EXPERIMENTAL AND THEORETICAL EVALUATION OF THE SOLAR ENERGY COLLECTION BY TRACKING AND NON-TRACKING PHOTOVOLTAIC PANEL

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ABSTRACT

Analysis of the effect of tracking is made upon collection of solar radiation in solar system without concentration, and in non-tracking system with conventional and bifacial photovoltaic solar panel. A simple model is developed to account for daily variation of solar irradiance. For the experiments, an original 2-axis Sun tracker was developed. The tracking effect calculated and measured shows an increase in energy collection around 30 – 40 %; bifacial panel with a small reflector collecting solar radiation for the rear face gives the corresponding increase of 50 – 60 % for the same panel area.
Keywords: Photovoltaic Solar Panel, Bifacial Panel, Sun Tracking, Irradiance Variations.

1. INTRODUCTION

The problem which is constantly in focus of attention of scientists and technologists in the field of solar energy conversion by photovoltaic (PV) panels is the restricted conversion efficiency. One of its many aspects is the concentration of solar radiation and/or tracking of the Sun, to increase the efficiency as well as the total energy collected for conversion. Essential progress achieved in the field (see, for example, [1-3]) was mainly due to employment of semiconductor high technology and high degree of concentration, and is clearly connected with high cost of the devices developed. The purpose of this paper is to analyse the possibilities to increase the efficiency of utilization of solar energy in more practical way, using traditional and bifacial PV panels, low concentration systems and economic Sun trackers. The basis for the investigation made was the study of the daily variations of Solar radiation intensity in conditions of Querétaro, México, with the North latitude close to 23°. These variations were found experimentally at the time of summer solstice (around June 22) when the position of the Sun at noon at this latitude is practically vertical, also at exuinox time and at winter solstice. The calculated and measured increase of the total energy collected by Sun-tracking panel in comparison with the immobile one is around 35 %; the larger effect could be obtained by using bifacial panels with sufficient illumination of their rear part.

2. MODEL FOR DAILY IRRADIANCE VARIATIONS

Variation of Solar irradiance during the day caused by the change of the angle φ between the Sun radiation flux and zenith (and of the corresponding atmospheric air mass) was theoretically modelled in many publications (see [4-9]). As a rule, these models demand very detailed information about the state of atmosphere to be used (like light dispersion and absorption caused by water vapor, ozone layer, aerosols, etc.), which makes their utilization for quick estimations practically impossible. We constructed a simple model to calculate the dependence of irradiance upon the position of the Sun in relation to the zenith. The data known for the radiation intensity at different air mass: AM0 (1367W/m^2), AM1 (925 W/m^2), AM1.5 (844 W/m^2) and AM2 (691 W/m^2), to serve as the reference points for calculations.

We consider the losses in solar radiation intensity I during passing through atmosphere as the result of absorption and scattering in it which we characterize with the summary coefficient α; the radiation loss (– dI) at the differential pass dx could be written as

$$dI = - I(x)\, \alpha\, dx \qquad (1)$$

which in very rough approximation of α = const ("uniform atmosphere") gives the following intensity variation with the distance "x"

$$I = I_C \exp(-\alpha x) \qquad (2)$$

Here I_C is the cosmic solar radiation (right outside the Earth's atmosphere, the AM0 value). When "x" is the total path of radiation in atmosphere (x = d), then I is the irradiation of Earth's surface. The shortest path (the Sun position at zenith, $\varphi = 0$, see Fig. 1) is equal to effective thickness of atmosphere h; depending on the angle φ, the value of d will change according to law

$$d = R\cos\varphi\,[(1 + 2h/R\cos^2\varphi)^{1/2} - 1] \qquad (3)$$

which could be easily obtained by application to scetch given in Fig. 1 of the theorem related to intersection of a khorde with diameter, and taking into account that h << R (the Earth's radius). At relatively small angles, when $2h/R\cos^2\varphi \ll 1$, (3) is converted to $d \approx h/\cos\varphi$, which could be written immediately if one neglects the Earth's curvature. In this case

$$I = I_C \exp(-\alpha h/\cos\varphi) \qquad (4)$$

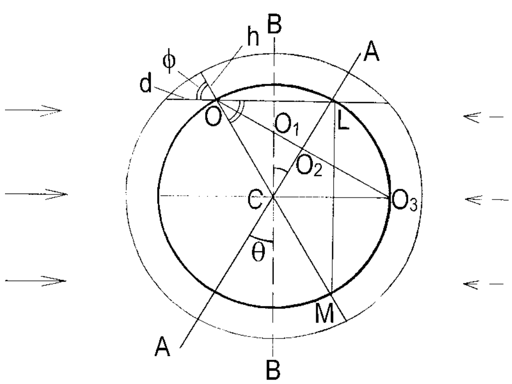

Fig. 1: A scheme of Earth with atmosphere.

To account for the atmosphere actual non-uniformity, we take two approximations: that of the linear decrease of absorption/scattering coefficient with the distance from Earth's surface, and the exponential decrease, in correspondence with the pressure dependence in isothermic atmosphere (we shall see from the results that the more accurate approximation for most practical purposes is not necessary). It is easy to see that in the first case the result of integration of (1) will be of the same form as (2) but with the path length equal to x/2. In other words, the expressions (2) and (4) still might be used, but the effective atmospheric thickness will be h/2.

In the case of exponential dependence of atmospheric absorption/scattering coefficient upon the distance from the Earth's surface h ($\alpha = \alpha_S \exp(-ah)$ where α_S is the coefficient value at h = 0, and *a* is the barometric constant), with account of the relation found between h and x (the expression (3) with "d" substituted by "x"), the differential equation (1) is transformed into

$$\frac{dI}{I} = -\alpha_S e^{-ax\cos\varphi - ax^2/2R}dx \approx -\alpha_S e^{-ax\cos\varphi}(1 - ax^2/2R)dx \qquad (5)$$

the last approximation being valid when

$$ax^2/2R \ll 1. \qquad (6)$$

Integration of (5) in its last form along the whole atmosphere (in this case, from x = 0 to ∞) gives the irradiation of Earth's surface

$$I = I_C \exp[-(\alpha_S/a\cos\varphi)(1 - 1/Ra\cos^2\varphi)] \qquad (7)$$

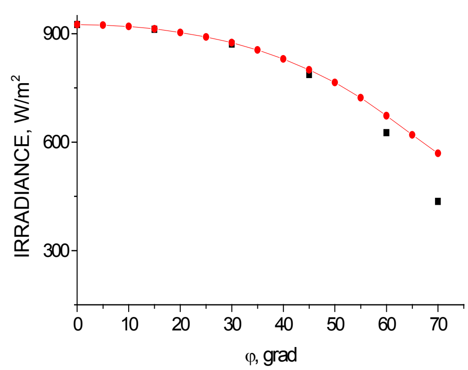

Fig. 2: Calculated dependence of irradiance upon the Sun position.

Fig. 2 presents the results of calculations according to expressions (7) (the curve) and (4) (squares), the constants in the expressions used were taken to get better ajustment of calculations with the known data for different air mass. It could be seen that the barometric atmosphere approximation agrees with the data mentioned in interval 0 – 60° with an accuracy better than 3 %, and even the uniform atmosphere approximation neglecting Earth curvature gives a good agreement for angles 0 – 45°, but for larger angles the calculated points are too low. Thus, we take expression (7) as reasonable theoretical approximation to treat the experimental results. For actual comparison of calculated results given in Fig. 2 with experiment, the relation between the angle φ and the time should be defined, based on the latitude of the observation point and the specific season of the year. To discuss the data obtained with the Sun-tracking PV panel, the curve in Fig. 2 must be used; for an immobile panel oriented in most profitable manner, the irradiance found from the corresponding curve must be multiplied by the value of cos ϕ, ϕ being angle of incidence (see examples below).

