A CASE STUDY OF IMPACTS, RISKS AND VULNERABILITIES OF THE LOCAL COMMUNITY OF MAKILING-BANAHAW GEOTHERMAL COMPLEX, PHILIPPINES

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ABSTRACT

Geothermal energy development requires vast areas of land for exploration, construction, steam harvesting and electricity production. The steam pipes, injection wells, and equipment facilities require large spaces in order to be installed. Geothermal plant facilities and geothermal reservoirs are typically located at higher elevations and mountainous areas which would usually have few, if any, residing local communities.

The Makiling-Banahaw (Mak-Ban) geothermal complex is quite unique among the geothermal plant sites in the Philippines because it is located in a relatively flat terrain compared to other producing geothermal areas. It is one of the most accessible and most populated geothermal complexes in the country, located 70 km south of Manila in Luzon island. The Mak-Ban geothermal complex occupies a geothermal zone covering seven designated *barangays* (smallest administrative division in the Philippines).

This study investigates the perception of the local community regarding the perceived impacts, risks and vulnerabilities from the operation activities of the Mak-ban geothermal plant. The social survey took place in 2013 using the questionnaire and interview method among 268 household respondents out of 7,179 households residing in the seven barangays in the Mak-Ban geothermal zone. Household respondents interviewed were predominantly female (62%) and middle-aged residents, from 30- to 50-year olds (62%). The questionnaire survey covered household characteristics, knowledge about geothermal energy, perceived impacts, risks and vulnerabilities, and social acceptability. First hand information from the social survey showed the local community's impressions, perceptions and experiences towards geothermal plant operation. Preliminary results from the survey indicate that majority of the local community identified air pollution, in the form of bad odor, and noise, as the main impacts of the geothermal facilities on the environment and community. With regard to the associated risks and natural hazards with geothermal activities, the majority of the local community identified earthquake and agricultural damages.

1. INTRODUCTION

The importance of renewable energy technology has been increasing significantly since the beginning of the 21st century. The use of renewable energy technology has become indispensable for economic development and promotion of 'green' energy sources. Thus, the growing demand for renewable energy has resulted in the need to tackle sustainability issues of production and utilization.

In 2012, the Philippines stands with an installed geothermal capacity of 1,848 MWe with total generation of 10,230.54 GWh (preliminary data as of Feb. 2013). This power generation is equivalent to 17.07 fuel oil displacement (MMBFOE) with foreign savings in $1,636.89M (Ogena & Fronda, 2013). The government's goal to increase renewable energy capacity to 15,304 MWe by 2030 includes 75% growth in geothermal power capacity. But despite this goal, social acceptance of local stakeholders still holds as one of the barriers towards harmonious geothermal energy development.

1.1 Discovery to Development

The Makiling-Banahaw (Mak-Ban; also known as Bulalo) geothermal field, with an area covering 1,575 km^2, is the second geothermal resource developed after Tiwi geothermal field. It is located in Luzon island, about 70 km south of Manila, at an elevation of 234 masl in relatively flat terrain (Fig. 1). It is on the southeast flank of Mt. Makiling, a dormant composite volcano.

Mak-Ban's proximity to Manila, as well as its flat landscape, makes it one of the most accessible geothermal complexes in the country. It is probably one of the world's most extreme examples of people living in an operating geothermal field. Due to its accessibility and the area's rapid development, resident population within the area increased drastically from about 1,500 in 1979 to about 32,000 by 2010.

From 1973 to 1978, the Philippine Geothermal Inc. directed the initial exploration and development of Mak-Ban and other geothermal steam fields. Mak-Ban is one of the oldest geothermal resources explored in the Philippines, which was first drilled in 1974. On the other hand, the National Power Corporation (a state-owned electric utility firm) was responsible for building and operating the electric power plants (Sussman et al., 1993).

In 1979, the 110 MWe plant in Mak-Ban steam field was commissioned. In 1984, an additional 220 MWe plant was built. Since 2010, a total of 113 wells have been drilled to support production and injection capacity requirements (i.e. 69 production wells and 23 injection wells). Ever since Mak-Ban's establishment more than 30 years ago, it has been a remarkable example of a mature, stable, problem-free geothermal reservoir (Capuno et al., 2010).

