Chapter 2

# Geothermal Energy as a Major Source of Renewable Energy - Learning from Asian Neighbours

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Additional information is available at the end of the chapter

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**Abstract**

Energy is one of the fundamental necessities for economic growth, increased social equity, and an environment that allows livelihoods to thrive. Development is not possible without energy, and sustainable development is not possible without sustainable energy. Renewable Energy (RE) is a key to sustainable development and offers an opportunity to improve access to modern energy services for the impoverished segments of society, which is essential for sustainable community development. In Asia, Indonesia and the Philippines are rich in Geothermal (GT) energy. Being a renewable, sustainable, and indigenous energy resource, GT is reliable because its supply is independent of season and global energy market dynamics. Japan has a huge potential for GT and wants to expand renewable energy resources after the Fukushima Nuclear Power Accident. In the near future, GT is set to play a major role in national energy supply in Japan. Therefore, the objective of this study is to look at various challenges and opportunities in GT energy policies of Indonesia and the Philippines to adopt them to meet Japanese needs in the future.

**Keywords:** Geothermal energy, Energy potential, Policies

## 1. Introduction

Global population has been increasing exponentially and we are estimating that between the years 2000 and 2050, the population will grow from 6.1 billion to 9.6 billion (United Nations 2012). The average energy consumption per person between years 1850 and 2010 has increased from about 4.8 x 109 to over 77.3 x 109 J/person/year. This means the average person is using more than 15 times the energy each year than they used previously [1]. Sustainable development goals adopted in September, 2015 calls for use of sustainable energy systems as one of its main agenda. Among all sustainable options available, development and optimization for the procurement of geothermal energy is one of the best because it is produced and used in a way that is compatible with the well-being of future generations and the environment [2]. Geothermal energy is one of the most significant alternate sources of energy, with a much higher output of electricity production per MW of capacity as compared to wind or solar. Most of the countries with GT resources should promote themselves to explore it with the technical advancement and social acceptance because it has various advantages like round-the-clock availability, independent of time and climatic conditions. This means that to generate electricity at a constant level, geothermal energy can be supplied as base load in contrast to hydro or wind power. Geothermal energy's potential is ubiquitous, environmentally friendly, and only marginally developed (International Geothermal Association). In general, global warming or climate change is not expected to have any substantial impacts on success rate of geothermal energy utilization. However, the wise implementation and inclusion of geothermal energy in our energy demand mix could play a meaningful role in mitigating climate change. Best suitable site for commercial production of geothermal energy are high-temperature (>180°C) hydrothermal systems associated with recent volcanic activity and located near active plate tectonic boundaries (i.e., convergence zones, subduction zones, transform faulting), or at crustal and mantle hot spot anomalies. On the other hand, regions with high radioactive isotope decay, which increases terrestrial heat flow or where aquifers are charged by water heated through circulation along deeply penetrating fault zones, cannot be neglected as potential sites to harness geothermal energy if managed efficiently.

The United States has the world's largest geothermal energy potential (39,325 MW) followed by Indonesia (27,791 MW), and the Philippines has about 6,000 MW, while the target country, Japan, has a potential of 22,540 MW (METI, 2010). However, geothermal energy generation requires a very high initial cost and involves a high development risk, which hinders its growth. There is a visible gap between the countries that have policies supporting deregulated energy markets and the ones that do not. Japan's energy policy has its shortcomings when it comes to enumerating specific mechanisms to support increased participation from the private sector and other stakeholders to promote inclusive growth and fuel greater investments in geothermal energy development. Also, use of geothermal energy for applications in agriculture, tourism, etc., and the policy aspects for the same need to be included. These low and medium enthalpy applications will take place at the community level and need specific inputs regarding the involvement of small households and other stakeholders in the process of development.

In Indonesia and the Philippines, increased investments, especially for research and exploration for geothermal energy development come from greater private sector partnerships, which are fuelled through a proactive energy policy pursued by the respective governments. Indonesia, under its "Roadmap for Geothermal power," pursues a policy of management of geothermal working areas (GWAs) by private entities, selected through a tender process and provides specific fiscal incentives for geothermal sector, like income tax facilities and customs duty exemption. The policy provides opportunities wherein the private sector can use CERs (Certified Emission Reductions) to generate carbon revenue. In the Philippines, for the past four decades, geothermal energy has been developed by fostering government and private sector cooperation. In 1990, the Philippine government passed the BOT (Build, Operate, Transfer) law to invite private sector investment, which helped to launch financing schemes with private contractors. The EPIRA (Electric Power Industry Reform Law) of 2001, led to the liberalization of the power industry. All these policy instruments have significantly contributed to the capacity addition in geothermal energy sector, with a possibility of offsetting the

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high costs involved in geothermal energy development. These successful cases will be used to review existing lacunae in the Japanese approach.

