Geothermal for Sustainable Green Energy in Indonesia

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Abstract

The increasing world population also raises energy demand. As a result of continually using fossil energy, carbon emissions increased, which is the main factor causing global warming. Over the past years, many efforts have been made to reduce the carbon emission produced by energy, searching for green future energy which has sustainability, environmentally friendly, and clean energy. Geothermal Energy is one of the alternatives that has been explored and researched accordingly. Sustainable development calls for the use of sustainable energy systems. The world's geothermal energy resources should be used in sustainable activity, which means that it is produced and used for the well-being of future generations and the environment. This paper reviews the connection between geothermal energy development, sustainable development, and future green energy. Previous publications related to geothermal, sustainability and green energy in journals indexed by Scopus were collected, mapped, and reviewed to provide a comprehensive recommendation. Then, semi-structured interviews with experts were conducted to validate the finding of this work. The results show that the impact occurred as a result of geothermal energy development for electricity generation, which can be positive or negative. The need for proper management of such impact follows a sustainability assessment process identified for geothermal energy development is built in this paper. Finally, gaps and future directions were summarized at the end of this paper. This paper contributes to fundamental knowledge introduced herein, which can inspire researchers to detect gaps and serve to motivate the high potential of utilizing a clean and sustainable source.

Keywords
Geothermal Energy, Sustainability, Green Energy, Future Energy and Energy Development.

1. Introduction

1.1. Background

One of the most significant and challenging problems facing the world today is energy-related issues. Humanity's energy needs have risen to new heights due to the growing global population (Muzayanah et al. 2022). The International Energy Agency (IEA) predicts that by 2030, global energy demand will be growing at a rate of 1.6% annually. According to Indonesia National Energy Council (2021), the usage of fossil fuels is still the primary method of meeting energy needs at the moment, which subsequently makes a significant contribution to the rising level of the greenhouse gasses such as Carbon Dioxide, Methane, Nitrous Oxide, and Fluorinated Gas that creates adverse effects impacting the environment (EPA 2022). Figure 1 shows the composition of global greenhouse gas emissions that cause harmful damage to the environment. These pollutants are created, released, or disposed of along the energy chains, from resource extraction to the delivery of energy services (Shortall et al. 2015). In order to tackle these issues, there is an urgent need to supply future green energy that is clean and sustainable.

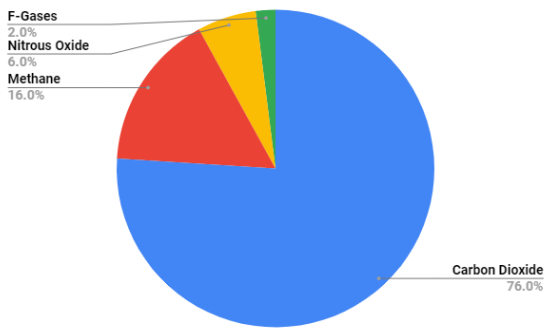

Figure 1. Global Greenhouse Gas Emissions
(EPA 2022)

Those issues have also become a global concern and have been raised as a target for the Sustainable Development Goals (SDGs) set by the United Nations General Assembly. SDGs was a global target action agreed upon by United Nations members that state action promotes sustainable development, protect the environment, and ensure that everyone lives in prosperity and peace for the future, specifically by the year 2030 (United Nation 2022). In this paper, the pursuit of geothermal energy is consistent with the objectives of United Nations Sustainable Development Goal 7, which is to ensure access to affordable, reliable, sustainable, and modern energy for all and also related to the fulfillment of the Sustainable Development Goal 13 which is to take urgent action to combat climate change and its impacts (Georgesson and Haraldsson 2018; United Nation 2022).

In line with the fulfillment of the SDGs targets, the Indonesian government participates in meeting this target by targeting an increase in the use of renewable energy sources and setting a net zero emission target by 2060 or sooner. Net zero emissions or zero carbon emissions can be defined as a situation in which the number of carbon emissions discharged into the atmosphere does not exceed the number of emissions the earth can absorb (Chiara et al. 2021). One of the ways to achieve net zero emissions is to make a transition from the conventional energy system (nonrenewable energy source) to future green and clean energy (renewable energy source) in order to achieve a balanced condition between human needs and the balance of nature (Indonesia National Energy Council 2019).

