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# Sustainable Development Model of Geothermal Energy (A Case Study at Darajat Geothermal Power Plant, Garut-Indonesia)

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**Abstract**

World consumption of energy from fossil fuels has continued to increase with the increasing world population growth. In Indonesia, the average growth of energy consumption is 8.5% per year due to economic and population growth. The majority of national energy demand is fulfilled by fossil fuels, but their reserves are decreasing. These situations have forced the government of Indonesia (GOI) to perform efficiency use of fossil fuels and find new alternative energies which are relatively cheaper and environmentally friendly. One of the new alternative energies that meets this criteria is geothermal, which is considered as a renewable energy, has ample reserve, and low $CO_2$ emission. GOI has established the 2006-2025 geothermal development roadmap targeting 9,500 MW in 2025 or a contribution of 5% to national energy consumption. However, current use of geothermal in 2012 is only 1,226 MW or 4% of Indonesia's geothermal potential (29,215 MW), therefore, this is considered a challenging target for Indonesia to achieve (Sukarna, 2012).This paper describes a conceptual model to develop sustainable geothermal energy to help achieve the GOI challenging target, based on a case study at a Geothermal Power Plant (GPP) in Darajat near Garut, Indonesia. It is intended to provide support for decision makers to accelerate sustainable development of geothermal energy based on social, environmental, and economic aspects. Therefore, some analyses are required to be performed and synthesized so that an optimal, comprehensive and an integrated model of sustainable geothermal development can be obtained. Various analysis conducted are based on a system approach, both hard and soft system approaches. The hard system approach is an analysis of economic investment feasibility of geothermal development at GPP Darajat Garut by calculating Net Present Value (NPV) and Internal Rate of Return (IRR). The soft system approach is a compilation result of the sustainable analysis of MDS (Multi-Dimensional Scaling), legal/regulation review, AHP (Analytical Hierarchy Process), and ISM (Interpretative Structural Modeling). These analysis results become inputs in designing a conceptual model of sustainable geothermal energy development. The financial analysis result indicates that investment for geothermal energy development is economically feasible with positive NPV and IRR. The MDS analysis result shows that geothermal energy development at GPP Darajat is relatively sustained. A regulation review indicates that there are government regulation inconsistencies and overlaps, and that permitting requirements need to be improved. The AHP analysis result indicates that the government policy consistency is the most important factor that influences improvement to other factors. The ISM analysis result indicates that 3 (three) elements have to be considered for sustainable geothermal development: 1) central government as an actor is the strongest driving power and influence for others, 2) government policy consistency is considered as a main obstacle, and (3) developing a long term strategy and policy are the key elements and main drivers that influence others. Based on those analyses results a conceptual model of sustainable geothermal energy development has been developed which consists of a management system, funding/budget support, actor to manage, and regulation management.

**Keywords:** Conceptual model, geothermal energy development, Darajat Garut, MDS, AHP, ISM.

## Introduction

Geothermal Power Plant (GPP) Darajat, Garut is located in the Garut Regency, in the Province of West Java, on Indonesia's Java Island. There are 3 generating units (Unit I, II & III) installed at the Darajat field which produce a total of 271 MW. Operated by Chevron since 1994, the vapor-dominated Darajat steam field is under a Joint Operations Contract with PERTAMINA (Indonesia's State Oil Company), and sells geothermal steam to PLN (State Electricity Company). Darajat Unit III geothermal project, has been registered to the Executive Board since June 2006 as the first geothermal power project for CDM (Clean Development Mechanism) in Indonesia (Newell *et al*., 2009).

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Geothermal energy is a renewable, environmental friendly energy-source based on the internal heat of the

Earth (Axelsson *et al*., 2003). In general, the Geothermal Power Plant (GPP) only emits a small amount of greenhouse gases. Research study done by IAEA (International Atomic Energy Agency) in 1989 shows that the geothermal power plant emits equivalent to 57 grams of $CO_2$ per each kWh of electricity generated, while another study in 1992 shows that GPP emits approximately 40 and 42 grams of $CO_2$ per each kWh (Hunt, 2001). In the meantime, the fossil fuel power plant emits equivalent to 460 – 1290 grams of $CO_2$ for each kWh electric generated. The low emission of $CO_2$ (external cost) from geothermal energy has an opportunity for future energy develoment. Furthermore, the low $CO_2$ emission can provide an economic advantage through carbon trading by applying clean development mechanism of Kyoto protocol and prevent the global climate change. The competitive advantage of geothermal energy should attract new investors to develop geothermal energy.

