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The multi-level perspective analysis: Indonesia geothermal energy transition study

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Abstract. The study adopts a multi-level perspective in technology transition to analyse how the transition process in the development of geothermal energy in Indonesia is able to compete against the incumbent fossil-fuelled energy sources. Three levels of multi-level perspective are socio-technical landscape (ST-landscape), socio-technical regime (ST-regime) and niche innovations in Indonesia geothermal development. The identification, mapping and analysis of the dynamic relationship between each level are the important pillars of the multi-level perspective framework. The analysis considers the set of rules, actors and controversies that may arise in the technological transition process. The identified geothermal resource risks are the basis of the emerging geothermal technological innovations in Indonesian geothermal. The analysis of this study reveals the transition pathway, which yields a forecast for the Indonesian geothermal technology transition in the form of scenarios and probable impacts.
Keywords: geothermal, multi-level perspective, renewable energy, transitions

1. Introduction

Energy sustainability requires innovation, planning and development to be conducted carefully in order to ensure energy sustainability. Hence, this paper suggests using the socio-technical multi-level perspective approach, which is the main theory of the socio-technical transition [1], to study the ways in which geothermal energy might replace mainstream energy in electricity generation. The levels are socio-technical landscape (ST-landscape), socio-technical regime (ST-regimes) and niche innovations [2], [3], [1]. ST-landscape includes prices, economic growth, conflicts, political status, environmental issues, etc. There are exogenous factors that exhibit high degrees of proximity and power across incumbent socio-technical systems [2]. The ST-regime is the set of rules or regulation that govern the activities within the broad communities [3]. Niche innovations represent radical innovations, which represents fundamental change that often depends on the integration of many interdependent systems to succeed [3], [1].

2. Research Method

As developed by [1], the multi-level perspective is a non-linear process and evolutionary framework in the process of technological transition [3]. This involves interactions between three levels across which society and technology co-evolve. The technique is also being used in other case studies, for example in car technology transitions, climate change responses, energy transitions, etc. [4], [5], [6] [7], [8]. There are many external factors included in a multi-level perspective framework, which are heterogeneous and related to the transition technology process. These factors fall within the ST-landscape at the highest level within a multi-level perspective framework. These are then followed by ST-regime while niches are at the lowest level of the perspective. In multi-perspective analysis, the success of a new technology is not only influenced by processes in niche innovation, but also by movements of, or changes in, the level of ST-regime and ST-landscape. However, in theory, resistance to change will be primarily at the ST-landscape level, since ST-landscape factors are less likely to change [3]. Any change within the ST-landscape may put pressure on the ST-regime and to open a new path for new innovations to enter and influence both ST-regime and ST-landscape. The basis of the niche innovation in geothermal exploration is to deal with resource risk that may arise during the process. Innovations in geothermal drilling and exploration attempt to mitigate this [9]. Some self-reinforcing innovations may initially require some degree of protection from external pressures (a protected environment: e.g. research universities, government research institutions, etc.). From here, niche actors can then nurture the path-breaking innovation so it becomes more robust through performance improvements and expansions in supportive socio-technical networks [10]. Examples of protected space are research institutions and research universities. In the past, society created technology to help itself, but some argue that technology has become so powerful that it has been able to “lock-in” societal activities [11], [12].

Path dependency is the way in which critical junctures at an early stage in the development of a socio-technical system persist through self-reinforcing means [13]. In multi-level perspectives, path dependency and technological lock-in are important in ST-regime level [15], [16], [17].

Controversy may be regarded as one of the side effects of technology transitions, especially if the transition implies societal change. Technological systems are dynamic and unstable, and any change in the components in the system (e.g. new entrant or a change in the institutional setup) may trigger actions and reactions within the system [7] at the ST-landscape development level.

3. Results and Discussion

3.1. ST-regime analysis

Published laws from 2007 and 2009 make it clear that renewable sources expected to be the main sources of energy in the future. However, the law of 2009 can be regarded as self-contradictory since it also requires optimisation of primary energy both local (preferred) and imported. The wording of the law indicates priority be given to primary resources such as coal, oil and gas.

