

Numerical Simulation Of A Evacuated Tube Solar Thermal Collector, A Review According To PRISMA Guidelines

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Abstract. In recent years, worldwide interest in the use of renewable energies has increased because they are inexhaustible and environmentally clean. The main objective of this article is to review a wide variety of research that is related to recent advances, practical techniques, mathematical models, simulations and appropriate specifications of solar systems for water heating. The methodology was conducted for the systematic review of publications, in relation to the simulation of a thermal solar collector vacuum tubes for obtaining solar energy optimal, is made on the basis of the guidelines PRISM, in the first instance, is appealed to technological tools, we selected the most appropriate and relevant in the databases: Web of Science, Taylor & Francis Group, AIP Publishing, Scopus, and publishers: Springer, Elsevier, IEEE Xplore, Wiley. Finally, a critical and reproducible summary of the results of the available publications on the simulation of solar thermal collectors was obtained. It is important that our society focuses on renewable energy not only for our carbon footprint, but also to decrease our dependence on resources that are depleted over time.

Keywords: Renewable energy, Solar energy, solar thermal collector, simulation

1. INTRODUCTION

In recent years, the world has seen increased interest in the use of renewable or alternative energies because they are inexhaustible and environmentally clean. Several countries are already moving towards a renewable energy portfolio to meet 100 percent of their energy demands for all business sectors. The list includes Tajikistan (76.0 percent), Paraguay (58.9 percent), Norway (35.8 percent), Sweden (20.7 percent), Costa Rica (19.1 percent),

Switzerland (19.0 percent), Georgia (18.7 percent), Montenegro (18.4 percent) and Iceland (17.3 percent). Renewable energy resources appear to be one of the most efficient and effective solutions, particularly solar energy. [33]

Ecuador is rich in renewable resources, in 2016 the National Energy Efficiency Plan 2016-2035 (PLANEE) was presented and approved by the National Assembly in April 2019 to encourage the substitution of fuels and energy sources with high environmental impact for others with low or zero carbon content,

including renewable energy sources. [2]. The insolation indexes (solar radiation) are among the highest in the world, which allows the installation of high performance photovoltaic plants (solar panels) and also to heat water efficiently and economically.

Solar energy is one of the reliable alternatives to conventional [29] sources offers many advantages in electricity generation, has zero raw fuel costs, unlimited supply and has no environmental problems such as transportation, storage or pollution. As a kind of renewable energy, solar energy has a bright development prospect. [1]

Solar collectors or solar panels have been the focal point of research in the field of solar energy, devices that are designed to collect the energy generated by the sun and convert it into thermal energy. Flat plate solar collectors have been commonly used for both domestic and industrial purposes. [8] The orientation and tilt angle of the solar collectors play an important role in minimizing shading and, consequently, increasing the efficiency of the solar collector for optimum performance. [5]

Therefore, many studies attempt to find the optimal tilt that maximizes the level of annual insolation. However, no general consensus has been reached so far, partly due to the different assumptions of the applied models. [35] Being able to accurately forecast how much solar energy reaches the Earth's surface is key to guiding decisions for operating solar power plants. [43]

According to the literature, data-driven methods, which have shown promise in the accurate modeling of solar collectors,

have not been used to model flat plate solar collectors. At the same time, accurate equations relating the thermal efficiency of solar collectors to operating and climatic conditions have not been obtained.

On the other hand, numerical simulation is a tool that could significantly reduce costs in these phases of implementation and testing of the improvements introduced. For all these reasons, having a validated model would be very useful and would reduce the costs of implementation and experimental testing of the improvements produced.

Concerns about toxic contamination, fuel leaks, nuclear radiation, global warming and what will happen if energy production prices increase, because of all these problems it is necessary to think out of the box and find new available and sustainable sources such as renewable energy, which plays an important role in the production of electricity due to its availability, good economy and environmentally friendly characteristics.

The research study to be carried out arises from the need to save resources when designing flat solar heaters, in the sense that, at the time of having the system and verified with existing experimental data, changes in geometry or materials can be used, which represents the possibility of other projects to optimize this type of systems. In addition to the time savings implied by knowing the behavior of the heater in different weather conditions over time, with which various projections can be made and the minimum and maximum operating conditions for a specific region can be known.

At present there is an abundance of information that is expressed in a growing number of publications in different areas of knowledge, so it is necessary to apply some methodology for a good selection of publications.

Taking into account the above mentioned, the main objective of this article is to review a wide variety of research already carried out related to recent advances, practical techniques, mathematical models, simulations and appropriate specifications of solar water heating systems, to improve the use of thermal energy and thus contribute to the needs of our country and provide applicable knowledge to meet a need such as the sustainable growth of the country and the improvement of the standard of living of the population.

2. METHODOLOGY

The methodology that was carried out for the systematic review of publications, in relation to the simulation of a solar thermal collector of vacuum tubes for obtaining optimal solar energy, was carried out based on the PRISMA guidelines [24] [19].

