312-8135 | Print ISSN: 1992-0652

[17] V. Pranesh, R. Velraj, S. Christopher, and V. Kumaresan, , A 50 year review of basic and applied research in compound parabolic concentrating solar thermal collector for domestic and industrial applications. Solar Energy, 187(2019): pp.293-340. doi.org/10.1016/j.solener.2019.06.008.

[18] M. Hayek, J. Assaf, and W. Lteif, Experimental investigation of the performance of evacuated-tube solar collectors under eastern Mediterranean climatic conditions. Energy procedia, 6(2011): pp.618-626.doi.org/10.1016/j.egypro.2011.05.071.

[19] C.O. Okoye, O. Taylan, and D.K. Baker, Solar energy potentials in strategically located cities in Nigeria: Review, resource assessment and PV system design. Renewable and Sustainable Energy Reviews, 55(2016):pp.550-566.

[20] A. Sohani, S. Hoseinzadeh, and K. Berenjkar, Experimental analysis of innovative designs for solar still desalination technologies; an in-depth technical and economic assessment. Journal of Energy Storage, 33(2021): p.101862. doi.org/10.1016/j.est.2020.101862.

[21] Q.S. Kadhim, I.H. Abdulkareem, and N.T.Ibraheem, February. Study of distribution ice-forming reagent in the boundary layer of the atmosphere when exposed by ground aerosol generators NAG-07M. In IOP Conference Series: Materials Science and Engineering, 1 (2021): pp.12047. **DOI**10.1088/1757-899X/1058/1/012047.

info@journalofbabylon.com | jub@itnet.uobabylon.edu.iq | www.journalofbabylon.com ISSN: 2312-8135 | Print ISSN: 1992-0652

مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية

الخلاصة

المقدمة:

يتناول هذا البحث قضايا استخدام مجمعات الطاقة الشمسية كمصدر بديل للطاقة في المناطق البعيدة عن شبكات الطاقة. أحد المعايير الرئيسية عند اختيار مجمعات الطاقة الشمسية هو اختيار سائل العمل لنقل الحرارة. تنقسم مجمعات الطاقة الشمسية حسب نوع سائل التبريد إلى سائل وهواء

طرق العمل:

يعمل المجمع الشمسي على مبدأ نقل الطاقة إلى السائل من مصدر طاقة مشعة يقع على مسافة معينة، على عكس المبادلات الحرارية التقليدية. في الاستخدام الفعلي، هناك نوعان من مجمعات الطاقة الشمسية: أحدهما يركز الطاقة الشمسية، والآخر لا يركز عليها.

الاستنتاجات:

العوامل الهيكلية والمناخية حاسمة في نتائج حساب كفاءة المجمع الشمسي. وتشمل هذه درجة الحرارة المحيطة، ونوع المجمع الشمسي المختار، وشدة التدفق الحراري. ويمكن أيضا أن نستنتج أن كفاءة المجمعات الشمسية ليست المعيار الرئيسي لاختيار نوع المجمع.

الكلمات المفتاحية: الطاقة الشمسية، الطاقة المستدامة، الإشعاع المنخفض، المجمع الشمسي، انتقال الحرارة

ISSN: 2312-8135 | Print ISSN: 1992-0652
info@journalofbabylon.com | jub@itnet.uobabylon.edu.iq | www.journalofbabylon.com

مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية مجلة جامعة بابل للعلوم الصرفة والتطبيقية