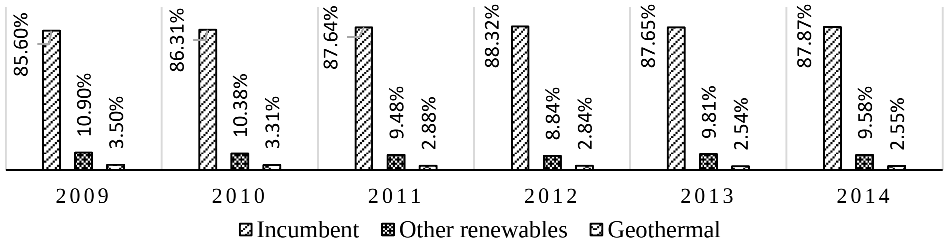

Figure 1. Indonesia geothermal installed capacity power plant distribution versus other resources.

Meanwhile, Figure 1 demonstrates this, where the planned use of fossil fuel as incumbent fossil energy still increases in comparison to renewables. Table 1 explains the currently applicable regulation and policies. The regulation basis pertaining to energy and electrification in Indonesia are [14] and [15] for electrification, followed by [16] and [17]. Indonesian Laws are the highest in the hierarchy and verified by the house of representative. Further examination of government regulations explains this anomaly. In table 1, regulations from the year 2012 show that economic values is the factor that the most difficult to change within ST-regime. Article [14] also underlined that renewable energy development depends on the economic value.

Table 1. Meanings of current applied national energy and electrification regulation and policy pertaining to source of energy.

Law no. 30 year 2007 *pertaining to energy*	**Law no. 30 year 2009** *pertaining to electrification*
Chapter 5, energy management. In article 20 (Energy supply), sentence no: (2) Renewable energy are preferred for energy development (4) Government must increase the use of renewables (5) Renewable energy suppliers will get convenience and incentives by the government, until it meets the economic valu In article 21 Energy utilization, sentence no: (2) Re-phrase article 20 sentence 4 (3) Re-phrase article 20 sentence 5, for energy utilization	Chapter 5, the primary energy utilisation. In article 6, sentences no: (1) The utilization of primary energy, which are taken from local resources and imported, must be optimised. (2) Renewable energy are preferred for energy utilisation. (3) Refer to sentence no. 1, local resources are preferred.
Government regulation No. 14 year 2012 *pertaining to electricity*	**Government regulation No. 79 year 2014** *pertaining to energy mix*
Chapter 5, electricity pricing-network-tariff. The articles in the chapter, explains the mechanism of pricing, network and tariff (economic value), which are determined by the decision and mutual agreement between the related governmental parties. Includes the minister, governor, mayor/residents, and house of representative.	Chapter 2, goals and target. On article 9, sentence (*f*) for energy mix: 1. Year 2030 Renewables increased 8% from year 2025. 2. Year 2030 oil decreased 5% from year 2025. 3. Year 2030 coal decreased 5% from year 2025. 4. Year 2030 natural gas increased 2% from year 2025. Chapter 3, national energy policy. On article 10, are mention the increasing exploration of the potential or proven reserves of fossil energ and renewables, decrease gas and coal export, to be used domestically, and make sure the environmental capacity support for renewables. Chapter 3, national energy policy. On article 11, are mention the maximisation of renewables, in regard to economic value; minimisation of oil, optimisation of renewables and natural gas; determination of coal as energy national supply.

That is why in [17], the government keen on energy mix policy, in which fossil fuels are still the main energy, and even coal being determined as the national energy supply. It shows the argument by Arthur, when usual policy of letting the superior technology reveal itself in the outcome that dominates, is proven [11]. The actors involved in this case study are shown in Figure 2. Central to the system are energy providers, the Indonesian national electricity company and consumers. Energy providers include multi-national companies, private local companies and the government-owned geothermal company. The other groups, which are government organizations, non-governmental organizations, environmental activist groups, and the media, also attempt to influence the system. The co-evolvement of society and technology demonstrated here at the ST-regime level.

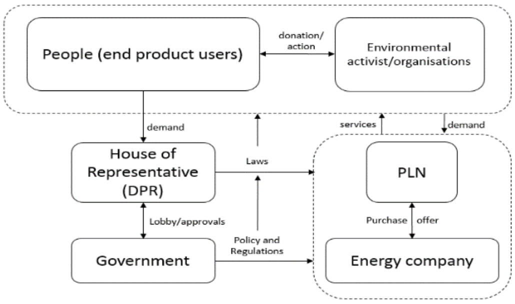

Figure 2. Identified actors in the socio technical regime of geothermal energy in Indonesia.

