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"A Bibliometric Analysis of Solar Energy Application on Organic Rankine Cycle"

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A bibliometric analysis of solar energy application on organic Rankine cycle

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Abstract

Solar Thermal is one of many heat sources that can be applied to support organic Rankine cycle (ORC) system. The advantage of using solar thermal as a heat source when combine with ORC system, it can provide affordable energy supplies in remote areas and suitable in disaster territory. Growth in solar-ORC research is not only on a lab/workshop scale but also on an industrial scale. Most articles refer to methods and tool in design process, combine heat and improvement of the cycle, working fluids selection and case study based on primary or secondary data. The paper is report of the newest trends on the research of solar application on ORC using bibliometric analysis. The study of bibliometric using VOSviewer was recognized as a captivating method in the literature that allows examining the scientific progress of a certain topic. Moreover, a qualitative approach can be performed by analysing the keywords contained in different documents to identify a circumstance that feature the research trend and to understand future viewpoint.

Keywords: solar thermal, improvement the cycle, VOSviewer, qualitative approach

1. Introduction

Mankind had lived over many decades depending on fossil fuel, such as coal, oil and natural gas to fulfil their needs. These fossil fuels are more convenient and cheaper to use rather than alternative energy source. But, using fossil fuel by combustion leads to emission of COx, NOx, SOx that bring harm to environment such as global warming and acid rains and this fossil fuels can't be replenished (Aboelwafa et al., 2018; IEA, 2016).

Renewable Energy sources is the key to overcome reducing usage of fossil fuel to generate electricity. Renewable energy like solar thermal, geothermal, biomass and waste heat sources from industries are capable not only in decreasing the rate of the consumption of fossil fuels but also reducing the affect that bring harm to environment. In addition, these of residual, moderate and/or low-medium temperature heat sources cannot be efficiently converted into electricity through the conventional Steam Rankine Cycle (SRC). So, it is necessary to study another type of process, such as Organic Rankine Cycle (ORC) that has been considered as most feasible cycle to generating electricity while recovering various heat sources as proposed by many authors (Israel et al., 2021; Lecompte et al., 2015; Aleksandar et al., 2020; Permana, 2019; Macchi, 2016)

ORC is a process of utilizing steam heat such as conventional Rankine cycle, but uses a low-set temperature of organic fluids rather than water. The leverage of ORC system are lower temperature and pressure of turbine inlet, greater condensing pressure, and no deaerator, robust and environmentally safe (Quoilin et al., 2013). The main disadvantage of the ORC system is that a separate precaution to prevent the leakage, contamination of organic fluid and have a lower efficiency compared to SRC (Wang et al., 2019). Despite ORC is capable of produce electricity in low-set temperature, however it needs another heat resource from another system. There’s a lot

of heat resource in Hungary that can combined with ORC among others is used solar thermal as a heat source.

Solar is the major source of renewable energy that sustain in our earth. Around the 1.75 $\times 10^5$ TW, and that is the entire solar energy received by the earth continuously (Goswami, 2015) and it has been weakened twice by both atmosphere (16% absorption, 6% reflection) and clouds (3% absorption, 20% reflection) as shown in **Figure 1**. Solar Thermal is one of many heat sources that can support ORC system. The advantage of using solar thermal as a heat source when combine with ORC system, it can provide affordable energy supplies in remote areas and suitable in disaster territory. Apparently, the amount of annual global horizontal irradiation for Hungary is between 1100 and 1350 kWh/m^2 which makes relatively good site for installing solar thermal collector (GHI, 2020).

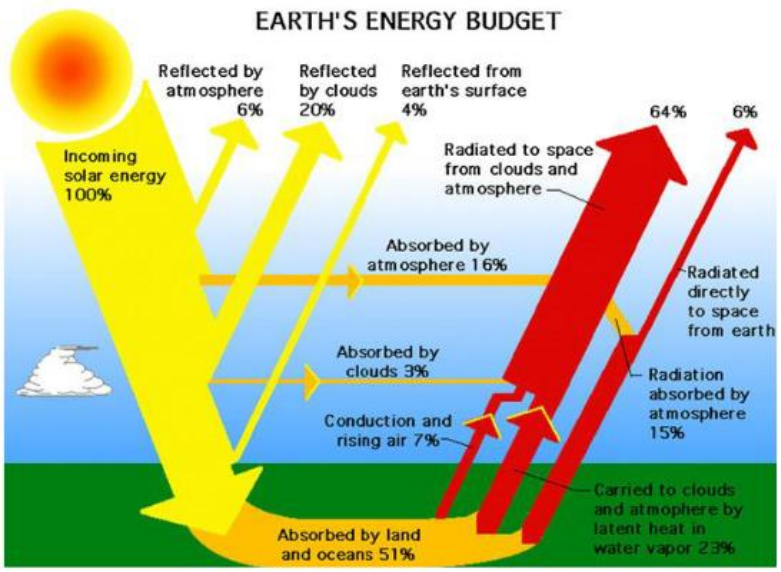

Figure 1. The earth's energy budget (Kim, 2015)

Solar collectors and thermal storage are the two core of subsystem components in solar thermal applications. A solar collector which is the components that converts solar irradiation energy to

the thermal energy through working fluid in solar thermal applications. It is required a good optical performance in order to absorb heat as much as possible. The heat carried by working fluid can be used to charge a thermal energy storage or either to provide domestic hot water (Tian, 2013; Hossain et al., 2011). Recent research recommends that small scale Solar Thermal systems combined with ORC power may compete with Photovoltaic (PV) and diesel generators on levelized cost of electricity basis for off grid duty (Orosz et al., 2008).

Nowadays, there are several researches related to ORC is using solar energy. Some authors (Kumar et al., 2016; Bellos et al., 2018) conducted a research of ORC based on solar parabolic through concentrator (PTC) type. Kumar et al. (2016) was analysis a solar thermal power plant using PTC model which reflects the solar radiation on the receiver and the result is the system has the highest output at 10 kW at the temperature 259 °C. While Bellos et al. (2018) conducted a hybrid ORC driven with solar collector PTC type and waste heat of low-grade temperature (>150 °C) and the prototype is resulting the power around 479 kW to 845 kW with efficiency system from 11.6% to 19.7%, respectively. Another scenario was presented by Villarini et al. (2014) who has reviewed of the solar ORC, and its focuses on the different typology and technology perspectives.