The policy frameworks related to the financing of geothermal energy and its applications will be reviewed in the proposed chapter, by looking at the existing practices in Japan, and comparing it from successful policies practiced in Indonesia and the Philippines. A review of the existing "feed-in tariff system" for renewable energy will be done, and suggestions for specific inclusions, regarding geothermal energy will be made, as currently the policy recognizes "other renewable energy sources" as cost-prohibitive. A thorough review of the mechanisms used for deregulation, especially in the selected cases of Indonesia and the Philippines will be done, to analyze the shortcomings and successes of the various policies like EPIRA. A criterion for implementation of these policies in the local Japanese context will be done. Also, a review of the processes utilized for policy implementation will be done, looking at the effectiveness of certain policy instruments. Another crucial aspect will be to assess community-based development of direct uses of geothermal energy, an area which has not been explored adequately. Heating, drying, agriculture, and tourism sector policies will be explored and cases of similar implementation in Indonesia and the Philippines will be looked at, to build policy capacity and to engage with stakeholders at different levels.

United Nations and its member countries have adopted sustainable development goals (SDGs) in September, 2015, where they sought for a total 17 goals for sustainable livelihood of the world community. Goal 7 clearly emphasizes on providing access to affordable, reliable, sustainable, and modern energy for all. Here every country is looking to increase substantially the share of renewable energy in the global energy mix and double the global rate of improvement in energy efficiency, enhance international cooperation to facilitate access to clean energy research and technology, expand infrastructure, and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least-developed countries, small island developing States, and landlocked developing countries, in accordance with their respective programs of support by the year 2030. In a nutshell, this goal is sought for potential renewable energy resource like geothermal. As population is increasing in geometric proportions and so is the demand for resources, it is the need of the hour to think diligently and act seriously to trap energy sources like geothermal, which is with us just around the corner. It is important to keep striving for better technology to harness this precious source of energy efficiently.

## 2. Energy scenarios

### 2.1. Current scenario in Japan

Japan ranks fifth in the world for the amount of annual energy consumed (following China, United States, Russia, and India), and third for fossil fuel consumption including oil and natural gas (BP, 2013). Also from the environmental perspectives, it would need to reduce GHG emissions and in 2013 Japanese government announced that Japan will achieve -3.8% targets as compared to 2005 by 2020. Considering the fact that Japan does not have fossil fuel deposit and only 25–30% of total energy demand is being supplied at domestic level (nuclear and renewable sources), it relies heavily on import of fossil fuels from other countries like Indonesia. In total, renewable energy contribution to total energy production is approximately 5% (with hydro being main contributor with 3.3%) in Japan, which is projected to increase to 20% by 2020 to become more energy independent as well as to overcome energy security challenges.

However, for achieving such a goal, Japan has to scrutinize and revaluate all the challenges and opportunities present in its geopolitical scenarios. Geographically speaking, Japan is considered to be one of the potential countries for geothermal energy because of its location within the Pacific "ring of Fire", and this potential is considered to be one of the largest in the world (Figure 1).

