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Challenges of Education in Indonesia in Facing Fossil Energy Problems and Renewable Energy Use

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ABSTRACT

Global demand for fossil energy continues to increase, affecting both the environment and energy availability. This study aims to describe the energy crisis and its impacts, the adoption of renewable energy (RE), and the educational challenges in addressing these problems in Indonesia. The Systematic Literature Review method was conducted using Harzing's Publish or Perish application, which indexed articles from Scopus and Google Scholar, using the keywords "energy crisis," "renewable energy," "energy education Indonesia," and "impact of fossil energy." The review covered publications from 2017 to March 2025. A total of 116 articles met the eligibility criteria. The results indicate that the environmental impacts include increases in CO2 emissions driven by urbanization, industrialization, and transportation. Globally, RE adoption remains at only 1%. The use of renewable energy in Indonesia is relatively low, at 11.31% of the available energy supply. Indonesia's educational strategies include establishing specialized schools for the development of RE, curriculum support, and implementing project-based learning. These strategies must be replicated and further developed by other institutions. Through these efforts, Indonesia is expected to become more aware of the limitations and impacts of fossil energy and better able to utilize the availability of renewable energy.

***Keywords*:**

Energy Crisis; Environmental Education; Fossil Energy; Indonesian Education; Renewable Energy.

ABSTRAK

Kebutuhan energi fosil global terus meningkat, berdampak pada lingkungan dan ketersediaan energi. Penelitian ini bertujuan menggambarkan krisis

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energi dan dampaknya, pemanfaatan energi terbarukan, dan tantangan pendidikan Indonesia dalam mengatasinya. Metode Penelitian Sistematyc Literature Review dilakukan dengan aplikasi Harzing's Publish or Perish untuk artikel terindeks Scopus dan Google Scholar dengan kata kunci "krisis energi", "energi terbarukan", "pendidikan energi Indonesia", dan "dampak energi fosil". Tahun publikasi dari 2017 hingga Maret 2025. Sebanyak 120 artikel memenuhi kriteria kelayakan. Hasilnya menunjukkan dampak lingkungan berupa peningkatan emisi CO2 berasal dari urbanisasi, industrialisasi, dan transportasi. Secara global, adopsi energi terbarukan sebesar 1%. Penggunaan energi terbarukan di Indonesia tergolong rendah, yaitu 11,31% dari ketersediaan energi yang ada. Strategi pendidikan di Indonesia adalah menerapkan pendirian sekolah khusus pengembangan energi terbarukan, dukungan kurikulum, dan pembelajaran berbasis proyek. Penerapan strategi tersebut harus ditiru dan dikembangkan oleh lembaga lain. Melalui strategi ini, Indonesia dapat menjadi negara yang sadar akan keterbatasan dan dampak energi fosil serta mampu memanfaatkan ketersediaan energi terbarukan.

***Kata kunci*:**

Krisis Energi; Pendidikan Lingkungan; Energi Fosil; Pendidikan Indonesia; Energi Terbarukan.

1. Introduction

Energy is an important pillar of development across various sectors. The adoption is also an engaging topic because it is directly related to sustainable development and has a significant impact on environmental quality. Urbanization and an increasing urban population lead to increased energy consumption and the development of urban environmental infrastructure (J. Zhu et al., 2021; Q. Zhu & Leibowicz, 2020). Economic growth is proportional to increased energy consumption. The increase in energy consumption causes global temperatures to increase due to increased CO_2 emissions (Anwar et al., 2020; Bashir et al., 2021; S.). One of the factors that influences carbon emission production is energy consumption in the transportation system (Xu & Xu, 2021; C. Zhu & Gao, 2019). The level of urban energy consumption and carbon emissions depends on the type of energy source used for transportation. The International Energy Agency states that the transportation sector contributes a third of global carbon emissions and is projected to exceed 50% by 2030 (Sun et al., 2018).

Industrialization is another factor driving CO_2 increases through electricity consumption and the combustion of fossil fuels (Lamb et al., 2021). Industrialized countries set high economic growth targets, which further raise global energy demand (S. Li et al., 2021). Both developed and developing countries are motivated to strengthen the renewable energy sector to reduce the energy crisis and the adverse effects of fossil fuel, while still pursuing economic growth (Barkdull & Harris, 2024).

Zaidi et al. (2021) and Zhang et al. (2022) reported that Financial Inclusion (FIN) and economic growth significantly worsen environmental quality. Indicators of economic growth and national welfare are often expressed in Gross Domestic Product (GDP). A high GDP value indicates strong

activity and high production output (Banday & Aneja, 2019). For example, in 2020, the United States had a GDP of approximately US$21 million, requiring energy consumption of 25,000 TWh, resulting in carbon emissions of 4.71 billion. Indonesia, with a GDP of US$1 million, required an energy consumption of 2,121 TWh, resulting in carbon emissions of 589.5 million tons. Generally, high energy consumption is correlated with high CO_2 emissions. This trend is influenced by population density, economic growth, and industrial activity in each country (Rahman & Vu, 2021; Solarin, 2020). Carbon management requires increased attention, as corporate emissions continue to rise and significantly contribute to environmental degradation (Mercer et al., 2022; Schernikau & Smith, 2022).

