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The global mapping of education and public outreach on geothermal energy

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Abstract: There is currently a global discussion related to education and public outreach on geothermal energy due to the wide application of this energy source in several fields. Moreover, people with high knowledge and trust have been observed to play a significant role in developing world energy infrastructure. This research aimed to provide an overview of the education and public outreach distribution of geothermal energy in different countries of the world. A systematic literature review was used through the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) method. The findings showed that the European continent has the highest number of articles, 48%, related to education and public outreach on geothermal energy due to its high-energy development effort, followed by the USA with 21%, while Asia, Oceania and Africa with 19%, 4% and 8%, respectively have not implemented geothermal energy.

Keywords: education and public outreach; geothermal energy; sustainable energy; systematic literature review.

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1 Introduction

Education and public outreach on geothermal energy are currently being discussed globally and recognised by scientists and engineers (Biddinika et al., 2017). The concept has become a trend to create relationships and enhance the development of world renewable energy technology (Lucas et al., 2018; Paul, 2013; Smith et al., 2014). This is associated with the ability of the interactions between scientists, communities, stakeholders, organisations, policymakers and governments to increase access to the capabilities required to influence science and technology research (Xexakis and Trutnevyte, 2019).

The concept of education and public outreach has also been widely applied in different fields such as education, technology, science (Caldwell, 2015; MacLeish et al., 2011), health (Hoffman et al., 2016) and the development of geothermal energy (Meller et al., 2018) by several countries. Some of the outreach observed to have been conducted include exhibitions, visits, focus group discussions, provision of guidance and training and interaction with the community, stakeholders, children, students or laypeople as a form of the participation process (Biddinika et al., 2017).

Many people previously were not privy to the technology and benefits of geothermal energy for the future, and this led to a low ratio of its utilisation and development in different countries. This is observed from the fact that the main energy supply in the world is mostly obtained from non-renewable energy, as indicated by 78.3% from fossil fuels and 2.5% from nuclear sources, while renewable energy is only estimated at 19.2% (Garret-Peltier, 2017). The severe environmental impact of global warming and climate change due to the continuous use of non-renewable energy sources makes it important to identify green and renewable energy with the potential to reduce CO2 emission, and an example of this is geothermal energy.

This source utilises heat energy stored in the earth's core (Ministry of Energy and Mineral Resources, 2016; Suhartono, 2012) as well as the natural process associated with the decay of radioactive materials below the earth's surface (Pambudi, 2018). It is important to note that heat is stored in hot rock at depths far below the earth's surface and the complex structure of hydrothermal reservoirs at high temperatures. Moreover, the presence of molten magma in the earth's core is giant thermal storage that continuously transfers heat to the earth's outer layers (Elders and Moore, 2016). The heat is pushed up to the surface through cracks in the earth due to pressure from below, such as volcanic eruptions, heat induction through rocks, hot springs or groundwater flows carrying heat (Deibert and Toohey, 2010; GEA, 2016; Zhou et al., 2015).

It is possible to exploit geothermal energy due to its larger reserves, wider distribution, good stability, high utilisation efficiency and usability for a long time compared to other renewable energy sources (Li et al., 2015; Zhu et al., 2015). Moreover, its great potential for future energy supply and carbon gas emission reduction has been assessed and recognised by different countries worldwide, with 40 estimated to be exclusively powered by geothermal resources (Bertani, 2016).

The global capacity for using geothermal as electrical energy in the world reaches 16 GW in 2020. The ten countries with the highest installed capacity for geothermal energy are the USA 23%; Indonesian 14%; the Philippines 12%; Turkey 10%; Kenya, Mexico and New Zealand 7%; Italy 6%; Icelandic 5%; Japan 3% and others 6% (Hurttrer, 2021; IEA, 2021). The IRENA report stated that the technical potential of using geothermal as electrical energy could reach 200 GW (IRENA, 2021). Geothermal energy offers a lot of potential for the ongoing energy transition in many countries. Many governments and private sector actors have widely recognised this potential. This shows the high interest in geothermal energy as part of the world's energy transition decarbonisation strategy. Moreover, the invasion of Ukraine requires Europe to reduce and even stop Russian natural gas. This condition further promotes to increase attention and discuss the use of geothermal energy (Spikjerboer, et al, 2022).