3. EXPERIMENT: RESULTS AND DISCUSSION

3.1 Two-Axis Solar Tracking

The two axis tracking system designed and made uses the solar panel composed in our laboratory from c-Si cells elaborated by Russian plant "Solar Wind" (Fig. 3). The system is equipped with two geared servo motors (Colman EYQF-33300-661 and Globe 407A-350); 2 pairs of phototransistors (1 pair for each axis) are positioned in such a way that the difference of photoresponce in each pair is zero when the panel is orientated normally to the Sun radiation flux, and grows with an increase of angle of desorientation. The system monitoring is based on microcontroller PIC16f877 with 4 input channels (one for each sensor); the input analog signals in each channel are digitalized with resolution of 8 bits, the differential signal for each pair is calculated, and the proportional output PWP (pulse width modulated) signal is applied to the motors, until the correct position is reached. After that, the system enters the "sleeping state" for the time interval X which could be chosen depending on the accuracy of tracking necessary. In our case, the value of X = 20 min was taken, giving the tracking accuracy (i.e. deviation of radiation intensity from maximum) better than 0.5 %: the largest corresponding variation of angle φ guring this interval (at summer time) is 6 grad, and cos $6^o = 0.995$.

Fig. 3: Automatic two-axis Sun tracking system.

To calculate the total solar energy captured daily by the Sun-tracking panel, it is necessary to change the horizontal axis in Fig. 2 from angle φ to corresponding time t, find the area under the I(t) curve and double it. Experimental conditions which correspond to calculation presented (i.e. with the maximum corresponding to $\varphi = 0$) could be realized at summer time, around June 22 (summer solstice), in geografical points with North latitude close to $\theta = 23.5^o$, like Guadalajara, Leon or Querétaro in Mexico. Our measurements were made in Querétaro on June 19, 2003, the results are shown in Fig. 4 (triangles with tracking, circles without it). Fig. 1 gives the scheme of experiment: line A-A denotes the Earth rotation axis, Sun radiation comes from the right (dashed arrows), the vertical line B-B indicates the boundary between illuminated and dark parts of Earth (day-night), O_3 is the observation point at noon; with time this point changes its position in relation to Sun following the circular line $O_3 – O$, the solar day ends when $\varphi = 90^o$ (corresponds to the point O_1). To estimate the duration of a solar day (the time interval above 12 hrs, to be exact), we have to calculate the distance between the points O_1 and O_2 of the circle mentioned; a reasonable approximation could be made on the basis of triangle O_1O_2C, neglecting the Earth curvature in the corresponding region. Thus we get $l = O_1O_2 = R\sin\theta \, tg\theta$, and the duration of the day in hours $t_s = 12 + 24 \cdot 2l/2\pi R\cos\theta = 12 + 24\, tg^2\theta/\pi$. In the case considered, the day duration is 13.44 hrs.

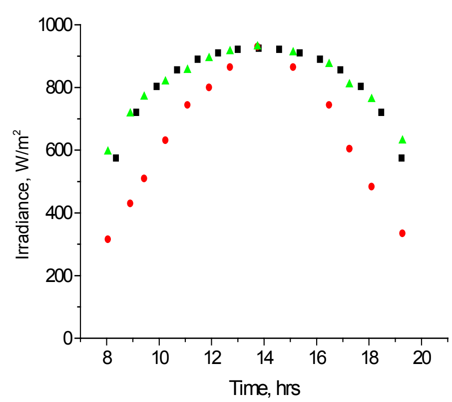

Fig. 4: Experimental and calculated irradiance (see text).

The squares in Fig. 4 show the transformed theoretical upper curve of Fig. 2, adjusted so that its maximum coinsides with the maximum of experimental curve, the left and right parts are symmetrical in relation to this point, and the angular scale is converted to time with an account that 90^o corresponds to 6.72 hrs. One could see that theoretical and experimental data have a reasonable coincidence, although theoretical curve goes a little lower than the experimental data at large angles φ. For non-tracking panel placed horizontally, the irradiation at arbitrary angle φ is proportional to cos φ. The ratio of the corresponding areas is 1.354 which means that the calculated tracking effect in the case examined (i.e. that of the vertical Sun orbit) constitutes 35.4 %. The experimental effect of tracking in this case (i.e. the ratio of areas under the upper and lower curves in Fig. 4) is 1.4, reasonably close to the calculated one.

For the case of winter insolation at the same latitude (winter solstice, illumination from the left in Fig. 1) our analysis gives the daytime of t* = 10.56 hrs; the maximum irradiance corresponds to the angle of 47^o in Fig. 2, and the part of the curve between 47 and 90 grad corresponds to dependence of insolation upon time from noon until the end of the day. The calculated dependence for the radiation flux captured by the tracking system is shown in Fig. 5 by squares (the curve starting at irradiance 825 W/m^2), here Δt is the time difference from noon.

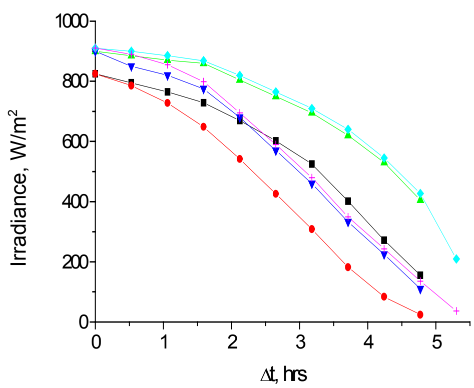

Fig. 5: Irradiance at different periods (see text).

The lowest curve in Fig. 5 gives the irradiance at winter solstice of non-tracking system orientated in the most favorable way – normal to the solar flux at noon, i.e. at 47^o to the Earth surface. During the day, the angle of incidence of this flux to the panel varies between $\phi = 0$ at noon and $\phi = 90^o$ (dawn, evening); multiplication of the former curve by corresponding cos ϕ gives the irradiance. In this case, the calculated tracking effect is 1.28, i.e. is lower than in summer, in good agreement with our experiment (not shown) performed on December 20, 2003.

In a similar way, we obtain the irradiance at equinox time, when the smallest value of φ at the latitude chosen is 23.5^o, and the solar day time is 12 hrs. The calculated data are shown in Fig. 5 by diamonds (the highest curve starting at irradiance 910 W/m^2) for tracking module, and by the curve with crosses starting at the same points for non-tracking one, orientated at 23.5^0 to the surface and normal to solar flux at noon. Two other curves in Fig. 5 (triangles up and down) are experimental ones (Querétaro, Mexico, March 23, 2004); they go a little lower than the calculated curves, but reasonably close to them. The experimental tracking effect is 33 % (theoretical one – 31 %),

3.2 Non-Tracking System with Bifacial PV Panel.

There exists another possibility to get more power from PV solar panel of a fixed area – to use bifacial panels [10] sensitive to illumination from both sides; the rear face is able to give up to 60 % of the power produced by the front one. These panels demand some arrangements to collect solar radiation for the rear face (for example, to use the diffuse reflectance from surfaces below the panel, and to paint them correspondingly [11]). The method mentioned needs relatively large areas of reflecting surfaces, which may be not practical; besides, the paint usually lasts less than the PV panel. We employed the technique demanding smaller area, which in fact is small concentrating reflector placed below the PV panel (ideally it should be a cylindric or spherical mirror, with the panel placed in its focal point, at half a radius from the optical center). We used the concentrator made of stainless steel plates, with area about twice as big as the area of panel. The bifacial panel employed was made in OKBZ "Krasnoe Znamya", Russia, the front side power at AM1.5 illumination was 60 W, and that of the rear side – 40 W. Thus an effect of the rear panel face is around 60 % (in different bifacial panels, it is between 50 and 60 %), which is better than the data given above for the tracking effect.