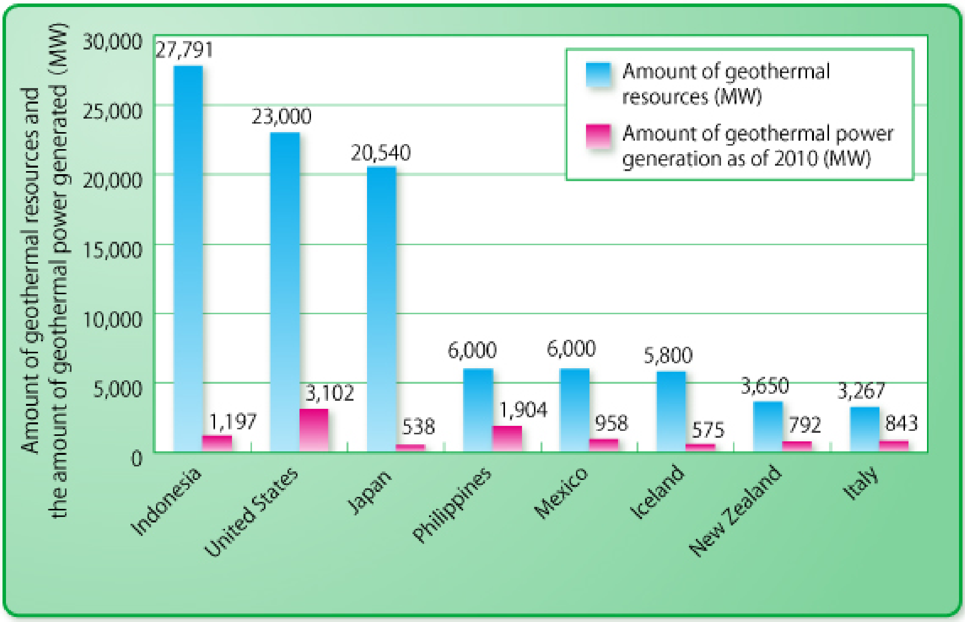


**Figure 1.** Amount of geothermal resources available worldwide and the amount of geothermal power generated (Source: http://www.asiabiomass.jp/english/topics/1208_04.html)

Before detailed feasibility analysis of technological advancement for geothermal energy harvesting, it is worth looking at the current status of this non renewable energy source in neighboring countries Indonesia and the Philippines.

It is observed that there is an increase in the direct use of geothermal energy from 58% to 78% in a decade (2000–2010) based on the data from 82 countries [4]. They mention that approximately 55% is used for ground-source heat pumps, followed by 20% for bathing and swimming (including balneology), 15.0% for space heating, 4.5% for greenhouses and open ground

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heating, 2.0% for aquaculture pond and raceway heating, 1.8% for industrial process heating, 0.4% for snow melting and cooling, and 0.4% for agricultural drying [4].

### 2.2. Status of geothermal energy in Indonesia

Indonesia is the largest archipelago in the world. It consists of over 17,000 islands and approximately 70,000 villages. Meanwhile, because of the large territory, 45% of the villages out of 70,000 are located in remote areas and about 6,200 villages have not been supplied by electricity. The population of Indonesia in 2010 reached 237 million, or is increasing by average of 1.48% per year. Indonesia's steady economic growth of more than 6%, even during the recent global recession, was accompanied by a 9% growth in electricity demand each year [5,6]. The increase of energy consumption is derived from the sectors of industry, transportation, and commercial. Total current annual primary energy demand in Indonesia is 168.7 MTOE (million tons of oil equivalents), which is predominantly fuelled by oil followed by coal, biomass, and gas, and supports the country's economy. It is reported that the ratio of production reserves for coal, gas, and oil in Indonesia are going to run out in 75 years, 33 years, and 12 years, respectively, so opting for renewable energy sources, especially untapped vast source of geothermal energy, is the viable solution to sustain its economic growth [7]. The current use of fossil fuel covers up to 32% of the share for total energy demand, which is expected to increase up to 42%, if Indonesia adopts MP3EI (Master Plan for the Acceleration and Expansion of Indonesian's Economic Development) scenarios. Since 2004, Indonesia withdrew its membership from OPEC (Organization of the Petroleum Exporting Countries) as it became a net importer of oil. Indonesia's huge geothermal potential is facing risks and challenges to meet the target of development as expected, while Indonesia as non-Annex-1 country is committed to reduce GHG emission from 26% up to 41% by 2020.

Indonesia's dependency on fossil fuels leads to two unwanted consequences – a strained government budget, while simultaneously undermining the country's climate change mitigation efforts. The fuel subsidy to ensure the availability of cheap energy (in order to achieve political mileage) has turned into a huge fiscal burden for the state, amounting to nearly 21% of total government expenditure in 2005, and continues to rise [8]. On the other hand, excess use of fossil fuels is also projected to raise Indonesia's greenhouse gas (GHG) emissions fourfold by 2030 [9]. This growth in emissions is in contradiction to the commitments made by Indonesia's President to reduce GHG emissions by 26% by 2020 and to increase the use of renewable energy so that it accounts for 25% of total energy production by 2025 [10, 11, 12].

