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Sustainable Energy Cyclic System: Massive Operation and Integrated System for Optimizing Renewable Energy Sources

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Abstract
Energy as basic need for life indeed face crisis of scarcity. Yet, the idea of using renewable energy becomes popular for example hydropower, solar energy, side product (i.,g biomass and domestic waste) that have been introduced. Each of them have advantages and found reliable to be implemented. Ascribe to the concept of law conservation of energy, these potentials can be integrated and be optimized to create energy cyclic system. Hence, this study introduces the concept of sustainable energy cyclic system by accommodating several resources namely hydropower, human side products, biomass and solar energy. This study used comprehend data which then analysed to purpose the idea. Data were collected and were projected to the focus of study. It is addressed to create systematic system of energy yet hampering energy crisis. This study shows that the idea to generate sustainable energy cyclic is reliable in which it compiles each of potential and integrates into systematic system. Moreover, the energy cyclic provides the sustainable solution facilitated by abundant resources such as human side product, biomass, hydropower, solar power, and salinity gradient energy.

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INTRODUCTION

Energy is a crucial aspect of life, the demand for which has been increasing along with the growth of the human population. Even during the COVID-19 pandemic, it has been found that the global economic issue (2021) has been dominated by an energy crisis that has led to an increase in fuel, gas, and electricity prices. This price increase is not a new phenomenon, as fuel price spikes have been occurring since the 1970s, exacerbating the global economy. The Russia-Ukraine conflict has also contributed to the rise in world oil prices. According to CNBC in 2022, the President of Indonesia, Mr. Joko Widodo, stated that almost all countries are experiencing an energy shortage due to this conflict. The increase in world oil prices has an impact on the increase in government subsidies, which amount to around IDR 2.56 trillion for every increase of 1 USD/barrel (Asmara and Guitara, 2022). This has become a global urgency to explore the potential and enhance the potential of energy sources.

Based on the availability in nature, energy can be classified into renewable and non-renewable. Renewable energy is a natural source of energy and the primary source of life. Types of renewable energy include solar energy, geothermal, wind, biomass from plants, and water. On the other hand, non-renewable energy includes petroleum and its derivatives (hydrocarbons), coal, and natural gas. These sources of energy come from ancient fossil materials that have been buried for millions of years, which cannot be replenished and are limited in quantity (Güney 2019).

As a heterotrophic organism, humans are naturally equipped to convert energy sources from nature to support their quality of life (Lam and Ravussin 2016). For example, food (a source of chemical energy) is used for bodily metabolism to produce energy. Ancient humans created fire from rubbing stones (friction force to thermal energy), as well as from the reflection of sunlight. With the passage of time, humans have been able to improve the conversion of other forms of energy, such as converting the potential energy of water into electrical energy, or wind energy into electricity etc (Syvitski et al. 2020). Moreover, crude oil, which comes from the biomass of ancient organisms, has been successfully converted into various forms of fuel and its derivatives, which have high consumption value (Mawad 2020).

Fossil fuels and their derivatives are projected to decline in the next 10 years. Data from the Director General of New and Renewable Energy and Energy Conversion (2018) shows that the current coal reserves, which are estimated at 7.3-8.3 billion tons, are predicted to be depleted by 2026. Meanwhile, the current oil stocks are 3.7 billion barrels and are predicted to be depleted by 2028. As for gas fuel, it is estimated to be 151.33 trillion cubic feet and predicted to be depleted by 2067. Fossil fuels have supplied more than 80% of the national energy needs, which certainly threatens sustainability (Indonesian Outlook, 2018). Several alternative efforts have been made, but they have not shown significant results. The use of biofuel and biomass-based energy has been researched with projections to complement fossil fuels. In reality, these efforts face obstacles due to biomass sources that threaten the food sector (Ulgiati et al. 2010). For example, bioethanol production, which often uses food sources such as corn, sugar cane, tubers, and so on.

