León, Jhon A. Pabón; Mendoza, José O. García; Abril, Sofia Orjuela

Article

Overview of policies for the generation from renewable energy focused in central tower concentrating solar power

IJEEP

INTERNATIONAL JOURNAL OF ENERGY ECONOMICS AND POLICY

EJ EconJournals

ISSN: 2146-4553

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

EconJournals

International Journal of Energy Economics and Policy, 2020, 10(4), 545-552.

Overview of Policies for the Generation from Renewable Energy Focused in Central Tower Concentrating Solar Power

Jhon A. Pabón León[1]*, José O. García Mendoza[2], Sofia Orjuela Abril[2]

[1]Grupo de Investigación en Gestión y Organizaciones (GYO), Departamento de Ciencias Administrativas, Universidad Francisco de Paula Santander, Cúcuta - 540001, (Norte de Santander) Colombia, [2]Grupo de investigación GEDES, Departamento de Ciencias Administrativas, Universidad Francisco de Paula Santander, Cúcuta - 540001, (Norte de Santander) Colombia.
*Email: jhonantuny@ufps.edu.co

Received: 22 March 2019 **Accepted:** 15 May 2020 **DOI:** https://doi.org/10.32479/ijeep.9820

ABSTRACT

Nowadays, it does exist a general awareness about climatic change and its implications for the environment across the world. The Paris agreement (2015) agreed that greenhouse gas emissions should be reduced to 0%. For this reason, many countries are in search of innovation, development, and application of energy generation systems from renewable resources (solar, geothermal, hydraulic, wind), which are capable of covering the great trail that fossil fuels (oil) leave. Colombia has committed to achieving a reduction of 20% in the emission of greenhouse gases by 2030. To accomplish this common worldwide objective, the governments of the different countries have established energy policies and incentives that allow the transition of the economy based on fossil fuels to clean energy. Countries such as the USA, Mexico, Spain, Japan, Australia, and Germany have implemented solar plants (CSP) coupled with thermodynamic cycles such as the supercritical Brayton, where the working fluid is in supercritical conditions. Colombia does not possess a great development in this sector even though it has a huge potential, especially the north part of the country, for the implementation of solar energy. Just as some countries, so too, Colombia can improve its economy through the use of renewable energies if it implements more supporting policies. There are already studies and researches that insists on the previous statement. One of those, which includes the simulation of a solar plant, estimated that a plant in Barranquilla could supply about 50% of the demand with an approximate LCOE of 9.76 cents/KWh. This work shows the different national and international policies, measures, regulations, projects, and laws taken to encourage this change as well as to show the energy potential that has the solar power concentrating solar power (CSP) as an option to diversify the energy matrix of Colombia.

Keywords: Alternative Fuels, Environmental Pollution, Energy Policy, Renewable Energy, Supercritical Brayton
JEL Classifications: L78, L90, O31, Q20

1. INTRODUCTION

The emission of greenhouse gases is the main cause of the deterioration of the ozone layer and the increase in the planet's temperature. Due to their composition, these gases can not leave the atmosphere, causing accumulation and flooding by rising sea levels. In addition, these gases have been shown to be harmful to human health, causing respiratory and heart problems, research has detected that a temperature increase equivalent to 2 degrees would produce an imbalance at the global level. Which would cause flooding in cities due to the accelerated melting of the poles (UN-FCCC, 2015; Tak et al., 2012). The International Energy Agency (IEA) showed that if the current trend of fossil fuel consumption for energy generation is not replaced, the emission of greenhouse gases is expected to increase the global temperature by six degrees Celsius (IEA).

Approximately 90% of the polluting emissions from thermoelectric power plants, industry, and the transport sector are residual products of the energy generation process (thermal, electrical) (IPCC, 2014; Caineng et al., 2016; Kalghatgi, 2018). Consequently, the transition of power generation from traditional fossil fuels to renewable energy is a necessary step for the sake of the environment.

Actually, there are several studies where the feasibility of using energy generation systems from clean energy (solar, geothermal, hydro) is demonstrated. And, as a result, these systems have decreased greenhouse gas emissions by being not dependent on fossil fuels (Masjuki et al., 2016; Qian et al., 2016; Bae and Kim, 2017; Carbot et al., 2017; Khandal et al., 2018; György and Bereczky, 2018). Many countries encourage the use of efficient systems with less environmental impact and have implemented policies that decrease the emissions of greenhouse gases according to the government policies of countries such as Germany, Japan, and the United States.

