RETHINKING OF GEOTHERMAL POWER DEVELOPMENT IN EAST ASIA: ECONOMIC OPPORTUNITIES AND TECHNICAL BARRIERS

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ABSTRACT

The global focus on finding practical solutions to climate change has added prominence to the geothermal sector in East Asian countries. Despite having a number of advantages over other forms of renewable energy production, geothermal still comprises a relatively small part of today's energy supply portfolio in South East and East Asian countries. With its vast resources, geothermal has the potential to provide an indefinite base load of energy produced sustainably and at low cost. It can thus pave the way for intermittent or variable renewables power sources (eg, solar and wind) to be accommodated by the grid. Support to Geothermal enabling policy frameworks, legislation and standards and quality infrastructure is required even as geothermal's use increases in countries like Japan, Korea, the Philippines and Indonesia. This paper analysis the sustainability aspect of geothermal development from the following requirements in these countries. 1) Long term commitment to creation of system that is resilient and to technology absorption 2) A system-level approach to geothermal energy deployment that considers the market and non- market barriers as well as the interests of different stakeholders in the energy sector 3) creation of enabling environment by addressing other aspects such as awareness creation and regulatory environment, energy pricing structures; 4) Support through targeted measures such as RD&D on understanding reservoir characteristics, timely planning and introduction of new technologies such as heat pumps and close coordination with different ministries and stakeholders. Based on meta-analysis method, it proposes a policy tool box for address the challenges being faced by the countries.

1. INTRODUCTION

Developing new methods of low carbon energy resource and consumption are crucial for meeting the climate goals as agreed in Paris. Against the backdrop of rising demand for sustainable energy solutions, there is a growing convergence that the role of renewables such as geothermal can play in addressing the climate change while providing access to affordable energy. Electricity production from geothermal only occurs in 24 countries worldwide, six which are in East Asia. Across these countries, installed power capacity for geothermal reached 3,743 MW between 2010 and 2011 (WWF, 2012). These countries produced around 3- percent of the world's geo thermal capacity. Philippines has the second largest most installed capacity in the world, after the United States of America. In 2012, the 1,904 MW of installed capacity in the country was enough to supply around 17% of total electricity need which was equivalent to 10,324 GWh (DOE, 2014). China is the world leader in direct use of geothermal energy with 12,605 GWh in 2010 (Zheng et al, 2015). There are strengths with geothermal energy in terms of steady supply, scalability and operation costs. Unlike wind and solar, electricity generated from geothermal is not intermittent, and it can be used to provide reliable base load power. Geothermal can be used for various purposes at various scales, ranging from heating for individual households to powering an entire city. Once constructed, geothermal generation can be operated cost effectively. But there are challenges to large scale application of geothermal application in the region, which includes high upfront cost (ESMAP, 2014) and limited areas for resource extraction (Ardiansyah, and Putri, 2013) and technologies for enhanced geothermal systems (Sanyal et al, 2014). Sanchez- Alfaor et al (2015), found that the absence of medium to long term energy policies and the lack of incentives for companies to overcome financial risks are perceived as main barriers in Chile. They have also identified the main perceived advantages, barriers and incentives related to geothermal development, assessing their relevance and feasibility through a survey to propose guidelines for geothermal stakeholders. Such structured analysis on a regional scale is lacking in East Asia region. This paper investigates the economic opportunities with geo thermal development in the East Asia region, analyses the barriers to achieving the targets and proposes integrated policy solutions.

2. GEOTHERMAL POTENTIALS IN EAST ASIA

Currently there is no single information source for existing geothermal energy use. Several initiatives exist within the region to collect geothermal data, but these often use widely different methodologies. The table 1 show the current ERIA (2015) estimates of geothermal use in the China, Indonesia, Japan, Korea, the Philippines, Thailand and Vietnam. The estimates conforms to Lund and Boyd (2015) and Bertani (2015) estimates on the direct utilization and power generation values. Nevertheless, estimating geothermal requires several distinct data set and various complex investigation and analysis (Hochstein, M.P., and Crosetti, M., 2011). Based on the available information Sakaguchi and Anbumozhi (2015) is working to provide such information in a consolidated way. Indeed the estimation currently consists of a combination of preliminary reconnaissance studies – geological, geochemical and geophysical surveys, all of which provide datasets that can increase the rate of geothermal energy development. However, for policy decisions and investment decisions, it may be sufficient to display basic data that provide some measures of the presence and significance of the resources wherever it was found.

Table 2 shows development trends of geothermal energy use in each country. All the study countries have target capacity addition within 5 years. However, the development plan differs from country to country.Some countries put geothermal development as national plans while only the private sector or institutes have plans in other countries. National plans on geothermal development may help its promotion since countries where geothermal development is advancing, such as the Philippines and Indonesia, have national plans. Only China has a clear plan for all power production, direct use, and GSHP. No other countries have plans for direct use,

while all countries show targets for power production. Long-term programmes for geothermal power generation are necessary because geothermal development takes 5 to 7 years. China, Japan, and South Korea, which have cold seasons, have targets for GSHP.