Indonesia has an abundance of geothermal energy, which is distributed at 285 locations throughout the country, and the potential to produce more than 29,000 MW. This is the world's largest geothermal energy potential, or more than 40% of the world's total potential. Yet, Indonesia has only utilized less than 5% of the potential. Total installed capacity of geothermal energy in 2012 is 1,226 MW (Sukarna, 2012). Having been urged by such situation, the GOI decided to promote geothermal energy development. The GOI released "National Energy Policy" (NEP) in 2002, and set a target of supplying 5% or more of the primary energy by renewable energy by 2020. In addition, the GOI enacted "Geothermal Energy Law" No. 27/ 2003 to promote participation of private sectors in geothermal power business. The Ministry of Energy and Mineral Resources (MEMR) established the "Development planning roadmap of geothermal energy" to implement the National Energy Policy in 2006. This roadmap states a high development target of 6,000 MW by 2020 and 9,500 MW by 2025. Thus, a basic framework for geothermal energy development has been formulated and the GOI has started its efforts to attain these development targets (ECFA, 2008).

However, thorough study on the sustainability model for the development is still limited. Such a model is required as guidance for further development of the geothermal energy without jeopardizing its sustainability aspect, which consists of three basic pillars: social, environmental, and economic. The model also required for identification of necessary efforts to be conducted in accelerating geothermal development to achieve the national targets as stated in the 2006-2025 geothermal energy development roadmap.

**Research Objective**

The objective of this research is to develop a sustainable development model of geothermal energy in an effort to achieve GOI target of 2006-2025 geothermal development roadmap based on Presidential Decree No. 5/2006 on National Energy Policy. Specific objectives of the research are: (1) Review of economic investment feasibility of geothermal energy development; (2) Analyze sustainability of the geothermal energy development; (3) Review policies of the geothermal energy development; and (4) Develop a conceptual model of sustainable geothermal energy development.

**Research Method**

GPP Darajat Garut is used as a study case for the model development. Primary data were obtained through direct field observation and recording the actual data at the plant. Moreover, questionnaire distribution to stakeholders, including community perspective on the sustainable development of geothermal energy, was conducted to accumulate the necessary data. Focus group discussion and interview with selected respondences and on some aspects was also conducted for data confirmation and provision of a more wide perspective associated with the research topic. The secondary data were obtained from literature and official publications from various associated departments such as Indonesia National Energy Board (DEN), Ministry of Energy and Mineral Energy Resources (ESDM), New and Renewable Energy Directorate (EBTKE), the Ministry of Environment (KLH), Ministry of Forestry, etc.

Analysis of economic investment feasibility was conducted through hard system by calculating Net Present Value (NPV) and Internal Rate of Return (IRR). This analysis is very important to support the decision making of geothermal project investment and prevent an unexpected failure. The financial analysis was conducted with and without the certified emission reduction (CER) from CDM. The incentive amount of CDM was obtained by calculating carbon dioxide ($CO_2$) emission reduction from the geothermal energy power plant (GPP) compared to baseline emission of the Jawa-Bali (coal) transmission by multiplying incentive CDM price per weight unit. Sustainability status of the geothermal energy development was analyzed using ordinansi technique Rap-geothermal, a modification of Rapfish with Multi-Dimensional Scaling (MDS). The sustainability dimension was valued from six dimensions: social, environmental, economic, policy, institution, and technology. The policy analysis and its priority were performed using legal or regulation reviews and Analytical Hierarchy Process (AHP) methods using Criterium Decision Plus (CDP 3.05). Structural model that can describe complexity of the review system so that can be utilized to formulize systematical and easy solution was developed with Interpretative Structural Modeling (ISM) techniques. Those analyses results become inputs in designing a conceptual model of the sustainable geothermal energy development.

**Result and Discussion**

**Economic Investment Feasibility of Geothermal Energy Development**

Calculation of $CO_2$ emission reduction by geothermal power plant, based on data obtained from GPP Darajat-Garut, showed that the GPP can reduce 698,471 ton $CO_2$ every year for 100 Megawatts (MW) capacity. Accordingly, from the $CO_2$ emission reduction every year, GPP Darajat has potential to get CDM incentive of approximately 3.5 to 7.0 million US dollars every year, or 100 to 200 million US dollars for 30 years production contract period (with the assumption of 5-10 US dollars value per each ton of $CO_2$ gas). This is called Certified Emission Reduction (CER) in the Clean Development Mechanism (CDM) of Kyoto Protocol. This CDM incentive can increase IRR 1.5%; from 15.3% become 16.8%. The incentives also increases NPV at amount of 15.9 million US dollars, from 56.8 million US dollars to 72.7 million US dollars with 10% tax assumption of CDM (Prihantono, 2004).