Fig. 6: Two bifacial solar panels at rural school

The actual system with two bifacial panels and reflectors (the total peak power of photovoltaic panels 200 W), having corresponding battery bank, charge controller and DC-AC converter, was installed in one of the rural schools in the state of Querétaro, Mexico, in Augist 2002 (Fig. 6 presents photo of the panels with reflectors on the roof of the school), and since then it is constantly used providing enough energy for functioning of the receptor of the satellite educational programs and TV-video set during 6 hours a day. At the moment, 85 solar electric systems of this kind having peak power 300 W each are installed in rural schools of the state of Querétaro, in places which do not have access to the electric network, with more systems to follow.

4. SUMMARY

Investigations made lead us to the conclusion that the use of solar tracking PV panels in absence of solar concentration gives relatively small (30 - 35 %) increase in the solar energy collection and electric energy production, and therefore could be practical only with very economic tracking systems. Larger effect could be achieved with bifacial PV panels, which production cost is not much higher than that of standard panels of the same area, and an increase in energy production caused by effective use of a rear face with a simple system of flat mirrors could be 50 – 60 %.

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M. Andersen, D. Ljubicic, C. Browne, S. Kleindienst and M. Culpepper, Massachusetts Institute of Technology, USA
Assessment of Luminance Distribution Using HDR Photography
L. Beltran and B. Martins Mogo, Texas A&M University, USA

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M. Schiler and E. Valmont, University of Southern California, USA
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Balancing Act: A Study of Daylighting and Thermal Performance in Ithaca, New York
C. Stansell, K. DiStefano, R. Millett, M. Ballantyne, Y. Terada and N. Rajkovich, Cornell University, USA
Low-Cost Dish Concentrator/Tracker Development for Hybrid Lighting
R. Taylor and R. Davenport, Science Applications International Corp., USA
New Designs in Active Daylighting: Good Ideas Whose Time Has (Finally) Come
L. Kinney, Synertech Systems Corporation; R. McCluney, Florida Solar Energy Center and G. Cler and J. Hutson, Synertech
Systems Corporation, USA
Study on Calibration Method for Direct Mirror Sunlighting System
T. Fujisawa and S. Ohya, Kanagawa Institute of Technology and S. Matsumura, Aihara Sangyo Co. Ltd., Japan
The Role of Daylighting in LEED Certification: A Comparative Evaluation of Documentation Methods
K. Carrier and M. Ubbelohde, University of California, Berkeley, USA
The Influence of Atrium Orientation on the Daylight Performance in an office building
E. Giovannopoulou, M. Schiler and R. Knowles, University of Southern California, USA
Daylight in Schools: R.D. & Euzelle P. Smith Middle School, Chapel Hill N.C. - Daylight Dividends Case Study
J. Zubizarreta and M. Nicklas, Innovative Design Inc. and P. Morante, Rensselaer Polytechnic Institute, USA
Luminous Efficacy Models of Solar Radiation for the Northeast of Brazil
S. Leal, C. Tiba, E. Barbosa and R. Melo, Universidade Federal De Pernambuco, Brazil
Analysis of the Indoor Daylight Performance of a Light-shelf System
Y. Cho, Korea Institute of Energy Research. (KIER) and B. Kim, Chungnam National University (CNU), Korea (South

SUSTAINABILITY
Sustainable Communities & Policies
Peer-reviewed Papers
Energy Considerations for Buildings and Cities, Based on Sustainable Development. Case S.M. De Tucumán
G. Gonzalo, S. Ledsma and V. Nota, Universidad Nacional de Tucumán, Argentina
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B. Del Brocco, Università degli Studi Roma Tre, Italy
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Nature Conservation + Spirituality = Sustainability
A. Rajvanshi, Nimbkar Agricultural Research Institute (NARI), India
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E. Löwendahl, Chalmers University of Technology and Göteborg University; J. Swahn, Chalmers University of Technology
and H. Eek, IVL Swedish Environmental Research Institute, Sweden
Solar Energy in Service of Faith-Based Organizations: Harvesting More Than Energy from Solar Power
G. Wolfson, Solar Alternatives, USA
Promotion of Sustainable Forms of Renewable Energy Key to Poverty Eradication Strategies among Poor People in Rural
Areas of Kenya - A Call for Support
J. Ndegwa, Rural Friends Kenya/IRDD Univ of Reading, United Kingdom and M. Githinji, Rural Friends Kenya
Renewable Hydrogen -- International Pathways and Progress
P. Middleton, Panorama Pathways; J. Ohi and D. Renné, National Renewable Energy Laboratory and C. Lowry, U.S. Agency
for International Development, USA
The Production Peaks in Petroleum and Natural Gas: Information, Misinformation, Awareness, and Implications

R. Swenson, EcoSystems® and F. de Winter, Francis de Winter & Associates, USA

Sustainable Urban Planning

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G. López Lara, F. Fernández-Llebrez Rosa and M. Villanueva Romero, Sociedad para el Desarrollo Energético de Andalucía,
Spain

The Growing Need for Solar-Access Zoning

R. Knowles, University of Southern California, USA

Solar Energy Systems and Environmental Comfort Techniques for an Allotment in Rio Das Ostras District - RJ, Brazil

H. Ribeiro and A. Serôa da Motta, Universidade Federal Fluminense, Brazil

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T. Bleiberg, I. Capeluto, A. Yezioro, E. Shaviv, Technion - Israel Institute of Technology, Israel

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H. Bryan, Arizona State University, USA; T. Elhinnawy, Zagazig University, Egypt and P. Sam Antia, Arizona State
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A. Deshmukh, Farnsworth Group, Inc. and R. Sutaria, Lord, Aeck & Sargent Architecture, USA

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N. Maritz, Nina Maritz Architects, Namibia

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A. Hathaway, Environment Resources Trust (ERT), Inc., USA

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C. Abbate, Rensselaer Polytechnic Institute, USA and AeV Abbate e Vigevano Architects, Italy

Beyond Zero Energy Homes

S. Heckeroth, Ovonic Solar and C. Heckeroth, USA

Sustainable Design, LEED, and the Rawlins Field Office

R. Azerbegi, Ambient Energy and J. Bradburn, The RMH Group, Inc., USA

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A. Barker, Cape Peninsula University of Technology, South Africa

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N. Maritz, Nina Maritz Architects, Namibia

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J. Wasley, University of Wisconsin-Milwaukee and M. Meiling, Foresight Home Performance, USA

"Milagro," a Sustainable Co-Housing Community Located in the Sonoran Desert in Tucson

N. Chalfoun, University of Arizona, USA

Results From HOSPITALS - Exemplar European Health Care Buildings - Case Studies from 5 European Demonstration Projects

O. Jørgensen, Esbensen Consulting Engineers A/S, Denmark

Trigeneration as a Modern Option of Energy Conservation in Buildings
D. Chwieduk, W. Pomierny and A. Umer, Institute of Fundamental Technological Research, PAS, Poland; R. Critoph,
University of Warwick, United Kingdom; G. Restuccia, CNR Instituto di Tecnologie, Italy; R. de Boer, ECN, The
Netherlands and V. Melisurgo, Centro Ricerche Fiat, Italy
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B. Roy and A. Joshi, The Barefoot College, India
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J. Green, University of KwaZulu-Natal, Pietermaritzburg, South Africa
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S. Kassels, W. Ratterman and M. Royce, Green Empowerment, USA
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M. Ross and T. Wilson, Sandia National Laboratories, USA and A. Romero Paredes, Ecoturismo y Nuevas Tecnologías,
Mexico
Photovoltaic for Sustainable Livelihoods in Off-Grid Areas of Bangladesh
F. Ahmed PPRE, C.v.O. University, Germany; J. Aman and M. Islam, Bangladesh Power Development Board, Bangladesh
Native American Sustainable Energy Systems - Navajo Solar Electric Case Study
S. Begay-Ca**SOLAR COLLECTOR TECHNOLOGIES**
Progress in Collector Design and Material
Peer-reviewed Papers
Limiting Stagnation Temperatures in Flat-Plate Solar Collectors
S. Harrison, Q. Lin and L. Mesquita, Queen's University, Canada
Sol-Gel Deposition and Optical Characterization of Multilayered Silicon Oxide/Titanium Silicon Mixed Oxide Thin Films on
Solar Collector Glasses
A. Schüler, E. De Chambrier, C. Roecker and J. Scartezzini, Ecole Polytechnique Fédérale de Lausanne EPFL, Switzerland;
D. Dutta, Indian Institute of Technology IIT, India and G. De Temmerman and P. Oelhafen, University of Basel, Switzerland
Study on Two-Phase Heat Transfer Mechanism from Heating Surface of Solar Collector to the Fluid
J. Kim, Korea Institute of Energy Research and M. Kim, University of Science and Technology, Korea (South)
Optimization of Solar Energy Collection Using SOCOL
J. Garrison, San Diego State University, USA
Application of Finite-Difference Time-Domain Method to Solar Light Absorption Coating of Al-N Films with Surface
Roughness
H. Iijima, K. Katazakai and T. Ishiguro, Nagaoka University of Technology, Japan
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T. Bostrom, E. Wäckelgård and G. Westin, Uppsala University, Sweden
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A. Delahaye, B. Hoffschmidt, F. Späte, U. Stuckmann and S. Warerkar, FH Aachen, Solar-Institut Jülich (SIJ); W. Fryn and
H. Kinast, Fischer Profil GmbH and B. Bonnema, Corus Building Systems, Germany
The Novel Solar Water Heating by means of Thermoelectric Modules
S. Maneewan and S. Chindaruksa, ISES and Naresuan University and J. Waewsak, ISES and Renewable Energy System