The use of geothermal energy as a power plant is claimed to increase regional economic development and become an opportunity for community investment, such as the geothermal power plant in Nga AWA Purua, New Zealand. Other research in British Colombia and Kenya also showed that geothermal has a high environmental and socio-economic impact on rural communities.

This energy source can be used directly for heating and cooling and indirectly for power generation (Yusupov and Almaktar, 2021). Geothermal energy was reported to have been used in 88 countries with an annual consumption of 1020887 TJ or 283580 GWh at the end of 2019 (Pambudi, 2018). According to the International Energy Agency, the total electricity production from geothermal energy is expected to increase to 1400 TWh/y while the direct use increases to 1600 TWh/y (Yusupov and Almaktar, 2021).

Lund and Toth (2021) showed the global development of the direct use of geothermal energy in 2020 is as presented in Table 1.

Table 1 Summary of worldwide direct usage data by region and continent in 2019 (Wojuola and Alant, 2019)

No.	*Region/ Continent (#Country/region)*	*MWt*	*TJ/Year*	*GWh/Year*	*Capacity Factor*
1	Africa (11)	198	3730	1036	0.597
2	America (17)	23,330	180,414	50,115	0.245
	Central America & Caribbean (5)	9	195	54	0.687
	North America (4)	22,700	171,510	47,642	0.24
	South America (8)	621	8709	2419	0.445
3	Asia (18)	49,079	545,019	151,394	0.352
4	*Commonwealth of Independent States (5)*	2121	15,907	4419	0.238
5	Europe (34)	32,386	264,843	73,568	0.259
	Central & Eastern Europe (17)	3439	28,098	7805	0.259
	Western & Northern (17)	28,947	236,745	65,762	0.259
6	Oceania	613	10,974	3048	0.568
Total (88)		107,727	1,020,887	283,580	0.300

Table 1 shows the total global installed capacity for direct use at the end of 2019 was 107,727 MWt, which was found to be a 52% increment from the value recorded in 2015. Meanwhile, the annual energy used in 2019 was 1,020,887 TJ which is a 72.3% increase from 2015.

A significant factor influencing the increase in direct use worldwide is the awareness and popularity of geothermal energy in society (Lund and Toth, 2021). People with high knowledge and belief in renewable energy play a role in determining the attitude toward the implementation of this source (Wojuola and Alant, 2019).

This means education and public outreach are critical to successfully adopting renewable energy technologies. It is important to note that the Chapter 36 Agenda 21 of the United Nations Commission on Environmental Development also establishes the importance of education in achieving sustainable development (Wojuola and Alant, 2019) and its role as an important tool for governance, good decision-making and promotion of democracy.

Education also plays a role in developing and strengthening the capacity of individuals, groups, communities, organisations and countries to make judgments and choices to support sustainable development (Wojuola and Alant, 2019). Moreover, the involvement of the public in energy development is important to avoid the risk of rejection of energy projects and to increase distrust concerning the information provided by the company (Payera, 2018).

This information showed the significant importance and need for education and public outreach on geothermal energy. Therefore, this research was intended to map and determine the distribution of education and public outreach on geothermal energy in different continents of the world.

2 Method

Several articles were collected from different countries' energy resources to determine the spread of education and community outreach worldwide, followed by the systematic literature review using Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) (Liberati et al., 2009). This was implemented based on the correct stages or research protocol. There are five steps usually used in a systematic literature review, and these include:

a) Defining the eligibility criteria based on the Inclusion Criteria (IC).

The definition of the literature eligibility criteria is determined by the preparation of inclusion and exclusion criteria, as shown in Table 2.

Table 2 Article eligibility criteria

Inclusion Criteria (IC)	Articles should be original research that has been reviewed and written in English.
	Articles are EPO research conducted by a geothermal company to increase public knowledge of geothermal energy development.
Exclusion Criteria (EC)	Articles that discuss the EPO method carried out by other than geothermal companies to increase public knowledge of geothermal energy development.
	Articles that discuss the EPO method to increase public knowledge of renewable energy development (including geothermal energy).

b) Defining sources of information using a database with a large repository for academic studies such as science direct.

1) The literature search is carried out through an online database with a high repository, namely Science Direct, via https://sciencedirect.com.