The use of energy in the form of fossil fuels plays a dominant role in the global energy system. Fossil fuel consumption in 2020 in the form of coal, oil, and gas was 128,550 TWh, larger than the use of renewable energy, which was only 934.44 TWh (BP Statistical Review of World Energy, 2021). The use of oil energy sources plays a significant role, accounting for 48,259 TWh. The large disparity between fossil and renewable energy consumption raises global concerns over the environmental impact of fossil fuel reliance (Asongu et al., 2020; Solarin, 2020). Efforts to mitigate the negative effects of economic growth on climate change pose a major challenge for all countries. Achieving environmental sustainability should be aligned with maintaining economic progress. Energy efficiency policies are crucial for reducing global warming and lowering CO_2 emissions. Effective regulations and proper guidance can facilitate the implementation of low-carbon transportation solutions (Axsen et al., 2020; Nieuwenhuijsen, 2020).

Renewable and strategic energy adoption present viable solutions to the environmental impacts of current practices (Adekoya et al., 2022). Renewable energy power plants in the EU, US, China, Japan, Southeast Asia, and Africa continue to increase the percentage of renewable resources in the global power generation mix (Gielen et al., 2019; Hoang et al., 2021). Agricultural countries have opportunities in the form of biomass, which is a sustainable energy source. This energy can also be harnessed from solar panels (Bartamani & El-Saleh, 2021; Dawoud, 2021; Paul et al., 2022), biomass (Alnhoud et al., 2021; Derakhshandeh et al., 2021; Hasan et al., 2022), air (Agyekum et al., 2021; Setiawan et al., 2021), and water (J. Li et al., 2021; Tian et al., 2020). These sources offer clean and sustainable alternatives to fossil fuels (Tawalbeh et al., 2021).

Indonesia is among the countries with abundant renewable energy potential (Gunawan et al., 2021). Government Regulation No. 79 of 2014 concerning the National Energy Policy (KEN) and Presidential Regulation No. Law 22 of 2017 on the National Energy General Plan (RUEN) reflects the government's commitment to tapping into this potential. The policies set renewable energy targets of 23% by 2025 and 31% by 2050 as a share of total national energy needs. However, by 2020, renewable energy accounted for only 11.31% of the energy mix (Ministry of Energy and Human Resources of Indonesia, 2021). The Institution's approach to increasing the renewable energy share still faces challenges.

Several factors influence the low realization of the renewable energy share in Indonesia. Household electricity consumption, which accounts for 43% of the total national electricity consumption, is primarily based on fossil fuels. The slow development of renewable energy has led to a continued dependence on fossil fuels, particularly oil and natural gas (Erdiwansyah et al., 2021).

The community views fossil fuels as cheaper than renewable energy (Egli et al., 2018). Communities that are not aware of the impacts of the crisis and the use of fossil fuels are unmotivated to undergo a transition to more sustainable energy sources (DeRolph et al., 2019). Policymakers need to build effective communication in raising community awareness regarding energy use through various strategies (Pagliaro & Meneguzzo, 2020; Surana et al., 2020).

Effective action to overcome the crisis and impacts of fossil fuels can be taken by promoting the use of renewable energy through education (Saheb et al., 2022). Education can play a crucial role in raising awareness about the negative environmental impact of fossil fuels and the limitations of these fuels. Education has been recognized as an important tool for achieving sustainability and protecting nature through transforming human attitudes towards nature (Ardoin et al., 2020; Gratiela & Saracli, 2019). In this case, there is a great opportunity for education to contribute to changing the way people think, thereby reducing their dependence on fossil fuels. The world of education should also be able to assist students regarding knowledge and developments in renewable energy technology (Derasid et al., 2021).

Environmental education addresses complex topics within dynamic systems to promote behavior change. It lays the foundation for richer discussions about environmental action by developing student capacity, supporting concrete behavioral changes, and engaging students in direct action that results in improvements related to conservation challenges and energy issues (Ardoin et al., 2020). Social Cognitive Theory illustrates the significant relationship between antecedents, including attitudes, knowledge, and skills, and actual behavior. Student behavior is influenced by the education they receive from role models.

Educational concept supports the achievement of environmental education. Education for Sustainable Development (ESD) is realized when there are exemplary teachers, good practices in schools, and an institutional culture that supports sustainability. The implementation of this learning will shape students' sustainable values, attitudes, and behaviors as an effort to address the fossil fuel crisis and transition to renewable energy through a supportive education system.

The presence of technology can lead to other actions to overcome the energy crisis and its impact. The United States, as the country with the highest GDP in the world, does not imply that it also has the highest consumption value. Low energy consumption values can be represented by effective energy use. Effective energy utilization can be carried out by using technology (Sgouridis et al., 2019). Technology development in the US is implemented through techno-infrastructure, environmental management, and public vehicle governance (Rames et al., 2021). This implementation has an impact on vehicle fuel savings. Gai et al., (2021) stated that education is one of the factors supporting technology development programs. Another finding oleh Chen et al., (2020) that an integrated strategy is needed to create a healthy environment from the aspects of governance, industry, and education.

Various energy-related research studies have been conducted. This review article explores how education is one approach to fostering community awareness and strategies for introducing energy-related technology. The article is written to answer the research questions:

1. How is the energy crisis occurring in the world, and what is the impact of the use of fossil fuels?
2. How is renewable energy being adopted, and what challenges are included?