1.1 Objectives

The objectives of this paper aim to provide a comprehensive explanation regarding the connection between geothermal energy development, sustainable development, and future green energy. In addition, this paper will also assess the supporting factors and barriers to the advancement of geothermal energy. By assessing the sustainability implications of geothermal energy for electricity generation that stand as green future energy, we might get the most important issues of concern that will be the main focus of the discussion and provide in-depth analysis and recommendations about the development of geothermal energy in Indonesia.

2. Literature Review

2.1. Green Energy

Green energy is a subset of renewable energy that consists of renewable energy resources and technologies that have the most significant positive impact on the environment. Green energy typically derives from renewable natural resources like bioenergy, solar, wind, geothermal, and ocean energy (del Granado et al. 2018). These energy sources did not produce any greenhouse gasses that may harm the environment (Liu et al. 2022). The current energy discussion primarily concentrated on developing the best green energy by harnessing potential energy resources using technological development that leads to sustainable development.

2.2. Geothermal Energy Development

Geothermal energy has become one of the green future energy potentials that have been thoroughly researched and studied. Geothermal energy is one of the renewable energy sources that can be predicted to play a significant role in the future as green energy where the focus is no longer on fossil fuels but instead on energy resources that are green, clean, renewable, and sustainable (Georgesson and Haraldsson 2018). Geothermal energy is a non-carbon-based renewable energy source that utilizes heat flux from the earth's core (Dickson and Fanelli 2013). In the global

transition to renewable and low-carbon energy systems, geothermal energy has an essential role due to its capacity to produce constant and flexible electricity (Hackstein and Madlener 2021). Moreover, geothermal energy does not affect the release of greenhouse gasses or other pollutants that harm the environment (Georgesson and Haraldsson 2018). Scientists predict that by 2050 it might meet about three percent of the world's electricity needs and may reduce over one billion tons of Carbon Dioxide (Shortall et al. 2015).