Growth in solar-ORC research is not only on a laboratory/workshop scale but also on an industrial scale. Several well-known manufacturers have made ORC coupled with solar heat source as presented by **Table 1.** Based on **Table** 1, it can be seen that only five ORC companies have carried out ORC projects with sources of solar energy with varied total capacity and temperature of the heat source. If based on data from the literature available, ORC companies that use solar as a heat source are measly compared to other heat sources such as geothermal, biomass, WHR, sewage gas, and waste water treatment (Anastasovski et al., 2020).

Table 1. The leading manufactures of solar-ORC

Company	Range Power (MW)	Tsource (°C)
Turboden	0.4 – 2.2	≥ 150
Prat & Whitney Power	0.22 – 0.26	91 – 149
FREEPOWER	0.12	> 110
Ormat	0.2 - 22	150 – 300
Exergy	4 – 6.5	230 – 315
Eneftech	0.02 – 0.03	≥ 120
Electratherm	0.03 – 0.05	> 88
GE Power & Water	0.12	≥ 115

Turboden company has working on five solar-ORC construction projects for power plants in several countries including Italy (1.7 MWe), Morocco (2MWe) and Denmark (3.8 MWe) is under construction (Turboden, 2021). In 2014 Exergy Company has construct power-plant based on solar-ORC with capacity of 1 MWe in Benguerir, Morocco (Exergy, 2021). Meanwhile in 2019, Ormat Technologie Inc has announced commercial operation of geothermal and solar hybrid project of 7 MWe in Tungsten, Nevada (Ormat, 2021) and lastly Luneng Group has been built the biggest tower concentrated solar power (CSP) in China, precisely in the Delingha and Gonghe Provinces that produce electricity of 50 MW, respectively (SolarPaces, accessed 2021-03-04).

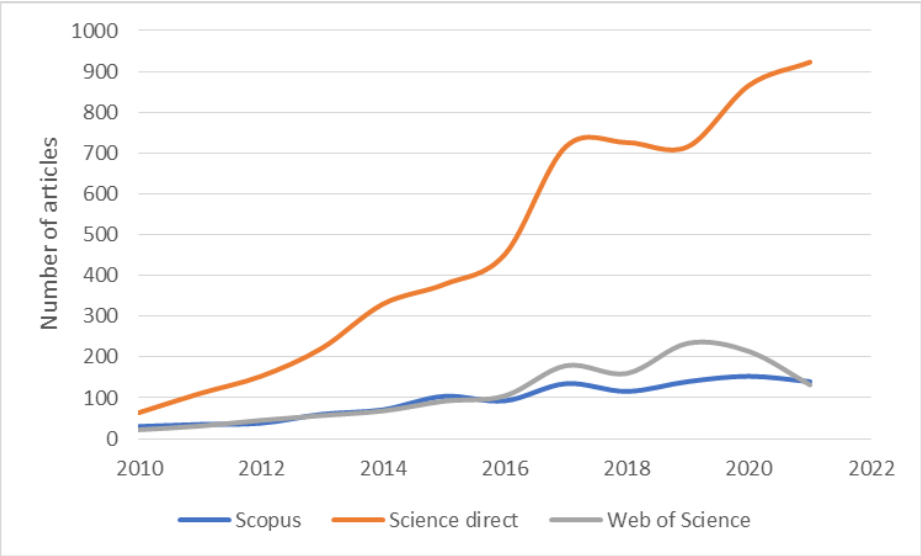

Figure 2. The number of published articles for selective topics in different databases

The growth of interest in the field of solar-ORC technology research is increase over time in the pass 10 years, and this can be seen from the number of publications of articles in Scopus, Science Direct and Web of Science databases, using" Solar AND Organic Rankine Cycle" keywords. A comparison concerning to the publications of these topic in different databases is given by **Figure 2.** It shows that exponential increase in the number of articles published from 2010 until 2021 with a note that in 2021, the collection of published articles data is taken in September, which means that the articles on solar-ORC will increase ahead. Most articles refer to methods and tools in the design process, combining heat and improvement of the cycle, working fluids selection and case study based on primary or secondary data. On the other hand, there are hundreds of the research and literature review about solar-ORC power but to attain appropriate guidelines for the prospective improvement and study related to solar-ORC. It implies the necessary to inspect the solar-ORC's studies over literature. One of the impressive methodologies to recognize the research roadmap that feature the present research and development.

This paper reports the cutting-edge of the current trends on the engineering analysis of solar application on organic Rankine cycle using bibliometric analysis and accommodate some guidance of the future analysis. The study of bibliometric using VOSviewer is recognized as a captivating method in the literature that allows examining the scientific progress of a certain topic. Moreover, a qualitative approach can be performed by analysing the keywords contained in different documents to identify a circumstance that feature the research trend and to understand future viewpoint. In the field of ORC, Imran et al. (2018) publish study of bibliometric analysis in ORC technology and resulting the most producing journal is Energy, the most active researcher is Ibrahim Dincer, and the most productive university and country is Tianjin University from China, respectively. Meanwhile, Dong et al. (2012) use the bibliometric analysis to conduct research trends of solar power from 1991 to 2010. Therefore, this paper serves a convenient way that can be used by researchers to understand the main networks and organizations that working on the topic of solar-ORC.

2. Methodology

This chapter describes the methodology used to develop literature study and bibliometric analysis which will be presented in the next chapter. In this study, the Scopus database was used as a reference due to the greater number of documents available than other databases such as the Web of Science (Cabeza et al., 2020) and the data bases such as ResearchGate and Google Scholar were eliminated in the source data collection, due to the low reliability of the bibliometric results.