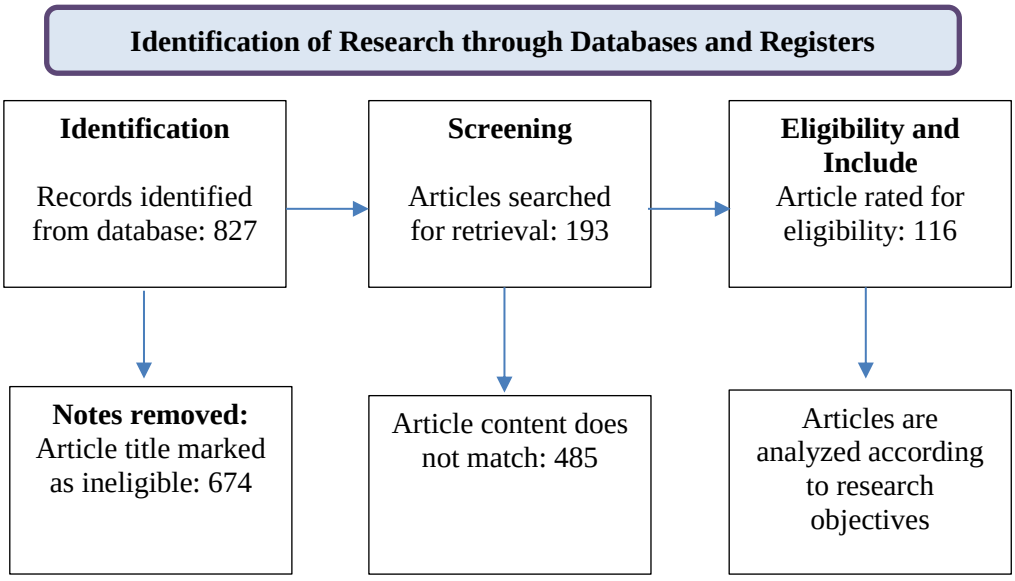
3. What is the role of education in addressing the energy crisis, particularly in Indonesia?

This research is expected to provide insight into the role of education in responding to the crisis and the impact of fossil fuel use, as well as maximizing the potential of existing renewable energy.

2. Methods

2.1. Research Design

This research is a systematic literature review. Fieldwork demonstrates the breadth of literature and the types of studies conducted on the energy crisis and renewable energy utilization. The issues of the energy crisis and the limitations of renewable energy utilization are explained through an educational approach. The systematic review was conducted using procedures adopted from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. This procedure consists of four main steps: identification, screening, eligibility, and inclusion (Page et al., 2021). A flowchart of the research procedures in this study is shown in Picture 1.



Picture 1. Flowchart of Research Procedures

2.2 Identification

A systematic search was conducted using Harzing's Publish or Perish 8 for articles indexed in Scopus and Google Scholar. Identification involved finding, considering, and refining appropriate keywords for article searches. These keywords were identified before retrieving the literature to ensure accuracy and relevance. Articles were searched by entering keywords into the title, abstract, and keyword fields: "energy crisis," "renewable energy," "energy learning," "energy learning Indonesia," "energy education," "energy education Indonesia," and "the impact of fossil energy." Articles published from 2017 to March 2025 were included. At this stage, 823 articles were identified.

2.3 Screening

The screening stage involved determining the inclusion and exclusion criteria used to develop the systematic literature review. This process was applied to the 823 articles identified during the

initial search, using several inclusion criteria. The first criterion was the publication year, limited to articles published between 2017 and March 2025. This ensured the inclusion of recent studies that can describe the current state of the fossil energy crisis, the utilization of renewable energy, and the role of education in addressing these issues. The second criterion concerned the type of publication. Only journal articles indexed in Scopus and Google Scholar were included, as these publications are considered to possess adequate quality and have undergone peer review before publication.

Another screening criterion was language, in which only articles written in English were selected. This was intended to reduce the risk of misinterpretation and to ensure clarity in presenting the review of the selected studies. The final criterion focused on thematic relevance, specifically studies addressing the energy crisis, renewable energy utilization, and the role of education in explaining these issues, both globally and in the Indonesian context. This screening stage resulted in 189 eligible articles, while 674 articles were excluded.

2.4 Eligibility

The eligibility stage aimed to identify articles that aligned with the research objectives. This stage ensured the selection of articles that provided substantive contributions to the research. The eligibility assessment involved analyzing the titles, abstracts, research findings, and discussions of the 189 articles that were screened. A total of 116 articles were deemed eligible for further analysis.

2.5 Data Extraction

The articles that passed the eligibility stage were subsequently analyzed to identify patterns relevant to addressing the research questions. The data analysis process involved a thorough examination of 51 articles designated as primary sources and 65 articles categorized as supporting sources. The supporting articles contributed to the introduction and background sections that contextualize the research problem. Meanwhile, the primary articles directly addressed the research questions concerning the energy crisis, the utilization of renewable energy, and the challenges faced by the education sector in responding to energy-related issues. The authors and main thematic classifications are presented in Table 1.