- i) Correct formulation of research questions,
- ii) Development of a protocol (inclusion and exclusion criteria),
- iii) Conduct a detailed and comprehensive literature search,
- iv) Screen abstracts of papers identified in the search and subsequently of selected full-text papers.

A. Research Questions

The information extracted from each document was based on the answer to the research questions, for which three questions were established to perform the analysis three points of view were taken into account (VP1) renewable energy, (VP2) optimal solar radiation capture (VP3) the simulation of solar collectors. Table 1 shows the questions asked.

Table 1. Research questions

Number	Research Question (RQ)	Motivation
RQ1	¿What is the importance of renewable energies?	Identify the importance of renewable energy in the current era
RQ2	¿For what angular inclination is the annual incoming solar radiation (insolation) maximized for a flat-plate collector?	Identify the optimal positioning of the solar vacuum tube collector
RQ3	¿What results would be obtained by using software applications in the simulation of input and output data?	Identify the difference between the results obtained from the solar collector simulation with the experimental data

B. Document Search

For the selection of articles to scientists, it is essential to have a knowledge reasonably complete magazines are available in the subject area determined, it is so in the first instance, is appealed to technological tools: Find My Journal, Journal Suggester, Enago Open Access Journal Finder, Edanz Journal Selector, MIAR, Journal Author Name Estimator (Jane), Journal Guide, Springer Journal Selector, Elsevier Journal Finder, DART, for the selection of scientific journals. [30] Taking into account that the article is directly related to the quality of the journal in which it is published, the search is performed on the basis of the content of the article,

considering accuracy, objectivity, coverage, timeliness, and relevance, in the databases: Web of Science, Taylor & Francis Group, AIP Publishing, Scopus, with publishers: Springer, Elsevier, IEEE Xplore, Wiley, and is delimited with the following features: all of open access, the 5 last years, subject area energy, document type article, the stage of final publication, and keywords.

The thoughtful and correct choice of terms is key to interrogating the source of information successfully, so with the search tools the terms were combined using “Boolean” operations (and/Y, NOT/NO, OR/O) to obtain sufficient and relevant results. For example: combined terms: ‘renewable energy’ AND ‘solar energy’, ‘solar panel’ OR ‘solar energy’, ‘mathematical modeling’ AND ‘solar panel’, ‘simulation’ AND ‘solar panel’, later this was extended combinations, using the Boolean operators and and OR as the case may be

C. Paper Selection

For the selection of scientific articles inclusion and exclusion criteria were applied, as shown in Table 1, the documents were sorted by relevance, perspective, title, abstract and keywords. In addition, the information in the introduction and conclusions section was reviewed in order to know if they are based on the research questions, finally, the references were verified.

Table 2. Inclusion and exclusion criteria

Number	Inclusion	Exclusion
C1	Scientific Dissemination in the English language	original studies not included in the latest systematic review
C2	Impact Factor of the journal	thesis
C3	Original articles published in journals with peer review process	duplicates of different databases
C4	Conference Communications	Conference summaries, opinion articles, editorials
C5	Methodological quality and, consequently, the applicability of the results.	Studies with follow-up times less than 2015
C6	Articles published from 2015 to 2021	articles not related to solar energy

D. Data Extraction

The 41 final works were validated by experts in the area of knowledge, to corroborate an adequate selection. Table 3 presents these articles sorted by year of publication. The information extracted from each document is based on the answer to the research questions.

Fig 1. it describes the flow of information through the different phases that was carried out for a good systematic review.