Deployment of these geothermal technologies also presents significant opportunities for economic development and employment. Their adoption is expected to be critical in meeting the goal of clean energy access and in stimulating socio economic development. Regionally installed geothermal capacity has doubled since 1990 to 11,765 MW in 2014 and equivalent planned capacity additions are in the early stages of development or under construction (Motek, 2013). By implication, investment and local employment opportunities can be assumed to have expanded considerably and will continue to grow. The largest installed geothermal power capacities are in the Philippines (1,884 MW), Indonesia (1,333 MW), and geothermal is also heavily used in Japan, Korea and New Zealand (Sakaguchi and Anbumozhi, 2015).

Countries with installed geothermal capacities derive employment benefits in construction and O&M, which are by nature more domestic; however, the production of geothermal energy may result in job creation elsewhere. The Japanese and New Zealand companies play a central role in manufacturing geothermal turbines, controlling more than half of the global market . In the Philippines, the energy development corporation (EDC) controls about 60% of the countries geothermal capacity and close to 2,500 employees. Local hires account for 75% of the company’s workforce (DOE, 2011). Though no robust investment figures exist, in general the investment and the number of jobs appears to expanding as new markets emerge for geothermal exploration and exploitation in South East Asia and East Asian countries.

Table 1. Present status of geothermal use in rach country

Country	Installed capacity			Used (produced) Energy			Reference
	PG (MW_e)	DU (MW_t)	GSHP (MW_t)	PG (GW_e-h/y)	DU (GW_t-h/y)	GSHP (GW_t-h/y)	
China	27.8	6,089	11,781	155.1	20,801	27,864	Zheng, et al. (2015)
Indonesia	1,341.0	2.3	-	9,332.32	11.8 *	-	MEMR (2013), Lund, et al. (2010)
Japan	540.1	2,099.5	44.0	2,688.82	7138.9	-	TNPES (2013), Lund, et al. (2010)
Korea	-	43.7	792.2	-	164.9	580.7	Song and Lee (2015)*
Philippines	1,848.0	-	-	10,230.5	-	-	Department of Energy (2014)
Thailand	0.3	-	-	-	-	-	DEDE (2012)
Viet Nam	0.0	30.7	-	-	22.36	-	Nguyen, et al. (2005)

DU =direct use, GSHP = ground source heat pump, PG = power generation.

Table 2. Development trends of geothermal energy use and opportunities

Country	Target Capacity Addition			Date
	Power generation	Direct use	GSHP	
China	100 MW_e (National plan)	3,700 MW_t (National plan)	18,200 MW_t (for residential, office buildings, school, hospital, mall, etc.) (National plan)	by 2019
Indonesia	1,160 MW_e (National plan)	NA	NA	by 2019
Japan	Several small binary (50 kW_e–1 MW_e) and a 40 MW_e (by private sector with government's support)	No specific plan	GSHP at 990 units (2011) to increase for next 5 years (Estimation by related organisation)	by 2019
Korea	Pilot plant, EGS technology (1-3 MW_e)	No significant development	>100 MW_t new installations each year (for large office buildings, green-house, small residential houses) (Estimation by related organisation)	by 2019
Philippines	1,465 MW_e (Fronda et al., 2015) (National plan)	-	-	by 2030
Thailand	at least 5 MW_e	Spa, drying system would be supported by hot springs	No application	by 2019
Viet Nam	20 MW_e	Agricultural drying, industrial process heat, bathing, swimming	Projects to find out potential and application for office buildings and residential houses	by 2019

(Source: Sakaguchi and Anbumozhi, 2015)

3. TECHNOLOGY AND MANAGEMENT OF GEOTHERMAL ENERGY

Geothermal resources are the thermal energy available and stored as steam or hot water in active geothermal areas. Higher temperature water or stream resources (>180ºC) are the best for electricity generation, as the liquid can be directly used by dropping the pressure to create stream, that can drive turbine. Where only medium temperature resources are available, more expensive binary plants are required. They use a heat exchanger to create steam from a liquid with a low boiling point for subsequent use in a steam turbine. Table 3 shows challenges for sustainable use of geothermal energy pointed out by the countries in the region. These topics are listed in order of priority are (i) Monitoring and reservoir engineering (ii) Reinjection (iii) Anti-scaling and (iv) Anti-corrosion and anti-erosion

In Korea, the sustainable issue of geothermal power generation is not of common interest yet. They focus on sustainability of GSHP, amongst others. Thailand and Viet Nam have yet to develop a binary system for sustainable use of geothermal energy. The study of the second year of this project was decided based on this result.