Research and Demonstration Center, Thaksin University, Thailand

Synthesis by Concentrated Solar Radiation of Fluorit-Like Solid Solutions on the ZrO_2-CaO (MgO) -Gd_2O_3 Systems and Their Properties

D. Gulamova, S. Gornostaeva, T. Ismailova, J. Turdiev, M. Zufarov and A. Lejebokov, Uzbekistan Academy of Sciences, Uzbekistan

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E. Aroudam. University Abdelmalek Essaadi, Morocco

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Y. Kim and T. Beom Seo, Inha University; Y. Heack Kang, Korea Institute of Energy Research and G. Young Han, Sungkyunkwan University, Korea (South)

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Investigation and Comparison of Different Model Equations

K. Vajen, E. Frank and C. Jipp, Universität Kassel, Germany

Analysis of the Collector Test Procedures for Steady State and Quasi Dynamic Test Conditions in View of the Collector Coefficients Uncertainties and Model Stability

M. Kratzenberg, Federal University of Santa Catarina, Brazil; H. Beyer, University of Applied Science Magdeburg-Stendal, Germany; S. Colle, Federal University of Santa Catarina, Brazil; A. Albertazzi, Federal University of Santa Catarina, Brazil; S. Güths, Laboratory of Porous Means and Thermo-physic Properties, Brazil; D. Fernandes, P. Oikawa and R. Machado, Federal University of Santa Catarina, Brazil and D. Petzoldt, University of Applied Science Magdeburg-Stendal, Germany

Design, construction and testing of a parabolic trough solar collector for a developing-country application

M. Brooks and I. Mills, Mangosuthu Technikon and T. Harms, University of Stellenbosch, South Africampbell, J. Coots and B. Mar, Sandia National Laboratories, USA

SOLAR COLLECTOR TECHNOLOGIES (continued)

Performance Evaluation Techniques and Tools (continued)

Experimental Investigation of Two-Phase Closed Thermosyphons with a Liquid Retention Structure for SDHWs

S. Abreu, J. Destri and S. Colle, Universidade Federal de Santa Catarina, Brazil

Test and Simulation of Solar Thermal Collectors with Multi-Axial Incident Angle Behavior

S. Fischer, W. Heidemann and H. Mueller-Steinhagen, Universität Stuttgart, Germany

Performance Model for Solar Thermal Collectors Taking into Account Degradation Effects

E. Streicher, S. Fischer, W. Heidemann and H. Mueller-Steinhagen, Universität Stuttgart, Germany

Design, Manufacture and Installation of a Solar Simulator for the Green Laboratory at Pontificia Universidade Catolica De Minas Gerais in Brazil

C. Zahler, F. Luginsland and A. Haeberle, PSE GmbH, Germany; E. Marques and D. Pereira, GREEN / PUC Minas, Brazil and J. Fraunhofer and M. Rommel, Fraunhofer ISE, Germany

Concentrating Solar Collectors

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S. Gallagher and B. Norton, Dublin Institute of Technology, Ireland and P. Eames, University of Ulster, N-Ireland

Quantum Dot Solar Concentrator Device Characterisation Using Spectroscopic Techniques

S. Gallagher, B. Rowan, J. Doran and B. Norton, Dublin Institute of Technology, Ireland

Numerical Simulation of Heat Losses by Natural Convection and Surface Thermal Radiation in an Open Tilted Shallow
Cavity

J. Hinojosa, University of Sonora; C. Estrado, Universidad Nacional Autónoma de México; G. Alvarez, CENIDET and R.
Cabanillas, University of Sonora, Mexico

Numerical Simulation of Heat Losses by Natural Convection in an Open Tilted Cubic Cavity

J. Hinojosa, University of Sonora; C. Estrado, Universidad Nacional Autónoma de México and G. Alvarez, CENIDET,
Mexico

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Nonimaging Reflective Lenses: A New Type of High-Heat Solar Collectors

S. Vasylyev, S.V.V. Technology Innovations, Inc., USA and V. Vasylyev, ISES-Ukraine, Ukraine

Construction of a 4 kWt Dish Concentrator System

R. Cabanillas, J. Perez and H. Munguia, Universidad De Sonora; C. Villegas and C. Iriarte, CIBNOR-Hermosillo and J.
Hinojosa, Universidad De Sonora, Mexico

Description and Performance of a TRNSYS Model of the Solargenix Tracking Power Roof

T. Cleveland, North Carolina Solar Center, USA

Stationary Focus Tracking Solar Concentrators for Cooking and Process Applications

D. Gadhia, Gadhia Solar Energy Systems Pvt. Ltd., India and T. Shah, Prime Resources LLC, USA

Optimal Design of Stationary Nonevacuated CPC Solar Concentrator with Fully Illuminated Wedge Receivers

C. Tiba, N. Fraidenraich and B. Brandao, Universidade Federal De Pernambuco, Brazil

Thermal Performance of Composed Pipe in a Parabolic Trough Collector

A. Torres, R. Lugo and J. Zamora, Universidad Autonoma Metropolitana, Mexico

Theoretical Analysis of a Conical-Bucket Solar Concentrator for Fluid Heating

M. El-Refaie, Cairo University, Egypt

Features of Properties of Materials Synthesized in Solar Furnace

D. Gulamova, Uzbekistan Academy of Sciences, Uzbekistan

Flow Distribution in a Solar Collector Panel with Horizontal Fins

J. Fan, L. Shah and S. Furbo, Technical University of Denmark, Denmark

Vacuum Collectors

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Long Term Performance and Reliability of Two Evacuated Collectors

W. Duff, Colorado State University, USA and K. Vanoli, Institut für Solarenergieforschungs, Germany

Numerical Investigations of an All-Glass Evacuated Tubular Collector

L. Shah and S. Furbo, Technical University of Denmark, Denmark

SOLAR COLLECTOR TECHNOLOGIES (continued)

Vacuum Collectors (continued)

Performance and Reliability Evaluation of the Sacramento Demonstration Novel ICPC Solar Collectors

W. Duff and J. Daosukho, Colorado State University; R. Winston, University of California at Merced; J. O'Gallagher,
University of Chicago Enrico Fermi Institute; J. Bergquam, Sacramento State University and T. Henkel, Solar Enterprises
International, USA

Theoretical Investigations of Differently Designed Heat Pipe Evacuated Tubular Collectors