Table 2 is a core of specific category in the solar-ORC sub-research where this category is used to find the number of documents or literature in Scopus by linking these categories with keywords that are often related. In this section, the bibliometric analysis is carried out considering the

application of solar-ORC with five categories of the terms including applications, working fluids, expander technology, cycle, design, dynamic and control. For example, the terms of applications in solar-ORC are associated with a commercial, demonstrative or small scale with the number result of 78 documents. Other examples are the term of cycle configuration often associated with keywords of recuperation, regeneration, trilateral, flash or comparison with the number result of documents at 33.

Table 2 Core category of solar-ORC that used for number of documents obtained

Category	**Query**	**Number of documents**
Applications	TITLE-ABS-KEY (“solar ORC” AND (“application” OR “utilization”) AND (“commercial” OR “demonstration” OR “small scale”))	78
Working Fluids	TITLE-ABS-KEY (“solar ORC” AND (“working fluid”) AND (“selection” OR “optimization” OR “performance” OR “properties” OR “zeotropic”))	298
Expander Technology	TITLE-ABS-KEY (“solar ORC” AND (“expander”) AND (“piston” OR “screw” OR “turbine” OR “vane”))	57
Cycle	TITLE-ABS-KEY (“solar ORC” AND (“cycle configuration”) AND (“recuperation” OR “regeneration” OR “trilateral” OR “flash” OR “comparison”))	33

Design	TITLE-ABS-KEY (“solar ORC” AND (“design” OR “architecture” OR “configuration”))	391
Dynamics and control	TITLE-ABS-KEY (“solar ORC” AND (“control” OR “dynamic”))	218

To identify the circumstance of the solar-ORC and to evaluate the research gap for each category related to the application of solar-ORC, the author keywords, bibliographical and citation were study using the software VOSviewer. This tool is an open software that can generate, visualize and analyze bibliometrics based on a network among many documents from scientific publications (Borri et al., 2020). In the process, the software uses several functions including: 1) importation of publication information in term of bibliographic coupling, 2) creating a co-occurrence map by text data, 3) retrieving data for citation analysis by analyzing co-citation reporting and, 4) clustering and visualizing keywords by co-occurrence in network and overlay form (Islam et al., 2018). This is one of the most automated and systematic approaches by which a large body of literature can conveniently be analyzed and the information of the publications, it can be selected to generate the lay-out of authors, institutions, countries and keywords.

3. Classification of solar-ORC

Solar-ORC is considered the most feasible and competitive power generation similar with Rankine cycle but using organic working fluid from solar heat source (Tzivanidis et al., 2016). The main system of solar-ORC has been touched on from previous paragraph and they are: 1) a solar thermal collector, 2) a thermal energy storage, 3) an ORC’s components as given by **Figure**

3. The essential of solar-ORC are evaporator, which is a part to evaporate the organic fluids or refrigerants, condenser is the component to condense a working fluid from vapour phase into fluid phase, and pump which is to pressurize a fluid phase of working fluid, and turbine is the component that expand the working fluid and convert to electricity. By virtue of energy utilization of the pump, the solar-ORC based may bear a low efficiency and energy output when the heating temperature of heat source is low. Some authors have been solved these problems with their methods, for example the replacement of components as carried out by Wang et al. (2019), Gao et al. (2015), Yamada et al. (2011), which replaces the electrical driven pump with thermal driven pump (TDP). The solar-ORC using TDP is consist of two heat exchangers, a turbine, a generator and other auxiliary components, and the result shows an improvement both of power output and efficiencies. This section describes the classification based on the heat carrier medium on the ORC and based on its temperature range.

3.1 Solar-ORC based on the heat medium

Another method to increase a thermal efficiency of ORC can be performed through working fluid selection, as it is an influent factor as it depends on the heat characteristic. Tchanche et al. (2009) conducted a thermodynamic analysis of performance and characteristic of different working fluids in a low-temperature solar-ORC. While, Rayegan and Tao (2011) make a simulation of 117 organic fluid selection based on T-s diagram, fluid effects and molecular components. The result is about improvement to thermal efficiency as well as choose the right working fluids.

In the solar-ORC applications, there are two ways to utilization the solar thermal energy. First, is using an evaporator to heated working fluids directly, namely direct vapor generation (DCG) and indirectly by using heat transfer fluid (HTF). **Figure 3** shows a solar-ORC scheme using HTF technology, while **Figure 4** is a solar-ORC scheme using DVG technology. Most of the solar-

ORCs, both the research scale and the industrial scale are generally use HTF technology (Torres et al., 2007; Kosmadakis et al., 2009; Wang et al., 2014; Manolakos et al., 2009; Li et al., 2016).

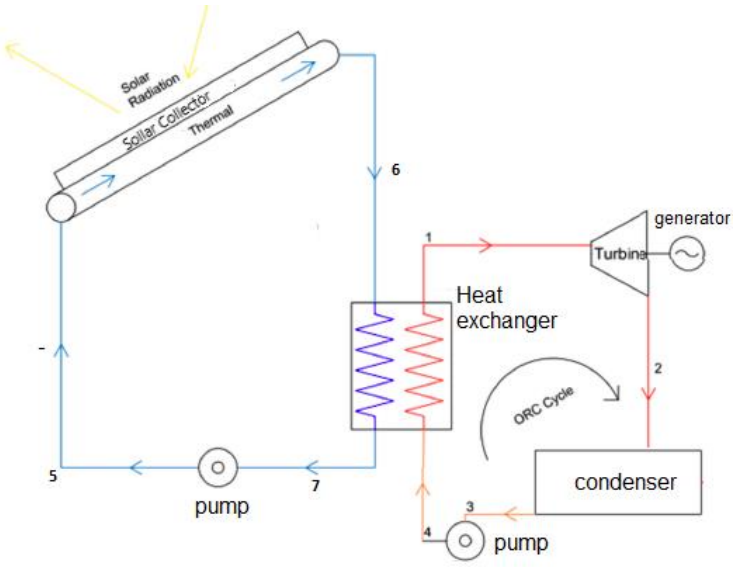

Figure 3. Scheme of solar-ORC

One of the advantages of using DVG technology is the absence of heat exchanger components to evaporate the working fluid as presented in **Figure 4**. Some projects of using DVG system has been demonstrated by Alguacil et al. (2014) which demonstrated plant of 2.67 MWe and has been built by Abengoa Solar. While the solar-ORC plant using DVG technology has been operated and generated of 5 MWe with parameters of temperature and pressure around 410 °C and 78 bar, respectively (Ochoa, 2014). Finally, the biggest solar-ORC plant has been built by Solar One Company with the capacity of 10 MWe and temperature around 425 °C in Barstow, USA (Feldhoff, 2012).