Nowadays, efforts to tackle the energy crisis face several challenges such as overlapping energy sources with other sectors, limited variation in utilizing natural energy sources, and their environmental impacts. Hydro energy sources have enormous potential, especially for countries with abundant water resources such as Indonesia (Taufiqurrahman and Windarta,2020). The potential energy of water has been developed into electricity. Additionally, water can be converted into thermal energy and then converted into electricity. Aside, the utilization of solar energy has not been optimized. The sun is the largest source of energy in the universe and the source of life on earth supposedly functioned as energy for daily needs. It can be implemented on car roof panel using solar panel for its internal energy supply, thus fossil fuel reduced or even abandoned. From an environmental perspective, fossil fuels emit polluted gases, which can be avoided by using solar energy (Yuwono, & Pratama.,2021).

The Other sources of renewable energy can be obtained from human side products. These side products can be obtained from metabolic waste (feces) and domestic waste. Metabolic waste (feces) contains methane gas that has a burning calorific value (Ardiansyah.,2017). Domestic waste can be classified into two types: organic waste and plastic waste. Both can be converted into biofuels and oil. These various side products have great potential for utilization (Aftab, Zhang, and Kung 2021). The resulting fuel can be channeled back to domestic units as a substitute or complement to commercial Liquefied Petroleum Gas (LPG) used by the community.

Based on the aforementioned issues, this study proposed novel approach to overcome energy crisis by generating energy cyclic system which also promotes sustainability attributed by natural energy sources. This study aims to provide innovation to maximize the potential of renewable energy. Through a systematic and integrated approach, the "Sustainable Energy Cyclic System" was formulated. This system is intended to create a sustainable energy flow and cycle in an effort to prevent energy scarcity crises. Humans as energy consumers produce side products from their metabolic waste, which are then processed into energy (biogas). This biogas is used as an energy source for human activities (domestic, electricity, fuel). From these domestic activities, biomass side products can be produced and converted into household fuel, which is consumed by humans. These various activities can be combined into a cyclic system that is mutually integrated. Moreover, the potential of natural energy sources (sun and water) is developed to maximize the results. In a cyclic system, the energy from these natural sources is used to support energy needs without adversely impacting the environment.

METHOD

This study used literature-based review comprehending several opportunities to create sustainable energy cyclic concept. All literatures were used to address the objective and to discuss the reliable solution. Data were carried out regarding to literatures which author perspective also included to formulate the solution. Mind map of the idea is depicted on Figure 1 as follows.

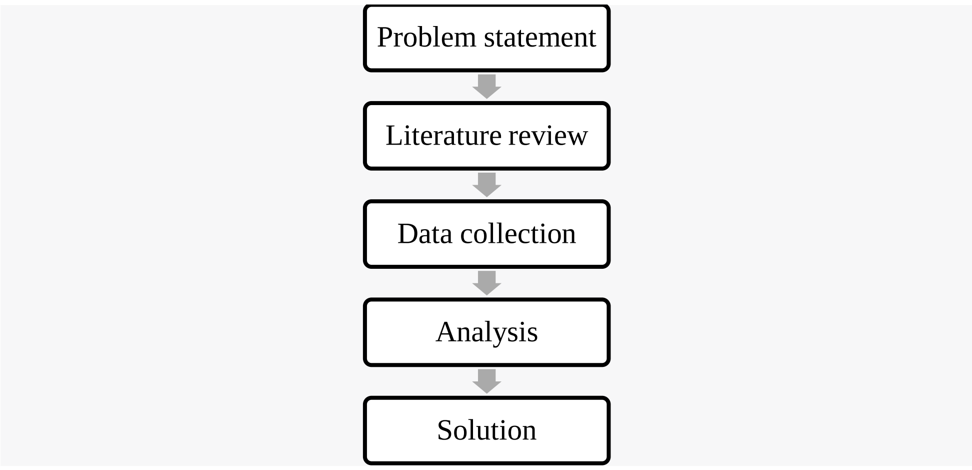

Figure 1. Mind map of Sustainable Cyclic Concept

RESULTS AND DISCUSSION

Sustainable Energy Cyclic System

Based on the issues that have been outlined, a suitable and widely beneficial solution (Figure 2) has been formulated. This solution is a massive integration of various renewable energy sources, both directly produced by nature and sourced from human activities.