L. Shah and S. Furbo, Technical University of Denmark, Denmark

Study on the Residual Gas in All-Glass Evacuated Collector Tubes

X. Zhou, Tsinghua Solar Ltd.; Z. Yin and G. Dong, Tsinghua University and S. Zheng, Tsinghua Solar Ltd., PR China

Long Term Thermal Performance of Evacuated Tubular Solar Collector System for Industrial Process Heat in Korea

H. Kwak, Korea Institute of Energy Research and C. Choi Jeonju University, Korea (South)

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I. Zumeta and L. Curbelo, University of La Habana, Cuba; J. Ayllón, Autonomous University of Barcelona, Spain and E.
Vigil, University of La Habana, Cuba

TiO_2/SiO_2 Nanocomposite Electrode Prepared by Electrodepositon for Dye-Sensitized Solar Cells

T. Nguyen, H. Lee, K. Kim and O. Yang, Chonbuk National University, Korea (South)

Industrial Design Way of DSCS Panel with High Efficiency

S. Dai, J. Weng, Y. Sui, S. Chen, S. Xiao, Y. Huang, F. Kong, X. Pan, L. Hu, X. Fan, et. al., Chinese Academy of Sciences,
PR China

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High Efficiency Concentrator Multi-Junction Solar Cells and Modules

M. Yamaguchi, Toyota Technological Institute; T. Takamoto, Sharp Corporation and K. Araki, Daido Steel Corporation,
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*Photovoltaic Effect and Photopoling of Polymethylmethacrylate Doped with Dimethylaminobenzylidene 1,3 - Indandione
Cells*

I. Kaulach, Institute of Physical Energetics LAS; I. Muzikante, Institute of Solid State Physics University of Latvia and P.
Shipkovs, J. Ekmanis and G. Kashkarova, Institute of Physical Energetics LAS, Latvia

Obtaining Heterostructures with Quantum Dots for Solar Cells

A. Minailov and T. Kupriyanova, Kherson State Technical University, Ukraine

Externally Unbiased Electron Injection from Copper Oxide to Porous

E. Vigil, University of La Habana, Cuba; J.A. Ayllón, Autonomous University of Barcelona, Spain; B. González, I. Zumeta
and L. Curbelo, University of La Habana, Cuba

Optimization of Organic/Polymer Solar Cells in both Space and Energy/Time Domains

S. Sun, Norfolk State University, USA

Solar Cell Materials & Manufacturing

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PV Energy Payback vs. PV Input Energy Due to Market Growth

A. Black, OnGrid Solar Energy Systems, USA

Aging Mechanisms and Delamination Behaviour of Polymeric Multi-Layer Films for PV Encapsulation

G. Oreski, Polymer Competence Center Leoben GmbH and G. Wallner, University of Leoben, Austria

Effect of Magnetic Field on Bifacial Silicon Solar Cell Studied in Modeling: Capacitance and Space Charge Region Width

Determination
S. Madougou, Université Abdou Moumouni de Niamey, Niger; I. Barro, Université Cheikh Anta Diop de Dakar, Dakar
(Sénégal) and G. Sissoko, Université de Ouagadougou, Burkina Faso
Ellipsometric Analysis of Cobalt-Oxide Solar Selective Coatings on Different Substrates
E. Barrera and J. Martinez, Universidad Autónoma Metroplolitana-Iztapalapa and A. Avila and M. Ortega CINVESTAV del
IPN, Mexico
Coefficient of Performance of Mono- and Multi-Crystalline Silicon Photovoltaic Panels
M. Bahadori and K. Zamzamian, Sharif University of Technology, Iran
Effect of Stainless Steel Substrate Thickness on the CIGSS Thin Film Solar Cell
A. Kadam, A. Jahagirdar and N. Dhere, Florida Solar Energy Center, USA
Review of Rapid Thermal Process and Setup for Fabrication of Absorber Layer for CIGSS Solar Cells by RTP
N. Dhere, S. Kulkarni, J. Shirolikar and M. Nugent, Florida Solar Energy Center, USA

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P. Fath and E. Rüland, GP Solar GmbH, Germany; P. Vandewalle, ICOS Vision Systems NV, Belgium and S. Wansleben,
ICOS Vision Systems GmbH, Germany
New Chlorine-Free Solar-Grade Silicon Technology
E. Belov, N. Efimov, E. Lebedev, V. Zadde, A. Pinov and D. Strebkov,
INTERSOLARCenter, Russia and K. Touryan and D.
Blake, National Renewable Energy Laboratory, USA
The Effect of the Growth Rate on Polycrystallinity
T. Razykov and K. Kouchkarov, Physical-Technical Institute, Uzbekistan

PV TECHNOLOGIES, SYSTEMS AND APPLICATIONS (continued)

Solar Cell Materials & Manufacturing (continued)

The Graded Optical Band Gap (GBG) in Hydrogenated Nanoamorphous Silicon (Na-Sih) Solar Cell Prepared by Plasma
Enhance Chemical Vapor Deposition (PECVD)
Y. Huacong, C. Rongqiang, M. Fanying and Z. Zhanxia, Shanghai Jiaotong University; W. He and Y. Hong, Xi' an Jiaotong
University and H. Yuliang, Jiangsu Weifu Nanometers Science & Technology Ltd., PR China
Performance Enhancement of CIGSs Absorber Layer on Glass Substrate
A. Kadam, A. Jahagirdar and N. Dhere, Florida Solar Energy Center, USA
Gigawatt-Scale Manufacturing of Discrete Flexible CIGS Solar Cells as a Near-Term Catalyst for the Transition to a "Solar
Economy"
J. Tuttle and T. Schuyler, DayStar Technologies, Inc., USA

PV Applications

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D. Strebkov, P. Litvinov, Y. Kuzhnurov, E. Tveryanovich and I. Tyukhov, All-Russian Research Institute for Electrification
of Agriculture, Russia and S. Kivalov, Renewable Energy Research, USA
Renewable Hydrogen Based Off-Grid Power System Control System
S. Uppapalli, University of Nevada; R. Denis, Donovan Sustainable Energy Solutions;
B. Wood, Utah State University and
R. Jacobson and M. Wetzel, Desert Research Institute, USA
Performance of Photovoltaic and Thermal Hybrid Air Collectors
S. Ito, K. Sato and N. Miura, Kanagawa Institute of Technology, Japan
Effect of Photovoltaic Cover on Urban Surface Energy Balance
S. Nagpal and S. Shah, Arizona State University, USA

Application of Wind Tunnel Testing and Finite Element Analysis to Development of a Photovoltaic Module Mounting System
M. Bowler and M. Huber, Eastwood Energy Corporation and M. Lobo, NovaComp Engineering, Inc., USA

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PV Research and Technological Development in Russia
D. Strebkov and A. Irodionov, All-Russian Research Institute for Electrification of Agriculture (VIESH), Russia

Two Decades of PV Lessons Learned in Latin America
R. Foster, New Mexico State University, USA and A. Cota, Universidad Autónoma de Ciudad Juárez, Mexico

Solar Lanterns for Remote Areas
S. Tavaranan and J. Duffy, University of Massachusetts Lowell, USA

Validated Simulation of the Influence of Insolation and System Sizing on the Performance of PV Pumping Systems
I. Odeh and Y. Yohanis University of Ulster, Northern Ireland, UK and B. Norton Dublin Institute of Technology, Ireland

Development of Hybrid Photovoltaic-Wind System for Academic Purposes
R.Soler-Bientz, Autonomous University of Yucatan, Mexico

Amorphous-Silicon Photovoltaic/Thermal Solar Collector System in Thailand
S. Jaikla, T. Nualboonrueng and P. Sichanugrist, National Science and Technology Development Agency, Thailand

Disasters: Photovoltaics for Special Needs
W. Young, Jr., Florida Solar Energy Center, USA

Experimental Performance of a Frequency Converter Driving a PV Pumping System
R. Melo, N. Fraidenraich and O. Vilela, Universidade Federal de Pernambuco, Brazil

Electrification of Villages: A Case Study of Mustung Village near Quetta (Pakistan)
S. Ilyas, S. Nasir and S. Raza, University of Balochistan, Pakistan