3.2. ST-landscape developments

Developments in the ST-landscape could affect and pressurize the socio-technical ST-regime; however, the impact and pressure from the ST-landscape is independent from (i.e. not influenced by) the ST-regime. The Indonesian primary national energy supply remains dominated by fossil fuels. The high levels of fossil energy supply reflects high demand for oil and gas products such as diesel for electricity and industry. In these cases, the fuel is a form of final energy that is relatively easy to use and reaches broad categories of consumer. Indonesia has one of the lowest electrification rates in Asia, where frequent rolling power blackouts are experienced in Sumatra, Kalimantan, Java (excepting the Jakarta rural area) and eastern part of Indonesia. Optimised use of geothermal energy could readily increase the electrification ratio (see Figure 3), especially in the eastern part of Indonesia. This is the main objective of government plans to increase the installed capacity of the energy mix. The problem of the demand for electrification directly pressurises the ST-regime.

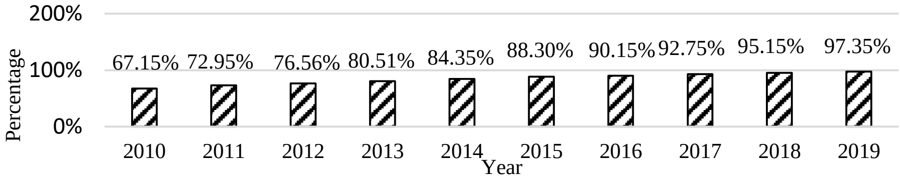

Figure 3. Electrification ratio (2010-2015 = actual and 2016-2019 = goals).

Regulatin [25] permits geothermal exploration inside the protected forest and conservation area (mostly located near volcanic areas) [18]**,** which allows geothermal exploration in conservation areas. However, controversies relating to geothermal development have arisen from cultural reasons and constraints, even though the law protects these projects. Despite the problem of increasing electricity demand, government policy to overcome energy deprivation is not always supported by a consensus from the broader cultural society. As evidenced by the examples above and argued by [8], public acceptance is needed if the aim to socially embed new technology is to be achieved. The existing policies and regulations were not publicly accepted within this Indonesian cultural context.

3.3. Technological niches

The identified geothermal resource risks are the basis of the emerging geothermal technological innovations in Indonesian geothermal development such as Enhanced Geothermal Systems (EGS), subsurface analysis and cross-field innovations. EGS is a technology that is able to perform geothermal exploration in areas that have technically and economically less potential, according to conventional geothermal systems by enhanced drilling techniques and reconditioning of the reservoir. There are very few activities evident in terms of EGS in Indonesia now, principally due to fewer hot dry rock resources and too many unexplored hydrothermal systems. EGS yet to be implemented in Indonesia since geothermal systems in Indonesia are generally convective hydrothermal [19] and the majority of the resources are not hot dry rock with low levels of water or vapour. Subsurface data modelling would be extremely useful to model the reservoir conditions during exploration. It would enable more efficient reservoir maintenance and management and serve as important data with regard to planning further developments, e.g. drilling new boreholes. According to Younger, reservoir modelling and management approaches need to be widely developed as common innovations in the geothermal industry [20]. Indonesian researchers have developed their own research studies in geothermal modelling fields as presented at a recent geothermal conference at Stanford University in early 2017 [21] [22]. This shows strong evidence that niche innovation in subsurface modelling is growing in Indonesia. Meanwhile, the most relevant potential cross-field technology is at the electricity production level, specifically hybrid power plants. There is only one new hybrid power plant in Indonesia (Yogyakarta area), which does not involved geothermal, and instead uses a combination of solar PV and wind turbines.