Table 3 Challenges for sustainable use of geothermal energy in East Asia

Country	Reinjection	Monitoring and reservoir engineering	Anti-corrosion and anti-erosion	Anti-scaling	Others
China	X	X			
	a) In key cities of geothermal utilisation the Geothermal Resources Administration stipulates that geothermal district heating has to install reinjection.				
	b) Geothermal monitoring is popularly carried out in key cities and developing areas.				
Indonesia	X	X	X	X	
Japan	X	X		X	
Korea	e) Sustainability issue of geothermal energy is not of common interest yet, because no systematic deep geothermal utilisation is operating now. There are concerns about sustainability of GSHP system, especially on water level change and subsurface temperature sustainability.				X
Philippines	X	X	X	X	
Thailand	e) To develop a binary system				X
Viet Nam	e) To develop a binary system				X

HSP =ground source heat pump.

Although geothermal power generation is a mature and commercially available solution to low cost base load capacity in areas with excellent high temperature resources close to the surface, several factors affects the overall cost of the geothermal generation. The levelized cost of geothermal plant is determined by the usual factors, such as installed costs, O& M costs, economic life time and the weighted average capital of the capital. However, the analysis of geothermal is a more dynamic question than for other renewables like solar, wind and biomass. One complication is a larger uncertainty in project development, due to the risk of poorly performing production wells. Similarly over the life of project, reservoir degradation can play an important role in costs and in performance. These factor tend to introduce greater uncertainty into the development of geothermal resources and projects and may increase financing costs, compared to other technologies such as wind (GeothermEx, 2010). However, this uncertainty factor is typically manageable in mature geothermal markets where financing institutions have previous experience with the industry.

4. TECHNICAL BARRIERS TO GEOTHERMAL DEVELOPMENT

Table 4 shows technical barriers for geothermal power generation for three stages: exploration, installation (development), and sustainable use based on the responses from each country, as obtained through an expert study meeting organized by ERIA. These barriers are derived from consultations with country experts and hence not listing of all barriers in a structured way. But, common problems for exploration for power generation are identified as (i) Drilling success: testing of new methods and applications to increase the success rate of exploration wells such as remote sensing, 3D inversion of MT, radon survey, and joint geophysical imaging, (ii) Lack of geophysical survey and (iii) Public acceptance: national and local governments should support renewable energy projects. The common challenges associated with power generation are (i) Drilling success of production well (ii) Reservoir characterisation, and (iii) Acidic and high silica fluid. Common problems for sustainability of power generation are (i) Sustainable reinjection: experience in different geothermal reservoirs (ii) Reinjection fluid return (short circuit), (iii) Decline of production wells (pressure drawdown), iv) Scaling in injection wells (v) Acidic fluid corrosion (vi) Shallow groundwater into reservoir, and (vii) Geo-hazard (landslide, subsidence, typhoon, volcanic eruption, earthquake). For all exploration, installation and sustainable power generation, more research funding is needed. International collaborative cooperation in R&D on solving those problems above is needed.

The technical barriers related to specific technologies such as GSHP are illustrated in Table 5.

Table 4. Technical barriers for geothermal power generation for different stages

Country	Exploration	Installation	Sustainable use
China	Well logging instruments and circulating technique in high temperature geothermal drilling	Domestic product limited in 5MW, no big capacity.	Sustainable reinjection has not yet done
Indonesia	Low drilling success ratio	Fluid characteristics (acidic fluid, high silica)	Decline of production well (5 to 10% per year in average) and reinjection well (scaling); Geo-hazards (landslide, earthquake, volcanic activity)
Japan	Limit of geophysical methods (Resistivity image does not always show reservoir shape).	Success rate of production well drilling Minimization of environmental impact Presence of acidic fluids	Scale, pressure decline, short circuit (reinjection fluid control)
Korea	Lack of deep well information, such as temperature, stress and fracture distribution	Lack of experience in deep drilling, measurement and reservoir engineering Difficulty of securing proper technical services and procurements	-
Philippines	Environmental permits (tree cutting permit, access to national parks, etc.), social acceptance and access permits, insurgents, finding good permeability and high temperature for the first three exploration wells. Presence of acidic fluids.	Simultaneous sustainability testing, establishing production sharing and injection interference, drilling interference. Matching of right power conversion system with reservoir characteristics to optimize resource and efficiency	Reservoir drawdown; mineral scaling in wells, surface pipeline network and reservoir; acidity of production fluids and attendant corrosion; reinjection returns; influx of shallow groundwater into reservoir; landslide risks and surface facilities' damages due to super-typhoon
Thailand	Geophysical survey and drilling technique	-	-
Viet Nam	Geophysical survey, drilling, reservoir modelling	-	-

(Source: proceedings of ERIA working meeting)