Solar Roof Špansko-Croatia, First Year of Operation
L. Majdandzic, Croatian Professional Society for Solar Energy and Z. Matic, Energy Institute Hrvoje Pozar, Croatia

Hybrid Solar Generation for Rural Decentralized Electrification in the Semi-Arid Northeast of Brazil
E. Barbosa, R. Oliveira, C. Tiba, N. Fraidenraich and E. Vieira, Federal University of Pernambuco, Brazil

Photovoltaic Reincarnation – Using Salvaged PV in the Eco Office
V. Sami, and J. Nicolow, Lord, Aeck and Sargent Architecture and A. Campolucci, Southface Energy Institute, USA

Characteristics of PV power generation system in Japan
N. Mori, Taisei Corporation; H. Fukao, M. Saito, M. Nakamura and Y. Sato, Taisei Corporation Technology Center and M. Morita, Taisei Corporation, Japan

PV TECHNOLOGIES, SYSTEMS AND APPLICATIONS (continued)

PV Balance-of-Systems

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Quantitative Design and Implementation of Two-Stage Grid-Connected PV Inverter With DSP-Based Controller
S. Chiang, National United University; Y. Lai, Material Research Lab, ITRI; K. Chai, HsinChu Research Center, Sysgration LTD. and Y. Tzou, Chiao Tung University, Taiwan

An MPPT Control Method to Acquire the Maximum Power over All Types of Irradiations Variously Changing with Weather Conditions
N. Mutoh, M. Ohno and T. Inoue, Tokyo Metropolitan Institute of Technology, Japan

Optimal Reliability Design Method for Remote Solar Systems
N. Suwapaet and J. Duffy, University of Massachusetts Lowell, USA

Peer-reviewed Abstracts

Innovative Micro-Inverter for the AC PV Building Block or AC Modules

W. Bower, Sandia National Laboratories; A. Dickerson, Bluepoint Associates and R. West, Distributed Power, USA

Review of PV Inverter Technologies for Practical Implementation

A. Wang, B. Chen and Y. Tzou, National Chiao Tung University, Taiwan

Characterization and Measuring in Test Facilities PV Grid Connected Inverters

L. Davila, Polytechnic University of Madrid; M. Castro, A. Colmenar, J. Carpio and J. Peire, Spanish University for Distance

Education and R. Jiménez, University of Cadiz, Spain

Development of a Low Cost Control System for a Solar Tracker

F. Monteiro, O. Vilela and N. Fraidenraich, Universidade Federal de Pernambuco, Brazil

A Side by Side Comparison of Maximum Power Point Tracking Charge Controllers for a Stand-Alone PV System

F. Collins and J. Kreider, University of Colorado, USA

Development of High-Frequency Transformer Inverter Topologies for Small-Power Grid-Connected PV Inverters

K. Chai, Y. Lin, J. Hsu and Y. Tzou, National Chiao Tung University, Taiwan

Modeling and Simulation of Stand-Alone Power Photovoltaic System Using Artificial Neural Network

A. Mellit, University Center of Médéa and A. Benghanem, University of Sciences and Technology Houari Boumediene

(USTHB), Algeria

Grid-connected PV System Performance

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An Alternative Method to Regression Analysis for PV System STC Rating

J. Bing, New Energy Options, Inc. USA; E. Kern Jr., Irradiance Inc., USA and C. Sumaoy, CEPALCO, Philippines

Experimental Validation of Algebraic Methods to Predict the Outdoors Electrical Performance of Monocrystalline Silicon

PV Modules in Southern Europe Climates

M. Fuentes, G. Nofuentes, J. Aguilera and D. Talavera, Universidad de Jaén and M. Castro, UNED - Ciudad Universitaria,

Spain

Comparative Analysis of the Influence of the Climatic Conditions in Europe on the Efficiency of a Grid-Connected

Photovoltaic System

G. Lopez, Sociedad para el Desarrollo Energético de Andalucía and I. Lillo, Universidad de Sevilla, Spain

Economic Analysis of Grid Connected PV Systems in South East Queensland

K. Khouzam, Queensland University of Technology, Australia

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Performance Monitoring of 900 Individual Photovoltaic Systems in Sacramento

O. Bartholomy, Sacramento Municipal Utility District and M. Sheridan, MSEE, USA

Results from the California PV Testing and Evaluation Project: A Third-Party Evaluation of Currently Available PV Systems

W. Brooks, J. Newmiller, T. Townsend and C. Whitaker, Behnke, Erdman, and Whitaker Engineering, Inc., USA

One Megawatt Photovoltaic Plant Completes Twenty One Years of Successful Operation

G. Nelson, Sacramento Municipal Utility District and A. Rosenthal, Southwest Technology Development Institute, USA

Multi-Year Performance Assessment of Two PV Installation Clusters

S. Wiese, Conservation Services Group and CSGServices Inc. and L. Moore and C. Hanley, Sandia National Laboratories,

USA

A 10 kWp Photovoltaic Grid Connected System – Planning and Checking the System Components

I. Farkas and I. Seres, Szent István University and L. Koksis, Hungarian Academy of Sciences-SIU, Hungary

PV TECHNOLOGIES, SYSTEMS AND APPLICATIONS (continued)
Grid-connected PV System Performance (continued)
Grid-Connected Photovoltaics in Brazil
R. Ruther, LABSOLAR - Universidade Federal de Santa Catarina; W. Reguse CELESC - Centrais Elétricas de Santa
Catarina; M. Dacoregio, LABSOLAR - Universidade Federal de Santa Catarina; P. Knob, C. Jardim and I. Salamoni,
LabEEE - Universidade Federal de Santa Catarina; R. Ricardo, LABSOLAR - Universidade Federal de Santa Catarina and A.
Diniz, CEMIG - Companhia Energética de Minas Gerais, Brazil
California's Self-Generation Incentive Program PV Systems: Measured Performance and Actual Costs
K. Scheuermann and P. Lilly, Itron, Inc. and P. Landry, Southern California Edison, USA
Analysis of PV System Performance Versus Modeled Expectations Across a Set of Identical PV Systems
J. Perlman, A. McNamara and D. Strobino, Big Apple Solar Installation Commitment (BASIC), USA
Predicting the Performance of Photovoltaic Cells Using a 5-Parameter Model
W. De Soto, S. Klein and W. Beckman, Solar Energy Laboratory, University of Wisconsin-Madison, USA
4.872 kW Grid-Connected PV System Results and Testing at Rajamangala University of Technology (RMUT), THAILAND
N. Watjanatepin and C. Boonmee, Rajamangala University of Technology (RMUT), Thailand
Fundamental Studies of Electrical Detection of Failed Modules in PV Array
T. Takashima, K. Otani and K. Kato, Research Center for Photovoltaics, AIST, Japan
Characterization of Photovoltaic Modules Via Artificial Neural Networks
L. Vilhena, L. Zárate and D. Soares, Pontifical Catholic University of Minas Gerais and A. Diniz, Energy Company of Minas
Gerais (CEMIG), Brazil
Solar Electric Concentrators
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Prismatic Stationary Concentrators in the Photovoltaic Modules
S. Kivalov, Renewable Energy Research, USA and D. Strebkov and E. Tver'yanovich, All-Russian Research Institute for
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A Novel 500W Photovoltaic Concentrator
S. Vasylyev, S.V.V. Technology Innovations, Inc., USA
A Miniature Building-Integrated Spherical Collector PV System
A. Kribus, J. Appelbaum and M. Arenson, Tel Aviv University, Israel; G. Grossman and I Capeluto, Technion-Israel Institute
of Technology; A. Kudish, Ben Gurion University, Israel; F. Martelli, University of Florence, Italy and T. Caselli, Solar Heat
and Power, Italy
A Miniature Concentrating PV System for Distributed Generation
D. Kaftori, DiSP - Distributed Solar Power Ltd. and A. Kribus, Tel Aviv University, Israel