It seems that the CDM incentive is relatively not significant compared with the amount of money invested to develop GPP geothermal Darajat. However, the CER can stimulate the geothermal energy development in Indonesia. Incremental of IRR was 1.2%, from 15.3% to 16.5%; and NPV was 12.3 million US dollars, from 56.8 million US dollars to 69.1 million US dollars. Even though the CDM incentive did not significantly improve the project economy, the CDM incentive can support the sustainable development of geothermal energy.

**Sustainability of Geothermal Energy Development**

In this study, the three sustainability pillars were extended into 6 dimensions for sustainability analysis: institutional, technology, policy, environmental, social, and economic dimensions. Multi-dimension Scaling (MDS) on the collected data, and taking a threshold level 50 to indicate the sustainability, it is obtained that out of the six dimensions of the sustainability, five dimensions met the sustainability aspect and only one dimension did not. The dimensions that exceed threshold of sustainability index were institutional dimension (55.14), technology dimension (54.58), policy dimension (53.49), environmental dimension (52.95), and social dimension (52.54), while the economic dimension (46.75) did not meet threshold of the sustainability index. Overall, the sustainability average value of the geothermal energy development at GPP Darajat is 52.75 which indicates that the current geothermal development at GPP Darajat is relatively sustained. Figure 1 represents the sustainability of GPP Darajat Garut graphically.

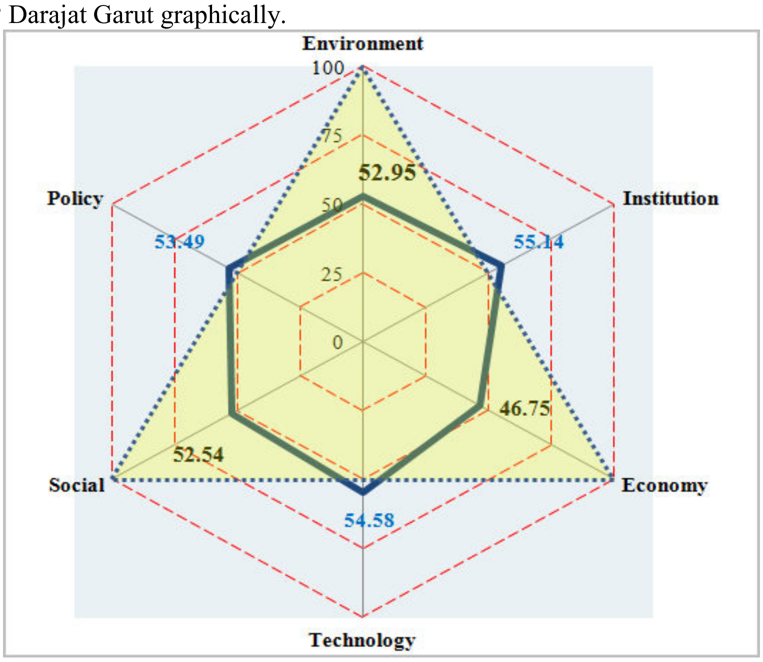


Figure 1: Sustainability of geothermal development at GPP Darajat, Garut

To increase sustainability of geothermal development, it requires improvement in some dimensions, especially at each leverage element. The leverage element in the economic dimension is to decrease investment cost or capital expenditure in the geothermal development. The leverage element in the social dimension is to increase the community empowerment in the GPP activities. The leverage element in the environment dimension is to increase areal of land conservation for GPP infrastructure. The leverage element in the policy dimension is to simplify permitting for GPP infrastructure. The leverage element in the technology dimension is to reduce import technology dependency in utilizing the geothermal energy. The leverage element in the institutional dimension is to increase participation of regional developers for building GPP infrastructure.

**Regulation Review of Geothermal Energy Development**

Comprehensive review on the existing regulation, associated with the utilization of geothermal energy in Indonesia, indicates that there are regulation inconsistencies and overlaps that need to be improved. The geothermal activity is regulated by Act no. 27/2003, which is intended to control geothermal utilization to support sustainable development and to promote participation by the private sector in the geothermal power business. It also provides added-value overall, and increases country income and community in encouraging national economic growth to improve welfare and prosperity. This Act explicitly states that geothermal is categorized as “mining”. In fact, it is different with the oil, coal, and other minings. Geothermal exploitation is not a “mining “ process since the energy removed from the resources is continuously replaced by more energy on time scales similar to those required for energy removal and those typical of technological societal systems (Rybach and Mongillo, 2006).