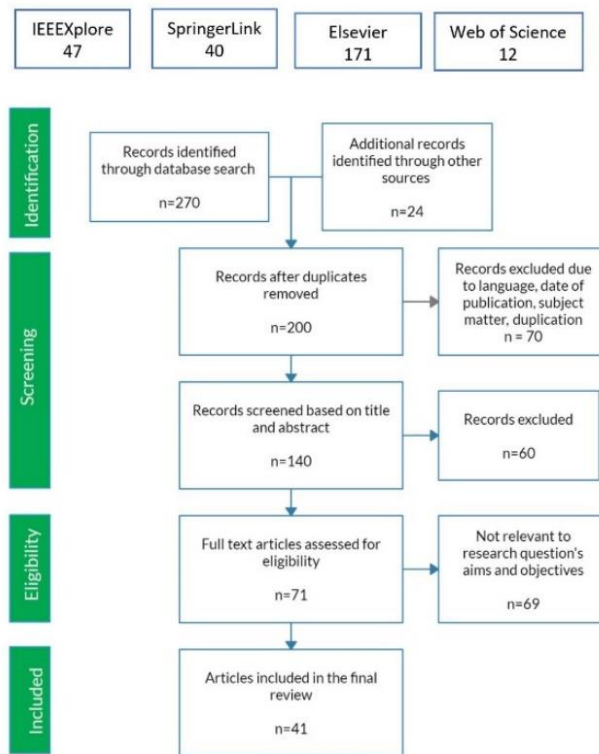


Fig 1. PRISMA flow diagram

Table 3. Selected papers objective

Code	Title	Database	Year	Viewpoint	Authors	Objective
P1	Worldwide annual optimum tilt angle model for solar collectors and photovoltaic systems in the absence of site meteorological data	Elsevier	2021	VP3	Chinchilla, M.; Santos, D.; Carpintero, M.; Lemon, L.	They provide several models to accurately calculate the optimal annual tilt angle for solar PV arrays or solar collectors, anywhere in the world. [4]
P2	Justice in solar energy development	Elsevier	2021	VP1	Heffron, R.; Halbragge, S.; Karner, M.; Obeng, N.; Sumarno, T.; Wagner, J.; Weibelzahl, M.	The research highlights that the development of solar energy has legal and economic benefits that have not yet been sufficiently explored. [9]
P3	Replacing natural gas with solar and wind energy to supply the thermal demand of buildings in Iran: A simulation approach	Elsevier	2021	VP3	Noorollahi, Y.; Khatibi, A.; Eslami, S.	They found a reliable solution to replace natural gas with solar or wind energy on a national scale using a simulation approach. [25]
P4	Design and experimental study of a solar CPV system using CLFR concentrator	Elsevier	2021	VP3	Wang, G.; Shen, F.; Wang, F. Chen, Z.	They describe a concentrating solar photovoltaic (CPV) system with a compact linear Fresnel reflector concentrator (CLFR) and the solar concentration processes of the four CLFRs are simulated using the MCRT method. [41]
P5	Role of solar energy in reducing ecological footprints: An empirical analysis.	Elsevier	2021	VP3	Sharif, A.; Saeed, M.; Ferdous, M.; Sohag, K.	Evaluate the dynamic impact of solar energy consumption on ecological footprints by applying quantile-on-quantile (QQ) regression in the context of the top ten solar consuming countries. [34]
P6	100 % Clean and Renewable Wind, Water, and Sunlight All-Sector Energy Roadmaps for 139 Countries of the World & Elsevier & 2021 & VP1 & Jacobson, M.;Delucchi, M.;Bauer, Z.;Goodman, S.; Chapman, W.;Cameron, M.;Bozonnat, C.; Chobadi, L.;Clonts, H.;Enevodsen, P.;Erwin, J.;Fobi, S.;	Elsevier	2021	VP1	Jacobson, M.;Delucchi, M.;Bauer, Z.;Goodman, S.; Chapman, W.;Cameron, M.;Bozonnat, C.; Chobadi, L.;Clonts, H.;Enevodsen, P.	They have developed roadmaps to transform multi-purpose energy infrastructures in 139 countries into wind, water and sunlight (WWS) - powered ones. The roadmaps foresee an 80% conversion by 2030 and 100 % by 2050. [14]

	Goldstrom, O.; Hennessy, E.; Liu, J.; Lo, J.; Meyer, C., Morris,				P.; Erwin, J.; Fobi, S.; Goldstrom, O.; Hennessy, E.; Liu, J.; Lo, J.; Meyer, C., Morris, S.; Yachanin, A	
P7	Enhancement of solar energy use by an integrated system for five useful outputs & Elsevier	Elsevier	2021	VP2	Temiz, M.; Dincer, I.	A newly developed solar-based integrated system with a supercritical geothermal, a Brayton cycle gas turbine power plant with heat recovery system and a copper chlorine (Cu-Cl) thermochemical hydrogen production cycle is presented. [39]
P8	Experimental study and numerical validation on the effect of inclination angle to the thermal performance of solar heat pipe photovoltaic/thermal system	Elsevier	2021	VP2	Tao Z.; Wenjie Z.; and Liuya W.; Zhiwei, Y.; Mingke, H	Se construyó un sistema HP-PV / T, donde se manejó experimentalmente el ángulo de inclinación como única variable. In addition, a complete numerical model for the HP-PV/T system was developed and experiments were validated. [38]
P9	Extensive comparison of physical models for photovoltaic power forecasting", journal	Elsevier	2021	VP3	Mayer, M.; Gróf, G.	They propose a physically inspired modeling to calculate expected energy production from numerical weather prediction data. [23]
P10	Worldwide performance assessment of 95 direct and diffuse clear-sky irradiance models using principal component analysis	Elsevier	2021	VP3	Sun, X.; Bright, J.; Gueymard, Ch.; Bai, X.; Acord, B.; Wang, P.	This study examines 95 and 88 popular clear-sky irradiance models to determine their global estimation capability of DNICs and DIFCs, respectively. [37]
P11	Climate change impacts on renewable energy supply	Web of Science	2021	VP2	Gernaat, D.; De Boer, H.; Daioglou, V. et al.	They use integrated assessment and climate models to estimate the effect on key renewable energies. [7]
P12	The effect of tilt angle and orientation of solar surface on solar rooftop miniature system in Bengkulu University	SpringerLink	2021	VP2	Yuliza, E., Lizalidiawati, L. and Ekawita, R.	Examining the potential results of solar mapping using solar panels and current sensors, the system's ability to collect solar energy by placing a solar panel on miniature buildings was evaluated. [44]