3.4. Discussion: Transition forecast

Based on the multi-perspective theory and analysis from the previous sections, the socio-technical pathway would be the transformation pathway, with incremental change [1]. In Figure 4, electricity demands and the environmental issue both create resistance in the ST-regime's path-dependence, which also supports the indication for a longer time for the transition. Based on the empirical data, ST-regime analysis and ST-landscape developments at the transition pathway:

a. ST-landscape development pressure from electrification demands, however environmental issues reduce this pressure. The Indonesian government plans to build a geothermal power plant totalling 7200 MW in order to increase the electrification ratio from 88.30%. Due to high demand, growth of renewables has previously been neglected in order to build and explore quick, cheap and powerful coal powered energy resources [23].

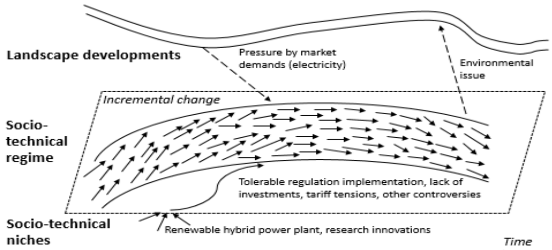

Figure 4. Geothermal energy transformation pathway, with incremental change.

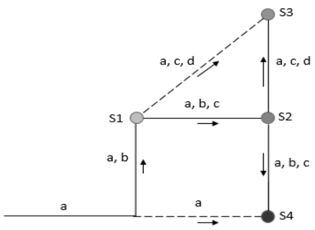

Figure 5. Four possible scenarios, with their transition seeds

b. Financially strong incumbent ST-regime. Funding and investment constraints has allowed the increase in the use of cheap and efficient fossil fuel energy sources, namely natural gas and coal, supported by numerous local reserves.
c. Policy change influence at ST-regime. Energy mix government regulation [17], creates both lock-in to fossil energy, but opens a path to incremental change with a very small number of niches in renewable and geothermal. The government power resources plan consists 23% renewables in 2025 [24].
d. Few niche innovations. Excitement for environmental friendly energy (e.g. solar, wind, hydro, geothermal) aligned with laws and government regulations will open the door for investment in renewables. With support from specific government regulation relating to geothermal sources [25], [26].

Based on the transition seeds, the potential scenarios for the next 20 years are:

S1. Geothermal energy with installed capacity of 5% of the total energy mix policy. Incumbent energy resources still leading, while geothermal energy development is stagnant. The instant solution to increase the electrification ratio is to push the usage of the local natural resources. This scenario is aligned with the current government decision to develop and commence several coal powered steam power plants in Indonesia between 2015 and 2019 [27], [28].

S2. Geothermal energy with installed capacity of 10% of the total energy mix policy. S2 occurs, when S1 fails to meet the target. Geothermal energy and other renewables still take a long time to grow in Indonesia. S2 only starts after S1 ends. The current local reserves of natural gas are extensive. Natural gas now leads the energy source.

S3. Geothermal energy with installed capacity of 20% of the total energy mix policy. Government gives more investment and support in renewables research to comply with the law and the government's recent plan [23]. The latest policy to support this scenario is government support in geothermal project funding by injection of project capital, allowing geothermal developers to seek financial support from state owned financing company [29].

S4. Geothermal energy with installed capacity of 5% of the total energy mix policy. Nuclear power plants alone also could raise the electrification ratio to 100% in combination with existing fossil and renewables. Controversies within the ST-regime will become constraints in this development. However, due to urgency, it becomes reality [30].

4. Conclusion

Based on the theory of the multi-level perspective framework as applied to technology transitions, conflicts were seen to be part of the ST-landscape development. Conflicts can act to trigger change in the ST-landscape, which may then put pressure on the ST-regime. However, conflicts within the ST-regime will only make the incumbent ST-regime path dependency stronger. Further study is needed to analyse this finding. The ST-landscape development on the other hand, helps to identify the potential changes in the level, which, in this case, are the demands for electricity. Based on the data, we conclude that these demands are due to electricity deprivation in large parts of Indonesia. According to the latest popular niche innovation in the global geothermal industry, the study points to multiple evidences of innovation in Indonesia. Unfortunately, at the current time, it still unable to influence the incumbent ST-regime. Overall, the framework smoothly connects the ST-regime with ST-landscape and niche innovations. The pathway analysis was able to help the study examine several scenarios, which forecast the outcome of technological transition in geothermal development in Indonesia.

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