The Sustainable Energy Cyclic System is a systematic, interconnected, and sustainable energy usage system. It revolves around humans as energy consumers and their various activities. As living beings, humans undergo metabolic processes that produce side products (feces) that can be converted into energy (biogas) (Emetere, Chikwendu, and Afolalu 2022). The biogas is then utilized as an energy source that supports human activities. Meanwhile, these human activities produce domestic waste side products (biomass and plastic) that can be converted into fuel. This process describes a continuous cycle of energy that can even be sustained. For optimization, the system can be supported by renewable energy units from nature such as solar energy and hydropower.

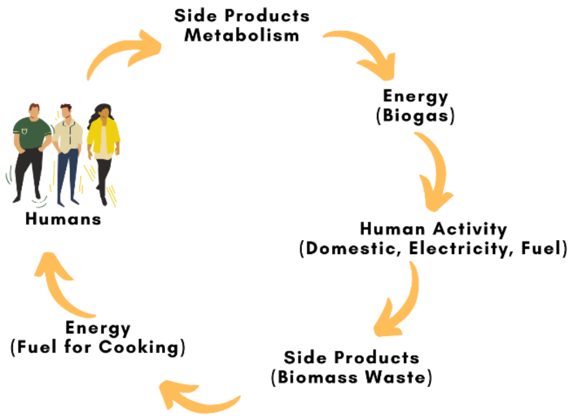

Figure 2. Mechanism of Sustainable Energy Cyclic System

The supporting technology used has been widely developed, but the integration and operation system have not been reviewed yet. For example, solar energy can be absorbed by solar panels which are then converted into electricity (Rizwan, Shaikh, and Labade 2018). Hydropower, which is based on potential energy, can also be converted into electricity. Therefore, the development plan for this system is outlined as follows:

Solar Energy

Solar energy comes from the radiation of sunlight, which is one of the main factors for life on earth. The global warming effect caused by the use of fossil fuels and non-renewable energy, which is threatened by a crisis, makes this energy a promising choice for the future. As a tropical country located along the equator, Indonesia has great potential for this energy (Handayani and Ariyanti 2012). The use of solar energy is not a new thing, and even solar panels have been widely developed through various research. Therefore, solar energy has a great projection to be implemented and developed.

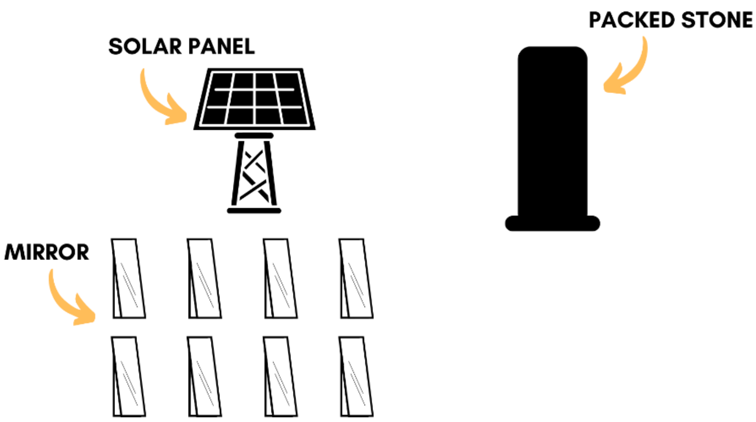

Figure 3. Improvement Design of Solar Energy

Solar Energy can be converted into electricity with the help of solar cells which are arranged into solar panels. Sunlight radiation emits photons which are then captured by solar cells and converted into electrons (Bozkurt, 2019). These electrons act as a source of electricity. The development of this technology involves adding mirrors to focus sunlight onto the solar panels (Patil et al. 2022). The mirrors are installed on the ground surface, while the solar panels are installed at a higher level. An automatic control system is used to change the orientation of the mirrors following the movement of the sun. Innovation in solar thermal energy storage systems was carried out by channeling it into packed stone (i.e.,storage material) (Bhalavi and Saini 2018). The stacked stones can be arranged in a cylindrical space (packed stone) which is then used to store the solar energy. The stored heat energy in the packed stone is utilized to generate electricity. The implementation of this system is illustrated in Figure 3.