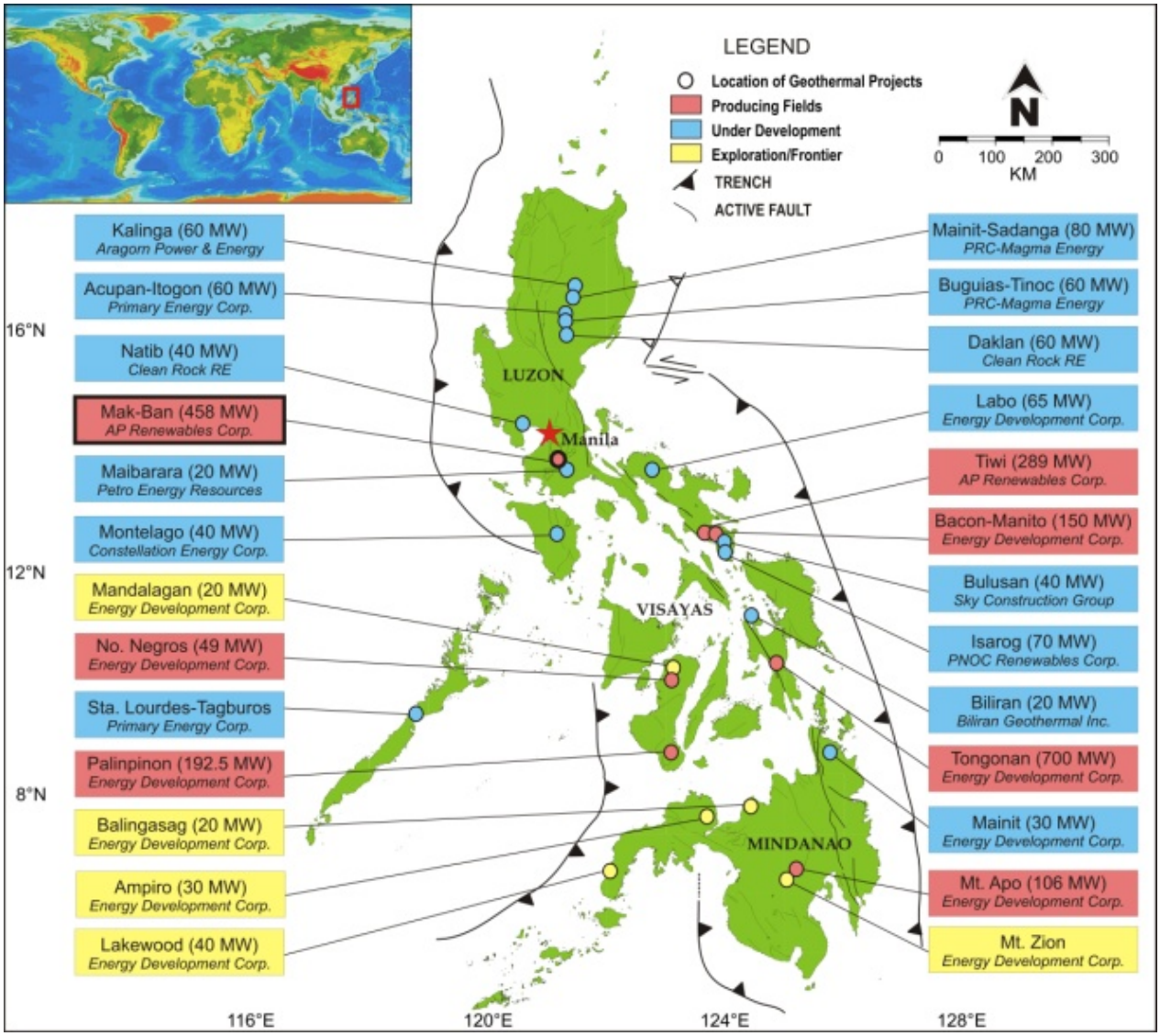

Figure 1: Map of Philippine geothermal exploration and development sites (modified from De Jesus, 2013).

1.2 Geothermal Resources and Potential

The occurrence of high enthalpy hydrothermal systems in the Philippines is closely related to subduction and subsequent volcanic arc formation. Several operating fields in the Philippines (Fig. 1) reflect the abundance of these high temperature systems. All of them are directly or indirectly correlatable with inactive volcanism (Ogena et al., 2010).