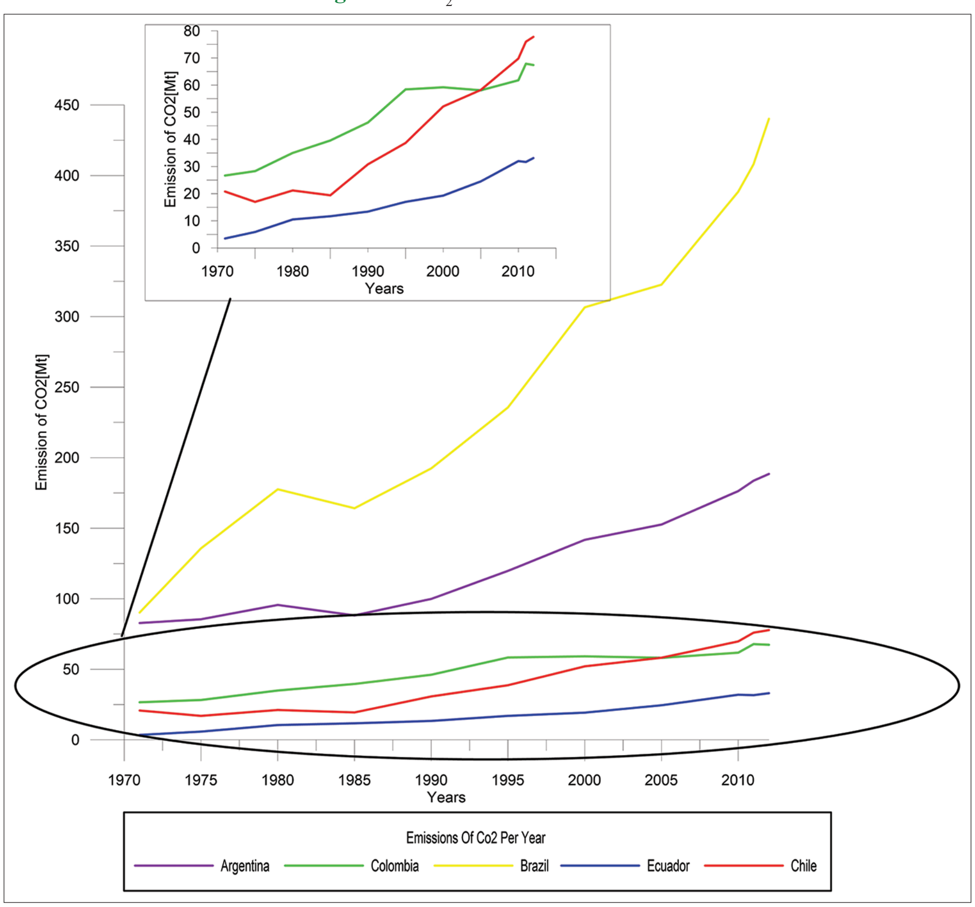
By 2050, greenhouse gas emissions must be reduced by 65% to avoid the increase of the global temperature (Gondal, 2016). Furthermore, Latin America has implemented fiscal and financial policies that allow the accumulation of greenhouse gas emissions. Research has shown that an effective way to achieve energy diversification is the implementation of new taxes that encourage the use of renewable energy systems with less ecological impact.

Latin American countries such as Brazil, (Ministerio de Minas e Energia, 2018.), Colombia (PARATEC, 2019), Argentina (CNEA, 2020.) and Ecuador (Agencia de Regulacion y control de Electricidad, 2020.) have included environmental policies conducive to implementing environmentally friendly systems in their development plan, to reduce CO_2 emissions, as shown in Figure 1. (Washburn and Pablo-Romero, 2019; Aquila et al., 2017; Apergis and Payne, 2011; Koengkan et al., 2019). However, in recent years, there has been a decrease in energy diversification in South America due to the fact that environmental policies have not been severe enough (Arango-Aramburo et al., 2020).

Many types of research have shown that the energy optimization of thermodynamic cycles for power generation maximizing their performance without having a negative impact on the environment. The organic rankine cycle is a variation of the Rankine cycle where the working fluid is an organic fluid like different types of refrigerants such as nitrogen, methane, etc. These fluids have a low boiling point with the purpose of recovering heat from a low-temperature source (Chen, 2010). Another cycle also studied is the supercritical Brayton cycle, which consists of bringing the working fluid, normally CO_2, to critical conditions (32°C and 7.4 kPa), which are much lower compared to water. That makes the components to be more compact and smaller in size, the supercritical Brayton cycle with carbon dioxide allows the use of renewable resources such as solar radiation (Fontalvo et al., 2013; Padilla et al., 2015).

The concentrating solar power (CSP) in the last decade has had a great development because it allows the integration of the Brayton supercritical cycle and the use of CO_2 as a working fluid and the possibility of using solar concentrators (parabolic, tower receivers, heliostats, etc.), thus using the Solar radiation as clean energy for power generation. any studies have shown that cycles in some configuration have high thermal performance and use of energy. (exergy) (Fontalvo et al., 2013; Padilla et al., 2015; energy global;

Figure 1: CO_2 emissions worldwide



Source of Data: Prepared by the authors based on data from (IEA, 2018)

Martín et al., 2015). Some countries with thermal solar plants are EEU (1.7 GW), Spain (3.8 GW), China (0.5 GW), United Arab Emirates (0.7GW) (Figure 2). For example, in 2022, China is expected to increase 11% of the generation capacity through new CSP plants under construction as Morocco.

This study presents a global overview of government policies and projects focused on the use of cycle supercritical Brayton integrated with solar collectors. A sustainable alternative is presented through primary sources of clean and renewable energy. The objective of this document is to show the energy potential based on the cycle supercritical Brayton economy in Colombia, which has a high potential in clean energy.

Colombia is a rich country in water resources due to its multiple rivers (Magdalena, Cauca, Orinoco, Sinu). Therefore, 63% of the national energy is generated by hydroelectric plants, 29.4% by fossil fuel-based energy sources and only 0.2% are generated from renewable energy (UPME, 2018; PARATEC, 2019).