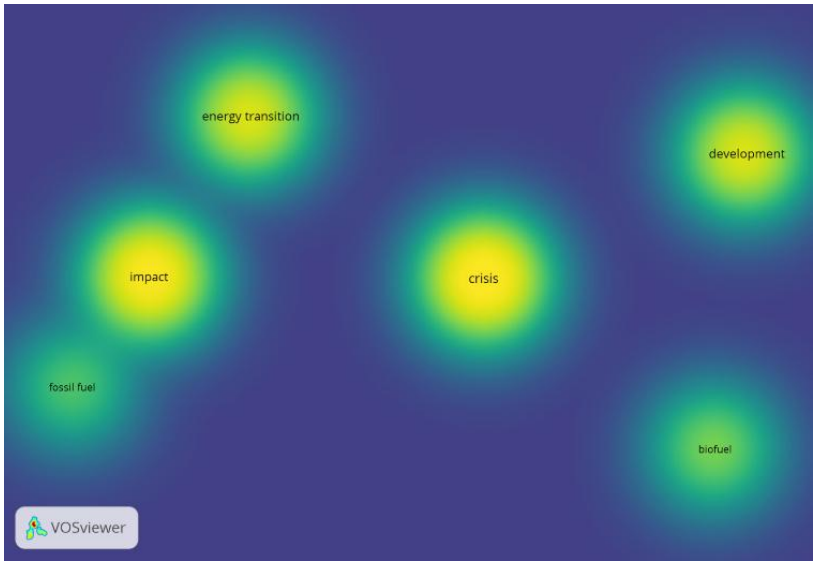
Table 1. The Authors' Data and Main Discussion Topics

No.	Main Discussion	Authors'
1.	*Fossil Energy Crisis*	Khan et al., (2021); Khan et al., (2018); Danish & Baloch (2018); Kim et al., (2019); Sun et al., (2018); Pata, (2018); Fan & Hao, (2020); Wasti & Zaidi, (2020); Ahmad & Zhang, (2020); Karamaneas et al. (2023); Zhu & Gao, (2019); Li et al., (2021); Rehman et al., (2019); Rauf et al., (2018)
2.	*Renewable Energy and Its Challenges*	Bartamani & El-Saleh, (2021); Pata & Karlilar, (2024); Smith, (2020); Rehman et al., (2019); Khan et al., (2021); Bieda & Cienciała, (2021); Mathpal et al., (2021); Vásquez et al., (2025); Naqash, (2023).

3.	*Challenges in the World of Education*	Aditya et al., (2025);Salvarli & Salvarli, (2020); Vakulchuk et al., (2020); Merritt & Bowers, (2020); Agusalim et al., (2025); Wilujeng et al., (2019); Derasid et al., (2021); Nakamura et al., (2023); Gai et al., (2021); Bieda & Cienciała, (2021); Mahler & Barber (2017); Ni et al., (2025); Leslie, (2021); Erdiwansyah et al., (2021); Raharjo et al., (2022); Muslim et al., (2021); Hidayati et al., (2021); Hakim et al., (2021); Anggraini et al., (2018); Sedayu, (2019); Priambodo et al., (2022); Sakti et al., (2022); Wilujeng et al., (2019); Andajani et al., (2019); Rahmawati et al., (2018); Koes et al., (2019); Mayasari et al., (2019); Ali et al., (2021); (Shamoon et al., 2022); Pambudi et al., (2024); Hakam et al., (2025); Nurwidodo et al., (2020).

3. Results and Discussion

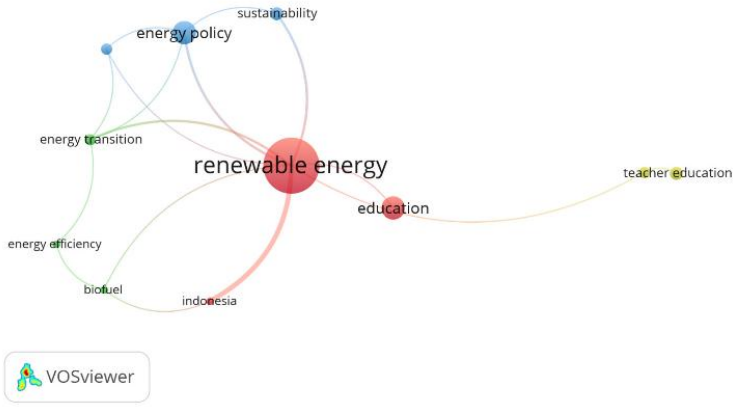
A total of 55 selected articles were grouped into three thematic categories. The VOSviewer application was used to help map the relationships among keywords. In the first stage, several keywords were selected to obtain an overview of the energy crisis and its related issues. The results of this analysis are presented in Picture 2.



Picture 2. Keyword Relationships on the Energy Crisis

Picture 2 illustrates that the energy crisis is linked to environmental impacts, sustainable development, energy transition, and the use of fossil fuels. The term' energy crisis' is closely linked to environmental impacts and the energy transition. Fourteen articles related specifically to the energy crisis were identified for further analysis. This analysis focuses on the utilization of fossil energy, the availability of fossil fuel reserves in both developed and developing countries, and the environmental impacts of fossil energy.

The next area of analysis examines the relationship between the keywords renewable energy and education. The results of this keyword mapping are presented in Picture 3.