The majority of prospect geothermal locations in Indonesia are located in the conservation forest area. Meanwhile the Act no. 41/1999 pertaining to forestry, and Act no. 5/1990 pertaining to natural biological resources and its eco-system, ban the mining activity (exploration and exploitation) within the conservation forest area. In other words, those regulations limit the utilization of geothermal energy at the conservation forest area. These regulations are not aligned with the intent of the Act. No.27/2003. Various official permissions are required by developer from the various government institutions such as recommendations from the Governor or Regent for areal loan and use, technical recommendation from Perhutani (Association of Indonesia Forest), Loan-use permitting from the forestry Ministry, permit for using aquifer and surface water, permit for project development from the National Land Body (BPN), agreement of AMDAL (Environmental Impact Assessment), Environmental management effort and monitoring plan, uncertainty of those permits completion time, impacts to deceleration of geothermal energy development (Darma, 2011). Financial issue is regarding government assurance for investment in geothermal infrastructure projects which guarantee business feasibility or viability of the State Electricity Company to purchase geothermal electric from Independent Power Producers. This requires a decision by Presidential Decree or Financial Minister that guarantees support for investment by feasibility assurance of the State Electricity Company. Inconsistency in the regulations, and requirements for various permitting or recommendations, as well as financial issues, are considered as impervious to optimum development of geothermal energy in Indonesia.

**Policy Priority**

AHP was conducted to identify various priorities at every hierarchycal structure, which is focused to obtain policy consistency associated with geothermal energy development, taking into account the huge potential of geothermal energy in Indonesia. Various actors that have significant roles in the development of geothermal energy, and to push participation of private and community sectors, within the central and regional government, were identified. This is intended to keep secure national energy to achieve the national target, increase national economics, and reduce air pollution. The prioritized policy that has to be performed are 1) clean energy through incentive and disincentive policy, 2) fair regulation on the utilization of conservation area for geothermal activity, and 3) economical price of the electric (kWh) resulted from geothermal operations.

Contributed element under objective level over focus level (Figure 2), indicates that national energy security is the biggest contributor that influence in the dermination of each element in achieving focus of objective level hierarchy. This indicates that the national energy security is the most influential objective towards achieving the focused objective. In addition to the weight factor at every level, it is obtained also aggregate that describes the important weight each element at every level hierarchy. This weight aggregate shows the importance scale that each element in every level hierarchy systematically associated with the established AHP structure. The result of the AHP structure weight can be seen in the following figure.

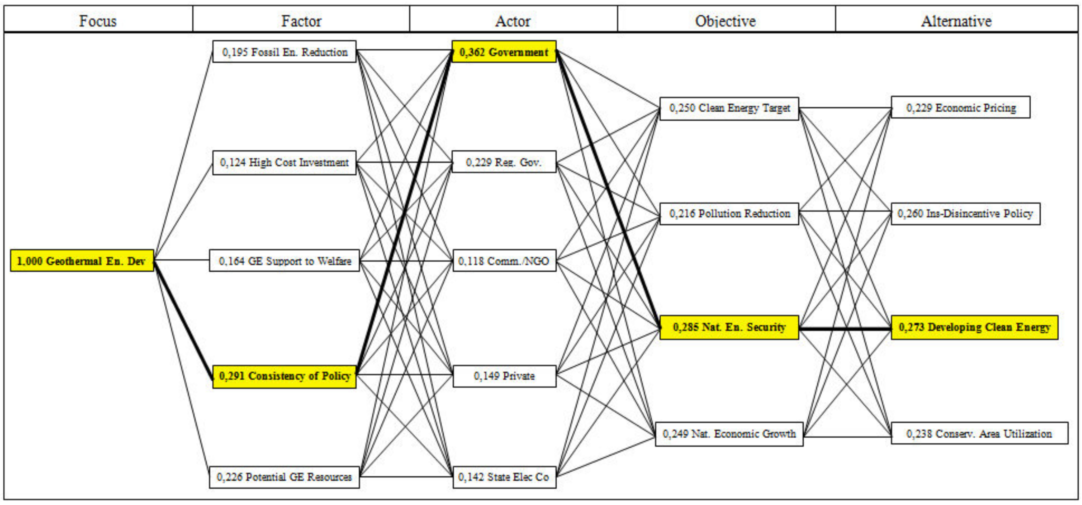

Figure 2: Agregate weight in established AHP structure in the sustainable development of geothermal energy at GPP Darajat.