2) Furthermore, the search for the reference list in the articles included in the IC is also carried out to find out if other related research is relevant to this research.

c) Selection of literature by determining keywords, exploring, reading full or partial papers and reviewing reference data.

1) Keyword Determination

The search for articles relevant to this method is carried out using the keywords:

a) Education and Public Outreach Geothermal Energy

b) Public Education and Communication Geothermal Energy

c) Public Outreach Geothermal Energy

2) Exploration and selection of titles, abstracts and keywords in articles obtained from search results based on previously defined eligibility criteria.

3) Reading full or partial articles that have not been eliminated in the previous stage to determine whether the articles should be included in the next research in accordance with the eligibility criteria.

4) The reference list of selected articles is reviewed to find other relevant research. Articles contained in the reference list related to this research will be reviewed by performing stages (c) and (d).

d) Data collection manually through the creation of an extraction form.

Data collection is carried out manually by creating a data extraction form as follows:

1) Article Type

2) Journal/Conference Name

3) Year

4) Topic

5) Title

6) Keywords

7) Research Methodology

e) Selection of data items by creating article demographics and acceptance factors with the focus on educational intervention methods and public outreach on geothermal energy

Two data items are obtained from selected articles consisting of

1) Article demographics (ID1)

a) Distribution related to EPO in increasing public knowledge about Geothermal Energy

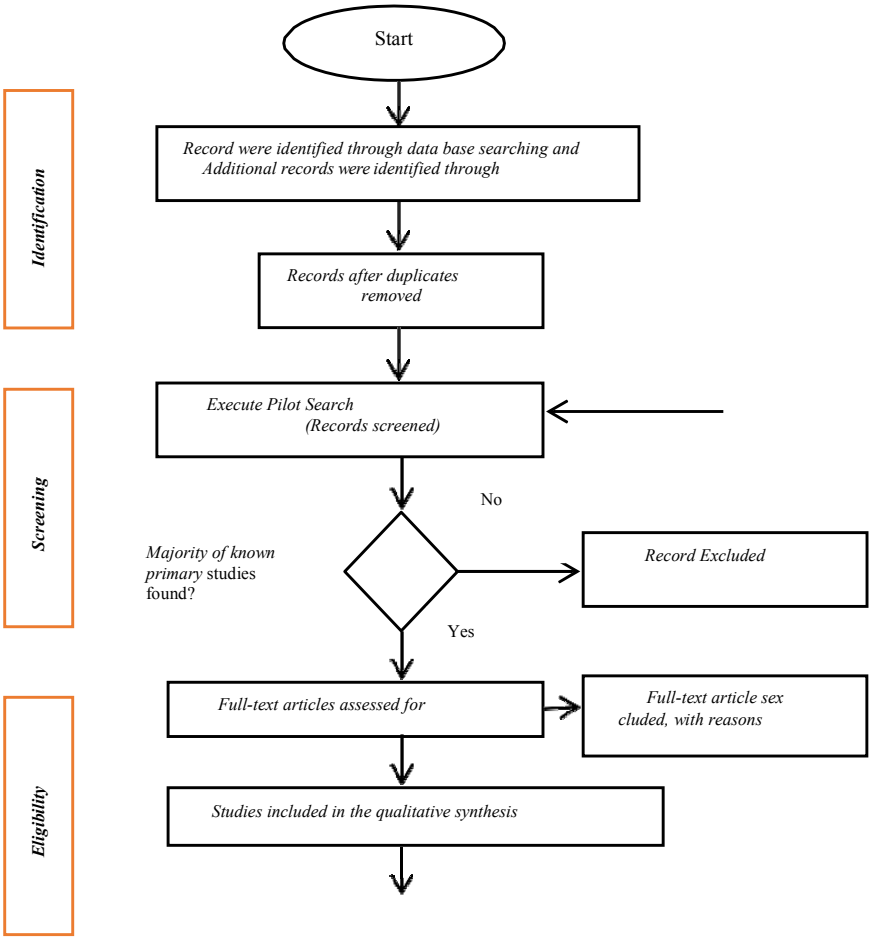
b) Countries that conduct research related to the EPO Method in increasing public knowledge of Geothermal Energy Development

c) Distribution of research methods

2) Factors of accepting the use of the EPO intervention method in increasing public knowledge of geothermal energy development (ID2)

The eligibility criteria were determined based on Inclusion (IC) with relevant articles searched using keywords such as Education and Public Outreach (EPO) geothermal energy, Public Education and Communication (PEC) geothermal energy and Public Outreach (PO) geothermal energy. The data were collected manually by creating a data extraction form followed by the mapping analysis of the distribution of education data and public outreach on geothermal energy globally based on continent and country.