1.3 Mak-Ban Geothermal Zone

The Mak-Ban geothermal complex is the designated geothermal zone covering areas of seven barangays from three different municipalities (Fig. 2). Among the seven barangays, Bitin, Limao and Sta. Elena are those with established geothermal facilities. The seven barangays were selected in order to provide current information about stakeholder perception regarding the presence of the geothermal power facilities.

2. PUBLIC PERCEPTIONS

Social acceptance often poses a barrier towards renewable energy development (Devine-Wright, 2005). Public consent and acceptability will need to be fostered in order to realize large scale plans for renewable energy systems (Pidgeon and Demski, 2012). Opinion polls offer insights into public perceptions of renewable energy as well as overall levels of support and opposition. Public perceptions of emerging technologies and energy development are likely shaped by several factors, among them socio-demographics (Boudet et al., 2014).

Perception of risk and benefit is also a relevant factor to consider in understanding public perception towards renewable energy (Boudet et al., 2014). Moreover, risk and benefit perception is influenced by mass media (Ho et al., 2013). Information often provided by mass media had an effect on how the public thinks about renewable energy technologies and about its risks and benefits (Scheufele and Lewenstein, 2005).

Trust and interaction with renewable energy-related agencies have an effect towards the public's attitude towards energy system transformation. Trust towards outside agencies related with renewable energy development and promotion is a significant key factor in influencing in risk and benefit perception (Visschers and Siegrist, 2013). Poorly executed dialogue and mismanaged communication processes also escalate concerns on social acceptability (Pidgeon and Demski, 2012).

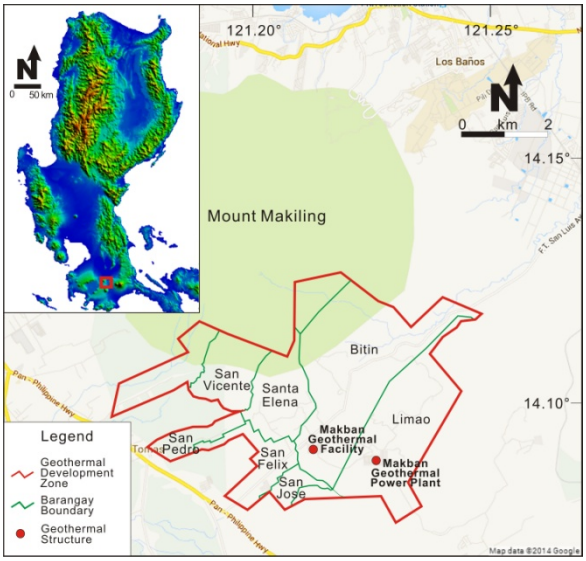

Figure 2: The Map of Makiling-Banahaw Geothermal Development Zone and the 7 barangays within its vicinity.

Regardless of the type of energy development, perceived risks and benefits are strong predictors of opposition or support on the individual and community level (Boudet et al., 2014; Hunter and Leyden, 1995). Impacts on environment and valued landscape are also found to have an influence on public opinion (Firestone and Kempton, 2007).

Location and geographic proximity to areas of energy development, such as distance from one's home, are often highly considered as a factor of support or opposition, although scholars have found mixed results (Boudet et al., 2014). The Not-in-my-backyard (NIMB) phenomenon is an attitude often characterized as an unreasonable reaction of the public to accept any kind of risk in favor of the society (Polyzou and Stamataki, 2010). This is often associated with opposition towards renewable energy development but it remains an insufficient and overly simplistic explanation that distance is associated with greater support (Devine-Wright, 2005; Boudet et al., 2014). Only few attitudinal factors, i.e. general attitude towards landscape aesthetics, recreation, and renewable energy, have a relationship with the intention to oppose renewable energy (Johansson and Laike, 2007). However, focusing also on the respondent's geographic location still has a value given the spread of renewable energy development to an area of a country. Considering geographic proximity also has a value because the potential for different types of experiences and impacts depends on location (Boudet et al., 2014).