SOLAR THERMAL SYSTEMS AND APPLICATIONS
Solar Thermal Systems and Applications
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S. Flores Larsen, Universidad Nacional de Salta - CONICET; C. Filippin, CONICET and G. Lesino, Universidad Nacional

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A. Martinez and O. Morales, Universidad Nacional de Ingeniería, Nicaragua and R. Komp, Sunwatt Corporation, USA

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B. Bauer, T. Williamson and P. McEntee, Thermomax Ltd., Northern Ireland, UK

AlB_2 - A New Selective Coating

N. Bhowmik, A. Kahn, J. Rahman, S. Kahdem and M. Azad, University of Dhaka, Bangladesh

Perspectives for Solar Thermal Energy in the Baltic States

P. Shipkovs, G. Kashkarova, K. Lebedeva and J. Shipkovs, Institute of Physical Energetics LAS, Latvia

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M. Brooks, Mangosuthu Technikon and T. Harms, University of Stellenbosch, South Africa

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L. Vant-Hull, University of Houston, USA

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H. Yamaguchi and X. Zhang, Doshisha University; K. Fujima, Mayekawa MFG. Co. Ltd.; M. Enomoto, Showa Denko K. K.
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I. Martinez and R. Almanza, Universidad Nacional Autonoma de Mexico, Mexico

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C. Papageorgiou, School of Electrical & Computer Engineering, N.T.U.A., Greece

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D. Mills, P. Le Lievre and G. Morrison, Solar Heat and Power Pty. Ltd. (SHP), Australia

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V. Fernández-Quero and R. Osuna, Solúcar Energía, S.A.; M. Romero and M. Sánchez, Ciemat/PSA and V. Ruiz and M. Silva, Escuela Superior de Ingenieros, Spain

Solar Ponds

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On the Turbidity of a Solar Pond Filled-Up with Bittern and Seawater

W. Sun, M. Xie, H. Pan and L. Huang, Dalian University of Technology and S. Ge, Liao Ning Technical University, PR China

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Solar Ponds (continued)

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Desalination and Power

A. Akbarzadeh and J. Andrews, RMIT University, Australia and P. Golding, University of Texas at El Paso, USA

Cost Effective Solar Thermal Technology for Rural Areas & Small Towns

K. Datye, Society for Advancement in Renewable Materials and Energy Technology, India; N. Pandit, International Institute
of Energy Conservation-North America, USA and P. Ashtunkar, Society for Advancement in Renewable Materials and
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M. Safi, Engineering School of Tunis, Tunisia

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E. Frank, K. Vajen and M. Bail, Universität Kassel, Germany

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Angle of 90°

A. Rojas and C. Estrada, Centro de Investigacion en Energia-UNAM and R. Dorantes, Universidad Autonoma Metropolitana,
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I. Budihardjo, G. Morrison and M. Behnia, University of New South Wales, Australia

Experimental and Numerical Evaluation of Solar Water Heaters with Vertical Mantle Heat Exchangers

Y. Too, G. Morrison and M. Behnia, The University of New South Wales, Australia

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S. Furbo and L. Jivan Shah, Technical University of Denmark, Denmark

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S. Raab, University of Stuttgart; D. Mangold, Solar- und Wärmetechnik Stuttgart; W. Heidemann, and H. Müller-Steinhagen,
University of Stuttgart, Solar- und Wärmetechnik Stuttgart, DLR Stuttgart Institute for Technical Thermodynamics (ITT)
Stuttgart, Germany

Solar Water Heating with Backup Heating: A Review

F. de Winter, Francis de Winter & Associates, USA

Venting Overheat Protection in Solar Water Heaters

J. Roberts, CTG Energetics; M. Brandemuehl, University of Colorado, Boulder and J. Burch, National Renewable Energy
Laboratory, USA

DHWcalc: Program to Generate Domestic Hot Water Profiles with Statistical Means for User Defined Conditions

U. Jordan and K. Vajen, Universität Kassel, Germany

Energy Conservation and Electric Energy Peak Reduction Potential During Peak Hours for a Group of Low-Income
Residential Consumers of a Brazilian Utility
J. Salazar, S. Abreu and S. Colle, Universidade Federal de Santa Catarina, LABSOLAR/EMC/UFSC and W. Reguse,
Centrais Elétricas de Santa Catarina, S.A (CELESC), Brazil
An Assessment of Unglazed Solar Domestic Water Heaters
J. Burch and J. Salasovich, National Renewable Energy Laboratory and T. Hillman, University of Colorado, USA
Effectiveness/Suitability of Coconut Oil (Cocos Nucifera) as a Heat Transfer Fluid and Heat Storage Medium for Solar
Thermal Systems
I. Haraksingh, The University of the West Indies, Trinidad

SOLAR THERMAL SYSTEMS AND APPLICATIONS (continued)
Solar Hot Water (continued)
Water Consumption from Freeze Protection Valves for Solar Water Heating Systems
J. Burch and J. Salasovich, National Renewable Energy Laboratory, USA
Monitoring Results from German Central Solar Heating Plants with Seasonal Storage
T. Schmidt, Solar- und Wärmetechnik Stuttgart (SWT) and J. Nußbicker and S. Raab, Universität Stuttgart, Germany
Novel Low Flow Heat Exchanger Design with a Prime Solar Energy System
M. Starkey and J. Bieri, Heliodyne, Inc., USA
Solar Hot Water and Thermal Energy Supply
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C. Snyder, J. Slomka, S. Bugyi, P. Eland, M. Oranchak and A. Shishkovsky, Lawrence Technological University; R.
Oraweic, BTF Ltd. and S. Santoro, Techbuilt, USA
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E. Andersen and S. Furbo, Technical University of Denmark, Denmark
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C. Li, X. Wang and D. Li, Tsinghua Solar Ltd. and Tsinghua University, PR China
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W. Nan, Z. Dong Sheng and L. Chao, South China University of Technology, China
Outlook of Solar Water Heaters in Taiwan
K. Chang, T. Lee and K. Chung, National Cheng Kung University; C. Lee, NCKU Research and Development Foundation
and W. Lin, Tainan Woman's College of Arts & Technology, PR China
Optimization Techniques for Solar Thermal System
R. Kalil, R. Shanmugam and K. Muralidharan PSNA College of Engineering and Technology , India
Use of Solar Water Heater for Domestic Purposes in Winter Season of Under Tropical Country (Sudan)
O. Elhussain, Omdurman Islamic University and E. Mizo, Atlas Trading Co., Sudan
Heat Transfer Correlations in Mantle Tanks
S. Furbo, Technical University of Denmark and S. Knudsen, RAMBØLL, Denmark
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M. Udagawa and N. Roh, Kogakuin University and M. Sato, Systech Environmental Research Laoboratory, Japan
Solar Cooling and Dehumidification
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A. Liete, F. Belo and R. Andrade, Federal University of Paraíba; M. Grilo, Federal University of Campina Grande, Brazil and
F. Meunier, Conservatoire National des Arts et Métiers, France
Thermoeconomic Model for a Solar-Powered Zeolite Cooling System

D. Baker and B. Kaftanoğlu, Middle East Technical University, Turkey
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G. Yoon, H. Tanaka and M. Okumiya, University of Nagoya, Japan
Influence of Ejector Geometry on Performance of R134A Vapour Ejector Refrigeration System Suitable for Solar Energy
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A. Selvaraju and A. Mani, Indian Institute of Technology Madras, India
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S. Alizadeh and K. Khouzam, Queensland University of Technology, Australia
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C. Martin, University of Florida, USA; S. Sadrameli, Tarbiat Modarres University, Iran and D. Goswami University of
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G. Oliveti, N. Arcuri, R. Bruno and A. Mazzuca, University of Calabria, Italy