Another the advantages of DVG technology are (1) the high evaporation temperature that increase of high efficiencies (2) low thermal inertia (3) fast ignition system as compared with HTF technology. However, the DVG technology have also disadvantages including the immense of

environmental sensitiveness where the intensity of sun-ray and cloudy periods can vary the temperature of evaporation that can lead to the vapour flow rate that enters the turbine and resulting low power output and efficiencies (Marion et al., 2014). A comprehensive comparison between HTF and DVG methods is given in **Table 3.** Commonly, the DVG has been well-known as a promising method in consequence of some prior advantages with respect of overpowering its disadvantages (Quoilin et al., 2011).

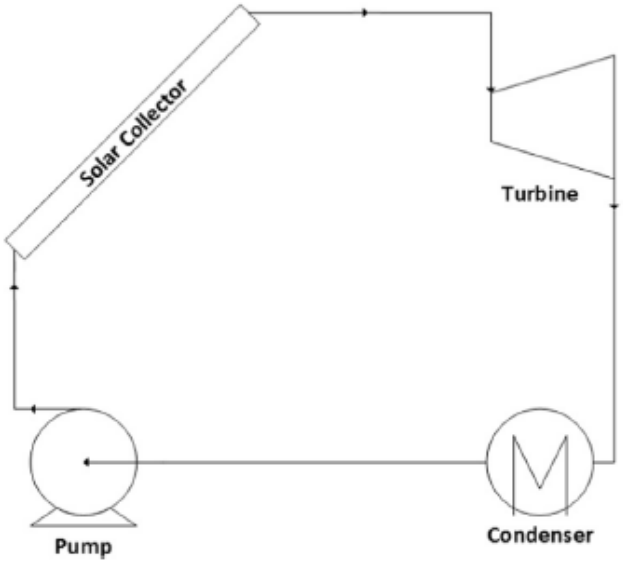

Figure 4. Solar-ORC based on using DVG technology (Aboelwafa et al., 2020)

Table 3. Comparison between HTF and DVG method (Behar et al., 2014; Feldhoff, 2012)

	HTF Method	**DVG Method**
Technology Level	Marketable	Definite
Process Stability	Reliable	Volatile
Configuration	Mode	Robust
Control Effort	Easy	Hard

Scaling-up	Easier	Complicated
Performance	Finite	Pledge
Operating Temperatures	Finite	Pledge
Efficiency	Moderate, limited	Immense, promising
Thermal Storage	Low-cost	Costly
Fluid Toxicity	Positive	Negative
Environmental Risk	High	Low

4. Result

This chapter reports the result of bibliometric analysis conducted to analyse the cutting edge of the solar application on ORC using VOSviewer. After being analysed with the keyword search of "Solar AND organic Rankine cycle", there were four clusters (red, green, blue and yellow) which showed the relationship between one topic to another. Therefore, the size of circles and letters are indicated as by the frequency of occurrences. The more often a keyword appears, the bigger size of the letters and circles.

In this study the result is extracted from titles and keywords found 1249 documents consisting of 607 documents in the last 5 years and the rest of documents published before 2017. Data consisted of various type of publication: article (764), conference paper (408), review (28), book chapter (26), and conference review (18).

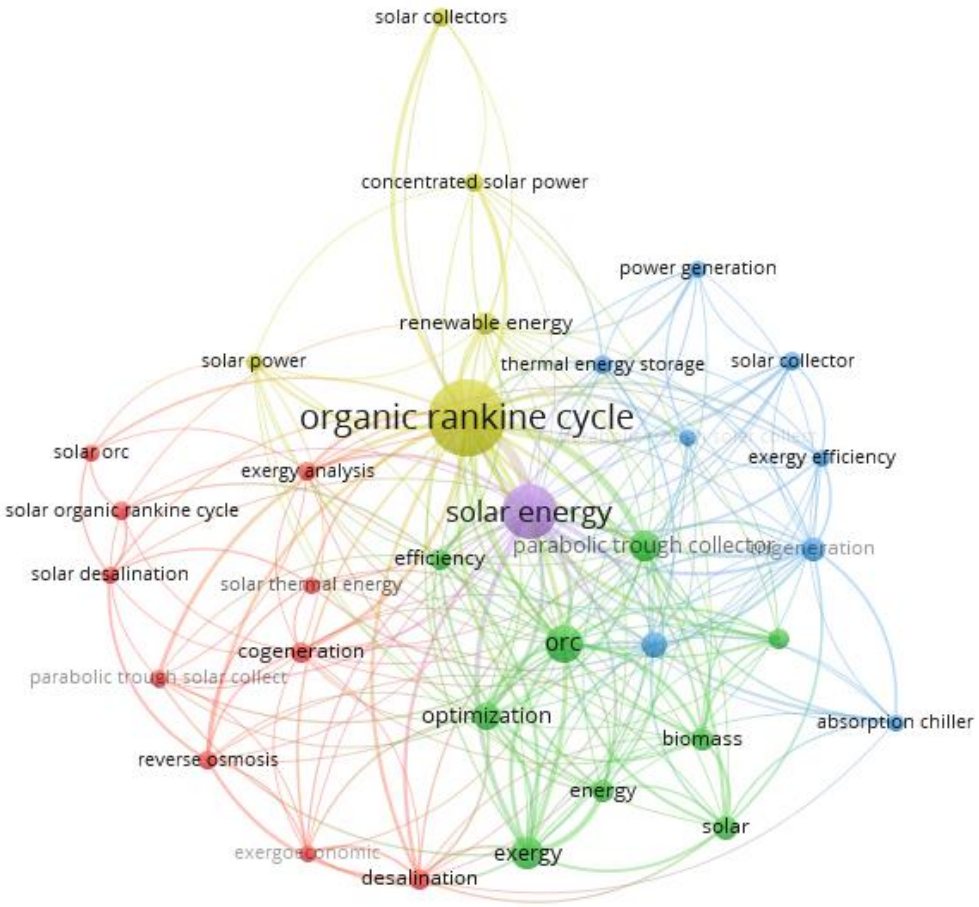

Figure 5. Networks visualization of author keywords on ”solar AND organic Rankine cycle”