Table 5. Technical barriers for GSHP for different stages

Country	Exploration	Installation	Sustainable Use
China	-	-	-
Indonesia	-	-	-
Japan	Geological and hydrological database, especially, estimation of groundwater flux	Drilling cost	Control of annual heat exchange balance (extraction and/or injection)

Korea	-	Lack of information on subsurface thermal properties associated with hydrology	Lack of long-term performance analysis in conjunction with monitoring of subsurface temperature and/or water level variation
Philippines	-	-	-
Thailand	Case study	-	-
Viet Nam	Need to do the detail research	Need to have one pilot installation	-

Table 6. Supportive measures in each East Asia country

Country	Are there FiT or RPS?		
	Power Generation	Direct Use	GSHP
China	No RPS for geothermal	No	Subsidy for Energy Saving of Building. Grant for Demonstration of Renewable Energy
Indonesia	in future (ceiling price increase @11.8-29.6), tax incentives	No	No
Japan	yes, >15 MW (~27JPY/kWh);<15 (~42JPY/kWh)	No	No
Korea	RPS with REC of 2.0	No	No but discussing about Renewable Heat Obligation
Philippines	Yes, RPS but no FiT for geothermal, FiT for wind/solar	No	No
Thailand	No FiT/RPS	No	No
Viet Nam	No	No	No

RPS = Renewable Portfolio Standard, MW = megawatt, kWh = kilowatt hour, JPY = Japanese Yen, REC = Renewable Energy

Certificate, FiT = Feed in Tariff

Challenges with GSHP are derived from, lLack of case study (showing successful case), (ii) Lack of database hydrogeological, (iii) high Drilling cost, and (iv) Lack of information on long-term performance . More funding is needed for domestic R&D for hydrogeological studies, case studies, and long-term monitoring. Also, international research collaboration is essential to share the knowledge obtained in each country. Drilling cost may be reduced by both mass production and technical improvement suitable for each local geology, which means that drilling cost can also be reduced by the accumulation of knowledge and number of installations supported by R&D on case studies, hydrogeological studies, and long-term monitoring.

Current policy frameworks to support geothermal development in East Asia countries are listed in Table 6.

5. RETHINKING OF GEOTHERMAL DEVELOPMENT IN EAST ASIA THROUGH INTEGRATED POLICIES

Globally many policy instruments have developed with the goal of accelerating geothermal development. An extensive data base containing examples of policies and measures is accessible are available elsewhere (Hori, 1990: Korjedee, 2002; Muraoka, 2008: Pastor, 2010), In East Asia, policy instruments in support of geothermal technologies such as power generation, direct use, GSHP include financial support for University research consortia, government sponsored R& D laboratories, and public – private partnership in applied R&D. Policy instruments to help move these technologies to market may include technology transfer programs, grants for pilot projects, loan guarantees and other financial instruments for constructing demonstration plants; and industry collaborations to promulgate standards to secure technology interoperability. Each of these policies serves a specific function of a country in question. A policy tool

Table 7. Policy Tool box for accelerated geothermal development in East Asia

Function	Example Policy Tools
Creating and sharing knowledge	Subsidies and incentives for research on geothermal technologies and equipment
Building competence, awareness and human capital	Subsidies and incentives for education and training, fellowships
Knowledge diffusion/creating collaborative networks	Joining or initiating international cooperation, supporting industry association and enforcement of measures and best practices
Rapid reconnaissance surveys and Assessment of potentials	Public private partnerships, incentivizing private development, and investment in public energy infrastructure
Providing finance	Loan guarantees, green banks and public venture capital style funds
Establishing governance and the regulatory environment	Setting standards, setting target, taxing negative externalities, subsidizing positive externalities.
Creating markets	Feed in tariffs, renewable portfolio standards, government/public procurement. Setting government requirements, taxing negative externalities, subsidizing positive externalities

box as shown Table 7.could broadly describe the set of instruments at the disposal of policy makers.

6. CONCLUSION

Geothermal energy represents one of the key options for South East and East Asian countries to achieve a comprehensive approach to national development, based on clean energy provision, social development and tackling climate change. But there are many technological, managerial and financial issues that are hindering geothermal power development. This paper identified key technological barriers for geothermal development. To remove the technology barriers and enhance the uptake of geothermal energy at regional scale, a key strategy could be building a cooperation platform among geothermal rich countries in East Asia, starting with China, Indonesia, Philippines, Japan and New Zealand, and then expanding to include Korea, Viet Nam, Thailand. Countries in the Asia-pacific region, the Philippines, Japan and New Zealand are the largest producers of geothermal power with good record in renewable energy policy development, technology development. China and Indonesia are large emerging economies with lofty targets on low carbon technology policies. Building a cooperation framework between these countries and relevant private sector stakeholders and academics will help shift their government's energy security agenda, drive private sector investment decisions and ensure that communities play an active role in promoting low carbon energy supply sustainability.

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