The biggest weight in the factor level hierarchy is 0.291 for the government's consistency in policy. Consistent policy by the government has to be improved so that it can support achieving sustainable geothermal energy development. This indicates that consistent policy by the government is the most important factor that influences improvement of the other factors.

The biggest weight in the actor level hierarchy is 0.362 for central government. This shows that the central government through the associated ministry as the most important actor that must push other institutions. The biggest weight in the objective hierarchy level is 0.285 for securing the national energy. This shows that the security of national energy is the main criterion that has to be well managed to achieve sustainable geothermal development, without ignoring the achievement of other criteria.

Alternative weight is the main issue that can describe priority to determine alternative policy to achieve sustainable development of geothermal energy development. The biggest alternative value of the weight for sustainable geothermal development at GPP Darajat is utilization improvement of the clean energy with the weight of 0.273. This gives a confidence that utilization improvement of the clean energy is the priority to work on to support the sustainable development of geothermal energy.

**Structural Model of Geothermal Energy Development**

Analysis results of the Interpretive Structural Modeling (ISM) indicatethat there are 3 (three) elements to create a development model of sustainable geothermal energy at GPP Darajat: (1) Involved actor; (2) Main obstacles; and (3) Strategy in the future. The three elements will be elaborated further towards various sub-elements.

**1. Involved Actor**

Figure 3 shows that sub-element central government (1), State Electricity Company (2), and Regional House of Representatives (3), are inside quadrant IV (Independent). This gives a guidance that the three sub-elements have a strong driving power for the success of the sustainable development of geothermal energy at GPP Darajat. While sub-elements Regent (4), and Regional Working Units (5), are included in quadrant III (Linkage). Community (6), Non-government organization/NGO (7), and private sector (8), are included in quadrant II (Dependent).

 

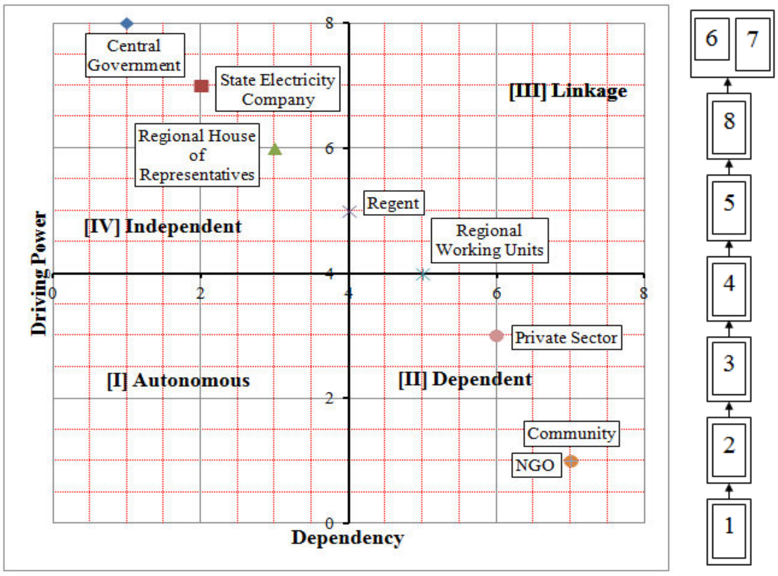


Figure 3: Actor element classification and hierarchi relationship.

Figure 3 describes the contextual relationship and hierarchy level of element actor of the sustainable development of geothermal energy at GPP Darajat. The hierarchy structure indicates that the sub-element of central government (11) exists at the top position or level 7. This indicates that the sub-element is the strongest driving power and influence for the other sub-elements at the lower levels. While sub-elements that exist at level 6, State Electricity Company (7) and level 5 is Regional House of Representatives (3). Sub-elements at further categorization are Regent (4) which is located at level 4 and involved Regional Working Units (5) at level 3. The last group is a group that has high dependency (dependent) is private sector/developer (8) at level 2, user community (6) and NGO (7) at level 1.

## 2. Main Obstacles

The analysis results indicate that sub-element lack of government policy consistency for the geothermal energy (1) is the key element of the main obstacle since it has the strongest driving power and the lowest dependency. This means that the main obstacle of the sustainable development of geothermal energy at GPP Darajat and determination for its success are those sub-elements themselves.