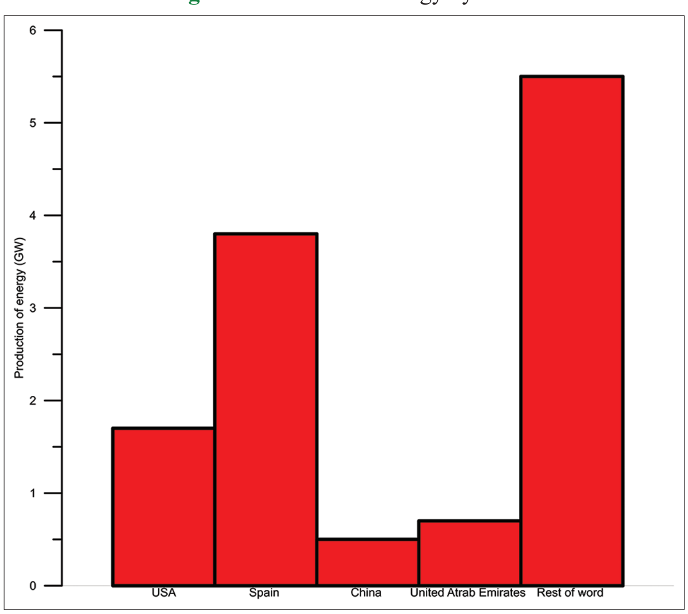
2. NATIONAL AND LATIN AMERICAN CONTEXT

2.1. Energy Policies in Colombia

Colombia, through the ministry of energy and mines, has formulated and adopted policies, plans, programs, projects, regulations in accordance with the guidelines of the national government in order to ensure energy efficiency and quality (DPN, 2018). In addition, the MME created law 143 of 1994 and by decree number 1258 of 2013 that supports the formulation and implementation of public policies for a sustainable future (MME.co, 2019).

One of the programs with the greatest impact is the program for Rational and Efficient Use of Energy and Non-Conventional Source (PROURE), which was created by Decree 3683 of 2003 together with Non-Convectional Energy Sources, which seeks to encourage the use of renewable resources for energy generation, 0.2% (Solar, Wind) of energy's Colombia comes from renewable resources (CIURE) (DPN, 2018; UPME, 2018).

Figure 2: Generation energy by CSP



Source of Data: Prepared by the authors based on data from (Renewable Now, 2019)

The Indicative Action Plan (PAI) 2017-2022, which controls the Program for the Rational and Efficient Use of Energy and Non-conventional Sources (PROURE), aims to increase global energy efficiency by 2022, which reaches 9.05%, relating changes in the transport and industrial sectors (UPME, 2019).

2.2. CSP's System in Latin America

Colombia is a rich country in renewable resources such as water, wind, and solar irradiance. However, only 0.2% of the total projected energy is generated by renewable energy. That is a low level in comparison to other countries like Spain, Brazil, in which 22% of the total energy produced comes from renewable energy and Chile that has 18.6% of the total energy generated by renewable energies, and 10% is from solar radiation equivalent to 0.681 GW.

The previously mentioned countries have other advances in contrast to Colombia. Chile, for example, has implemented photovoltaic systems, TES (thermal storage system) and CSP, for production (Servert et al., 2014; Valenzuela et al., 2017). And Spain has more than 40 CSP with a total production equal to 3.8 GW (Renewable Energy, 2019). In addition, this country has installed the largest energy capacity in the CSP Word with more than 500 GW of capacity. Spain's Policies have incentives for development and investment with the creation of financial and fiscal incentives through its renewable energy plan (PER), which was created in 1999 (IDEA, 2000) and changed every period of the year. In fact, currently, Spain has a goal of producing 4800MW (Martín et al., 2015).

Latin American countries such as Brazil have implemented concentrated solar power (CSP) systems. This country has studied how the national policies and tax incentives have allowed the development of new generation systems (Malagueta et al., 2013), for example, Table 1 shows a direct normal irradiance (DNI) average of 5.0 KWH/day for Brazil. In order to maintain and increase that development, Brazil has an auction-based incentive policy to promote the generation and utilization of renewable energies (Malagueta et al., 2013). Despite these incentives and the huge potential of this country for the solar-based energy, the majority of the electric power is actually generated in hydroelectric plants.

At present, Brazil has pilot CSP plants thanks to its topographic conditions, such as the DNI (Malagueta et al., 2013.). That is

Table 1: DNI of principal cities in Brazil

Cities	DNI [kWh/m^2/day]
Santa Catarina	5.0
Acre	4.5
Amapa	5
São Paulo	6

Source of Data: Prepared by the authors based on data from (Geospatial Toolkit, 2019) shown in Table 1, where talks about four different cities in Brazil, in comparison with Table 2, where are presented the DNI of four different cities in Colombia. The previous analysis was done with the objective of explaining the similar behavior that radiation handles in these two Latin American countries. As observed in the difference between both cities, Colombia could enter the phase of study for the implementation of plants CSP in cities with higher solar radiation such as Valledupar.

2.3. CSP Policies in Colombia

Currently, Colombia does not have an established policy for the regulation for the implementation of CSP's plants as an alternative energy source. However, exist laws and resolution that can be applicated in the system of CSP are:

- Law 697 of 2001, Ministry of Commerce, Industry and Tourism, "Through which the rational and efficient use of energy is promoted, the use of alternative energy and other provisions are issued" (Ley 697, 2001).
- Law 99 of 1991, Ministry of Envioremt, "establishes the mechanisms for the fulfillment of the environmental goals in relation to the mitigation of impacts" (Ley 99, 1991).
- Law 629 of 2000, Ministry of Commerce, Industry and Tourism, "Promote sustainable development and policies to promote efficiency and sustainable development" (Ley 629, 2000) (Ley 1715, 2014).
- Law 1715 of 2014, The law 1715 has as its main objectives to encourage, promote energy efficiency and the use of unconventional renewable energy sources, also promote the use of agricultural biomass, energy from agricultural residues, and forest crops (Ley 1715, 2014).
- Law 788 of 2002 Declares the exemption to income tax on income from the sale of energy generated from agricultural waste, wind sources, and biomass (Ley 788, 2002).
- CREG Resolution 005 of 2010, regulates the measurement, energy audits, sale of surplus, and equivalent performance (REE) (Resolucion CREG 005, 2018).