Hydropower : Salinity Gradient Energy

One potential source of hydropower with significant potential is salinity gradient energy (SGE) found in the mixing of seawater and river water (Micale, Cipollina, and Tamburini 2016). This technology can convert the mixture of these two fluids into electrical energy facilitated by pressure retarded osmosis (PRO) membranes, driven by osmotic pressure differences. River water with low salinity (high osmotic pressure) will flow into seawater (high salinity) through the membrane. This process occurs spontaneously without the need for external force (pumps) (Itano et al. 2019). PRO membranes are installed between seawater and river water, and then the river water (low salinity) will penetrate the membrane to reach the seawater zone. As a result, there is an increase in seawater volume (decrease in salinity) which is then directed to a hydro turbine to generate electricity (Chang and Elimelech 2013). The osmotic pressure from seawater is equivalent to 20 atm, or it can be said that the energy that can be generated from the mixing of seawater and river water is equivalent to the pressure of a waterfall with a height of 680 ft (200 meters) (Emamia, 2012).

The development of the SGE system is carried out during the installation process. SGE is built at the estuary where seawater meets the river water. This is done to obtain a feed by reducing production costs. River water is obtained from a dam system located on high ground from the SGE unit. Thus, the river water automatically flows (due to gravitational force) towards the central unit. Meanwhile, seawater is pumped with a pipe location 100 meters from the shoreline to maintain its salinity. Both flows are equipped with filtration units before entering the central unit. SGE is illustrated in Figure 4.

SGE is known to have minimal environmental impact compared to other power generation methods. This is because the use of PRO membrane is a zero-emission power generator (Ripna, 2015). In addition, SGE is a renewable and environmentally friendly technology, and its installation does not threaten ecosystem sustainability. Based on these descriptions, it can be concluded that SGE has great potential as a new and renewable energy source that is environmentally friendly. Its installation and operating conditions are relatively easy, safe, and environmentally friendly. In fact, SGE is projected to generate a total global power of 3.1 TW (Renewable Energy Agency., 2014), which can certainly support national energy needs.