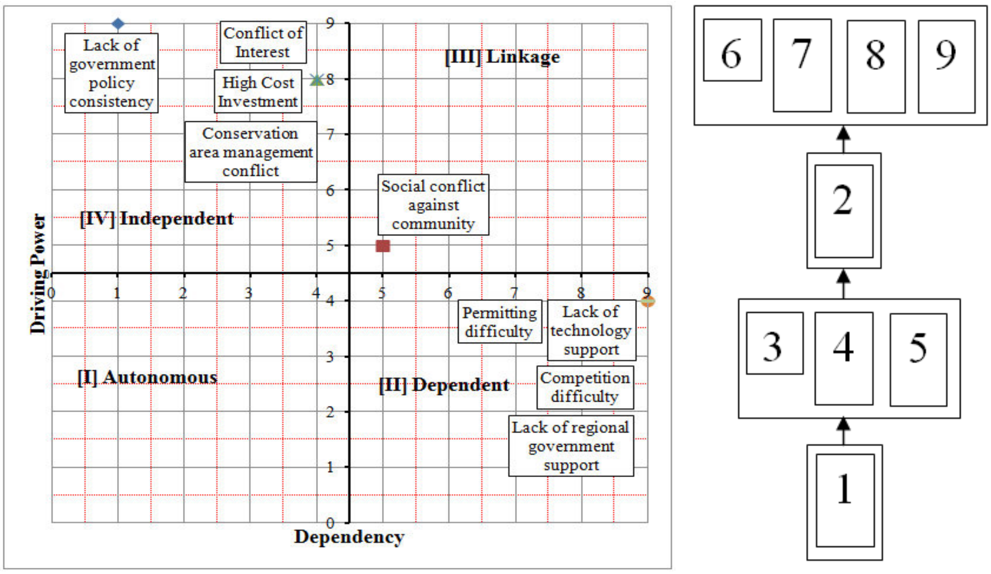


Figure 4: Obstacle element classification based on dependency level and driving power

The contectual relationship and hierarchi level of main obstacle element on the sustainable development of geothermal energy at GPP Darajat is presented at Figure 4. The hierarchi structure indicate that sub-element lack of technology support (6), permitting difficulty (8), competition difficulty (7) and lack of regional government support (9), are located at the lowest position or level 1. This indicates that the sub-elements are the most influenced and moved by other driving powers from other sub-elements, which are located at the higher levels. If it is considered the driving power and the dependency level, sub-element at level 1 together with the sub-element at level 2, have low driving power and strong influenced by the sub-elements at level 3 and 4. While the sub-element at level 4, the government consistency policy related with the geothermal energy development is the most influential for the sustainable development of geothermal energy at GPP Darajat.

## 3. Strategy

The hierarchi structure of sub-elements at the strategy element of the geothermal energy development as presented at Figure-5, explains the relationship of the key sub-elements at the highest level compared with other sub-elements at the lower levels. The figure means that the sub-elements at the higher level influence sub-elements at the lower level. Figure-5 shows that sub-elements developing long term policy for geothermal energy establishment (4) is located at level 4. This means that this sub-element is the key element and main driver that influences other sub-elements at the lower level.

The sub-elements that align policies of geothermal energy development between central government and regional government (1) are located at level 3. While sub-element prioritizing the clean energy usage (3) and formulizing policy for the utilization of conservation area for geothermal development (5) at level 2. The lowest sub-elements, consists of sub-elements priorotizing the clean energy usage (2), availability of institutions that specially focus to manage geothermal energy availability at region (6), government participation in subsidizing infrastructure availability and geothermal technology (7), and human resources availability that support geothermal management (8) is located at level 1.