P13	The quest for the optimum angular-tilt of terrestrial solar panels or their angle-resolved annual insolation	Elsevier	2020	VP2	Schuster, C.	A technique is proposed to use real and historical solar spectra for the rigorous evaluation of the tilt of a panel at a specific site. [35]
P14	CFD modeling of a thermal energy storage based heat pipe evacuated tube solar collector	Elsevier	2020	VP3	Pawar, V.; Sobhansarbandi, S.	Computational fluid dynamics (CFD) modeling of an ETC heat pipe (HPETC) with and without the integration of phase change materials (PCM) is performed. [27]
P15	Environmental quality effects of income, energy prices and trade: The role of renewable energy consumption in G-7 countries	Elsevier	2020	VP1	Ike, G.; Usman, O.; Alola, A.; Sarkodie, S.	They analyze the effect of renewable energy consumption, energy prices and trade on emissions in the G-7 countries. [13]
P16	Computational simulation as an optimization tool for photovoltaic solar energy generation.	Elsevier	2020	VP3	Imaia, H.; Bósiob, L.; Bertoa, L.; Yamaguchid, N.; Soto, L.	Apply mathematical and simulation models using MATLAB software to a company's solar photovoltaic power generation. [11]
P17	The impact of renewable energy on carbon emissions and economic growth in 15 major renewable energy-consuming countries	Elsevier	2020	VP1	Saidi, K.; Omri, A.	Utilize environmental and growth functions to demonstrate the effectiveness of renewable energy in promoting economic growth and mitigating carbon emissions. [32]
P18	An estimation model based on solar geometry parameters for solar power production	Elsevier	2020	VP3	Lazar, I.; Szegedi, S.; Tóth, T. Csákberényi, J.	A model for estimating solar energy potential that can be used anywhere on Earth is presented. [17]
P19	A cross-country perspective on solar energy in urban planning: Lessons learned from international case studies, journal	Elsevier	2020	VP1	Lobaccaro, G.; Croce, S.; Lindkvist, C.; Munari Probst, M.; Scognamiglio, A.; Dahlberg, J.; Lundgren, M.; Wall, M.	They examine the challenges, barriers and opportunities for active solar systems and passive solar strategies taking into account the interrelated technical and non-technical aspects in ongoing and completed projects. [20]
P20	Development of a new vacuum-based photovoltaic/thermal collector, and its thermal and exergy analyses", journal	Elsevier	2020	VP2	Radwan, A.; Katsura, T.; Memon, S.; Abo-Zahhad, E.; Abdelrehim, O.	A new vacuum photovoltaic thermal collector (VPV/T) is designed and compared with the conventional photovoltaic collector. [28]

					Serageldin, A.; Elmarghany, M.; Khater, A.; Nagano, K.	
P21	Regression analysis to design a solar thermal collector for occasional use	Elsevier	2020	VP2	Ciulla, G.; Dámico, A.; Lo Brano, v.; Buscemi, A.	They propose a set of simple and reliable correlations that allow the determination of the best tilt angle for monthly or seasonal use. [3]
P22	Evaluation of the Peak-Sun Hour on a Tilted Surface in the City of Juliaca	IEEE xplore	2020	VP2	Tito, U.; Quispe-Huaman, L.; Vilca-Huayta, O.	The calculation of the Pico-Sun Hour is the main objective of this work. For this purpose, the global solar radiation incident on an inclined surface is considered, and it is determined by daily, monthly and annual solar periods.
P23	Energy Forecasting: A Review and Outlook & IEEE Open Access Journal of Power and Energy	Elsevier	2020	VP1	Hong, T.; Pinson, P.; Wang, Y.; Weron, R.; Yang, D.; Zareipour, H.	This article provides a brief review of influential energy prediction articles; summarizes research trends; discusses the importance of reproducible research and identifies six valuable open data sources; makes recommendations on publishing high-quality research articles. [10]
P24	Solar photovoltaic interventions have reduced rural poverty in China	Web of Science	2020	VP1	Zhang, H., Wu, K., Qiu, Y. et al	They propose several policy recommendations to sustain progress in China's efforts to deploy photovoltaics to alleviate poverty. [45]
P25	Renewable energy for sustainable development in India: current status, future prospects, challenges, employment, and investment opportunities	SpringerLink	2020	VP1	Kumar. C.; Majid, M.	The aim to present important achievements, prospects, projections, electricity generation, as well as investment and employment challenges and opportunities due to the development of renewable energy in India. [16]