3. SOCIAL SURVEY PRELIMENARY RESULTS

3.1 Household Characteristics

In order to obtain first-hand information, the author conducted the social survey by using questionnaire. The questionnaire survey was developed and designed to include these major sections: household characteristics, perceived impacts of geothermal energy, and perceived risks and disasters.

The questionnaires were distributed and the survey was conducted through the help of research assistants (graduate students from the University of the Philippines). Unstructured interview was also conducted after the questionnaires were answered by the respondents. The results were summarized and interpreted to gather information on the different aspects investigated.

The social survey was conducted on 268 household respondents of the seven barangays (Table 1) using random sampling method. The household respondents were predominantly female (62%) and middle-aged, from 30- to 50-year old (62%). About 75% of the household respondents have an educational attainment of high school level and below.

Table 1: Sample size of the household respondents by barangay

Barangay	Number of Household	Sample Size	Percentage
Bitin	1,428	43	16%
Limao	969	40	15%
San Felix	954	40	15%
San Jose	470	46	17%
San Pedro	1,131	31	12%
San Vicente	1,871	30	11%
Santa Elena	356	38	14%
Total	***7,179***	***268***	***100%***

The Mak-Ban geothermal complex has been established during the 1970's. Only 24% of the respondents have been living in the vicinity prior to the construction of the geothermal plant facilities. 72% of the respondents lived in the area after the facilities have been constructed. This indicates that they have either been born in the area or migrated to the area knowing that the presence of geothermal plant facilities would be proximate to their residences.

With regard to migration in the barangays within the geothermal zone, 46% of the respondents have been born in the area. On the other hand, 49% of the respondents migrated from other provinces for the following reasons: personal reasons (52%), employment opportunities (41%), and regional development (6%).

3.2 Perceived Impacts

Perceived impact towards renewable energy development has been one of the factors that contribute to social acceptance of stakeholders. In the case of Mak-Ban, 83% among the respondents believe that geothermal energy development has an impact on the environment.

When the respondents were asked to identify only one major impact of geothermal development on the environment: air pollution and odor (51%) has been considered as having the most impact (Fig. 3). This is followed by noise (20%) which is caused by the normal operations associated with power houses, transformers, and cooling towers. Although this is not considered as an issue according to common sound level standards, the respondents consider it as a nuisance. The third major impact according to the respondents is ground water pollution (9%), followed closely by ground pollution (7%). Visual impact (1%) has been considered as having low impact. On the other hand, the respondents identified that geothermal facility operations, through acid rain from gas release, have damaged their properties and crops.

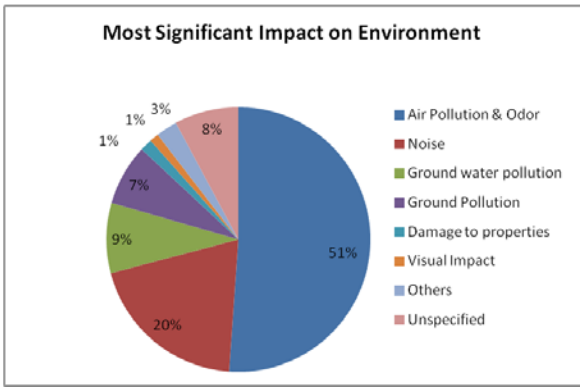

Figure 3: The most significant impact of geothermal development on the environment.

When the respondents were asked to identify any of the impacts of geothermal development on the environment (multiple answers), air pollution and odor, and noise were mostly selected because these two impacts were mostly observable and casually experienced by the respondents. However, ground pollution and ground water pollution have lower number of respondents probably because these two are less observable, especially in the case of ground water pollution. Very few respondents consider visual impact as having an effect on the environment (Fig. 4).

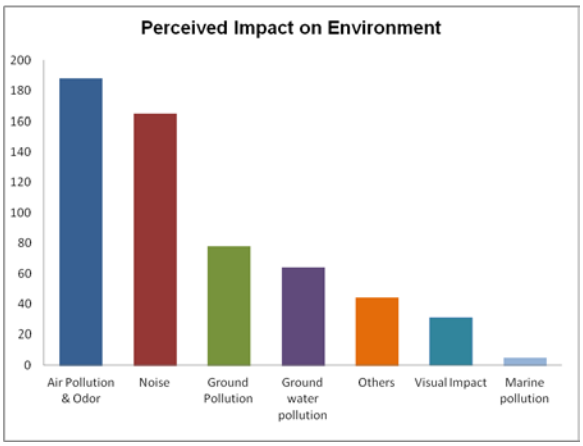

Figure 4: Summary of perceived impact on environment by number of respondents.