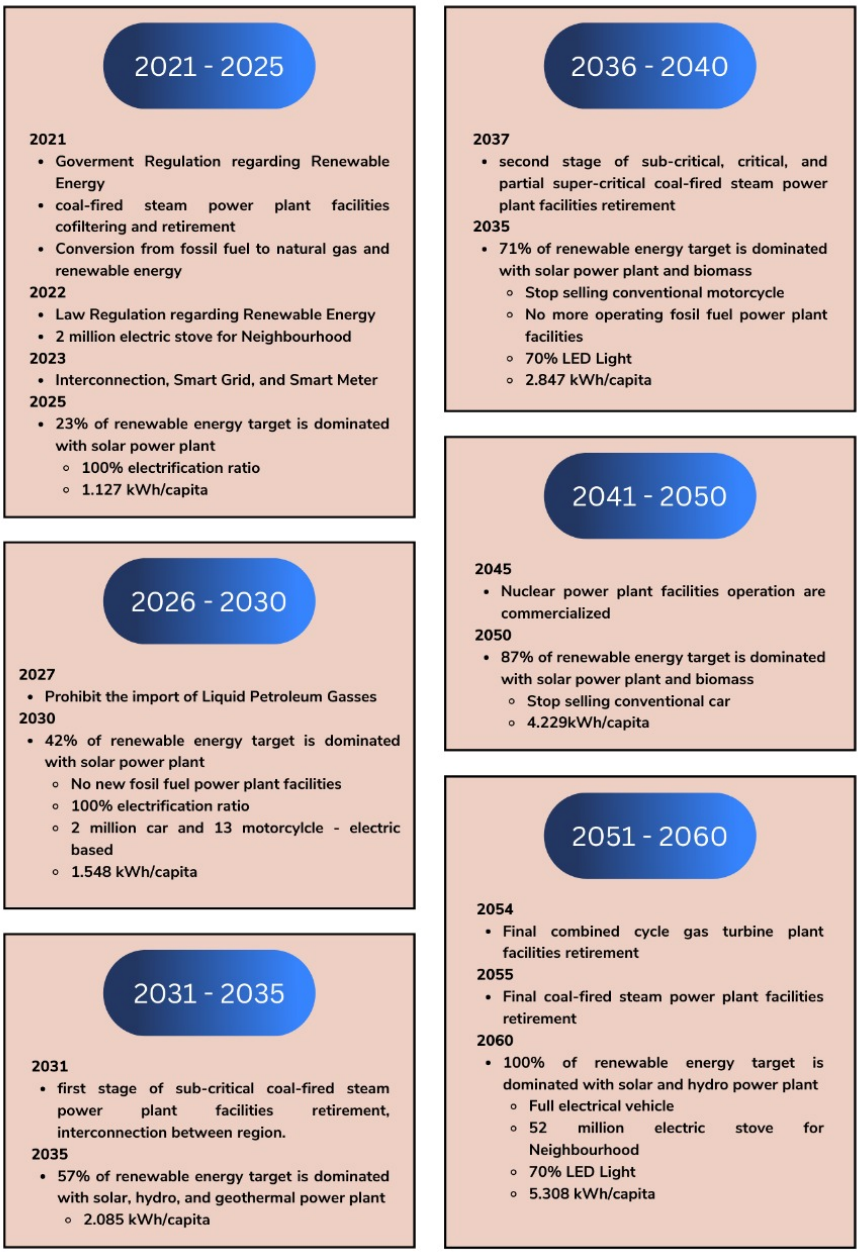

Figure 2. Indonesia transition towards net zero emission target
(Indonesia National Energy Council 2019)

Geothermal energy is one of the ideal renewable energy sources that can be utilized and developed by Indonesia (Yudha 2021). Most of Indonesia's territory is located inside the ring of fire, which traverses the Pacific Ocean's margins (Manalu 1988). This situation is very beneficial because it increases the possibility of energy intake

utilization for sustainable development. It is estimated that Indonesia has one of the highest geothermal energy potentials in the world, with a capacity of about 28,617 MW (Nassrudin 2016).In the Indonesian road map target towards net zero carbon emission set by the government, by 2035, geothermal energy is expected to become one of the factors that compose 57% of the renewable energy target.For more details, the net zero emission target of the Indonesian government can be seen in Figure 2.

2.3. Sustainable Development

Sustainable development has been defined as development that fulfills existing demands without impacting the capability of future generations to satisfy their own needs (World Commission on Environment and Development 1987). The fundamental principle of sustainable development is the integration of environmental, social, and economic considerations into all decision-making processes (Global Sustainable Development Report 2015). There are three main critical challenges affecting sustainable development: rapid expansion of the global population, energy crisis and shortages, and environmental issues regarding pollution (Zhu 2015).

3. Methods

In this article, we complement the analysis process by providing secondary data analyzed by the Indonesian government, focusing on the current status and prospects of geothermal energy in Indonesia. This secondary data comes from governmental reports regarding energy balance, national energy general plan, national energy mix target, and regulations relating to renewable energy, especially geothermal energy. This paper will also discuss the connection between geothermal energy, sustainable development, and future green energy by analyzing previous journal publications that Scopus have already indexed. The collected, mapped, and reviewed journal would then serve as the basis for analysis to make comprehensive recommendations. We reinforce and validate this work's finding by conducting a discussion process with geothermal energy experts through a Focused Group Discussion regarding geothermal energy and conducting semi-structured interviews with sources who are eligible and have the capability in energy study fields.

4. Results and Discussion

Based on Presidential Regulation number 112 of 2022 concerning the Acceleration of Renewable Energy Development for the Provision of Electricity, the president has decided to stop the plan to build coal-fired Steam Power Plant facilities in Indonesia. Coal-fired Steam Power Plant facilities are currently the leading energy supplier in Indonesia, amounting to 36.98 Gigawatts or equivalent to 50 percent of meeting national energy needs (Indonesia National Energy Council 2021). Furthermore, based on presidential regulation number 22 of 2017 concerning the general national energy plan, it is written that the Indonesian government targets that national energy needs are expected to be supplied by the provision of renewable energy by 31 percent in 2050. Targets and developments for Indonesia's national energy mix in 2025 and 2050 can be explicitly seen in Figure 3. In this case, based on Indonesian law number 30 of 2007 concerning energy, renewable energy sources are defined as energy sources that are produced from sustainable energy resources; these include geothermal, wind, bioenergy, sunlight, water flow, and waterfalls, also the movement and temperature difference of the ocean layers.