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Experimental Study of an Intermittent Refrigerator System Operating with Barium Chloride-Ammonia and Lithium Nitrate-
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C. Blanco, I. Figueroa, and W. Gómez, Universidad Nacional Autónoma de México, México
Performance of a Solar Powered LI-BR Air-Conditioning System with a Partitioned Storage Tank
K. Sumathy, University of Hong Kong, Republic of China
Simulation and Economic Optimization of a Solar Assisted Combined Ejector – Vapor Compression Cycle for Cooling
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H. Vidal, University of Magallanes, Chile and S. Colle, Federal University of Santa Catarina, Brazil
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B. Blum, Solar Cookers International, USA
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S. Nandwani, Universidad Nacional, Costa Rica
Design, Development and Thermal Performance Evaluation of a Heat Exchanger Unit for SK 14 Parabolic Cooker for Off-
Place Cooking
V. Murty and A. Gupta, Holkar Science College, India
Solar Cooking Kitchen Studies with Building Size Nonimaging Reflectors
J. Goodman, Consultant, USA
Semi Log Plot and An Approximate Expression to Find Second Figure of Merit of Box Type Solar Cookers
S. Mullick, S. Khan and B. Chourasia Indian Institute of Technology, Delhi, India
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A. Mani and G. Sesha Girish, Indian Institute of Technology Madras, India

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S. Singal and S. Singal, CCS Haryana Agricultural University, India
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C. Tiba, Grupo Fae-Den-Ufpe and R. Ghini, Embrapa Meio Ambiente, Brazil
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J. Waewsak, ISES and Renewable Energy System Research and Thaksin University and S. Chindaruksa and C. Punlek,
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J. Lodos Fernández, Ministry of Sugar (MINAZ) and E. Vigil Santos, University of La Habana, Cuba
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P. Purohit and J. Parikh, Integrated Research and Action for Development (IRADe), India
Investigation of Wind Energy Potential in the Baltic Region
V. Bezrukov, P. Shipkovs, V. Pugachev and G. Kashkarova, Latvian Academy of Sciences, Institute of Physical Energetics
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V. Lertsathapornsuk, R. Pairintra and K. Krisnangkura, King Mongkut's University of Technology Thonburi, Thailand
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S. Merrett and K. Janda, Oberlin College, USA
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K. Taale, University of Education, Ghana
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C. Lee and W. Park, Korea Institute of Energy Research (KIER), South Korea
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C. Kim, Seoul National University of Technology and C. Lee and W. Park, Korea Institute of Energy Research (KIER),
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B. Chen, National Taiwan University and W. Lee, National Taipei University of Technology, PR China
Performance Analysis of Packed Bed Solar Energy Storage System Having Large Size Material of Different Shapes
R. Singh, R. Saini and J. Saini, Indian Institute of Technology, Roorkee, India
Advanced Phase Change Materials Development for High Temperature Storage of Thermal Energy
M. Hadjieva, M. Bozukov and I. Gutzow, Bulgarian Academy of Sciences, Bulgaria
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I. Hmouda and C. Bouden, Ecole Nationale d'Ingenieurs de Tunis, Tunisia
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M. Hadjieva, V. Stojanova, T. Vassilev and I. Gutzow, Bulgarian Academy of Sciences, Bulgaria
Pore Structure of New Composite Adsorbent for Adsorption Heat Storage
J. Cheng, D. Zhu, Z. Yang, H. Wu and C. Wang, South China University of Technology, PR China
Comparison of the Energy Storage Potential of Different Absorption Modes for Air Dehumidification in Liquid Desiccant Cooling Systems
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L. Rihimaki and F. Vignola, University of Oregon, USA

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J. Page, University of Sheffield, UK
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M. Vazquez, J. Santos, M. Prado and D. Vazquez, University of Vigo, Spain

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M. David, L. Adelard, P. Lauret and E. Fock, University of La Reunion, France
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Preliminary Study of One Minute Solar Radiation Measurements
T. Soubdhan and T. Feuillard, Universite Antilles Guyane (UAG- GRER), France
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J. Bing, New Energy Options Inc., USA
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Broadband Model Performance for an Updated National Solar Radiation Data Base in the United States of America
D. Myers, S. Wilcox, W. Marion, R. George and M. Anderberg, National Renewable Energy Laboratory, USA
Validation of DNI Estimations in Brazil Using Brazil-SR Model
F. Martins and E. Pereira, Brazilian Institute of Space Research and S. Abreu, University of Santa Catarina, Brazil
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F. Martins and E. Pereira, Brazilian Institute of Space Research and S. Abreu and S. Colle, Solar Energy Laboratory - University of Santa Catarina, Brazil

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C. Whitlock, W. Chandler and J. Hoell, Science Applications International Corporation; T. Zhang, Analytical Services and Materials, Inc. and P. Stackhouse, NASA Langley Research Center, USA
Progress on an Updated National Solar Radiation Data Base for the United States
S. Wilcox, National Renewable Energy Laboratory; R. Perez, State University of New York at Albany; R. George, W. Marion, D. Meyers and D. Renné, National Renewable Energy Laboratory; A. DeGaetano, Northeast Regional Climate Center; C. Gueymard, Solar Consulting Services; F. Vignola, University of Oregon and P. Stackhouse, National Aeronautics and Space Administration, Et al, USA
Use of Long-Term Solar Irradiance Products Derived from Satellite for Solar Power Project Development
R. Meyer and S. Lohmann, DLR Institut für Physik der Atmosphäre; C. Hoyer and C. Schillings, DLR Institut für Technische Thermodynamik and E. Diedrich and M. Schroedter-Homscheidt, DLR Deutsches Fernerkundungs-Datenzentrum, Germany
Gridded Aerosol Optical Depth Climatological Datasets over Continents for Solar Radiation Modeling
C. Gueymard, Solar Consulting Services and R. George, National Renewable Energy Laboratory, USA
Estimation and Contour Mapping of Global Solar Radiation under Tropical Climate of Southern Thailand
S. Phethuayluk, Renewable Energy System Research and Demonstration Center (RESRDeC); J. Waewsak, ISES and RESRDeC and J. Keaw-On RESRDeC, Thaksin University, Thailand
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Y. Park, Seoul National University of Technology; D. Jo and Y. Kang, Korea Institute of Energy Research, Korea (South)
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S. Munawwar and T. Muneer, Napier University, Scotland, UK
Experimental and Theoretical Evaluation of the Solar Energy Collection by Tracking and Non-Tracking Photovoltaic Panel
Y. Vorobiev, P. Vorobiev and P. Horley CINVESTAV-Querétaro and J. González-Hernández, CIMAV, Mexico
Sequential Properties and Modeling of Daily Global Horizontal Solar Radiation, in Tropical Climates
A. Siqueira and C. Tiba, Universidade Federal de Pernambuco, Brazil

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M. Mahashi, S. Vijayaraghavan, D. Deshpande and D. Goswami, University of Florida, USA

CIGSS Thin Films for Photoelectrochemical Water Splitting Using Multiple Bandgap Combination of Thin Film Photovoltaic

Cell and Photocatalyst: Clean and Renewable Hydrogen Source

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CPC Type Secondary

J. O'Gallagher, University of Chicago, Enrico Fermi Institute and A. Lewandowski, National Renewable Energy Laboratory,

USA

A 1,000 MW Windplant Delivering Hydrogen Fuel from the Great Plains to a Distant Urban Market

W. Leighty, The Leighty Foundation, USA; J. Holloway, Pipeline Technologies, Inc., Canada; R. Merer, Stuart Energy

Systems, Canada; B. Somerday and C. San Marchi, Sandia National Laboratory, USA and G. Keith, Synapse Energy

Economics, USA

Optimization of a Scroll Expander Applied to an Ammonia/Water Combined Cycle System for Hydrogen Production

H. Ingley, R. Reed and D. Goswami, University of Florida, USA

Solar Water Electrolysis for Hydrogen Production under Climate of Egypt

E. Mettawee, A. Elfoly and H. Sharawee, National Research Center of Egypt and O. El-Farouk, Cairo University, Egypt

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