### 2.3. Indonesia's energy security

Dependency on imported oil does not look promising in terms of long run of viable economy, although there is a potential for other energy resources such as geothermal. Even energy mix policy for the country led to high dependency on oil in the recent past. A cumulative impact of economic slowdown, increasing rate of fuel, and increasing energy subsidy results in high economic instability. In general, subsidies tend to cause overconsumption of the resource, since the market price does not reflect the actual cost of producing one unit of petroleum product.

They also discourage energy efficiency measures and the development of alternative or renewable energy sources by way of low electricity tariffs. The state budget is heavily burdened by this policy and in order to provide low-priced electricity, access is denied to nearly half the population. "This policy mostly favors the urban population or those who are privileged enough to have access to electricity while forgoing the development of necessary new infrastructure needed to deliver electricity to those without it" [8]. Against the backdrop of increasing fossil fuel prices, as well as growing concerns over energy security, renewable energy is well-positioned to play a critical role in Indonesia's energy mix. By expanding the use of geothermal energy in particular, the government has within its means another tool to better manage its economic future. Use of geothermal energy can ease high dependency on oil and it will consequently reduce the burden from fossil fuel and electricity subsidy [13].

Currently Indonesia practices fixed type of Feed-in Tariff (FIT) fund, set by the government to support geothermal projects that have won tenders but cannot continue development as they need a tariff above the fixed amount. The FIT fund helps in the payment of the difference between the price required by geothermal developers and the current electricity price. Indonesia introduced the concept of a ceiling price (9.7 USD/KWH) in 2009, below which the winning tender bid would automatically be accepted, but above which the bid was subject to negotiation with local government. With this model, the risks now lie with the local governments.

Geothermal energy production is capital-intensive, and will require billions of dollars in debt and equity to realize the targets set by government. The cost of exploration alone, for the next 3,000 MW is estimated at 2.8 billion USD. With little of this likely to come from government, the bulk of this will need to be raised from the local private sector and donor agencies. In principle, there is no shortage of potential sources of concessionary finance: the World Bank Group, Asian Development Bank, IFI, JICA, and JBIC have ambitious plans to provide support, including CTF funds. Still, the limitation here is no visibility about the hidden cost of geothermal energy generation (cradle-to-grave concept), so it should not be limited to estimates of the levelled cost of energy, but also take into account the likely financial costs. For instance, one should consider cost for risk of non recovery, grid and storage technology, and political barriers. One of the most fundamental obstacles to reaching the government target is the fact that most geothermal resources are located in remote areas, which means additional financing is required to connect electricity production to the main grid [14].

Another source of uncertainty, which translates to risk, is the confusion when it comes to division of power between central and local governments. With decentralization, regional governments are important because they become the official owners of the steam resource, whereas the central government plays an equally pivotal role providing expertise and underwriting the power purchase agreements [15]. While fine in theory, decentralization seems to have only raised transaction costs. Apart from institutional challenges, i.e., bureaucratic delay and no proper coordination between different ministries only leads to delay in executing all projects on time and thus further financial burden. Low purchase price of electricity by the state-owned power companies further deters the progress of geothermal power generation in Indonesia (Asia biomass office).

The other institutional challenge is the involvement of ministry of finance and forestry. Ministry of finance is engaged in driving financial incentives crucial to attracting investors into the sector. Furthermore, the ministry, through its sovereign wealth investment agency, plays an important role in creating publicly funded initiatives designed to mobilize private capital, such as the Clean Technology Fund [16]. On the other hand, The Ministry of Forestry also plays a crucial role in geothermal energy development as most identified reservoirs lie beneath protected forest areas. With some explicit policy support for accelerating geothermal energy development, it is imperative that measures are taken so that lands acquired for geothermal energy use are not high conservation value forests or sensitive ecosystems, and that the impacts and risks on forests are mitigated. To increase the geothermal energy production there is need to develop a cooperative and cross-sectoral approach to minimize the conflicts and make a progressive move toward the development of geothermal energy resources.

Another major concern about development of geothermal energy production system is the mind-set of local authority. Activities related to geothermal energy production is considered as mining activities, resulting in prohibition of use of protected/conserved areas like forest area. Local government or nongovernmental agencies should make an effort to classify the geothermal activities as extraction of thermal energy, which is different from mining activities of coal or other mineral resources with potential to lead to deterioration of environmental essence.