Picture 3. Keyword Relationships on Renewable Energy and Education

Picture 3 indicates that renewable energy is associated with several other keywords, including sustainability, energy transition, and education. The keyword "RE" appears within the same cluster as "Indonesia" and "Education," suggesting a close conceptual relationship among these terms. However, the keyword Indonesia is not yet directly linked to education in the context of renewable energy utilization, revealing a gap that requires further elaboration. The discussion on renewable energy (RE) is based on nine articles that address globally and nationally utilized renewable energy sources, as well as the challenges faced by several countries in adopting renewable energy. The subsequent analytical focus concerns challenges within the education sector. A total of 32 articles were examined, covering the role of education, strategies for integrating RE, and recommendations for educational implementation in the Indonesian context.

3.1 Fossil Energy Crisis

The burning of fossil fuels started with the onset of the Industrial Revolution. The exponential growth in industrialization, population, and urbanization led to a global energy crisis and increased concerns over dependence on non-renewable energy sources (Khan et al., 2021). In 2019, fossil fuels, including gasoline, diesel, coal, and natural gas, supplied 84% of the world's primary energy consumption. Khan et al. (2018) stated that there was a two-way causality between renewable energy consumption and economic growth in both the short and long term. Similarly, Danish & Baloch (2018) showed a dynamic relationship between economic growth, road transportation energy consumption, and environmental quality. Both developed and developing countries became major energy users. Fossil fuel energy reserves of these countries in 2020, based BP Statistical Review of World Energy, are shown in Table 2. Coal, oil, and gas remained the primary sources of energy.

Table 2. The Size of Global Fossil Energy Reserves and Various Countries

No.	Country	Fossil Energy Reserves		
		Coal (tonnes)	Oil (barrels)	Gas (m^3)
1	World	1.07 trillion	1.73 trillion	188.07 trillion

2	United States	248.94 billion	68.76 billion	12.62 trillion
3	China	143.20 billion	25.96 billion	8.40 trillion
4	United Kingdom	26.00 million	2.50 billion	186.98 billion
5	India	111.05 billion	4.54 billion	1.32 trillion
6	Indonesia	34.87 billion	2.44 billion	1.25 trillion

The global fossil fuel reserves-to-production (R/P) ratio was estimated to be on a declining trend. This ratio measures the number of years remaining for fuel supply based on current consumption levels. According to data from the BP Statistical Review of World Energy (2016), as of 2024, coal was projected to last for 105 years, natural gas for 54 years, and oil for 42 years. These estimates may change depending on the discovery of new fuel reserves and changes in annual consumption.

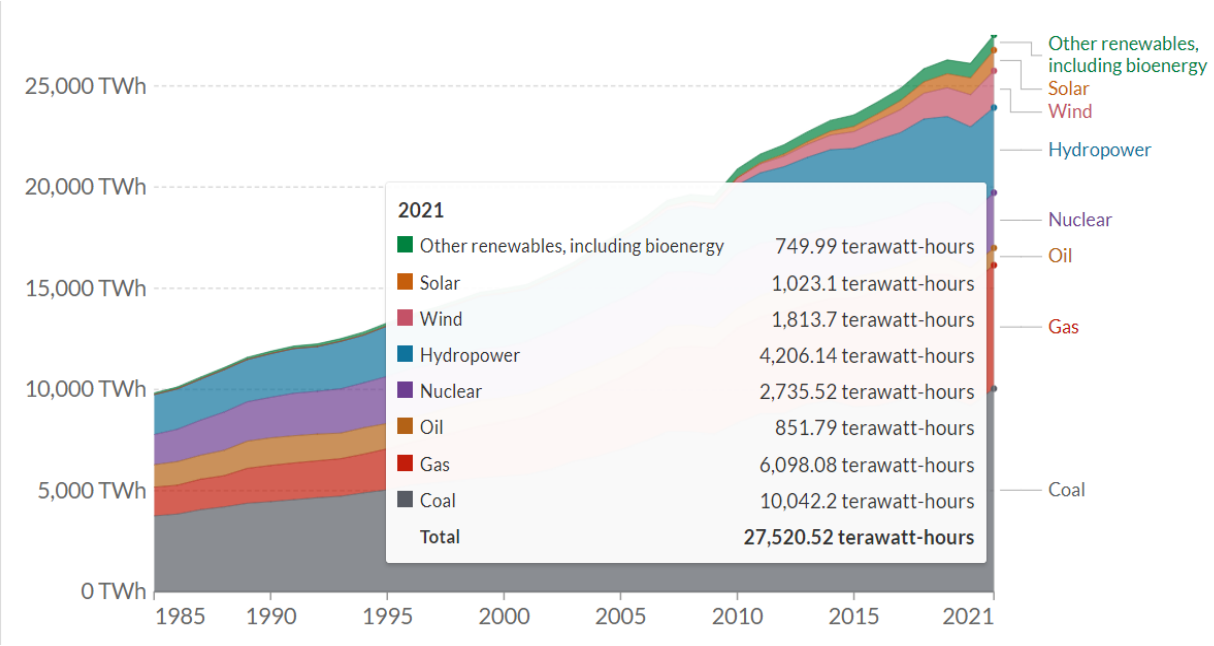
Energy performance was one of the core pillars of every policy aimed at ensuring inclusive and sustainable economic growth. The building sector accounted for approximately one-third of global energy consumption (Kim et al., 2019), while the transportation sector accounted for another third (Sun et al., 2018). Rapid economic development has led to an energy crisis and environmental pollution, resulting in increasingly serious problems with the structure of energy consumption (Pata, 2018; Fan & Hao, 2020; Wasti & Zaidi, 2020).