In a more detailed summary per barangay, in Bitin (being a barangay with geothermal facilities) there are similar number of respondents who identified air pollution and odor, and noise as having the highest impact (Fig. 5). Similar to the results of Bitin, in Sta. Elena (being a barangay with geothermal facilities), there are very close number of respondents who identified air pollution and odor, and noise as an impact on environment. In Limao (being a barangay with geothermal facilities), a high number of respondents identified noise as having the main impact on the environment. The numbers of respondents from these three barangays, which are proximate to the geothermal facilities, are closely similar with regard to identifying air pollution & odor.

On the other hand, the respondents of the other four barangays without geothermal facilities have identified air pollution & odor as the main impact in the environment. This implies that their distance from the geothermal facilities may have lesser impact on them compared to noise, which is related to proximity.

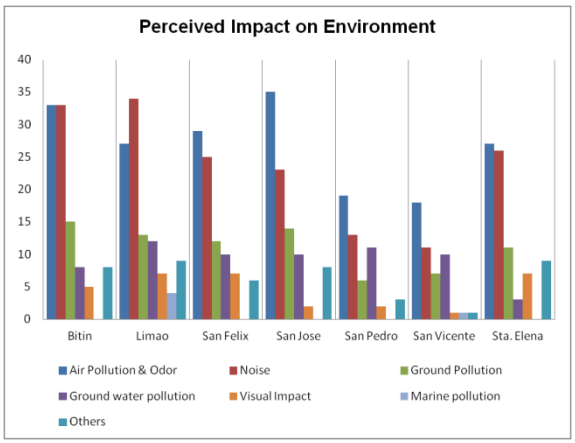

Figure 5: Summary of perceived impact on environment by barangay.

The presence of geothermal development facilities in the low-land makes it very accessible. With this accessibility, industrial and commercial development followed the development of geothermal resources. With the presence of geothermal facilities and operations, economic activities improved (Capuno et al., 2010). Regarding the impact of geothermal operations on economic activities, many of the respondents (42%) believe that it has negative impact on agricultural activities in the form of crop damages (Fig. 6). With regard to tourism activities, almost half of the respondents (49%) believe that geothermal power facilities and operations have no impact. Similarly, majority of the respondents (61%) also believe that geothermal power facilities and operations have no impact on the fishery industry.

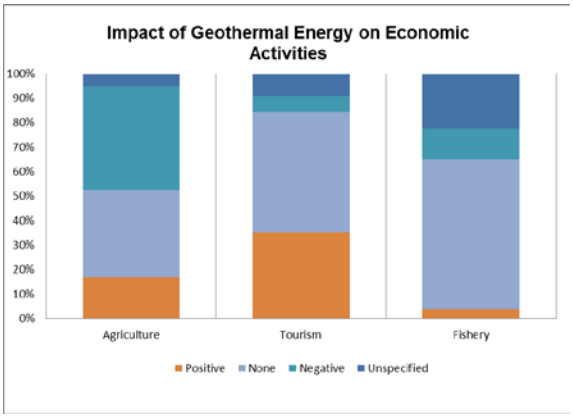

Figure 6: Summary of perceived impact of geothermal energy development on economic activities.

3.3 Perceived Risks and Vulnerabilities

3.3.1 Frequency of Risks and Disasters

Seven risks and natural disasters were considered for this study: earthquake, landslide, volcanic eruption, agricultural product damages, subsidence, flooding and forest destruction. The respondents were asked to identify the frequency of their experience with these risks and natural disasters on a 1-5 scale.