Last but not the least, some other issues not listed above are lack of technique/data to estimate the actual potential of geothermal resources availability to generate more interest among investors, no lucrative price of per unit of energy, limited equity funds and uncertainty in legal aspects, and the lack of cross-sector coordination.

Finally, it can be said that Indonesia has huge geothermal resources, but to date arrangement (technical and other setups) can only harness approximately 5% of the potential. Up to September, 2014, only 1396 MWe or approximately 4.5% of the potential has been installed. There is a need to harmonize and to synchronize the regulation among difference stakeholders, different government and financial institutions, etc. Indonesia also requires support on capacity building, in order to increase expertise and also to recruit human resources ready to support geothermal development to realize its goals.

### 2.4. Status of geothermal energy in the Philippines

The Philippines is an archipelago of 7,107 islands surrounded by South-East Asia's main bodies of water. The population continues to grow at 1.5% annually, reaching 135.2 million by 2035. This rapidly developing nation is certain to face significant challenges to energy security if it intends to maintain the current course of its economic development over the next few decades. The total current annual primary energy demand for the Philippines is around 39.4 MTOE (million tons of oil equivalents). About 59% of it is being supplemented by fossil fuel, while 40% is supported by renewable energy. The Philippines, however, imports most of its oil and is likely to continue to do so to sustain the economy's total petroleum requirements of 27.9 MTOE by 2035. The largest consumer of this energy is the transportation sector (35%), followed by residential and industrial sectors, roughly the same, accounting for about 26% each. The commercial sector constitutes about 11.9% and agriculture, forestry with the smallest portion is 1.3%. To provide energy security, although indigenous energy generation in the Philippines is quite modest and accounts for 22% from geothermal, 12% from biomass, and 6% from hydropower, it still has to cover a large distance to minimize the dependency on imported oil. As the major instrument for realizing the energy sector's vision of achieving energy independence, the Department of Energy (DOE) is currently crafting the 2012–2030 Philippine Energy Plan (PEP). As embodied in the Electricity Power Industry Reform Act (EPIRA), the economy's electricity supply industry has been restructured, paving the way for the privatization of the state-owned National Power Corporation (NPC). While oil pricing is deregulated, electricity pricing is a regulated energy commodity. The price for electricity is set by the Energy Regulatory Commission (ERC). Alongside the implementation of the EPIRA is the unbundling of electricity rates. In view of the Philippines' wide-ranging geographical situation, to fully connect the entire population to the national grid is a significant hurdle. Servicing the most remote and difficult-to-electrify rural areas will require significant resources; hence, achieving a 100% electrification level over the outlook period remains a challenge for the economy. Among all the other types of renewable energy sources like hydro and wind power there are lots of constraints because of geoclimatic factors, which ultimately leads to further push to geothermal energy as potential source of energy.

### 2.5. Solution common for both countries

#### *2.5.1. Energy mix policy*

Sustainable energy policies are likely to succeed if they also contribute toward other societal and economic development objectives in the future. From the standpoint of economic analysis, the optimum quantity of geothermal energy that should be in energy mix is given by intersection of the geothermal supply curve with the avoided social costs of thermal energy.

#### *2.5.2. Feed-in Tariff*

Should tariff ceilings be based on estimates of production costs, or on the basis of estimated benefits?

A tariff should be rational, and in support of clearly defined objectives. This would ensure that the resources are not developed for their own sake simply because they exist, and because it is generally held to be desirable. The tariff methodology should be transparent (and documented as part of a tariff issuance), with clearly stated assumptions.

- A tariff should promote economic efficiency. A tariff should be adaptable to changing circumstances. This requires the methodology to have a defined basis and provide for review and updating to a clearly stated timetable.
- Stakeholders should be consulted. While consensus is not always achievable, concerns should be addressed.

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FIT is generally understood as being based on the production costs of the technology in question, as in the original German model. The distinguishing feature of FITs is that they are technology specific, and often differentiated by project size and other technical characteristics (such as additional bonus payable for projects that meet criteria for domestic content or other technical attributes seen as desirable). Competitively determined tariffs are the best guarantee of economic efficiency. It is sometimes assumed that tariff ceilings should be based on today's costs (if based on production costs), or today's benefits (if based on PLN's avoided costs). But that is not reasonable if the intent is to apply the ceilings to a tender for a project that will deliver benefits only 6–8 years from the tender date. It should include the cost of non recovery of energy resources, establishing grading and storage technology after that period of time from tender date.