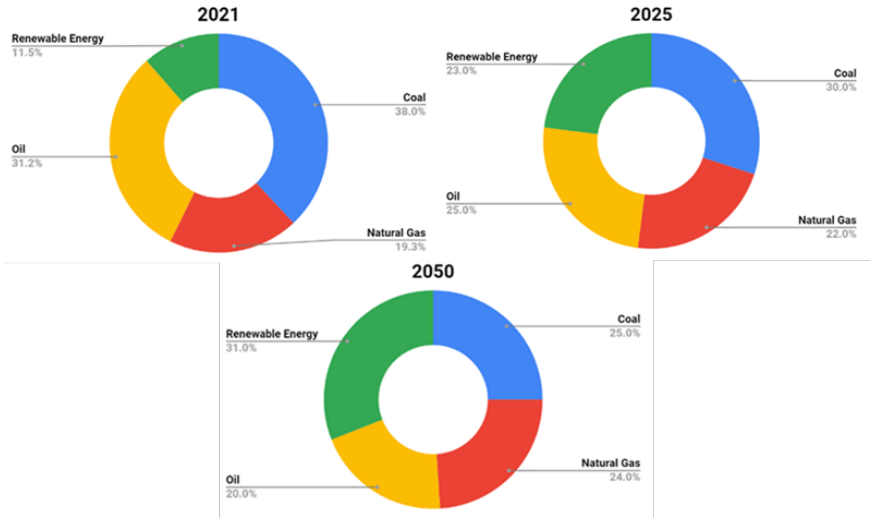

Figure 3.Indonesia's national energy mix condition in 2021 and target for 2025 and 2050 (Indonesia National Energy Council 2021)

With most of its territory located inside the ring of fire that traverses the Pacific Ocean's margins, Indonesia is the most suitable country to utilize geothermal energy as one of Indonesia's electrical energy providers (Yudha, 2021). This, of course, also supports the country's achievement of meeting the national energy mix target, which significantly impacts Net Zero emissions. Geothermal in Indonesia has a potential of 28.5 Gigawatts of electricity and is estimated to have utilized 2,131 Megawatts of electricity or about 8,9% of the total available energy; this value consists of 13 Geothermal Power Plants in 11 Geothermal Working Areas (Indonesia National Energy Council 2021). Due to the small utilization of geothermal energy sources, the Indonesian government targets the utilization of geothermal energy to reach 7,241.5 Megawatts of electricity in 2025.The projected utilization of geothermal distribution in Indonesia by year and region until 2020 can be seen in Table 1 and Table 2.

Table 1. Distribution of Indonesia's geothermal potential (by year) (Indonesia National Energy Council 2021)

Year	Resource (Megawatt Electric)		Reserve (Megawatt Electric)		
	Speculative	Hypothesis	Possible	Probable	Proven
2015	7,055	4,943	14,435	823	2,288
2016	6,596	4,477	12,046	2,493	2,967
2017	6,617	4,456	11,975	2,493	2,967
2018	6,407	3,852	10,099	2,016	3,013
2019	5,952	3,387	9,696	1,876	3,055
2020	5,981	3,363	9,547	1,770	3,105

Table 2. Distribution of Indonesia's geothermal potential (by region) (Indonesia National Energy Council, 2021)

Location	Resource (Megawatt Electric)	Reserve (Megawatt Electric)	Total

	Speculative	Hypothesis	Possible	Probable	Proven	
Sumatera	2,276	1,551	3,594	976	1,120	9,517
Java	1,259	1,191	3,403	377	1,820	8,050
Bali	70	21	104	110	30	335
Nusa Tenggara	225	148	892	121	12,5	1,399
Borneo	151	18	6	0	0	175
Sulawesi	1,365	343	1,063	180	120	3,071
Maluku	560	91	485	6	2	1,144
Papua	75	0	0	0	0	75

If we review Indonesia's energy consumption, the value of energy use in Indonesia is equivalent to 861 Million Barrel of Oil Equivalent in 2020, and it is estimated that this consumption trend will continue to increase to the equivalent of 2.9 billion Barrels of Oil Equivalent in 2050 (Indonesian statistical Bureau Center 2022). The projected increase in energy demand from 2020 until 2050 can be seen in Figure 4.Increasing Energy demand is also inseparable from economic growth, population, energy prices, and government policies.