Figure 1 Systematic literature review (Liberati et al., 2009)



3 Results

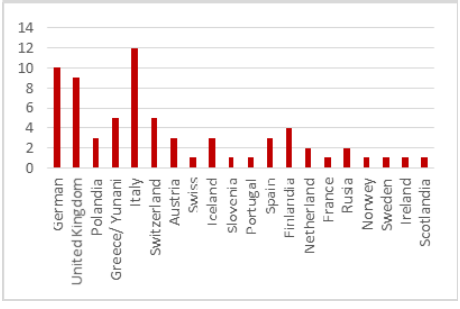
The systematic literature review was used to screen the articles, and the results are presented in Table 3.

Table 3 Results of the systematic literature review

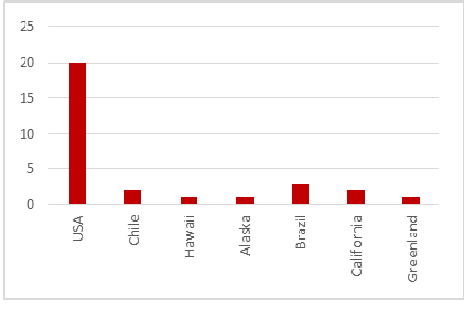
	Keywords	*Screening 1*	*Screening 2*	*Screening 3*
No.				
1	EPO	58	16	10
2	PEC	354	114	110
3	PO	93	36	32
Total		505	166	152

Table 3 shows that 152 articles out of the 505 met the criteria. This was followed by the conduct of a systematic review and analysis to determine the spread of education and public outreach on geothermal energy. The results are presented in Figures 2 and 3.

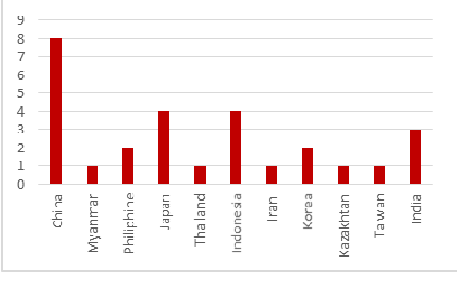
Figure 2 The distribution of education and public outreach application on geothermal energy by country in the world