Cost-effective measures to improve welfare, ensure energy supply security, reduce the climate footprint of the energy network, and enhance competitiveness continued to be implemented (Ahmad & Zhang, 2020). Future energy demand was examined through alternative trends to explore different perspectives on energy transformation and development. A transformation towards a low-carbon fossil fuel mix characterized the outline. Karamaneas et al. (2023) emphasized that a diverse energy supply mix, combined with energy efficiency strategies, was key to rapid and feasible decarbonization in the country. Changes in technological assumptions and stakeholder policies supported this transformation.

The next energy crisis was seen from an environmental perspective. Several factors contributed to air quality issues, including climate change. These factors may be attributed to urbanization, the use of fossil fuels in transportation, and industrialization (Zhu & Gao, 2019). According to Çetin & Ecevit (2015), it was found that the amount of CO2 emissions in developing countries resulting from energy consumption increased significantly. Countries with high growth rates of fossil energy consumption were concentrated in Asia and North Africa (S. Li et al., 2021). The use of fossil fuel energy has contributed to global warming and increased carbon dioxide emissions, with adverse effects on the environment (Rehman et al., 2019). The combustion of fossil fuels could emit gaseous pollutants (e.g., carbon dioxide (CO2), carbon monoxide (CO), nitrogen oxides (NOx), sulfur oxides (SOx), volatile organic compounds (VOCs), and particulates (PM)). These gaseous pollutants can alter the atmospheric composition, resulting in harmful effects on climate and human health (Rauf et al., 2018). Conventional energy consumption was one of the primary determinants of environmental pollution, necessitating policy measures to mitigate environmental damage (Çetin & Ecevit, 2015).

3.2 Renewable Energy and Its Challenges

The increasing global energy demand, coupled with the harmful environmental effects of fossil fuels, has triggered the search for alternative renewable energy sources (Khan et al., 2021). Renewable energy was a type of energy produced from naturally occurring renewable resources such as sunlight, waves, rain, wind, biofuels, and geothermal heat (Bartamani & El-Saleh, 2021; Pata & Pata, 2024). It provided energy for various purposes, including electricity generation, heating and cooling air and water, and transportation. The discovery and adoption of renewable energy continued to be developed. Renewable energy adoption remained at only 1% of the total energy used globally. Picture 4 shows a comparison of renewable energy source production for electricity up to 2021. These sources included sunlight, wind, water, and other renewable energy. Hydropower held the largest proportion among renewable energy sources. Overall, the utilization of renewable energy sources accounted for 7,792.93 TWh of global electricity production (Ember Global Electricity Review).



Picture 4. Comparison of Renewable Energy Source Production for Electricity

Considering the condition of global fossil energy reserves and the imbalance in the development of renewable energy utilization, it was necessary to establish a framework for the future energy system. Assessing the future of energy remained difficult. The transition to renewable energy must be driven by various stakeholders (Smith, 2020). Governments were expected to take action to increase the use of renewable energy resources and implement new policies to reduce CO_2 emissions (Rehman et al., 2019). These efforts also contributed to mitigating the climate crisis and addressing projections of further ecological disasters (Bieda & Cienciała, 2021).

The development of renewable energy was not without challenges. The use of plants and animals for energy required large plantations, a large labor force, extensive land occupation, and was both non-portable and expensive to handle (Mathpal et al., 2021). As the world began transitioning

from high-carbon to low-carbon energy systems, a key issue to address was energy security. Although many countries had invested significant time and resources in reducing fossil fuel supply vulnerabilities, similar security analyses had not been conducted for renewable energy sources (Vásquez et al., 2025). The reliability of renewable energy was threatened by factors such as extreme weather events, which were exacerbated by climate change (Naqash, 2023). Additionally, materials required for renewable infrastructure, such as wind turbines, solar panels, and mining products, were concentrated in a relatively small number of countries.

A real-world example of renewable energy development challenges was found in China, which was a major producer of Li-ion batteries, with production in 2023 targeted at 1,235 GWh. However, this development led to policy-driven reductions in wind power (7%) and solar power (3%) in 2018 (Pagliaro & Meneguzzo, 2020). A key challenge of Li-ion battery production was that the materials needed for renewable energy storage required increased mining. India also faced challenges in using renewable energy. Although solar power was predicted to become the largest in the world at 2,255 GW, and wind power the fourth largest at 36,625 GW, the development of solar projects remained difficult due to land requirements. These projects required large tracts of land, often converted from agricultural use or located in deserts and coastal regions, necessitating the construction of long-distance transmission lines and substations to connect to urban and rural areas. Challenges require ongoing scientific research to ensure environmental protection.

3.3 Challenges in the World of Education

The transition from fossil fuels to renewable energy cannot be avoided, despite various challenges (Salvarli & Salvarli, 2020; Vakulchuk et al., 2020). Education as a tool to build knowledge and impact skills played a crucial role in addressing the problems (Merritt & Bowers, 2020). The learning study took the form of Environmental Education (EE), Education for Sustainable Development (ESD), or a religious approach (Agusalim et al., 2025; Wilujeng et al., 2019). Educational programs were developed to promote environmental awareness and support, as well as to enhance the use of renewable energy (Derasid et al., 2021). Building public opinion can be crucial in shaping how a country implements renewable energy policies in the future (Nakamura et al., 2023). Education was a strategy in building awareness and introducing technology to energy crisis problems (Gai et al., 2021).