3. EUROPEAN, ASIAN AND AUSTRALIAN CONTEXT

The power sector makes an important contribution to the economy of a country (Sharma et al., 2012). That is the reason why many developed countries make efforts to encourage the application of renewable energy sources and technologies. In fact, by 2017, more than 70 countries and thousands of cities in the world had adopted renewable energy policies and laws to mitigate the effects of climate change (Sahu, 2015).

In the actuality, grid-connected photovoltaic is the fastest growing alternative power generation technology (Malagueta et al., 2013).

Table 2: DNI of principal cities in Colombia

Cities	DNI [kWh/m^2/day]
Monteria	3.67
Valledupar	5.88
Barranquilla	4.87
Cartagena	4.58

Source of Data: Prepared by the authors based on data from (Geospatial Toolkit, 2019)

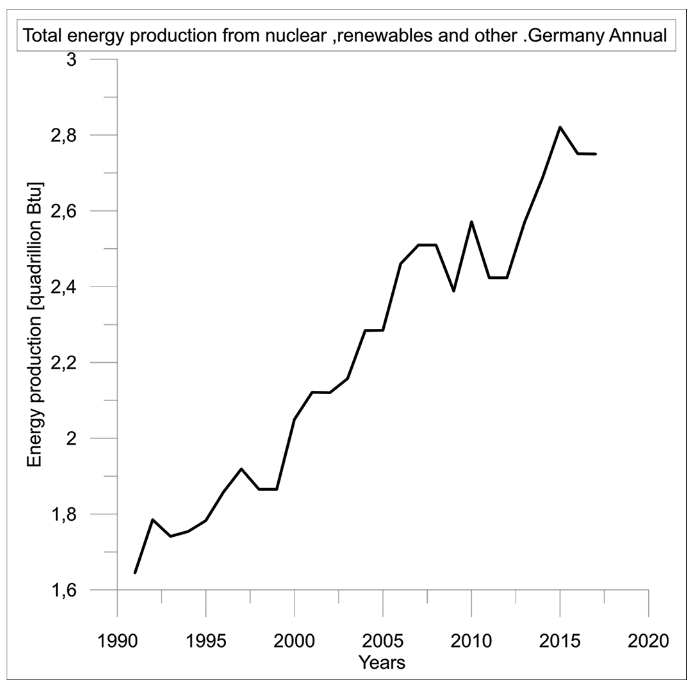
Due to that, several countries have taken the initiative by setting laws and policies to promote it. Each government had considered parameters like cost, potential, scalability, efficiency a lifetime before the implementation of the following policies, laws, and decrees (Kyriakopoulos and Arabatzis, 2016).

3.1. Polices in Europe

Just like all the European countries, so too, Germany uses different policies to increase the share of renewable energy, reduce CO_2 emissions and reduce the dependency on fossil fuels (Hosenuzzaman et al., 2015). This country started its renewable policy after the oil crisis in 1974 (Sahu, 2015) when were established measures such as regulating prices and supporting investment in this sector. In order to promote and incentivize the renewable energy sectors, the German government has adopted laws and politics such as Electricity laws and Renewable laws in 2000 that guaranteed subsidies and loans to local producers and mandated the purchase of generated electricity by companies of electric utilities (Sahu, 2015). Consequently, many of Germany's companies, backed by the local government, have grown to be part of the top global renewable energy producers (Sahu, 2015). The increment in the energy generation with CSP systems across the years showed in Figure 3, confirms the previous statement.

Italy has adopted a National Renewable Energy Action Plan in which is established a target of sharing 26.4% of electricity from renewable energy (Sahu, 2015). Through the implementation of laws and policies such as green certifies, feed-in tariffs, market premiums, tax-based policies, and reverse auctions for renewable energy generation, heating or cooling, and transportation. They had nearly reached their goal by the end of 2011, almost eight years before scheduled (Sahu, 2015).

Figure 3: Generation energy by CSP



Source of Data: Prepared by the authors based on data from (US, 2020, Energy Information Administration, based on German Association of Energy and Water Industries)

By 2030, France plans to increase renewable energy shares by 35% and more than 55% by 2050 (Sahu, 2015). The law that has had more impact on the development of renewable energy, which implemented an incentive regime, was introduced in 2000 (Sahu, 2015). However, the support policies that permitted the growth of solar energy was just introduced in May of 2011 (Sahu, 2015). Besides, the French policy is based on providing feed-in-tariffs tax reductions and subsidies.

In Spain, the development in renewable energy (especially solar and wind energy) began since 1998 by the feed-in-tariffs support policy introduced in the Royal Decree 2818/1998, being called the Special Regime (RE), that offered an incentive to solar based energy (Malagueta et al., 2013). This law adjusted in 2004 and 2007 (Sahu., 2015) even though the real development stared until 2006 because the support levels were relatively low. Due to the feed-in-tariffs, Spain turned into a world's leader in solar PV installed capacity in 2008 (Sahu., 2015). As is shown in Figure 4, wind and solar energy actually have a significant percentage of the total energy generated in the country. This kind of policy has proven to be one of the most efficient to incentivize renewable energy. Due to that, it is one of the most used, not only in Spain but in the United States, too (Malagueta et al., 2013).

3.2. Polices in the USA

Federal and state governments in the USA have established some financial incentives and regulations to promote the adoption of this kind of energy. Those include financial support to de development of this industry in order to minimize the investment cost (Zhao et al., 2011), feed-in-tariffs (previously mentioned), reducing tax and facilitating credits. The reason behind the implementation of those policies is the increasing awareness the climate change that has become a priority due to the huge amount of emissions provided by the combustion of petroleum, coal, and natural gas (Delmas and Montes-Sancho, 2011). Some of the most used regulations that contribute to the cause are Renewable Portfolio Standards, Mandatory Green Power Options, and fuel disclosure rules. In fact, by 2007, all states except Alabama, Alaska, and Mississippi had already established at least one of these three policies (Delmas and Montes-Sancho, 2011). The current distribution of the energy generation in the United States is detailed in Figure 5.