P26	Forecasting the RES generation in developed and developing countries: a dynamic factor model approach	SpringerLink	2019	VP1	Romano, A.; Scandurra, G.; Carfora, A.; Ronghi, M.	Research the path to cleaner generation systems, based on forecasting the spread of renewable production in developing countries. [31]
P27	Mathematical model development and optimal design of the horizontal allglass evacuated tube solar collectors integrated with bottom mirror reflectors for solar energy harvesting	Elsevier	2019	VP2	Mao, Ch. Li, M.; Li, N. Shan, M. Yang, X.	Proposes a conceptual design of an integrated solar collection unit consisting of horizontal evacuated tube solar collectors and bottom mirror reflectors. [22]
P28	Simulation of Energy Input to Solar Panels & IEEE Xplore, & 2019 & VP3 & Platonova, E. V.; Toropov, A. S.; Tuliko, A. N.	IEEE Xplore	2019	VP3	Platonova, E. V.; Toropov, A. S.; Tuliko, A. N.	The article reviews the methods of evaluating the energy delivered to the surface of solar panels and a technique for estimating the solar energy reaching the surface of the panels is developed. [26]
P29	Standard of reference in operational day-ahead deterministic solar forecasting	Elsevier	2019	VP2	Yang, D.	Three classes of commonly used reference methods are studied: climatology, persistence and their linear combination, in a daily solar forecast scenario. [43]
P30	Simulation Approach to Determine Position of the Fixed Installed Deployable Solar Panel	IEEE xplore	2018	VP3	Septanto, H.; Sudjana, O.	Proposes a simulation-based method to determine the location (position) of the deployable solar panel system installed such that maximum power can be provided. [36]
P31	Analysis and Positioning of 2D Solar Panel & Elsevier & 2018 & VP2 & Lohar, S.; Hirpara, R.; Kalsara, T.; Patil, S. & They develop a system where the location of the place where the installation of solar panels is required is searched in Google Maps and processes that information to create a solar analysis of that location. \cite{Lohar8537321}\	Elsevier	2018	VP2	Lohar, S.; Hirpara, R.; Kalsara, T.; Patil, S.	They develop a system where the location of the place where the installation of solar panels is required is searched in Google Maps and processes that information to create a solar analysis of that location. [21]

P32	Effect of light scattering on the performance of a direct absorption solar collector	SpringerLink	2018	VP2	Won, K.; Lee, B.	They investigate the effect of dispersion on the thermal performance of the direct absorption solar collector(Dasc) using plasmonic nanofluid as working fluid. [42]
P33	Analysis and Positioning of 2D Solar Panel	IEEE xplore	2018	VP2	Sanjay Lohar; Ridhesh Hirpara; Tushar Kalsara; Sharvari Patil	The objective of this study is to show a pictorial view of the solar panel installation with a 2D representation in a company, and to calculate the number of panels needed to satisfy the energy requirement. [21]
34	CFD Simulation of Enhancement Techniques in Flat Plate Solar Water Collectors	SpringerLink	2017	VP3	Hassan, J.; Qussai J.; Mohammed, F.	It is a numerical study of the thermal behavior of modified flat plate solar water collectors. [8]
P35	A review of sustainable energy access and technologies for healthcare facilities in the Global South	Elsevier	2017	VP2	Franco, A.; Shaker, M.; Kalubi, D.; Hostettler, S.	An optimization was performed to determine the optimal position of the solar collectors according to the Generalized Reduced Gradient Algorithm (GRG2) which is commonly used to optimize nonlinear problems. [6]
P36	Optimum solar power generation using Tamil calendar	IEEE xplore	2017	VP2	Kaliraja, T.; Manickam, J.	This work is based on optimizing the power generation by rotating the panel according to the Tamil calendar. The power generated after panel rotation and the power generated without rotation are compared. [15]
P37	Optimal solar panels positioning for Beirut	IEEE xplore	2016	VP2	Sassine, E.	The optimal position of the solar sensors located in Beirut is studied in 3 configurations: constant optimal angle; monthly variable tilt angle; and solar sensors with a solar run tracking system. [33]
P38	Optimum tilt and azimuth angles for fixed solar collectors in South Africa using measured data	SpringerLink	2016	VP2	Le Roux, W.	They calculate the annual solar insolation on fixed collectors at all

						possible installation angles, using SolTrace software for validation. [18]
P39	Numerical Analysis of Heat Transfer Performance of Flat Plate Solar Collectors	Elsevier	2015	VP3	Rangababu, J.A.; Kiran Kumar K.; Srinivasa Rao, S.	A numerical and thermodynamic analysis is performed to understand the performance of the solar flat plate collector (SFPC) in order to improve its performance. [29]
P40	Optical performance of inclined south–north axis three-positions tracked solar panels	Elsevier	2015	VP3	Zhong, Hao, Guihua Li, Runsheng Tang, and Wenli Dong.	The optical performance of solar panels is theoretically investigated with a new solar tracking technique based on the proposed mathematical method and monthly horizontal radiation
P41	Modelling and analysis of the effect of different parameters on a parabolic-trough concentrating solar system, journal	Elsevier	2015	VP3	Islam, M.; Hasanuzzaman, M.; Rahim, N.; Ren, X.	This paper simulates and analyzes the design of a parabolic trough concentrating solar system [12]
		Elsevier	2021	VP3		

3. RESULTADOS

A. Literature Review

Below is a summary of the selected works, in relation to the questions that were raised in the methodology section.