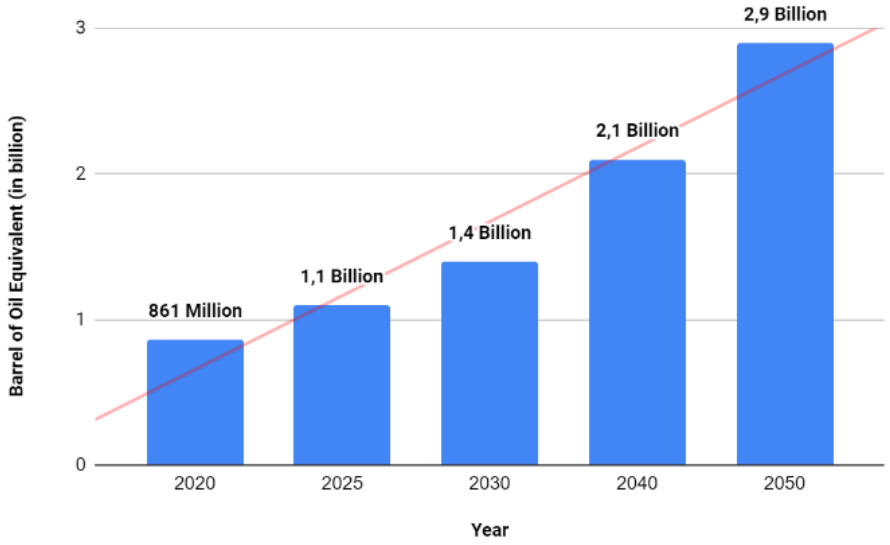

Figure 4. Projected consumption of Indonesia's energy needs
(Indonesian statistical Bureau Center 2022)

With a myriad of potentials that support the increasing energy demand, the Indonesian government continues to intensify efforts to implement geothermal energy utilization. The Indonesia National Energy Council (2021) noted that the Indonesian government is targeting the construction of geothermal power plants of 7,239 Megawatts in 2025 and 17,546 Megawatts in 2050as shown in Table 3. This development effort continues to be followed and strengthened by regulations that support the government's efforts to strengthen the use of geothermal energy. In addition, the government also focuses on optimizing geothermal power plants that already exist in 16 points spread throughout Indonesiathat can be explicitly seen in Table 4. Hopefully, the energy produced by this facility can support the government's national energy mix target in supporting sustainable energy development.

Table 3. Target of building renewable power plants
(Indonesia National Energy Council 2021)

Type of power plant (Megawatt)	**2025**	**2050**
Geothermal	7,239	17,546
Hydro and Microhydro	20,960	45,379
Bioenergy	5,532	26,123
Solar	6,379	45,000
Wind	1,807	28,607
Others	3,128	6,383

Table 4. Distribution of 16 Geothermal Power Plants in Indonesia
(Indonesia National Energy Council 2021)

Operating Facilities	**Location**	**Total Capacity (Megawatt Electric)**
PLTP Kamojang	West Java	235
PLTP Lahendong	North Sulawesi	120
PLTP Sibayak	North Sumatera	12
PLTP Salak	West Java	376.8
PLTP Darajat	West Java	270
PLTP Wayang Windu	West Java	227
PLTP Dieng	Central Java	60
PLTP Ulubelu	Lampung	220
PLTP Ulumbu	East Nusa Tenggara	10
PLTP Mataloko	East Nusa Tenggara	2,5
PLTP Patuha	West Java	55
PLTP Sarulla	North Sumatera	330
PLTP Karaha	West Java	30
PLTP Lumut Balai	South Sumatera	55
PLTP Sorik Marapi	North Sumatera	42.4
PLTP Muaralaboh	West Sumatera	85
Total		**2,130.7**

The construction of energy generation facilities using geothermal, of course, also brings various positive impacts. In addition to supporting the government in the Net Zero Emissions target, we as humans also feel positive impacts, including the increasing number of employment opportunities due to the construction to be carried out, improving health due to the low level of pollutants in the air, a more well-maintained climate, and also the availability of

sustainable energy for the future of the world. In addition, Indonesia will also get an advantage from the emergence of an increase in the country's economy due to cooperation in constructing energy generation facilities from geothermal energy. Table 5 shows the projected expansion plan for the development of geothermal utilization until 2025 from an additional electricity capacity, investment, labor absorption, oil production equivalent, and carbon dioxide reduction point of view.