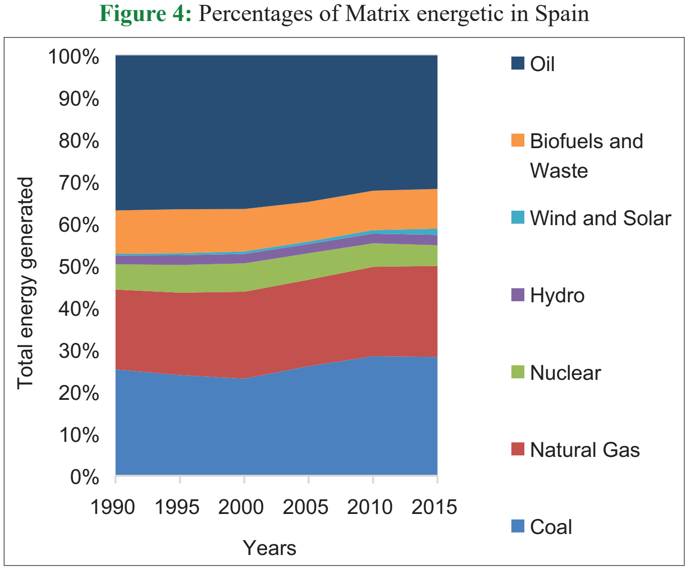
3.3. Polices in Asia

Certainly, the most advanced Asian country in this industry is Japan and China, even though other countries in this continent have also made great policies and projects to encourage the development and utilization of these technologies. For example, thanks to Malaysian policies and incentives, more than 4000 houses have installed solar home systems (Hosenuzzaman et al., 2015).

In order to resolve the problems of its electricity industry, China planned to support power generation based on renewable sources. It was knowing that the main problem was that the supply couldn't embrace the increase in the demand rate (Cherni and Kentish, 2007). The main objective is promoting the development and utilization of renewable energy with a view to protect the environment and increase energy supplies (Schuman and Lin, 2012). China's renewable policy incorporates promoting renewable energy technologies in rural areas and some incentives. The Chinese government also introduced a feed-in-tariffs regulation in order to promote the development of solar energy technologies across the country, which the help of the regulations implemented by the State Regulatory Commission (SERC) and the National Energy Administration (NEA) (Schuman and Lin, 2012).

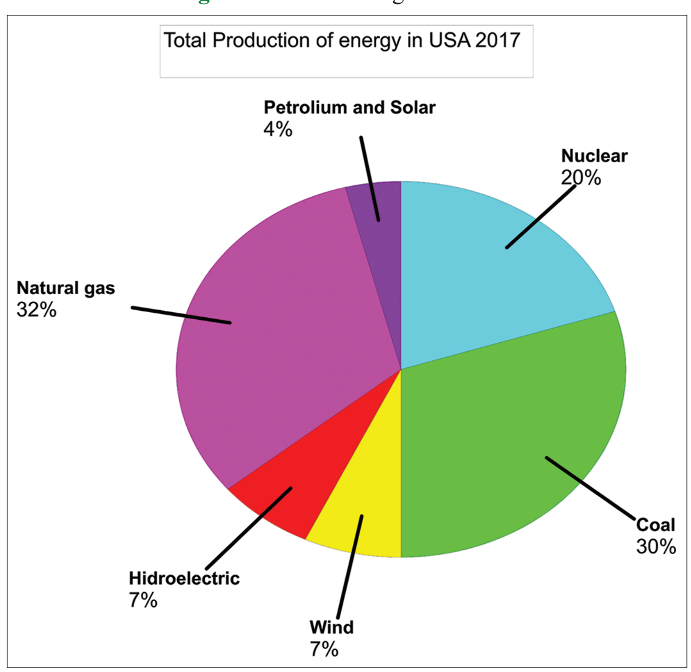
The Building Integrated Photovoltaics subsidy program (BIPV) and The Golden Sun program are the two main subsidies programs in China focused on solar-based power generation. The first one offered a certain stimulus for BIPV and rooftop systems (Hosenuzzaman et al., 2015). And other program includes a

Figure 4: Percentages of Matrix energetic in Spain



Source of Data: Prepared by the authors based on data from (IEA, 2019)

Figure 5: Matrix Energetic of USA



Source of Data: Prepared by the authors based on data from (Popovich, 2018, New York Times) national renewable energy target and local plan to promote this energy, a price regulation system, a feed-in-tariffs system and subsidies of part of the investment cost in the generation of solar power (Sahu, 2015; Schuman and Lin, 2012).

The government of Japan has made projections for renewable energy to be about 25-30% of the power generation by 2030 (Sahu, 2015). They have been increasing the investment in renewable sectors and also have offered subsidies for residences using power generation systems. The ministry of the economy started to promote photovoltaic power through a policy of subsidies for installation, distribution, and technological development for photovoltaic generation power (Sahu, 2015).

The initiatives implemented by the Indian government have caused a great impact on the development of renewable energy, especially solar energy. Some are the Electricity Act in 2003, the National Electricity Policy in 2005, the National Tariff Policy in 2006, The National rural Electrification policies (NREP) in 2006, and Solar Photovoltaics generation-based incentive (Sharma et al., 2012). Some examples of the plan of the Indian government to promote the renewable energies are incentives for grid-connected solar plants, providing suitable measures of connectivity, providing reliable electric energy to households in rural areas with off-grid solar photovoltaic solutions and determining deferential prices to encourage distribution companies of these technologies (Sharma et al., 2012).