Access to reliable, affordable and sustainable energy is essential for improving living standards, development and economic growth. [6] the seriousness of the problems of air pollution, climate and energy security around the world requires a massive and almost immediate transformation of the global energy infrastructure towards 100% clean and renewable energy that produces zero emissions. [14]. Solar energy as a renewable source has the potential to reduce the ecological footprint.

Studies by Ike et al [13] point out that the consumption of renewable energy is directly linked to the reduction of pollution in the industrialized countries of Europe. Likewise Saidi & Omri [32] claim that the energy efficiency of renewable energies mitigates carbon emissions and expands economic growth in the short and long term.

Rangababu & Kiran [29] presents a method for evaluating the performance of the flat plate solar collector (SFPC) in terms of thermal efficiency. The evaluation is carried out in an analytical, numerical and experimental way. Due to its higher thermal conductivity, CUO-based SFPC is found to offer higher uptake efficiency compared to Al₂O₃-based and water-based SFPC. It is also observed that the increase in entropy generation is proportional to the intensity

of solar rooting. Therefore, performance can improve if irreversibility's are minimized. The procedure for simulating the SFPC is performed in ANSYS Fluent. The temperature of the working fluid along the length of the riser increases and this increase is higher for nano-Fluid based SFPC.

Lazar et al [17] the solar energy potential estimation model they propose, shows an accuracy of 90% in relation to incoming solar radiation based on the available data. Differences of this value can be found only in tropical and subtropical zones with 80% -85% agree, which shows that the model provides a good estimate of the amount of solar energy available in different regions in the middle and high latitude zones of the Earth based on the parameters of solar geometry. At the same time it provides less accurate estimates for low latitudes, as it still cannot handle the effects of cloudiness.

Schuster [35] shown in fig 2. (a) how the incident solar energy is dispersed over the angles of incidence α for an inclined surface; α is defined as positive if measured from the normal of the surface to the position of The Sun (b). The ANRANIP depends on the angular inclination β plano of the plane, measured from the ground of the Earth, and is normalized to its global maximum value.

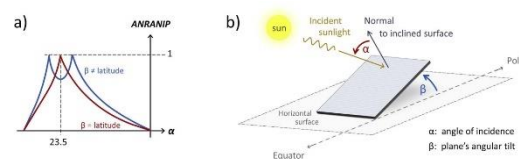


Figure 2: The angle-resolved annual insolation profile (ANRANIP).

Ubaldo et al [40] have found a hourly peak of sun for a plate inclined at 16° , in the period from January to December of 2018, obtaining an annual average of 5.41 for Juliaca, which coincides with what was obtained in Cúcuta (Colombia) and in Cuitláhuac (Mexico). An annual average of the optimum inclination angle of -15.44 was also obtained for the efficient operation of the photovoltaic solar panels.

Yuliza et al [44] show that the energy collection capacity of each solar panel is strongly influenced by the inclination of the roof and the orientation of the surface of the solar panel towards the sun. Solar panels with a smaller tilt angle can produce a higher average power. In addition, cloud cover also affects the performance of solar panels in electricity production. The location of the solar panels was adjusted in relation to the inclination and orientation of the roof of the building.

Chinchilla et al [4] has found that, due to the lack of access to meteorological data in many parts of the world, or the small size of the installation, it is desirable for designers or users of solar collectors or photovoltaic (PV) systems to have access to a mathematical model to determine their optimal orientation. He has proposed a simple but accurate polynomial model to calculate the optimal annual angle of inclination, at any latitude, which maximizes the annual incident solar irradiance. Accurate estimates of direct normal irradiance (DNIs) and diffuse horizontal irradiance (dihcs) in clear skies are crucial in the evaluation of solar resources [37]. To facilitate the application, the authors suggest the use

of quadratic or cubic polynomial models. These models are considered more accurate to date, due to the size and quality of the datasets used.

Imai, et al [11] in your article proposed to optimize the power generation system solar photovoltaics (pv) of a company with the purpose of contributing to the energy mix and sustainable urban development, through the application of modelling and mathematical simulation with the use of the software MATLAB[®] (version 2018), through the analysis of the meteorological data and the specifications of the system modules, for a period of 12 months.

Platonova et al [26] the article reviews the methods of evaluating the energy supplied to the surface of solar panels. A technique is developed to estimate the solar energy that reaches the surface of the panels. The degree of influence of cloudiness on the input of solar energy for the considered area is identified. Modeling of incoming solar energy for the existing solar power plant showed a higher quality of the developed technique compared to specialized computer programs. The optimal angle of inclination of the solar panel is calculated and the reduction of incoming energy is analyzed when the angle deviates from the optimal value.

Chunliu Maoa, Muran Lib [22] a detailed mathematical model of this unit was developed and an optimal analysis was performed to evaluate the optimal angles of inclination of the collectors and reflectors. Finally, the performance of horizontal vacuum tube solar collectors with and without reflectors

was compared using an improvement index. The optimal inclination angles were obtained in both the heating season and the summer when maximizing the solar energy collected and reducing the solar energy through the use of the design unit. To assess the risk of overheating, the maximum possible reduction of intercepted solar radiation achieved by the design unit was calculated.