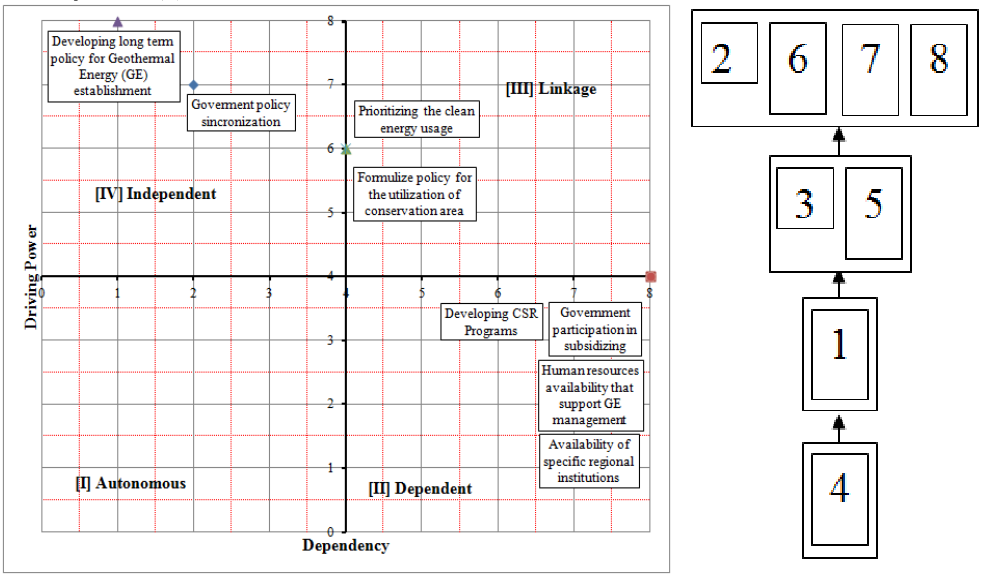


Figure 5: Obstacle element classification based on dependency level and driving power

**Conceptual Model of Geothermal Energy Development**

Compilation of all synthesis is described into conceptual schema that presented at the following Figure 6.

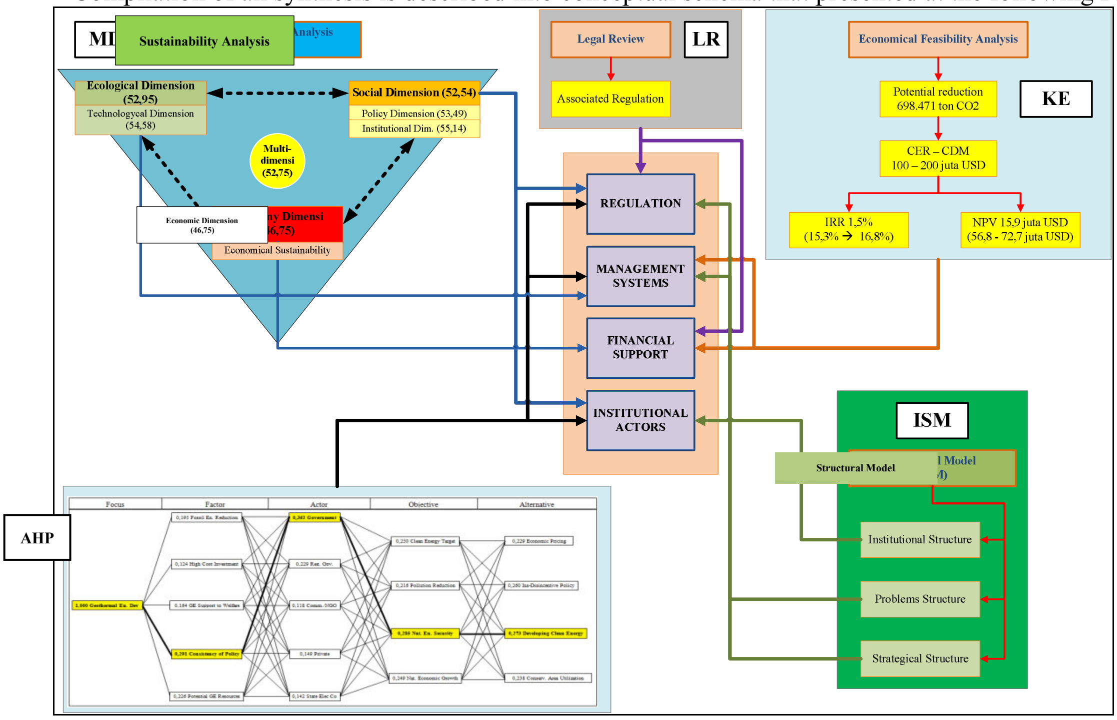


Figure 6: Conceptual model of sustainable geothermal energy development

The above figure shows a conceptual model of sustainable geothermal energy development which consists of the management system, funding/budget support, management actor, and regulations management. The regulation management is formulized based on legal review analysis and policy dimension in the MDS analysis. The management system is arranged based on solution for obstacle and strategy application from ISM result, alternative choices of the policy priority from AHP, and economic feasibility. Besides, environmental management is referred to analysis result of MDS at environmental dimension. Optimal involved actor is formulized based on the actor weight at AHP, actor structurization at ISM, and analysis result of institutional dimension at MDS analysis. While the budgeting support framework is arranged based on analysis result of economic feasibility and economic dimension of the MDS analysis.