Figure 5 is shows clusters in each of the topic areas studied. It can be seen that the keywords of “organic Rankine cycle” (yellow circle), “solar energy” (purple circle), “orc” (green circle) and “cogeneration” (red circle) are the keywords that have most occurrence with the minimum ten times in Scopus database. In other side, **Table 4** shows the author keywords with the highest number of occurrences with the keyword of “organic Rankine cycle” and “solar energy” with the number of occurrences at 193 and 103, respectively.

Table 4. Author keywords with the highest number of occurrences on "solar AND organic Rankine cycle"

Cluster Colour	Observable Keywords	Number of occurrences
Red	Solar orc, solar organic Rankine cycle, exergy analysis, solar desalination, solar thermal energy, parabolic through solar collect, cogeneration, reverse osmosis, exergoeconomic, desalination	121
Blue	Power generation, thermal energy storage, solar collector, exergy efficiency, absorption chiller, trigeneration, parabolic through solar collect, organic Rankine cycle (orc)	108
Green	Efficiency, parabolic through collector, orc, optimization, energy, biomass, solar, exergy, concentrating solar power	228
Yellow	Organic Rankine cycle, renewable energy, solar power, concentrated solar power, solar collectors	244
Purple	Solar energy	103

Figure 6 shows the keywords visualization of the trend from year to year related to this research. It can be seen that the keywords of “solar energy” has been used since 2015. Furtherly, the keywords of “parabolic through collector”, “cogeneration” and “optimization” were only used in the last three years, so that research conducts to these keywords or this method is still lacking and is one of the research gaps that will be sought by further research in organic Rankine cycle scope.

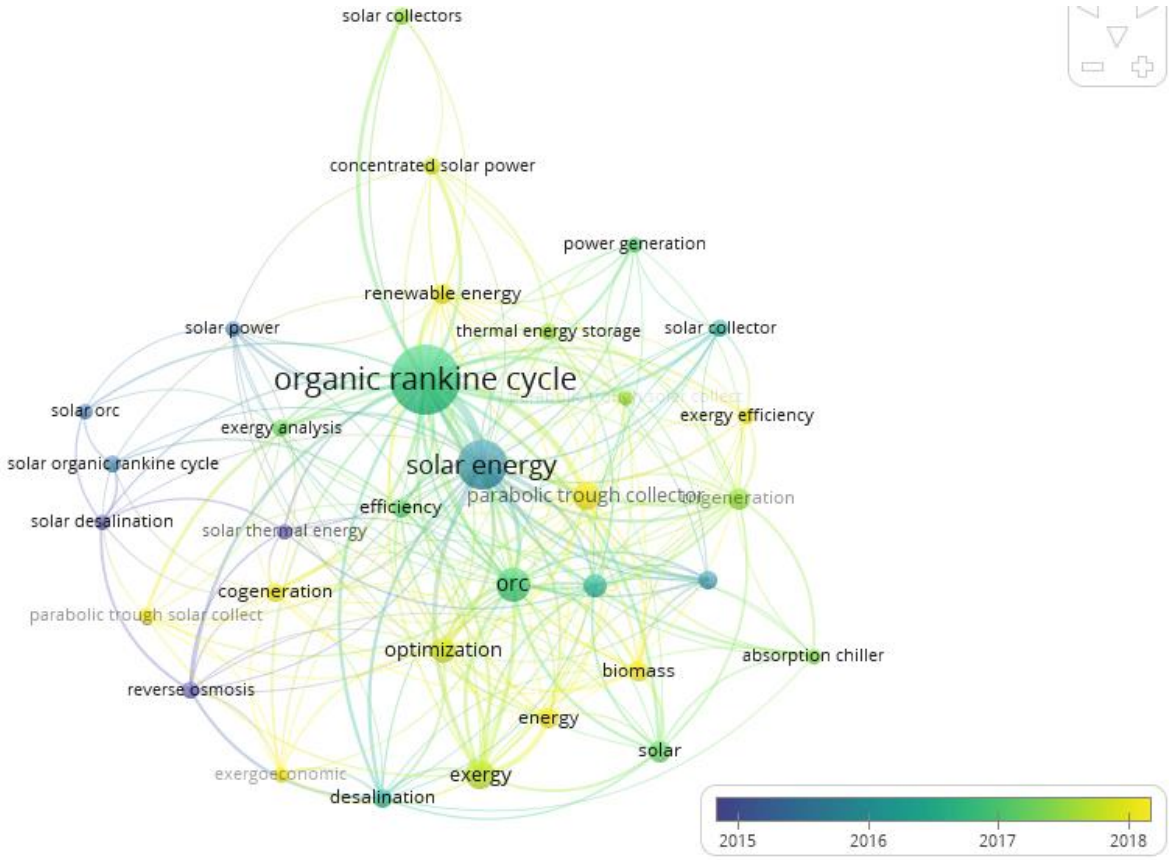

Figure 6. Networks visualization of author keyword on ”solar AND organic Rankine cycle” using overlay visualization