*2.5.3. Measures to manage social issues*

**i.** **Conduct "free, prior and informed consent" public consultation: "**Free, prior and informed consent" (FPIC) is the principle that an indigenous community has the right to give or withhold its consent to proposed projects that may affect the lands they customarily own, occupy, or otherwise use.

**ii.** **Implement awareness and acceptance programs:** Prior to any discussion about a project, the company/developer must introduce itself to its various stakeholders, consisting of the local government units (LGUs), government agencies, host communities, nongovernmental organizations (NGOs), peoples' organizations (POs), and private business.

**iii.** **Create a multistakeholder monitoring team:** Ensure that mechanisms are in place so that project activities can be monitored by a Multisectoral Monitoring Team (MSMT) composed of representatives from the local government units, host community, NGOs, the Department of Environment and Natural Resources (DENR), and other concerned sectors in the area.

**iv.** **Set up an environmental guarantee fund:** This is a financial arrangement negotiated between the proponent, the government, and the affected community. The amount is intended for rehabilitation and payment of damages due to the accidents from the operation of the project.

**v.** **Provide economic packages:** Social acceptability is often equated with the stakeholders' access to meaningful benefits or benefits that have direct positive impacts. These need to be shared equally with communities in recognition of their contribution to national security and national development for hosting the project.

**vi.** **Resettle dislocated communities, if necessary**

**vii.** **Protect prior and ancestral rights:** Ancestral domain shall be fully recognized and protected by the project.

**viii.** **Protect forest patrimony:** Ensure that the project will not disrupt forest patrimony.

#### *2.5.4. Funding the large project*

Recently, most of the geothermal projects have received a positive nod from UNEP's Sustainable Energy Finance Initiative and Bloomberg's New Energy Finance for big financial help in response to high oil prices and the threat of climate change.

### 2.6. Challenges and opportunities for geothermal energy: A road map for Japan

The Philippines and Indonesia are classified as non-Annex-I countries in the United Nations Framework Convention on Climate Change (UNFCCC), but Japan is different as it comes under the list of Annex-I countries. Countries like the Philippines and Indonesia have adopted emissions reduction targets under the Copenhagen Accord, and have adopted national policies and strategies for climate change adaptation and mitigation. But for Japan, international pressure to reduce the GHGs emission and per capita energy consumption rate is mounting. One of the obstacles against geothermal energy development in Japan is the fact that most of the promising fields are located near or inside national parks or spa resorts. Recently, the Ministry of Environment of Japan allowed the extraction of geothermal energy from national parks that could potentially be developed into a big renewable energy source and reduce its dependence on nuclear and other resources. Looking at the neighboring countries as stated in section above and being prone to natural disasters (especially Fukushima nuclear disaster, 2011), Japan should look for safe and potential energy source, particularly geothermal energy. So far, photovoltaic-cells-based solar energy has been the most dominant renewable energy source, mainly because it can be easily deployed on rooftops of existing buildings and houses and connected to grids in the form of distributed power supplies requiring much less effort and cost than that for geothermal energy. The adoption of renewable energy in general, visible in the electricity source mix, has grown gradually, but it is still less than 2% of overall electricity. Since the government is the key stakeholder in energy business, this is certainly a great advocacy move for renewable energy to grow further in the Japanese market by following institutional strengthening factors:

- Continue favorable Feed-in Tariff (FIT) as fundamental policy
- Develop better energy mix policy
- Shorten the time taken for environmental assessment in developing renewable energy sites
- Address and solve current problems like high costs for electricity generation, intermittent energy supplies, restriction of development locations, through feasible long-term and short-term policy measures

Looking for small-to-medium-scaled geothermal power aligned with technological advances such as low cost binary cycles utilizing existing hot springs and heat pumps utilizing temperatures differences just beneath the surface of ground, both of which do not require a huge risky investment such as drilling the new ground very deeply, do not take years for addressing the impact on surrounding nature and for exploration, and can be implemented without a huge distribution plant will be a good source as primary energy because they can continuously provide stable sustainable energy source throughout a year regardless of changes in weather and no ill-effect on the grid stability.