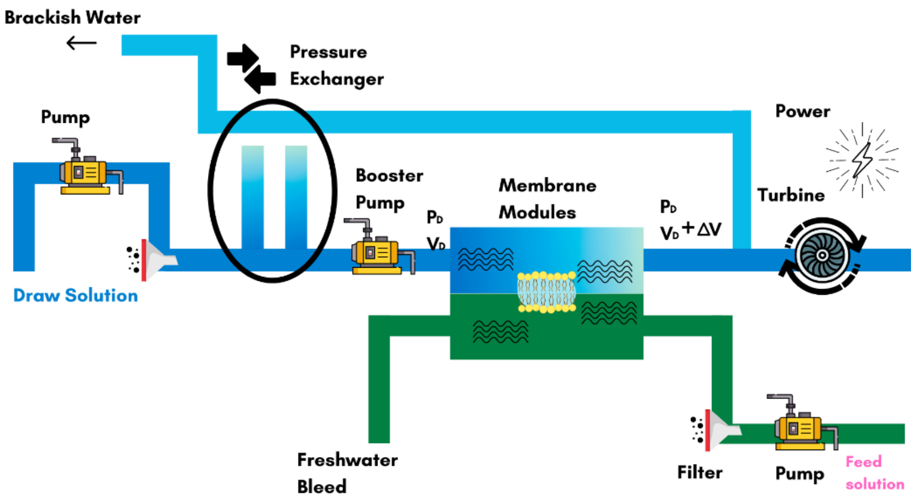

Figure 4. Design of Salinity Gradient Energy Using PRO Membrane

Side product (Domestic Waste) : Biofuel dan Liquid Fuel

Currently, the potential of renewable energy sources is being extensively explored and developed. These sources vary from geothermal, solar, hydroelectric, wind, and biomass. Biomass is projected to replace fossil fuels because it is renewable and sustainable. Its contribution is projected to increase by 62% from 2012 to 2035. If combined with other renewable energy sources, it can meet 50% of energy needs by 2035 (Kummamuru, 2016).

In terms of population, Indonesia produces 3.51% of the world's total waste. According to Indonesia's waste data in 2020, the total national waste production reached 67.8 million tons. This means that 185,753 tons of waste are generated by 270 million people per day. Meanwhile, the amount of waste in Central Java currently reaches 5.7 million tons or 15,671 tons per day. To accommodate this amount, Central Java only has 144 final disposal sites and 542 Junk Houses that can only accommodate 4.71% of the total waste (Setiawan, 2021). The remaining unmanaged waste worsens the environmental conditions and threatens human health

Domestic waste can be classified into organic waste and plastic waste. Both can be converted into fuel through distillation (condensation) technology. Organic waste is fermented for 7-10 days and then distilled to obtain bioethanol. Meanwhile, plastic waste is processed through pyrolysis, where the combustion vapors are distilled into a ready-to-use fuel. The key to the success of this technology depends on the condensation system. It should be noted that bioethanol distillation takes place at a temperature of 84 °C (Bibra et al. 2023), close to its boiling point. This certainly requires precised temperature control. The condensation of plastic pyrolysis only serves to convert the vapor phase into the liquid phase. This fuel product can be redirected to the domestic sector to substitute household fuel needs. The domestic waste processing flowchart can be seen in Figure 5.

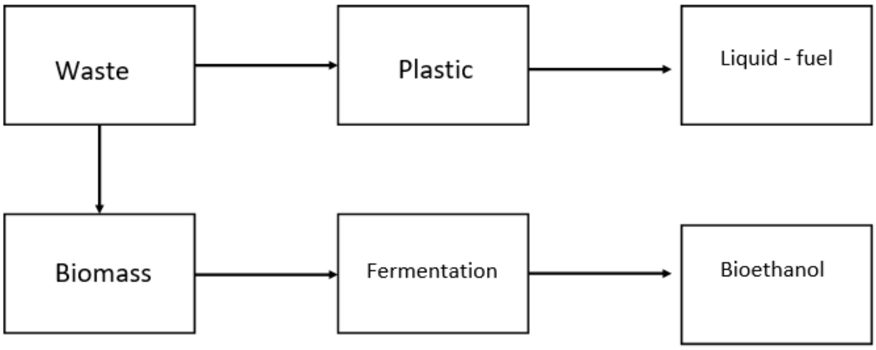

Figure 4. Domestic Waste Products Attributed for Sustainable Energy Cyclic System

Side Product : Biogas

Biogas has great potential for development, especially in Indonesia with a large and growing population of 1.3% per year (Riswanto and Sodikin, 2018). Naturally, humans and animals produce a byproduct in the form of feces, which is the residue of their metabolism. Feces contain methane gas that is produced directly when it is stored in a septic tank. The calorific value produced ranges from 4000-6000 kcal/m3 (Riswanto and Sodikin, 2018).

On its implementation, biogas can be directly used as a substitute for LPG fuel, a supply for generators to generate electricity, and a vehicle fuel without producing greenhouse gas emissions. Biogas synthesis is often carried out through anaerobic fermentation, which is the process of decomposing a substance using microorganisms in a closed system (not in direct contact with free air), which generally takes up to 30 days (Riswanto and Sodikin, 2018). After that, the resulting biogas can be distributed and used according to the intended target, either as a substitute for LPG fuel or on a larger scale as a source of electricity.