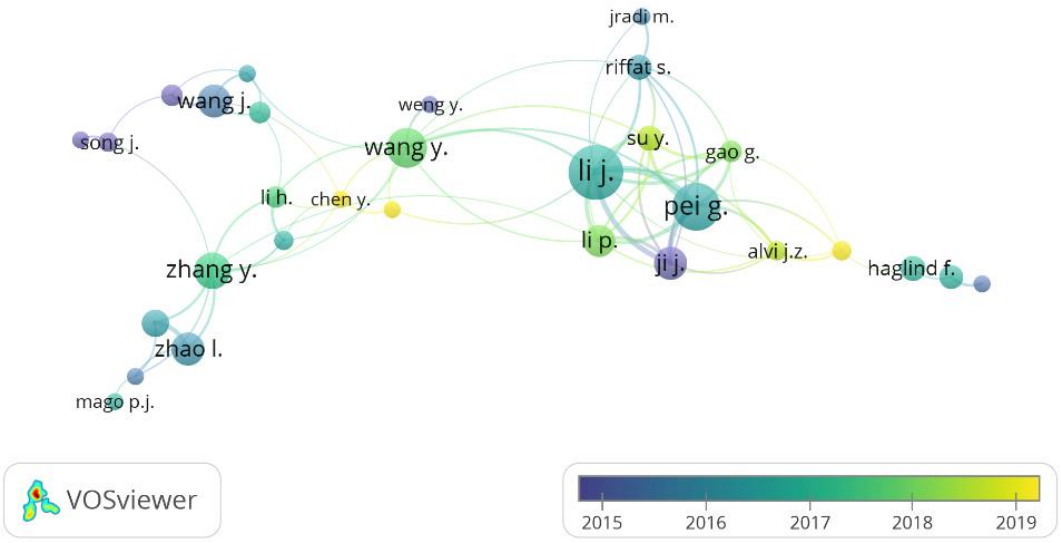

Figure 7. Visualization of overlay authors and co-authorship relations

Collaboration analysis between authors and co-authors on research with keywords of ”solar AND organic Rankine cycle” in the last 5 years is shown by **Figure 7**. In these networks, the size of circles and colors represent the most active in collaboration between author with the minimum five publication in Scopus database. According to observable keywords, Li J and Pei G (blue circle) has strong connection research collaboration around 2015 – 2017, meanwhile Wang Y, Zhang Y, and Su Y (green circle) are the most active authorship in the last 3 years. **Table 5** presents the authors with the most contributions of work in the last decade with the keyword "solar AND organic Rankine cycle" in the Scopus database. Dincer I has the most publications with 29 documents followed by Bellos E and Li J with 24 and 22 documents, respectively.

Table 5. Top 10 authors on documents of ”solar and organic Rankine cycle”

Author name	**No publications**	**Affiliation**	**Country**
Dincer, I	29	Ontario Tech University	Canada
Bellos, E	25	National Technical University of Athens	Greece
Li, J	22	University of Hull	England
Papadakis, G	20	Geoponiko Panepistimion Athinon	Greece
Tzivanidis, C	19	National Technical University of Athens	Greece
Pei, G	18	University of Science and Technology of China	China
Manolakos D	18	Geoponiko Panepistimion Athinon	Greece
Petrollese, M	17	Università degli Studi di Cagliari	Italy

Markides, C.N	16	Imperial College London	UK
Lemort, V	15	Universite de Liege	Belgium

However, the university rankings with the most documents were dominated by university from Greece in the last ten years including National Technical University of Athens with 40 documents, followed by University of Tehran, Ontario Technology University and University of Science and Technology of China with 38, 31 and 26 documents, respectively. **Figure 8** represented the timeline of publications of these universities every year. Based on the graph, it can be seen that Ontario Tech University and Tianjin University both are consistently publish a journal related to solar ORC every year, while National Technical University of Athens and University of Tehran are the most active institute in solar organic Rankine cycle research publication in the last 5 years with 26 and 32 documents, respectively.

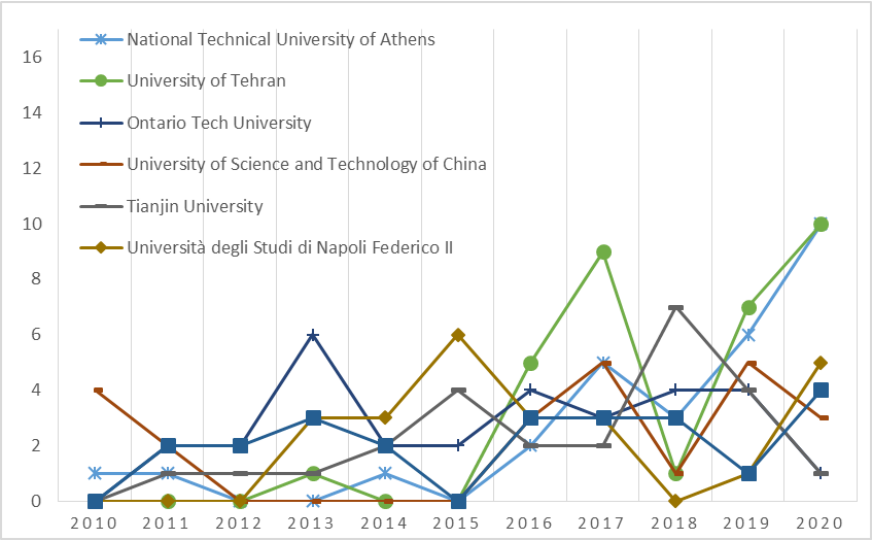

Figure 8. Timeline of publication of the world's university on "solar AND organic Rankine cycle"