Finally, apart from the challenges, optimization of geothermal energy usage will lead to all win-win situation for all around the society by giving positive social impacts (reducing poverty, enhancing equality, health, community safety), being environmentally benevolent (no environmental pollution as well as biodiversity conservation) and renewable, efficiently produced, country like Japan must have a big go to these projects.

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## References

[1] Ingvar, B., Fridleifsson, Ruggero Bertani, R., Ernst Huenges, E., John, W. L.und, Arni Ragnarsson, A., Ladislaus Rybach, L. 2008.The possible role and contribution of geothermal energy to the mitigation of climate change. IPCC Scoping Meeting on Renewable Energy Sources – Proceedings, 59-80.

[2] Shortall, R., Davidsdottir, B., Axelsson, G. 2015. Geothermal energy for sustainable development: A review of sustainability impacts and assessment frameworks. *Renew Sustain Energy Rev*, 44: 391-406.

[3] Asia biomass office report: Indonesia is Doubling the Purchase Price of Electricity from Geothermal Power Generation to Accelerate its Adoption (http://www.asiabiomass.jp/english/topics/1208_04.html)

[4] John, W. L.,und, Tonya, L. B.oyd, 2015. Direct Utilization of Geothermal Energy 2015 Worldwide Review. Proceedings World Geothermal Congress 2015, Melbourne, Australia, 19-25 April, 2015.

[5] Ministry of Finance. 2009. Ministry of Finance Green Paper: Economic and Fiscal Policy Strategies for Climate Change Mitigation in Indonesia, Ministry of Finance & Australia Indonesia Partnership, Jakarta.

[6] PwC (PricewaterhouseCoopers). 2011. Electricity in Indonesia – Investment and Taxation Guide, PwC, Jakarta, viewed 2 January 2012, at (http://www.pwc.com/id/en/publications/assets/Indonesian-Electricity-Guide_2011.pdf).

[7] Nasruddin, M., Alhamid, I., Daud, Y., Surachman, A., Sugiyono, A., Aditya, H.B., Mahila, T.M.I. 2016. Potential of geothermal energy for electricity generation in Indonesia: A review. *Renew Sustain Energy Rev*, 53, 733-740.

[8] Resosudarmo, B.P., Alisjahbana, A., Nurdianto, D.A. 2010., "Energy Security in Indonesia, ANU Working Papers in Trade and Development No. 2010/08, Canberra.

[9] Fiscal Policy Office of the Ministry of Finance) & World Bank. 2011. "Phase 1 assessment of emissions – key findings," viewed 16 March 2011, at (http://www.esmap.org/esmap/sites/esmap.org/files/factsheet04.pdf). IGA-International geothermal association, http://www.geothermal-energy.org

[10] Fadillah, R.D. 2011. "More German companies eye renewable energy sector," *The Jakarta Post*, 25 October, viewed 16 March 2011, at (http://www.thejakartapost.com/news/2011/10/25/moregerman-companies-eye-renewable-energy-sector.html).

[11] President of the Republic of Indonesia. 2011. "Peraturan Presiden no. 61 tahun 2011 tentang Rencana Aksi Nasional Penurunan Emisi Gas Rumah Kaca" (Presidential Decree No. 61 of 2011 on National Action Plan for the Reduction of Greenhouse Gas Emissions), The Secretary of the Cabinet of the Republic of Indonesia, Jakarta.

[12] The Secretary of the Cabinet of the Republic of Indonesia 2011. "Cabinet Secretary: President Yudhoyono signed presidential decree on national action plan to reduce GHG emissions," Press Release, 26 September 2011, the Secretary of Cabinet of the Republic of Indonesia, Jakarta.

[13] WWF., 2012. Igniting the ring of fire: A vision for developing Indonesia's geothermal power.

[14] Tanoto, Y., Wijaya, M.E. 2011. Economic and Environmental Emissions Analysis in Indonesian Electricity Expansion Planning: Low-rank Coal and Geothermal Energy Utilization Scenarios, *International Journal of Renewable Energy Research*, Vol. 1, 2011.

[15] de Wilde, A. 2010. Accelerating Geothermal Development in Indonesia. Jakarta.

[16] The World Bank Energy Sector Management Assistance Program. 2010. Geothermal handbook: planning and financing geothermal power generation. Washington DC: The World Bank. 2010.