3.4. Polices in Australia

This country has a great potential for the implementation of solar energy. Consequently, there are already photovoltaics policies that are related to state-level incentives (Sahu, 2015) and several agencies such as The Australian Renewable Energy Agency and The Solar Flagships program, dedicated to the investment in the development of the renewable sector. Australia also has feed-in-tariffs to promote this industry. However, it is focused on small-scale technologies, which is inconvenient for the medium a large-scale generation (Sahu, 2015). The previous problem not only exists in Australia; besides, it does exist in some European and Asian countries too (Sahu, 2015).

Finally, several countries have already anticipated the inevitable transition to renewable energy resources from traditional fossil fuel sources. Consequently, they have implemented policies, regulations, laws, and projects in order to incentivize the development of renewable sectors. However, these countries are a minority in comparison to all other countries in the world. In fact, a study about the role of social political and economic interest in promoting green electricity states that "about the 80% of the generation of electricity from wind and solar power is concentrated in Germany, Denmark, India, Japan, Spain, and the United States" (Vachon and Menz., 2006, p. 2).

4. CSP INTEGRATING THE SUPERCRITIC BRAYTON CYCLE POTENTIAL IN COLOMBIA

In reality, there are not many studies and projects about the use of CSP plants and the energy potential even though they have demonstrated to be beneficial in other countries. However, the few existing studies confirm the high potential of Colombia, especially the north part of the country, for the implementation of CSP. For example, a simulation of a solar plant in Barranquilla using the SAM method, which is a techno-economic model that allows obtaining the costs of operation, installation of the plant and energy production, shows that the construction of this kind of generation plants can bring positive results to the country depending on some conditions (Guzman et al., 2014). The previous study asserts that a CSP plant located in Barranquilla could generate 50% of the demand of likely 140 GWh, for this city with an estimated LCOE of 9.76 cents/KWh (50Mwe) (Guzman et al., 2014).

The implementation of these plants in Colombia could have a positive impact on greenhouse gas emissions as a source of renewable energy. It is important to highlight the need for this transition in Colombia. The government must adjust and create policies and regulations that allow a raise in the local development for this industry in order to impulse the national economy and benefit the environment. Jimenez, Cadavid and Franco's research (Jiménez et al., 2013) insists the huge potential of the solar energy in Colombia in the case to get more support and incentives by the government such as subsidies in order to decrease the investment cost and the final price for the consumers, strategies to instruct and accustom the community to increase the acceptance among them and policies to ease the credit and bank loans for the producers (Jimenez et al., 2013).

5. CONCLUSIONS

Just like other Latin American countries and the rest of the world so too Colombia is committed to reducing greenhouse gas emissions, which endanger the ozone layer and deteriorate the atmosphere and the health of living beings that inhabit the earth. To meet this challenge, all these countries have created financial and fiscal policies as well as incentives that allow the increase of the shares of clean energy (hydraulic, solar, geothermal, wind). Some of the most used strategies across the world are policies such as feed-in-tariffs, tax reductions, and auctions.

Colombia has the mission to decrease by about 30% in greenhouse gas emissions by 2030. Moreover, the Indicative Action Plan (PAI) 2017-2022 has set as a goal for 2022 the increase in energy production from renewable resources achieving that 9.05% of the energy produced is from clean energy.

Many countries have promoted research for the creation or optimization of more efficient and clean energy systems capable of curbing the footprint that fossil fuels would leave. Different researches have shown that there are many systems with a high energy potential for applications, such as photovoltaic panels and CSP. Some research has shown that variances in classic settings in power cycles can achieve a measurable increase in performance. Furthermore, the Brayton supercritical cycle has proven to be a viable option for energy integration with solar contractors capable of bringing the working fluid to surgical conditions, which is why CSP plants are generally integrated with this cycle (Herrera Palomino et al.,.2018; Padilla et al., 2015).

The plants CSP has shown to be a useful alternative for countries with a large solar ratio such as Spain, the United Arab Emirates, Dubai, USA, China, at present, Latin American countries such as Brazil and Chile have shown the possibility of integrating pilot solar plants for the production of energy from the sun, Table 1 and Table 2 shows the average DNI for cities in Colombia and Brazil, for four random cities, where the comparison between the data shows a maximum difference of 2.33 between the city with the highest number of cities in Brazil and the In Colombia, this analysis shows that Colombia could implement this energy production system from renewable resources for energy generation and the diversification of the energy matrix.

REFERENCES

Agencia de Regulacion y Control de Electricidad. (2020), Balance Nacional de Energía Electrica. Available from: http://www.regulacionelectrica.gob.ec/?page_id¼1998. [Last accessed on 2020 Apr 09].

Apergis, N., Payne, J.E. (2011), The renewable energy consumption-growth nexus in central America. Applied Energy, 88(1), 343-347.

Aquila, G., de Oliveira Pamplona, E., de Queiroz, A.R., Junior, P.R., Fonseca, M.N. (2017), An overview of incentive policies for the expansion of renewable energy generation in electricity power systems and the Brazilian experience. Renewable and Sustainable Energy Reviews, 70, 1090-1098.

Arango-Aramburo, S., Ríos-Ocampo, J.P., Larsen, E.R. (2020), Examining the decreasing share of renewable energy amid growing thermal capacity: The case of South America. Renewable and Sustainable Energy Reviews, 119, 109648.

Bae, C., Kim, J. (2017), Alternative fuels for internal combustion engines. Proceedings of the Combustion Institute, 36, 3389-3413.