Energy was one of the central ideas that connected all disciplines. The crisis conditions and impacts of fossil fuels led some people to start discussing the need to collect information about the energy potential of certain parts of the environment where they live (Bieda & Cienciała, 2021). Mahler & Barber (2017) found that the way of thinking of students who initially did not believe in using renewable energy sources could be changed to accept the use of renewable energy. Those who were previously reluctant to consider renewable alternatives changed their minds through appropriate educational methods. Abichandani et al. (2014) taught students to explore wind energy adoption using a virtual reality ecosystem. The program enhanced students' independent thinking and developed the design and operational skills for renewable technologies. This educational method needs to be implemented more widely in various countries. The method also required the participation of adults, governments, and companies through inclusive communication strategies, financial support for the

adoption of green technologies, and intergenerational collaboration to share knowledge and experience within communities (Ni et al., 2025).

Indonesia was one of the countries committed to reducing greenhouse gases while maximizing the potential of renewable energy resources (Leslie, 2021). Although Indonesia had abundant renewable energy sources, the country was not utilizing them optimally, as only 9.07 GW out of a potential 441.7 GW had been harnessed (Erdiwansyah et al., 2021). The target for the use of renewable energy in the energy mix was 23% by 2025 and 31% by 2050 (Raharjo et al., 2022).

Indonesia's commitment to reducing its use of fossil fuels faces challenges. These challenges hamper the adoption of renewable energy, including disparities in energy access and inadequate policy implementation. The government's financing mechanism is unreliable, and there is a lack of education and awareness among the general public (Aditya et al., 2025).

Awareness of the energy crisis continues to increase, but behavioral changes towards sustainable energy use remain limited, especially among students (Pambudi et al., 2024). Existing studies often focus on individual knowledge or the social environment separately, leaving a gap in understanding how sustainability literacy and social support, both of which collectively influence sustainable energy consumption behavior (Hakam et al., 2025).

Increasing sustainability literacy through education system resilience and adaptive learning technology has not been sufficiently discussed in existing studies. The causal attributes of sustainability literacy encompass adaptive learning technology, resilient education systems, sustainability-focused courses, and sustainability innovation. The impacted attributes of sustainability literacy include financial literacy, sustainability awareness, and the global citizenship curriculum.

Indonesia's national education curriculum also needs refinement. The number and quality of eco-schools in the Adiwiyata program must be continuously increased. The implementation of the Adiwiyata program has a positive impact on students' environmental literacy (Nurwidodo et al., 2020). The government must be directly involved in improving the quality of educators and supporting infrastructure, which are considered weak. The resulting sustainability literacy will equip students with the knowledge to use energy wisely, supported by social conditions to strengthen these choices through motivation and affirmation from peers and social networks. This demonstrates the importance of combining educational interventions and social reinforcement to encourage behavioral change.

The government worked across various sectors to realize these targets through education. The following were various strategies implemented in the Indonesian education system.

1. Designing energy-related education in a curriculum. A comprehensive curriculum was implemented through the Adiwiyata program (environmentally friendly schools) to increase students’ knowledge and awareness of renewable energy. The government established renewable energy-based Vocational High Schools (Muslim et al., 2021). At the time, there were 12 vocational schools based on renewable energy. The results of the implementation

were reinforced through an evaluation or final assessment. Hidayati et al. (2021) further developed HOTSEP (High-Level Thinking Skills for Environmental Problems) questions in the context of environmental problems related to electricity. The HOTSEP question instrument consisted of three categories of thinking levels: criticizing environmental problems, solving environmental problems, and developing innovations about the environment.

2. Adopting school buildings as models of "smart buildings" and "smart energy systems". School buildings were designed with energy efficiency in mind. These designs incorporated the use of renewable energy, eco-friendly architecture (with proper air circulation and lighting), and energy-efficient electrical equipment (Hakim et al., 2021). The Green School Bali served as an exemplary institution that implemented sustainable energy management. The learning model integrated entrepreneurship with nature-based education. This facilitated sustainable energy management and provided hands-on experiences with adoptable, scalable green technologies (Anggraini et al., 2018). Another example was the Islamic boarding school in Al-Fatah, Malang, which featured a green and smart building concept that was environmentally friendly, energy efficient, and resource-conscious (Sedayu, 2019). The use of buildings and land for renewable energy power plants had a significant impact on reducing CO_2 emissions (Priambodo et al., 2022; Sakti et al., 2022).
3. Using supporting media and teaching materials. Wilujeng et al. (2019) developed a student worksheet based on the Education for Sustainable Development (ESD) framework, specifically the Education for Environmental Sustainable Development (EESD) component. The implementation provided benefits related to insights into environmental literacy. Other learning media were developed by Andajani et al. (2019) in the form of Edukit 4.0. The served as an application designed as a learning tool for junior high school students. It was easy to use, engaging, and included a measurable evaluation system. The application enabled students to monitor the energy output from solar panels, including voltage, amperage, and power graphs. Media tools were also developed by Rahmawati et al. (2018), who created a renewable energy simulator.
4. Providing support for project creation. Project-based learning played a significant role in developing students' technological skills. Koes et al. (2019) applied the STEM method in the form of designing a water pressure booster pump. The STEM method was also used by Mayasari et al. (2019) in designing a solar energy project in the form of a prototype. Another project-based learning was by Ali et al. (2021), who designed and implemented a trainer kit for an on-grid hybrid solar power generation system. The implementation of project-based learning proved effective in improving student knowledge and producing meaningful educational experiences. The gradual development of renewable energy technology helped address energy shortages by reducing dependence on fossil fuels and promoting environmentally friendly solutions (Shamoon et al., 2022).