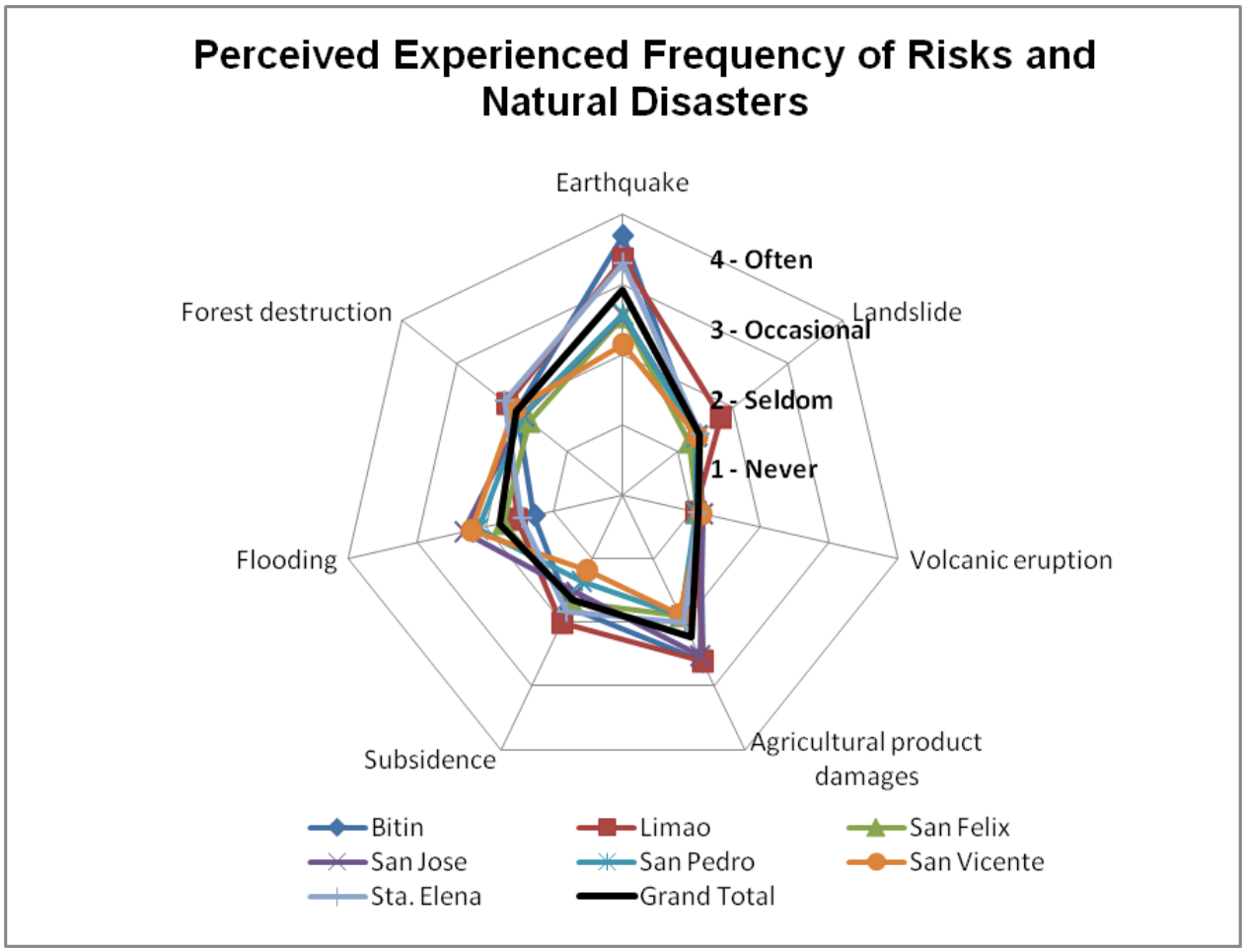

Figure 7: The summary of respondents' experienced frequency of risks and natural disasters.

According to the respondents living in the areas with geothermal facilities, they have had higher frequencies of experiencing earthquakes compared to the other four barangays (Fig. 7). These three barangays, Bitin (3.7), Limao (3.4) and Sta. Elena (3.3), have "often" and "occasional" frequency of experiencing earthquakes. The other barangays have "seldom" as frequency of experience of earthquakes.

As for landslide, only Limao residents (1.8) "seldom" experience it and the rest of the other barangays answered "never." For volcanic eruption, the respondents from all the barangays have "never" experienced it.

According to the respondents, agricultural product damage has been observable through decades but was "seldom" experienced. Among the seven barangays, Bitin, Limao, San Jose and Sta. Elena have values more than "2" which may be interpreted as more than "seldom" (Fig. 7).