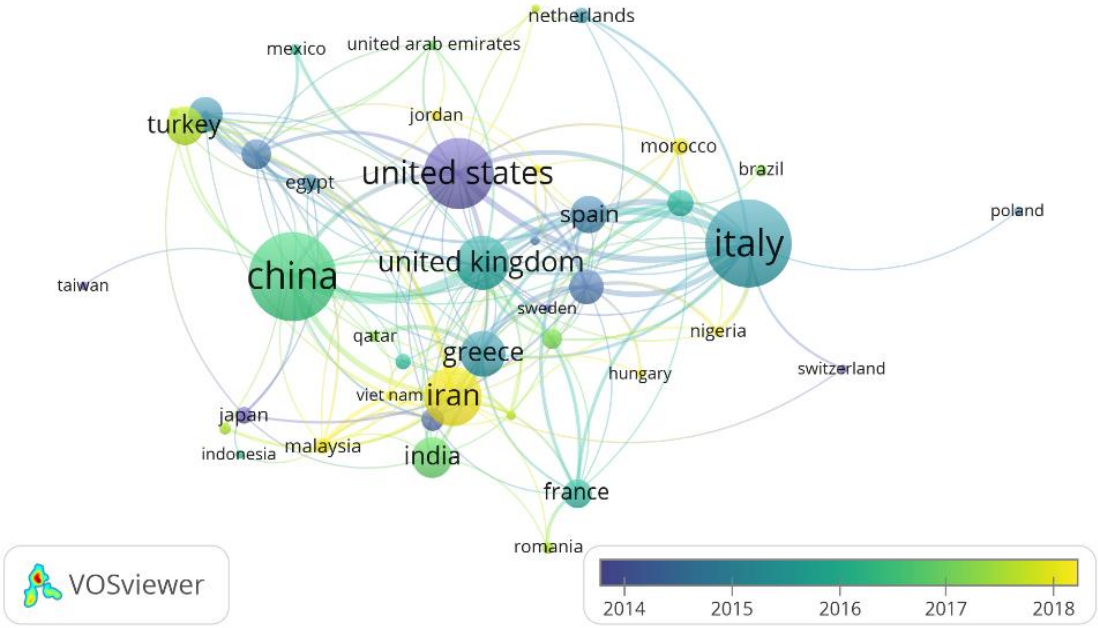

Figure 9. Country of study in keywords ”solar and organic Rankine cycle”

In the previous paragraph, we discussed about bibliometric analysis in the scope of keywords that often appear and the relationship between keywords, it also discussed the relationship between authors and institutions that were the most active in the last decade with the use of keywords “solar AND organic Rankine cycle” based on Scopus database. Specifically, for the country of study, the bibliometric analysis is show in **Figure 9**. It can be seen in the **Figure 9** that around 70 countries that study of “solar AND organic Rankine cycle” and only 30 countries that produce minimum 5 documents in the last ten years and were dominated by China, Italy and United States with 180, 172 and 131 documents, respectively. Surprisingly, Iran and Turkey have produced a significant number of publications in the last three years with 109 and 58 documents, respectively.

Table 6. Top 10 countries of publications on ”solar and organic Rankine cycle” from 2011 to 2020

	Total		Hot articles	
Country	**Publications**	**Citations**	**Reference**	**Citations**
China	180	1429	Wang, M et al. (2013)	163
Italy	172	1910	Astolfi, M et al. (2011)	136
United States	131	1391	Rayegan, R (2011)	317
Iran	109	1204	Boyaghchi, FA (2015)	157
United Kingdom	90	902	Qiu, G et al. (2011)	235
Greece	72	1420	Tchanche, B.F et al.(2011)	783
India	67	340	Garg, P et al. (2013)	98
Turkey	58	456	Ozturk, M (2013)	85
Spain	53	1302	Vélez, F et al. (2012)	372
Canada	49	625	Al-Sulaiman, F.A (2014)	148

In the mean time, Italy has the country that the most citations, followed China and Greece with 1910, 1429 and 1420 citations in the last decades, as shown by **Table 6**. Apparently, in the category of one article that has the most citations written by Tchanche et al. (2011) from Greece with the title of “Low-grade heat conversion into power using organic Rankine cycles – A review of various applications” with 783 citations, which also discusses the ORC application with a solar collector. Meanwhile, Boyaghchi et al. (2015) with the title of ”Thermoeconomic assessment and multi objective optimization of a solar micro CCHP based on Organic Rankine Cycle for domestic

application" is the highest citation article in the last 5 years with 157 citations, and apparently it is an update of research in solar organic Rankine cycle for domestic application.