Sassine [33] in his article presents a theoretical method for determining Beirut solar irradiation for different panels at any time of the Year (Day and time). It analyzes three optimal configurations: a constant tilt angle, a tilt angle and a solar tracking system. In addition to these configurations, the placement of traditional solar collectors with constant angles of inclination (30° , 45° and 60°), proposes a numerical model which was validated by comparing it with the data of a meteorological file; he determined the optimal position of the solar collectors according to the Generalized reduced gradient algorithm (GRG2).

B. Paper Selection

In Figure 3, it can be seen that, of the 41 scientific articles selected, 16.67% corresponds to point of view 1 (renewable energy), 28.33 % to point of view 2 (optimal capture of solar radiation and finally 55% to point of view 3 (the simulation of solar collectors)

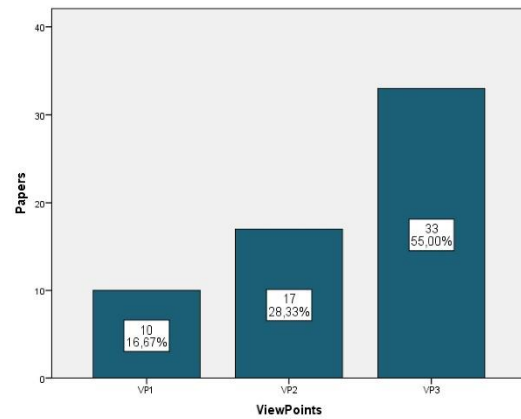


Figure 3: works selected by classification

In Figure 4, you can see an analysis in percentages of publications by years, it has been considered in higher percentage publications in the years 2020 and 2021 which corresponds to 31.71% and 29.27%.

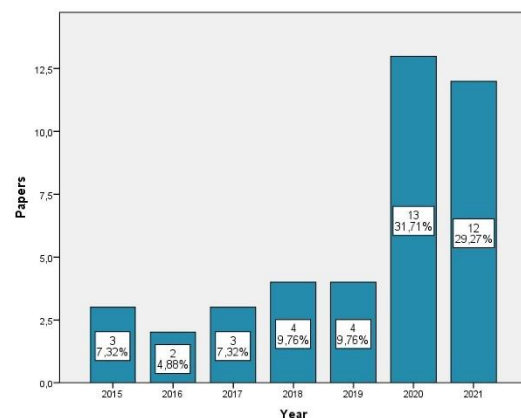


Figure 4: Years of analysis

Figure 5 shows the number of articles that were selected according to the analysis phases: included, eligibility, screening identification, in each of the databases: IEEExplore, SpringerLink, Elsevier, Web of Science.

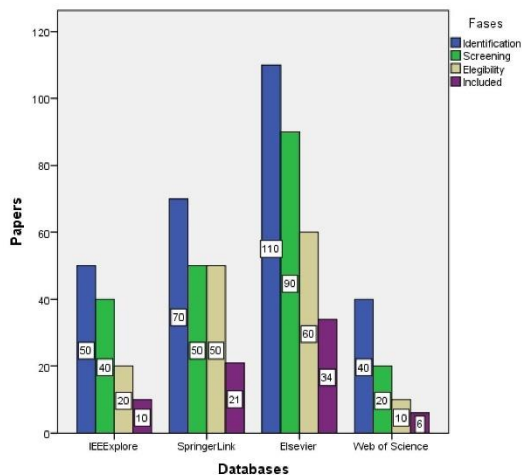


Figure 5: Phases analysis

4. DISCUSSION

what is the importance of renewable energy?

Fluctuating oil and coal prices and concern about global warming have significantly increased demand for alternative energy. Oil and coal are diminishing resources, which also contributes to significant pollution of the environment with hazardous CO₂ emissions. Alternative energy has focused on wind, geothermal and solar generation. While the availability of oil and coal will be depleted, solar energy is an infinite source of energy without harmful residues such as CO₂.

Solar generation can have a positive impact on energy prices and global warming. As solar power generation increases, some difficult questions about the generation process must be answered. Solar energy unlike other energy is generated in direct current (DC).

Many countries are endowed with enormous resources needed for the production and consumption of renewable energy. However, the ability to tap into sustainable renewable energy sources has been a major challenge, along with the enormous detrimental effect of non-renewable sources on health and the environment.

The cost, pollution and rapid decline of fossil fuels are forcing humanity to look for new energy sources that are environmentally friendly and Renewable, that is, draw on unlimited resources.

Sunlight offers an unrivaled reserve of energy that can be harnessed to boost the production of basic fuels and chemicals to sustain human society in the long term.

Harnessing solar energy as renewable energy is continuously increasing and available every day in an immeasurable amount everywhere, they are among the main interests of many engineers and researchers due to their wide applications and cost reduction, including electricity generation and domestic hot water production.

The use of wind, solar, geothermal, and water would significantly reduce the energy consumption would decrease deaths due to air pollution, create millions of jobs, stabilize energy prices and save billions of dollars in costs related to climate and health care, we should certainly explore and increasing the use of increasingly efficient this type of energy.

for what Angular inclination is the incoming annual solar radiation

(insolation) maximized for a flat surface?