## Conclusion and Suggestions

### Conclusion

1. Financial analyses results indicate that investment for geothermal energy development is economically feasible with positive NPV and IRR. Even the CDM incentive could increase IRR from 15.3% to 16.8%, and NPV from 56.8 million US dollars to 72.7 million US dollars (with tax assumption of 10% for CDM). Even though the CDM incentive did not significantly improve the project economy, it can support sustainable development of geothermal energy in Indonesia.
2. Sustainability analyses results show that geothermal energy development at GPP Darajat is relatively sustainable. Of the six dimensions of sustainability, five dimensions relatively met sustainability aspect and only one dimension (economic) that did not meet. Providing various kind of incentive and disincentive mechanism by GOI, simplifying permitting process for GPP infrastructure, and ensuring policy consistency, will help increase the economic dimension.
3. Regulation review results indicate that some challenging issues currently facing developers (private sectors) are government regulation changes, inconsistencies and overlapping, and a drawn-out permitting process, which all need to be improved. The term "mining" is explicitly stated in the Act. No.27/2003 that geothermal is categorized as "mining". In fact, geothermal exploration and exploitation is not a "mining "process. Meanwhile, the Act no. 41/1999 and Act no. 5/1990 ban utilization of geothermal energy within the conservation forest area. Review the Act no.27/2003 for possible deleting the "mining" word, will be a good solution of conflicting regulations. Process approval of various permitting requirements need to be simplified.
4. AHP results indicate that the consistent government policy is the most important factor that influences improvement to other factors. The main focus is to conduct a consistent policy associated with geothermal

energy development. Actors that have roles to coordinate are central and regional governments to push participation of private sectors, State Electricity Company, and community, to keep secure national energy by achieving the national target, increase national economics, and reduce air pollution. Four prioritized policies whereas the GOI has to focus include: 1) clean energy through incentive and disincentive policy, 2) permit to utilize conservation area for geothermal activity, 3) economic price of electricity to be more attractive, and 4) GOI guarantee business feasibility of State Electricity Company to purchase electricity from GPP.

5. ISM results indicate that 3 (three) elements have to be considered for sustainable geothermal development: 1) central government as an actor, has the strongest role to drive State Electricity Company and the Regional House of Representatives. They have to drive Regent and Regional Working Units as a linkage in driving participation of private sector, community, and NGO, 2) government policy inconsistency is considered as a main obstacle as well as conflict solution of vested interest parties in developing government policy, and (3) developing a long term strategy and policy are the key elements and main drivers that can influence others. This could reduce high cost investment of geothermal energy development and manage conflict of land use of conservation area. It is suggested for GOI to subsidize infrastructure and technology as well as to provide supporting resources, increase Corporate Social Responsibility (CSR), and establish a special institution or optimize institution function at the regional level.
6. A conceptual model of sustainable geothermal energy development has been developed to help and support decision makers to accelerate sustainable development of geothermal energy in an effort to achieve national target of 9,500 MW by 2025. The model consists of the management system, funding/budget support, management actor, and regulations management.

**Suggestions**

1.Some ways to improve sustainability of geothermal development are: 1) increase community empowering and community development in GPP activities from social aspect, 2) increase areal of land conservation for GPP infrastructure., 3) improve policy by simplifying permitting process for GPP infrastructure and ensuring policy consistency, 3) reduce import technology dependency in utilizing geothermal energy, and 4) increase participation of regional institutions for GPP infrastructure by optimizing functions and managing of existing regional institutions.

2.Even though the economic investment is feasible, it still needs to be supported by the government through various kind of incentives and disincentives mechanism to accelerate geothermal energy development. Examples of the incentives are fiscal terms such as corporate income tax and custom duties exemption for developer; electricity price certainty as purchase price by State Electricity Company (PLN) in the Power Purchase Agreement; mechanism of Feed in Tariff to make geothermal business more attractive to investors, etc.

3.Government policies of geothermal energy development can be improved by focusing on 3 (three) things: (a) regulation improvement; (b) solution of obstacles, objective achievement, and institution improvement; and (c) policies prioritization and implementation. Improved regulations can be performed by revising Act no. 27/2003 and taking out “mining” wording, making a MOU (memorandum of understanding) between Ministry of Energy and Mineral Resources (MEMR) and Ministry of Forest to help accelerate geothermal utilization permit, simplifying permitting approval process, etc. This should be supported by solving the main obstacle (policy inconsistency), meeting the objective (national target) and optimalization and better coordination of institutions aligned with the study results. Regulations and institutions can be used as a basis to a manage varity of issues that support sustainable geothermal energy development. An alternative action that can be performed is by implementing an established conceptual model of geothermal energy development to ensure its sustainability and achieve the national target of 9,500 MW by 2025.

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