Caineng, Z., Qun, Z., Guosheng, Z., Xiong, B. (2016), Energy revolution: From a fossil energy era to a new energy era. Natural Gas Industry B, 3, 1-11.

Carbot, D.A., Escobar, R.F., Gómez, J.F., Téllez, A.C. (2017), A survey on modeling, biofuels, control, and supervision systems applied in internal combustion engines. Renewable and Sustainable Energy Reviews, 73, 1070-1085.

Chen, H. (2010), The Conversion of Low-grade Heat into Power Using Supercritical Rankine Cycles. Florida: University of South Florida Scholar Commons.

Cherni, J.A., Kentish, J. (2007), Renewable energy policy and electricity market reforms in China. Energy Policy, 35(7), 3616-3629.

CNEA. (2020), Síntesis del Mercado Electrico Mayorista de Argentina. Available from: http://www.electrico.com.ar/web/pdfs/SINTESIS_MEM_2020_ENERO.pdf. [Last accessed on 2020 Apr 09].

Delmas, M.A., Montes-Sancho, M.J. (2011), US state policies for renewable energy: Context and effectiveness. Energy Policy, 39(5), 2273-2288.

DPN. (2018), Departamento Nacional De Planeación. Energy Demand Situation in Colombia. Available from: https://www.dnp.gov.co/Crecimiento-Verde/Ejes-estrategicos/Paginas/Eficiencia-energ%C3%A9tica.aspx. [Last accessed on 2019 Jun 27].

Fontalvo, A., Pinzon, H., Duarte, J., Bula, A., Quiroga, A.G., Padilla, R.V. (2013), Exergy analysis of a combined power and cooling cycle. Applied Thermal Engineering, 60(1-2), 164-171.

Geospatial Toolkit. (2019), Version 1.2.0. Available from: http://www.nrel.gov. [Last accessed on 2020 Apr 09].

Gondal, I.A. (2016), Hydrogen transportation by pipelines. Compendium of Hydrogen Energy, 2, 301-322.

Guzman, L., Henao, A., Vasquez, R. (2014), Simulation and optimization of a parabolic trough solar power plant in the city of Barranquilla by using system advisor model (SAM). Energy Procedia, 57, 497-506.

György, S., Bereczky, A. (2018), Experimental investigation of physicochemical properties of diesel, biodiesel and TBK-biodiesel fuels and combustion and emission analysis in CI internal combustion engine. Renewable Energy, 121, 568-578.

Herrera Palomino, M., Pacheco, E.C., Forero, J.D., Lascano, A.F., Padilla, R.V. (2018), Análisis exergético de un ciclo brayton supercrítico con dióxido de carbono como fluido de trabajo. Inge CUC, 14(1), 159-170.

Hosenuzzaman, M., Rahim, N.A., Selvaraj, J., Hasanuzzaman, M., Malek, A.A., Nahar, A. (2015), Global prospects, progress, policies, and environmental impact of solar photovoltaic power generation. Renewable and Sustainable Energy Reviews, 41, 284-297.

IDEA. (2000), Plan de Fomento de Las Energías Renovables en España 2000-2010. Ministerio de Ciencia y Tecnología. Instituto Para la Diversificación y Ahorro de Enegía. Available from: http://www.idae.es/index.php/mod.documentos/mem.descarga?file=/documenttos_4044_PFER2000-10_1999_1cd4b316.pdf. [Last accessed on 2020 Apr 23].

IEA. (2018), Global Energy and CO_2 Status Report. Available from: https://www.iea.org/geco/data. [Last accessed on 2019 Jun 26].

IEA. (2019), Global Energy and CO_2 Status Report. Available from: https://www.iea.org/geco/data. [Last accessed on 2020 Apr 15].

IPCC. (2014), Climate Change 2014 Mitigation of Climate Change: Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Available from: https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_frontmatter.pdf. [Last accessed on 2019 Jun 21].

Jiménez, M., Cadavid, L., Franco, C. J. (2013). Scenarios of photovoltaic grid parity in Colombia. Dyna, 8(188), 237-245.

Kalghatgi, G. (2018), Is it really the end of internal combustion engines and petroleum in transport? Applied Energy, 225, 965-974.

Khandal, S.V., Banapurmath, N.R., Gaitonde, V.N. (2018), Effect of hydrogen fuel flow rate, fuel injection timing and exhaust gas recirculation on the performance of dual fuel engine powered with renewable fuels. Renewable Energy, 126, 79-94.

Koengkan, M., Fuinhas, J.A., Marques, A.C. (2019), The effect of fiscal and financial incentive policies for renewable energy on CO_2 emissions: The case for the Latin American region. In: The Extended Energy-growth Nexus. United States: Academic Press. p141-172.

Kyriakopoulos, G.L., Arabatzis, G. (2016), Electrical energy storage systems in electricity generation: Energy policies, innovative technologies, and regulatory regimes. Renewable and Sustainable Energy Reviews, 56, 1044-1067.

Ley 99 de 1993. (1993), Congreso de la República, Bogotá, Colombia, 22 de Diciembre de 1993.

Ley 629 de 2000. (2000), Congreso de la República, Bogotá, Colombia, 27 de Diciembre de 2000.

Ley 697 de 2001. (2001), Congreso de la República, Bogotá, Colombia, 05 de Octubre de 2001.

Ley 788 de 2002. (2002), Congreso de la República, Bogotá, Colombia, 27 de Diciembre de 2002.

Ley 1715 de 2014. (2014), Congreso de la República, Bogotá, Colombia, 13 de Mayo de 2014.