Solar power generation is taking various approaches, the most popular method is to use photovoltaic cells. Photovoltaic cells are matrix-shaped cells that are mounted on solar panels. Photovoltaic cells consist of semiconductor materials that help in the generation of electric charge. The solar cell with the help of its semiconductor nature will convert the photonic energy of the sun into an electron. The electrons created by this process can maintain an electric charge and can easily flow through a Medium resulting in electric current.

In relation to solar panels there are two types of mounting systems: fixed system and tracking system. The fixed system consists of stationary solar panels. These panels are fixed to the assembly station and cannot be moved. This system is inefficient because the panels are not able to track the movement of the sun. This means that the solar panels only receive the maximum amount of sunlight for a few hours, the solar panel needs to track the movement of the sun and direct the photovoltaic cell towards the sunlight.

The optimum angle of inclination of the collector surfaces of a solar system is determined by many factors, including the incident radiation at the site of the installation and the solar sky, which is influenced by the shadow of objects that cannot be eliminated.

Being able to accurately forecast how much solar energy reaches the Earth's surface is essential for calculating performance levels related to solar energy systems, such as solar water

heaters, photovoltaic systems, solar concentration, building constructions with a view to better thermal insulation adapted to the local climate and also for heating houses and rooms by solar energy.

Currently, some researchers use nanofluids as a working medium in SFPCS to increase the overall heat transfer coefficient, as well as have found suitable angles of inclination for the location of solar panels that provide better solar radiation, being crucial to investigate the angles formed between the sunlight and the surface of the Earth in question, caused by the geometry of the sun to move the panel between the direction of direct solar irradiance.

As mentioned in the literature, solar radiation is strongly related to the location of the solar collector, so the model that will be used for the simulation of the solar collector of flat plates, will be validated with the studies found, and this will allow to evaluate the feasibility of a photovoltaic system in terms of useful energy production.

To achieve maximum energy captured by the solar panel, The Sun's Rays must be perpendicular to the surface of the solar panel at every instant during the day. The orientation of a solar panel is defined by two angles: the angle of inclination, which is the angle between the panel and the horizontal, and the azimuthal angle, which is the angle between the south and a projection of the normal surface of the panel on a horizontal plane. The angle of incidence of solar rays is different in latitudes, using the same angle of inclination for solar collectors will not help to get the

best capture of thermal energy. Then it is interesting to evaluate the effectiveness of traditional configurations of solar collectors with a constant angle of inclination and an azimuth angle of 0° (south orientation).

The research works described above will serve as a reference for this research study, which contribute to the environmental energy and economic aspects of our country.

what results would be obtained by using software applications in the simulation of input and output data?

Computer simulation as an optimization tool in the generation of solar photovoltaic energy proves to be an effective practice of resource management applied in the urban context, in order to contribute to the achievement of the Sustainable Development Goals.

The design using mathematical modeling has been used mainly in solar collectors. The effectiveness of this procedure lies in the simplification of the model, using differential equations whose solution is made by numerical methods and computer programs with a high degree of complexity, but highly efficient results are obtained and that in our country very few have been applied, due to the difficulty of the physical and meteorological conditions.

Simulation of photovoltaic systems is useful for: performing a detailed analysis of system performance under real field operating conditions, investigating the impact of different load profiles, checking system sizing, determining the ideal size of photovoltaic components,

evaluating the feasibility of a photovoltaic system in terms of energy production and system life cycle cost, and verifying process optimization options to increase energy production and energy efficiency.

Reviewing the literature modeling of incoming solar energy for the existing solar power plant has shown a higher quality of the developed technique compared to specialized programs. Some authors have calculated the optimal angle of inclination of the solar panel and have analyzed the reduction of incoming energy when the angle deviates from the optimal value. It should be understood that the application of the modeling of the solar energy input allows to obtain daily graphs of the generation with the Daily graphs of the electric charge which is optimal for consumers.

With the solar collector simulation it is intended to make known the usefulness of mathematical models as well as why photovoltaic energy should be used for commercial, governmental and individual use. It is expected to provide an excellent teaching and demonstration tool for all sectors and allow broad access to agencies, businesses and individuals to inspire them to incorporate solar energy.

5. CONCLUSIONS

Following the PRISMA guidelines of empirical studies published specifically in the English language, a critical and reproducible summary of the results of the available publications on the

simulation of solar thermal collectors was obtained.

It is important that our society focuses on renewable energy not only for our carbon footprint, but also to decrease our dependence on resources that are depleted over time. Therefore, photovoltaic power generation can undoubtedly be considered a fundamental technology to overcome global environmental and energy problems.

It is up to the Ecuadorian State with individual and collective social support to promote the use of clean and non-polluting and/or low impact alternatives. We must promote the efficient use of energy in all its forms, increase energy security, build a culture of sustainability and energy efficiency, contribute to climate change mitigation and ensure the right of people to make informed decisions.

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