Though subsidence may not be an easily observable phenomenon, the respondents of the three barangays with geothermal facilities, Bitin (1.7), Limao (2) and Sta. Elena (1.8), have higher frequency of experiencing it.

According to the respondents of Bitin (1.3), they have almost "never" experienced flooding in their area. However, the respondents of the other barangays, Limao (1.6), San Felix (1.7), San Jose (2.3), San Pedro (2.1), San Vicente (2.2) and Sta. Elena (1.5), experienced "seldom" flooding.

Among the 7 barangays, Limao (2.1) and Sta. Elena (2.2) have relatively higher frequency of having experienced forest destruction compared to the other barangays. This is probably because these two barangays are located near Mt. Makiling National Park and Mt. Bulalo. Bitin (1.9) and San Vicente (2) are also located by the foot of the national park. San Pedro, San Felix and San Jose are farther from the two mountains and are located near the town proper and national highway.

Overall, among the risks and natural disasters, earthquake is the most experienced phenomenon by the respondents. Earthquake (2.9) was "occasionally" experienced. Among the other risks and natural disasters that were "seldom" experienced by the respondents are agricultural product damage (2.2), forest destruction (1.9), flooding (1.8), and subsidence (1.6). Those that were evaluated as "never" experienced by the respondents were landslide (1.3) and volcanic eruption (1.1).

3.3.2 Association of Geothermal Energy with Risks and Vulnerabilities

According to the respondents, they believe that the top three risks and vulnerabilities that are strongly related with geothermal power operations are earthquake, agricultural product damages, and subsidence.

Many respondents (69%) believe that the occurrence of earthquakes or even micro-earthquakes is strongly associated with geothermal power operations (Fig. 8).

According to respondents, the Mak-Ban geothermal facilities release gases from the well from time to time. Despite geothermal plants having lower hydrogen sulfide emissions compared to coal plants, effects of acid rain has been observable such as damages on crops, flora and personal property (i.e. roof). Because of this, 39% of the respondents associate agricultural product damage with geothermal plant operations.

Although ground subsidence in the Mak-Ban geothermal complex has not caused any adverse effects to the production facilities, it had reached a maximum of little over 0.5 m near the central part of the production area (Protacio et al., 2000). Among the environmental impacts of geothermal energy, the residents consider subsidence (32%) to be associated with geothermal plant operations.

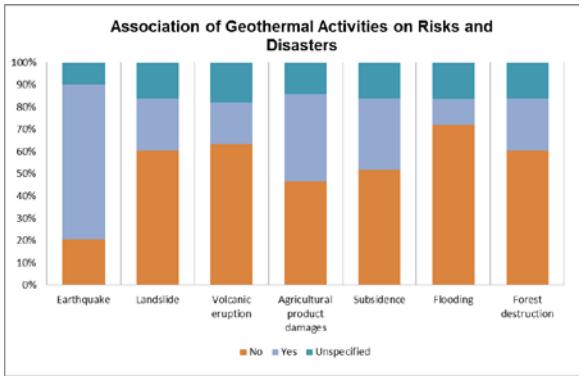

Figure 8: Summary of respondents' perception towards the association of risks and vulnerabilities with geothermal power operations

Although Mak-Ban geothermal complex is surrounded by the following dormant volcanoes: Mt. Makiling (North), Mt. Bulalo (within the geothermal zone) and Mt. Banahaw (East), it has not experienced any occurrence of volcanic eruption. Since there has been no recorded historic eruption around the area of the Mak-Ban geothermal complex, only very few respondents associate volcanic eruption (19%) with geothermal power operations.

There are very few respondents who associate geothermal power operations with other natural risks and vulnerabilities: landslide (24%), flooding (12%), and forest destruction (24%). According to the respondents, they associate landslide from flooding, and flooding from increase in volume of rainfall during the recent years.

4. SUMMARY

In the case of the Mak-Ban geothermal complex, 83% of the survey respondents believe that geothermal energy development has an impact on the environment and the top two major effects are air pollution & odor, and noise. This is especially true with Bitin, Limao and Sta. Elena, which are the barangays hosting geothermal power facilities. On the other hand, the other four barangays without geothermal facilities only identified air pollution and odor. Proximity to the facilities may be a key factor in this scenario.