3.4 Recommendations

Various strategies have been implemented in Indonesia to address the energy crisis and promote the use of renewable energy in education. However, the actual use of renewable energy remains low. Research by Leslie (2021) further stated that the majority of students in major cities (Jakarta and

Medan) were not taught about the application of environmentally friendly energy sources. This situation does not correlate with the government's commitment to maximizing the potential of renewable energy. The Department of Education should further prioritize and include environmental publications and renewable energy as compulsory subjects in schools. Education in Indonesia can also adopt strategies that have been implemented in other countries. The following are global education strategies that have been adopted in Indonesia's education system.

1. The development of "smart buildings" for campuses and schools can be expanded. Nachabe et al. (2025) provided an overview of electricity generation for smart homes using the Adaptive Hybrid Energy System (AHES), which consists of two renewable energy sources: sunlight from solar panels and wind from wind turbines. The smart home is IoT-based, enabling real-time monitoring and control. Tushar et al. (2023) also described an integrated financial and environmental evaluation framework for optimizing building photovoltaic solar power systems in Australia under recessionary uncertainty. Other smart building concepts have been widely applied in the United Kingdom to achieve net-zero carbon emissions (Kourgiozou et al., 2021).
2. Strengthening curriculum materials. Many people are unaware that environmental participation in overcoming global warming and climate change can begin at home. Excessive land use for buildings, overuse of electricity and water, and underutilization of natural energy remain common issues (A. Rahmawati et al., 2018). Learning about energy use is essential for building awareness of fossil fuel consumption, the impact of energy waste, and the potential for renewable energy in local environments (Hidayati et al., 2021; Zidny et al., 2021). Textbooks that cover topics such as renewable energy, energy conservation, and energy crises can help raise student awareness (Revák et al., 2023; Rom, 2024).
3. Technology learning is further enhanced at secondary and higher education levels. Technology learning can be a potentially effective strategy for reducing production costs. The total cost of electricity production required to achieve long-term renewable energy targets is 4-10% lower than in scenarios that ignore technological advancements (Handayani et al., 2019). Scholars have developed various innovations to produce energy sources that meet the increasing energy demand while being pollution-free (Bhawna et al., 2023). Learning the progress of computational technology for hybrid energy network scheduling can address the challenges of renewable energy uncertainty (Khalid et al., 2024)
4. Technology learning that has been developed needs to be evaluated continuously. Evaluation activities can further include exploring and identifying renewable energy technologies that are most effective in practice. For instance, optimizing wind energy often requires a focus on motor engines (Altuntas & Gök, 2020). Khan et al. (2024) and Alayi et al. (2022) comprehensively reviewed microgrid energy management strategies consisting of various energy resources by considering electric vehicles, energy storage systems, and AI methods to strengthen existing smart grid technologies and address uncertainty in load management. Ultimately, political and economic factors play a crucial role in determining the success of renewable energy in replacing fossil fuels and advancing bioenergy (Taylor et al., 2024).

Develop more vocational high schools that focus on addressing the energy crisis by utilizing renewable energy and technology. The government also needs to build collaboration with various parties according to expertise (Tàbara et al., 2020). Furthermore, government policies play a major role in reducing emissions, developing the potential for renewable energy use, and subsidizing energy technology (Fardnia et al., 2025; Fikru et al., 2024; Gu et al., 2024). Green education is essential for maintaining a sustainable world and preserving it for future generations (Javed et al., 2025; Kasztelewicz et al., 2022). In the face of a climate crisis, raising public awareness through both formal and non-formal education is important.

4. Conclusion

In conclusion, Indonesia is one of the countries with low utilization of renewable energy. Various challenges arise in utilizing renewable energy, such as government policies, the need for extensive land, adequate human resources, and supporting infrastructure. Education must be a key component in addressing the challenges of utilizing both fossil fuels and renewable energy. The ever-increasing demand for fossil fuels leads to increased CO2 emissions and a diminishing supply of fossil fuels. Educational strategies to address these issues can include establishing specialized schools focused on renewable energy development, providing curriculum support, promoting smart building practices, and implementing project-based learning.

Educators and researchers may also expand their investigations into the implementation of learning models related to renewable energy–based instructional materials and technologies, students' sustainable attitudes and behavioral changes, ecoliteracy studies, and efforts to enhance teacher competencies in achieving these goals. Through these strategies, Indonesia is expected to become a nation that is increasingly aware of the limitations and environmental impacts of fossil energy and capable of optimizing the utilization of renewable energy resources, thereby contributing to addressing both the fossil energy crisis and the advancement of renewable energy adoption.

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