Previous research by the Research and Development Agency of the University of Padjajaran found that to generate power of 450-1000 watts, an electricity generator requires 0.6-1 m3 of biogas. Furthermore, with the addition of purification technology, biogas can produce various types of products, including natural gas, raw materials for the chemical industry, fuel cells, and electric energy (Konvacs et al., 2012).

Based on the supply of raw materials, biogas utilization can be applied in various sectors, including domestic, hospitality, and livestock sectors, both collectively and individually. The domestic sector, especially in densely populated residential areas, can be managed systematically to produce biogas. The feces collected in septic tanks will be directed towards a central biogas unit, which will then be processed to produce methane gas. Some aspects that need to be considered include the handling of flammable methane gas, pipeline distribution to consumers, and biogas storage.

Implementation

In order to realize the idea of a "Sustainable Energy Cyclic System," the implementation plan is outlined in Table 1. The development of these stages takes into account several factors including the availability of raw materials and technology, as well as the readiness of the community to embrace this idea. The social conditions of the community need to be prepared by providing education, socialization, and training on how to operate this system. This is particularly important for units installed in the domestic sector (biogas). The government plays an important role in the success of this idea by providing policies. Technology experts, economists, technicians, academics, etc. are also involved in promoting this idea to ensure quality, quantity, and control and security systems.

Table 1. Strategy for Implementing "Sustainable Energy Cyclic System"

No	Action	Periode (Year)	Output
1	Socialization of technology introduction to Indonesian society through various written, digital, and social media	1	Society awareness, Avoidance of social conflict
2	Mapping of energy sources: solar, SGE, side products through various environmental agencies	2	Distribution data of energy sources in Indonesia
3	Literature studies and case studies for installation preparation involving experts.	3-5	Detailed design and operational conditions of each unit (solar panels, SGE, biogas, biofuel).
4	The installation process includes: field surveys, design of construction materials and models, construction process throughout Indonesia in accordance with the results of energy potential mapping	5-10	Technological facilities and infrastructure that support this idea
5	Implementation of the "Sustainable Energy Cyclic System" nationally.	➢ 10 etc	Overcoming energy scarcity, providing affordable and environmentally friendly energy.

CONCLUSION

Sustainable Energy Cyclic System is a strategic and implementable solution to solve the problems of energy crisis and scarcity in Indonesia. This is supported by the abundance of natural resources in Indonesia which also serve as renewable energy sources such as solar energy and SGE from the mixing of seawater and river water. In addition, renewable energy sources can also be obtained from human side products such as metabolic waste and domestic waste. These various units produce a variety of products including electricity, biogas, biofuel, plastic-liquid fuel, and vehicle fuels. This system integrates all units and connects them in a sustainable cycle.

This idea is projected to be realized in the next 10 years, taking into account social, economic, and cultural factors of Indonesian society. The development process is carried out gradually, starting from preparation studies, design, manufacturing of machines and involved technologies, infrastructure development, and implementation. In order to implement this idea, cooperation is needed from various parties including the government, society, and experts (economics, technology, and environmental experts).

The implementation of Sustainable Energy Cyclic System in Indonesia provides many benefits to society in various sectors. This is because the system optimizes the use of energy, which is a crucial sector for all aspects of life. The most basic benefits include being able to supply national energy needs, an alternative solution to the rising prices of fossil fuels, preventing greenhouse gas accumulation, reducing environmental emissions, and contributing to national energy resilience. Globally, this system also supports the achievement of Sustainable Development Goals 2030. Hence, this study can be used as reference to solve energy crisis as it is attributed by aforementioned sources.

RECOMMENDATIONS

The idea of creating sustainable cyclic system indeed needs more comprehend research supported by experiment. Thus, the results can be implemented in Indonesia to support energy consumption as well as contributing to the SDGs 2030.

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