In terms of economic activities, the respondents believe that geothermal power facilities have a negative impact on agricultural activities but on the other hand, has no impact on tourism and fisheries.

Based on the results, the local community have had "occasional" experiences of earthquakes and followed by "seldom" experiences of agricultural product damage, forest destruction, flooding and subsidence. There were quite many respondents who believe that, among the number of risks and natural disasters, earthquake, agricultural product damage, and subsidence are strongly related with geothermal power operations.

Along with energy prices and technological advancement, social acceptance will play a critical role in shaping the rate of progress of renewable energy development. In the same way, active public participation from local communities shapes the potential viability of other emerging technologies (Boudet et al., 2014). Effective and various methods of risk communication efforts with local communities can help increase awareness of impacts of these energy systems and technologies. Wide-range and inclusive public dialogue about its potential risks and benefits can solicit support and active participation from local communities.

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REFERENCES

Boudet, H., Clarke, C., Bugden, D., Maibach, E., Roser-Renouf, C., and Leiserowitz, A.: *"Fracking" controversy and communication: Using national survey data to understand public perceptions of hydraulic fracturing*. Energy Policy 65, 57-67. (2014).

Capuno, V. T., Sta. Maria, R. B., and Minguez, E. B.: Mak-Ban geothermal field, Philippines: 30 Years of commercial operation. *Proceedings World Geothermal Congress 2010, Bali, Indonesia.* (2010).

De Jesus, A. C.: *Sustainability as a business model for Philippine geothermal*. Oral presentation. (2013).

Devine-Wright, P.: *Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind* energy. Wind Energy 8, 125-139. (2005).

Firestone, J., and Kempton, W.: *Public opinion about large offshore wind power: Underlying factors.* Energy 35, 1584-1598. (2007).

Ho, S. S., Scheufele, D. A., and Corley, E. A.: *Factors influencing public risk-benefit considerations of nanotechnology: assessing the effects of mass media, interpersonal communications, and elaborative processing.* Public Understanding of Science 22, 606-623. (2013).

Hunter, S., and Leyden, K. M.: *Beyond NIMBY*. Policy Study Journal 23, 601-619. (1995).

Johansson, M., and Laike, T.: *Intention to respond to local wind turbines: The role of attitudes and visual perception*. Wind Energy 10, 435-451. (2007).

Ogena, M. S., and Fronda, A.: *Prolonged geothermal generation and opportunity in the Philippines*. Oral presentation in Geothermal Resources Council 2013 Annual Meeting, Las Vegas, Nevada. (2013).

Ogena, M. S., Sta. Maria, R. B., Stark, M. A., Oca, R. A. V., Reyes, A. N., Fronda, A. D., and Bayon, F. E. B.: Philippine country update: 2005-2010 Geothermal energy development. *Proceedings World Geothermal Congress 2010, Bali, Indonesia*. (2010).

Polyzou, O. and Stamataki, S.: *Geothermal energy and local societies—A NIMBY syndrome contradiction?* Proceedings of World Geothermal Congress 2010. (2010).

Pidgeon, N., and Demski, C. C.: *From nuclear to renewable: Energy systems transformation and public attitude*. Bulletin Atomic Scientists 68, 41-51. (2012).

Protacio, J. A. P., Golla, G. U., Nordquist, G. A., Acuña, J., and San Andres, R. B.: *Gravity and elevation changes at the Bulalo geothermal field, Philippines: Independent checks and constraints on numerical simulation*. Proceedings, 21st New Zealand Geothermal Workshop, 115-119. (2000).

Scheufele, D. A., and Lewenstein, B. V.: *The public and nanotechnology: How citizens make sense of emerging technologies*. Journal of Nanoparticle Research 7, 659-667. (2005).

Sussman, D., Javellana, S. P., and Benavidez, P. J.: Geothermal energy development in the Philippines: An overview. *Geothermics*, Vol. 22, No. 5/6, pp. 353-367. (1993).

Visschers, V. H. M., and Siegrist, M.: *How a nuclear power plant accident influences acceptance of nuclear power: Results of a longitudinal study before and after the Fukushima disaster*. Risk Analysis 33, 333-347. (2013).