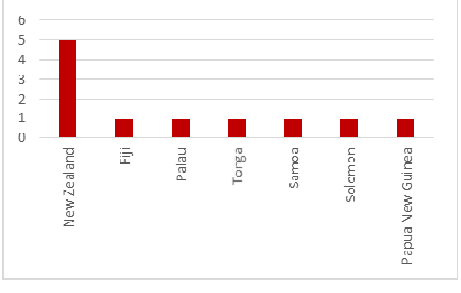
(a) Europe



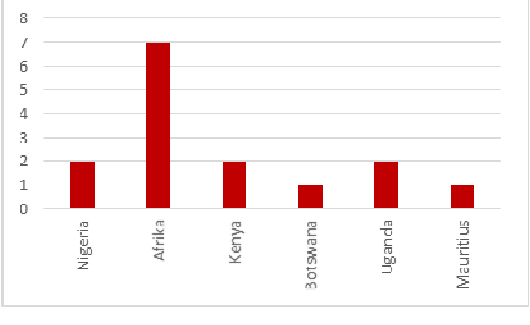
(b) America



(c) Asia



(d) Oceania



(e) Africa

3.1 Mapping of Geothermal Energy EPO Distribution by country

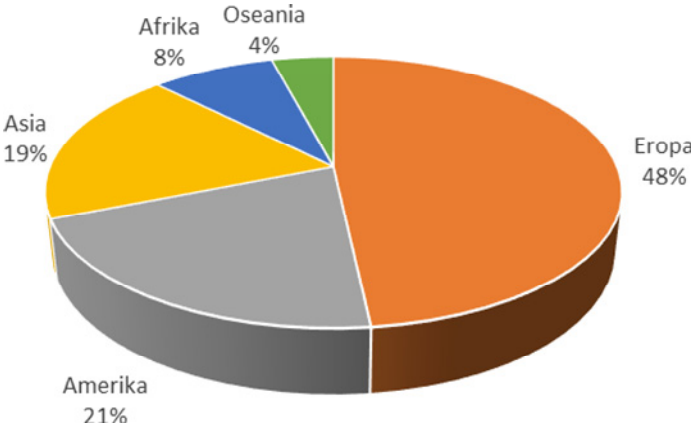
Figure 2(a) shows the distribution graph in the European continent, and the data indicate the three countries with the most research: Italy with 12 articles, Germany with 10 articles, and the United Kingdom with 9 articles. Meanwhile, Figure 2(b) focuses on the Americas, and the highest was found with the USA, which has 20 articles. Figure 2(c) is on the Asian continent, and those with the most research are China, with 8 articles, followed by Japan and Indonesia, with 4 articles each.

Figure 2(d) shows the distribution in the Oceania continent, and New Zealand was found to have the most research with 5 articles, while Figure 2(e) focuses on the African continent, and Africa has the highest with 7 articles.

3.2 Mapping the distribution of geothermal energy EPO application by continent

Figure 3 shows the highest percentage of studies conducted in relation to education and public outreach on geothermal energy was in Europe at 48%, followed by the Americas at 21%, Asia at 19%, Africa at 8% and Oceania at 4%.

Figure 3 Graph of geothermal EPO distribution by continent in the world (see online version for colours)



4 Discussion

Figure 2 shows the countries with the most research conducted related to education, and public outreach on geothermal energy are the USA)with 20 articles, Italy with 12 articles, Germany with 10 articles and the UK with 9 articles while the countries with the lowest are on Oceania continent.

This means Europe and America have continued to improve the education and public outreach on geothermal energy in line with the increasing infrastructure development. Meanwhile, Asia, Oceania and Africa have not maximised the concept to increase their knowledge and understanding of geothermal energy. This shows there is still low public

awareness of this renewable source, with some countries reported to have rejected its development (Adityatama et al., 2019; Yasukawa et al., 2018). Further research on education and public outreach is, therefore, recommended in these continents to ensure geothermal energy is prioritised globally.

There is a need for every country to implement education and public outreach towards increasing public knowledge, understanding, and awareness in order to ensure global participation in geothermal energy development. Moreover, the support, participation, and public awareness of stakeholders, students, government, organisations and industry have the ability to assist the rapid development of this energy through the improvement in the decision-making process (Ernst, 2019). It was also discovered that a high level of awareness also has the ability to increase public confidence in geothermal energy.

Geothermal is a non-carbon renewable energy that has great potential to reduce the threat of climate change in the world (Soltani, et al., 2021). The energy transition from fossil to renewable energy has challenges and obstacles that need to be explored to find the best solution. Based on various previous research, geothermal energy can show significant potential in reducing carbon emissions from electricity production (Moya, et al., 2018).

There is a need for the continuous development and dissemination of information on geothermal as future energy. This means the education and public outreach implemented in a country needs to pay attention to the demographic conditions and natural resources. There is also the need for the full support and participation of different parties, including the government, companies, stakeholders, communities, academics and the public to ensure future energy growth.

5 Conclusion

The implementation of education and public outreach was observed to have succeeded in increasing the development of geothermal energy in different countries of the world. It also assisted in ensuring effective relationships and interaction between the government, policymakers, stakeholders, organisations, communities, companies and society. The most research on this concept was recorded in Europe and America continents while Asia, Africa and Oceania were observed not to have maximised education and public outreach on geothermal. Therefore, there is a need for the implementation of this concept in developing countries through an initial analysis of the conditions and situations of the community as well as the demographic conditions and natural resources available in each country. Moreover, there is also a need for full awareness for different parties to achieve future energy goals.

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Nomenclature

EPO = Education and Public Outreach
IC = Inclusion
GW = Giga Watt
MW = Mega Watt
PEC = Public Education and Communication
PO = Public Outreach
TJ = Tera Joule