Malagueta, D., Szklo, A., Borba, B.S.M., Soria, R., Aragão, R., Schaeffer, R., Dutra, R. (2013), Assessing incentive policies for integrating centralized solar power generation in the Brazilian electric power system. Energy Policy, 59, 198-212.

Martín, H., de la Hoz, J., Velasco, G., Castilla, M., García de Vicuña, J.L. (2015), Promotion of concentrating solar thermal power (CSP) in Spain: Performance analysis of the period 1998-2013. Renewable and Sustainable Energy Reviews, 50, 1052-1068.

Masjuki, H.H., Ruhul, A.M., Mustafi, N.N., Kalam, M.A., Arbab, M.I., Rizwanul, I.M. (2016), Study of production optimization and effect of hydroxy gas on a CI engine performance and emission fueled with biodiesel blends. International Journal of Hydrogen Energy, 41, 14519-14528.

Ministerio de Minas e Energia. (2018), Boletim Mensal de Monitoramento do Sistema Eletrico Brasileiro. Available from: http://www.mme.gov.br/web/guest/secretarias/energia-eletrica/publicacoes/boletim-de-monitoramento-do-sistema-eletrico/1004. [Last accessed on 2020 Apr 09].

MME.br. (2016), Energy in South America. Year of Reference: 2015. Available from: http://www.mme.gov.br/documents/10584/3580500/05+-+Energy+in+South+America+%28Year+-+2015%29+%28PDF%29/503b06ae-aafb-47e9-84cd-c0acf7028005?version=1.2. [Last accessed on 2019 Jul 04].

MME.co. (2019), Ministerio de Minas y Energía-misión y Visión. Available from: https://www.minenergia.gov.co/mision-y-vision. [Last accessed on 2019 Jul 02].

Padilla, R.V., Too, Y.C.S., Benito, R., Stein, W. (2015), Exergetic analysis of supercritical CO_2 brayton cycles integrated with solar central receivers. Applied Energy, 148, 348-365.

PARATEC. (2019), Parametros Tecnicos Del Sin. Capacity Efectivi by Type of Generation. Available from: http://www.paratec.xm.com.co/paratec/SitePages/generacion.aspx?q=capacidad. [Last accessed on 2020 Apr 09].

Popovich, N. (2018), How Does Your State Make Electricity? New York Times. Available from: http://www.nytimes.com.

Qian, Y., Sun, S., Ju, D., Shan, X., Lu, X. (2017), Review the state-of-the-art of biogas combustion mechanims ans applications in internal combustion engines. Renewable and Sustainable Energy Reviews, 69, 50-58.

Renewable Now. (2019), Globlas State Report. Available from: https://www.ren21.net/wpcontent/uploads/2019/05/gsr_2019_full_report_en.pdf2015. [Last accessed on 2020 Apr 20].

Resolucion CREG 005. (2018), Comisión de Regulación de Energía y Gas,1 de Febrero de 2010. China: CREG.

Sahu, B.K. (2015), A study on global solar PV energy developments and policies with special focus on the top ten solar PV power producing countries. Renewable and Sustainable Energy Reviews, 43, 621-634.

Schuman, S., Lin, A. (2012), China's renewable energy law and its impact on renewable power in China: Progress, challenges and recommendations for improving implementation. Energy Policy, 51, 89-109.

Servert, J.F., Cerrajero, E., Fuentealba, E., Cortes, M. (2014), Assessment of the impact of financial and fiscal incentives for the development of utility-scale solar energy projects in Northern Chile. Energy Procedia, 49, 1885-1895.

Sharma, N.K., Tiwari, P.K., Sood, Y.R. (2012), Solar energy in India: Strategies, policies, perspectives and future potential. Renewable and Sustainable Energy Reviews, 16(1), 933-941.

Tak, I., Zhang, Y., Wai, W., Hua, Q., Xu, Y., Xun, X., Wu, W., Ma, W., Wei, L., Ah, L., Qian, X. (2012), Effect of ambient air pollution on daily mortality rates in Guangzhou, China. Atmospheric Environment, 46, 528-535.

US. (2020), Energy Information Administration, based on German Association of Energy and Water Industries. Available from: https://www.eia.gov/international/overview/country/DEU. [Last accessed on 2020 Apr 23].

UN-FCCC. (2015), Adoption of the Paris Agreement. Available from: https://www.unfccc.int/resource/docs/2015/cop21/eng/l09.pdf. [Last accessed on 2019 Jul 05].

UPME. (2018), Energía Eléctrica SIN (Sistema Interconecntado Nacional). Available from: http://www1.upme.gov.co/InformacionCifras/Paginas/PETROLEO.aspx. [Last accessed on 2019 Jun 23].

UPME. (2019), Proure-programa de Uso Racional y Eficiente de Energía y Fuentes No Convencionales. Available from: http://www1.upme.gov.co/Paginas/PROURE.aspx. [Last accessed on 2019 Jun 23].

Vachon, S., Menz, F.C. (2006), The role of social, political, and economic interests in promoting state green electricity policies. Environmental Science and Policy, 9(7-8), 652-662.

Valenzuela, C., Mata-Torres, C., Cardemil, J.M., Escobar, R.A. (2017), CSP+ PV hybrid solar plants for power and water cogeneration in Northern Chile. Solar Energy, 157, 713-726.

Washburn, C., Pablo-Romero, M. (2019), Measures to promote renewable energies for electricity generation in Latin American countries. Energy Policy, 128, 212-222.

Zhao, J., Mazhari, E., Celik, N., Son, Y.J. (2011), Hybrid agent-based simulation for policy evaluation of solar power generation systems. Simulation Modelling Practice and Theory, 19(10), 2189-2205.