Table 5. Development of geothermal utilization until 2025
(Indonesia National Energy Council 2021)

	Expansion Plan				
Year	**Additional Capacity (Megawatt)**	**Investment (Million USD)**	**Labor Absorption (Person)**	**Oil Production Equivalent (BOE/Year)**	**Carbon Dioxide Reduction**
2015	35	140	105	150,645	209,714
2016	205	820	615	882,349	1,228,327
2017	165	660	495	710,183	988,654
2018	250	660	495	710,183	988,654
2019	160	880	660	946,911	1,318,205
2020	266	3,464	2,598	3,727,385	5,188,933
2021	355	1,800	1,350	1,936,863	2,696,328
2022	585	3,432	2,574	3,692,952	5,140,999
2023	305	2,600	1,950	2,797,691	3,894,696
2024	880	4,700	3,525	5,057,364	7,040,412
2025	2,632	37,200	27,900	40,028,498	55,724,112

Another part of the discussion in this paper is about the barriers and challenges of the geothermal energy facilities development. The development of geothermal energy is anticipated to take between five and six years, including the preliminary survey, research process, test drilling, field development, construction of the power plant, and operation and maintenance (Pan et al. 2018).Of course, in this process, there will be many barriers and challenges that should be considered so that the development and utilization of Geothermal Energy can be carried out more optimally.An overview of the barriers and challenges from the development of geothermal energy can be categorized into four types of discussion, which is institutions, regulations, technology, and finance.

The biggest institutional obstacles and difficulties can often be discovered in the feasibility and land availability study process (Pan et al. 2018). About 80% of Indonesia's geothermal assets are situated in forests and conservation areas under strict protection (Indonesia-Investments 2015). Based on this, we can conclude that many areas of Indonesia are classified as high-risk to be used as project target locations. Additionally, there is a general lack of direction in the government on the use of geothermal resources in national energy strategy. Local government officials occasionally lack knowledge of the advantages of geothermal energy installations. This prevents the government from paying more attention to the possibility of using geothermal energy to meet the nation's energy needs.

Regarding regulation, Indonesia has made rapid progress in developing a regulatory system to support geothermal energy utilization. However, the bureaucratic legal system in Indonesia makes it easy to change applicable laws so that there is no regulatory certainty that supports potential investors in investing in Indonesia (Wahjosoedibjo and Hasan 2018). Regulations related to geothermal are also often found to overlap with each other, resulting in legal confusion in the utilization process (Pan et al. 2018). The length of the permit and license process is another factor that becomes a barrier and a challenge in geothermal energy utilization in Indonesia.

Technological factors should also be an essential discussion in focus of this discussion. This form of deficiency is indicated by the lack of domestic experts who are experts in geothermal energy issues, the lack of research and development centers that are the key to the success of the construction of energy generation facilities, the lack of understanding related to the latest technology used in the geothermal power sector, and the complexity faced in building an Indonesian energy generation unit (Pan et al. 2018). The final challenge is the financial factor. The challenge in finance lies in the high value of the investment at the beginning to finance power plant construction projects (Pan et al. 2018). To create a generating unit in an unknown area with a generating capacity of 20 MW to 60 MW, the estimated cost is approximately 1,440 USD/KW (Stefansson 2002). Compared to other renewable energy power plants, geothermal power plants typically have more significant investment costs and longer payback times (about 5-7 years) (Pan et al. 2018).

6. Conclusion

According to the analysis and discussion process, we may conclude that geothermal energy is one of Indonesia's most promising renewable energy sources that has to be explored. With the various positive values offered by Geothermal Energy, as explained in the previous section, the Government of Indonesia is expected to carry out active development in the sector of providing renewable energy, especially in Geothermal Energy, as one of the supporters of the fulfillment of Net Zero Emissions and also in supporting sustainable Energy Development. The Indonesian government is expected to be able to encourage the construction of geothermal power plants to optimize the utilization of existing geothermal potential, which is 17,546 Megawatts in 2050, in order to achieve the national energy mix target of 31% of the energy supply. Utilizing geothermal power plants is also expected to support the fulfillment of the 7th and 13th SDGs targets, namely ensuring access to affordable, reliable, sustainable, and modern energy for all and taking urgent action to combat climate change and its impacts. These two things will again support the achievement of our goal of building a sustainable and sustainable system for the life of humanity.

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