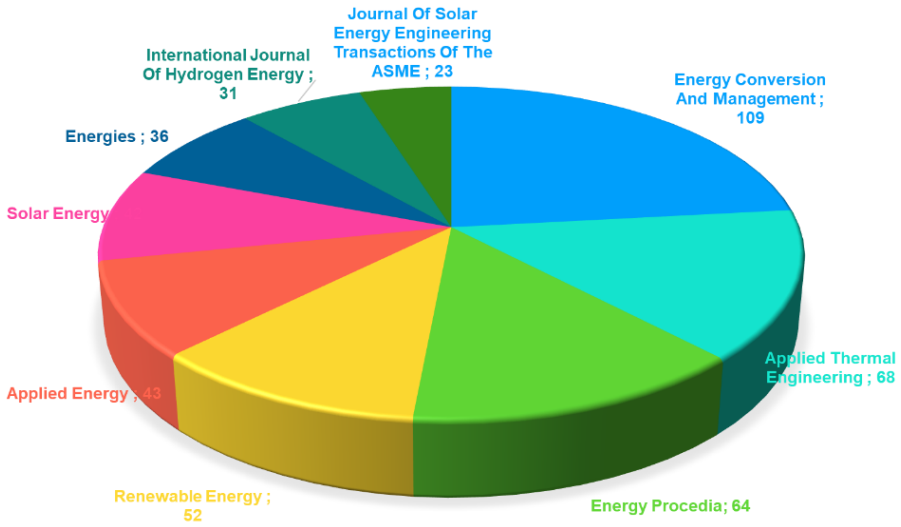

Figure 10. Top 10 journals publishing of solar and organic Rankine cycle

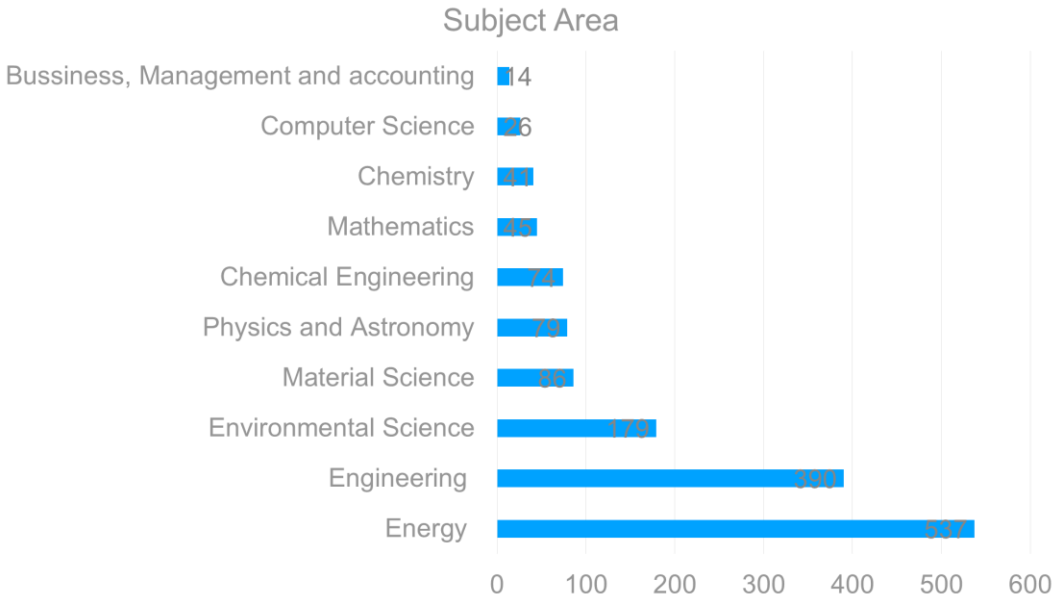

Figure 11. Subject Area of solar and organic Rankine cycle

Figure 10 shows the top 10 most published journals in research of solar and organic Rankine cycle in the last decade, based on Scopus database. It can be seen that Energy Conversion and Management is the most published journals related to solar and organic Rankine cycle with 109 documents followed by Applied Thermal Engineering (68 papers), Energy Procedia (64 papers), Renewable Energy (52 papers), Applied Energy (43 papers), Solar Energy (42 papers), Energies (36 papers), International Journal of Hydrogen Energy (31 papers) and Journal of Solar Energy Transactions of The ASME with 23 papers. Most of the papers published in journals are incorporated into the Elsevier Publisher and only two journals are not included, namely energies that belong to MDPI and Solar Energy Transactions of The ASME is belong to ASME group.

According to collected papers' classifications were identified in **Figure 11**, most of the documents are the subjects of Energy and Engineering with 537 and 390 documents, respectively. It surprisingly that the subject of business, management and accounting are part of the solar and organic Rankine cycle research with 14 documents. It should be noted that some published documents may fall into interdisciplinary, which is shown by most of the papers is related to more than one subject area. **Table 7** is containing the hot articles of each subject area of keywords "solar AND organic Rankine cycle" based on Scopus index in the last ten years starting from 2011 until 2020.

Table 7. Top citation titles of the subject area

Subject Area	**Hot Articles**			
	Citations	**Title**	**Authors**	**Source**
Energy	785	Low-grade heat conversion into power using organic Rankine cycles - A review of various applications	Tchance, F.B et al.; 2011	Renewable and Sustainable

				Energy Reviews 15(8), pp. 3963-3979
Engineering	236	Expanders for micro-CHP systems with organic Rankine cycle	Qiu, G et al., 2011	Applied Thermal Engineering 31(16), pp. 3301-3307
Environmental Science	198	Systematic optimization of subcritical and transcritical organic Rankine cycles (ORCs) constrained by technical parameters in multiple applications	Maraver, D et al., 2014	Applied Energy 117, pp. 11-29
Physics and Astronomy	43	Experimental and thermoeconomic analysis of small-scale solar organic Rankine cycle (SORC) system	Baral, S et al., 2015	Entropy 17(4), pp. 2039
Materials Science	285	Performance and design optimization of a low-cost solar organic Rankine cycle for remote power generation	Quoilin, S et al., 2011	Solar Energy 85(5), pp. 955-966
Chemical Engineering	119	Exergy and thermo-economic analyses of a combined solar organic	Sharaf, M.A et al., 2011	Desalination 272(1-3), pp. 135-147

		cycle with multi effect distillation (MED) desalination process		
Mathematics	56	Systematic methods for working fluid selection and the design, integration and control of organic Rankine cycles - A review	Linke, P et al., 2015	Energies 8(6), pp. 4755-4801
Chemistry	72	Thermo-economic analysis of a combined solar organic Rankine cycle-reverse osmosis desalination process with different energy recovery configurations	Nafey, A.S et al., 2010	Desalination 261(1-2), pp. 138-147
Computer Science	20	Performance analysis of solar parabolic trough collectors driven combined supercritical CO2 and organic Rankine cycle	Sing, H et al., 2018	Engineering Science and Technology, an International Journal 21(3), pp. 451-464
Earth and Planetary Sciences	136	Technical and economical analysis of a solar-geothermal hybrid plant based on an Organic Rankine Cycle	Astolfi, M et al., 2011	Geothermics 40(1), pp. 58-68

Concluding remarks

Since 2010 to 2020, 1249 documents were published in the solar organic Rankine cycle field based on Scopus indexed journals, by 1217 authors from around 140 institutes, originating from 56 countries that dominated by China, USA and Europe. Apparently, National University of Athens is the institutions that has the highest documents with 42 documents, and Dincer I is the most active author with 29 documents in the last ten years. Furtherly, Energy Conversion and Management is the most published journals with 109 documents, with mostly included in subject area of Energy. According to the analysis of keywords using VOSviewer, 1005 keywords have been used with the minimum 10 occurrences, and "organic Rankine cycle" &"solar energy" are keywords that mostly appear with 193 and 103 occurrences, respectively.

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