Design of water hyacinth utilization as renewable electricity energy source in Tondano Lake

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Abstract. Energy security includes three aspects, namely the availability of energy sources, affordability of energy supply, and the continuation of new renewable energy development. This study aims to contribute in overcoming energy problems while solving environmental problems by utilizing water hyacinth in Lake Tondano, North Sulawesi Province, Indonesia. Through the approach of environmental science, developed scenario of water hyacinth utilization design to become energy source of biomass power plant (PLB). This scenario is the initial concept of the creation of water hyacinth as an alternative renewable energy. In order to ensure the sustainability of this scenario, a technological, technical, environmental and social assessment of technology diffusion was developed. The results show PLB design scenarios to be a new business that is profitable for the community in encouraging local economic development and becoming a solution to the problem of water hyacinth. Utilization of water hyacinth as an alternative energy in addition to improving the economy of society also increases the economic activities of a region. This design scenario provides insight into steps to develop new findings such as small-scale PLB designs in rural areas of the developing world. Finally PLB design scenarios can be a transfer of knowledge to local communities, empowering them to utilize biomass resources as a stimulus for economic prosperity in the region.

1 Executive summary

Summary of the results of this study is a comprehensive research conducted to find solutions to the problem of water hyacinth in Lake Tondano while providing alternative energy resources for people around Lake Tondano in Minahasa District, North Sulawesi, Indonesia.

Suggestions in this research is the utilization of water hyacinth as biomass and can be converted into electrical energy and organic fertilizer in the region of Tondano lake. For its implementation, technology is needed to meet the needs of the community and can be affordable without neglecting the economic value of the life of the Power Plant Biomass (PLB).

Previous research demonstrating Supply Chain Biomass with scenarios utilizing technology from Bandung shows a centralized production scale in one location with great resources, but in this study offers a smaller scale of production for local community level needs around Lake Tondano. This study shows that small-scale utilization of biomass from water hyacinth at the community level can increase access to cheaper and environmentally friendly energy and can help overcome the problem of water hyacinth and local economic development. For policy makers, this research summary also shows the importance of utilizing water hyacinth as a method of economic development of a region.

1.1 Problem statement

In the last few decades, it is clear that hyacinth creates problems to Lake Tondano [1]. Lakes and waterways throughout the tropical zone of the world face this problem because of the wealth of water nutrition [2]. Decayed hyacinths consume so much oxygen that it causes a significant reduction of the oxygen available in the water [2]. As a result, less oxygen is available for fish, leading to a decrease in fish populations. This in turn affects people's food security around the lake and the income of fishermen. In addition, water hyacinth may affect public health around Lake Tondano because water hyacinth serves as a breeding ground for vector organisms that carry bilharziasis, malaria, and river blindness [3]. Concrete steps of the government and PLN to address this issue through cleansing activities by appointment in an attempt to limit the number of water hyacinths in Lake Tondano. However, this effort produces nothing but the temporary elimination of water hyacinth because the hyacinth seeds have spread will remain active for more than six years and allow plant regeneration [4].

The most likely solution to the problem of water hyacinth is to use it as a biomass source [2], which can be done by a biochemical conversion technology called anaerobic digester [5]. The advantages of anaerobic digesters are energy, in the form of biogas, and organic fertilizers [2,6]. This would be an excellent choice to

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increase the low electrification rate and provide enough organic fertilizer to the farmers to carry out their agricultural activities. In developing solutions using anaerobic digesters, it is important to design all BSC [7, 8]. Furthermore, it is important that PLB technology will be distributed in the community to ensure its sustainability [9]. To ensure this, economic and technical aspects, environmental issues, and social issues were considered in this study.

The advantages of this solution are numerous. First of all, PLB will generate profits [10], increase revenues and provide local economic development benefits to rural areas [11], which can be translated into increasing welfare for society [10]. With regard to environmental issues, PLB will contribute to the mitigation of greenhouse gas emissions and help communities diversify their energy sources and achieve energy independence without threatening food supply [10]. In addition, new job opportunities are created that provide job opportunities in the area [7,8,11].

To summarize, the problem of water hyacinth in Lake Tondano is comprehensive and difficult to solve. It is stressed that utilizing water hyacinth can provide

economic development benefits to the area, making it a very attractive solution to the problem.

1.2 Methodology

This research, utilizing research method of design science. The research model was developed to visualize and guide precisely the research activities undertaken. In general, four phases of research can be seen (see Fig. 1). Phase 1 takes place at Manado State University in Tondano and is oriented towards defining the scope of this research. Phases 2 to 4 consist of field research activities around Lake Tondano. Phase 2 consists of sub-phases 2A and 2B that occur in each of Lake Tondano region and at Manado State University in Tondano. This phase aims to investigate the context of the problem, after which a potential PLB solution is developed in phase 3. Phase 3 takes place in the Lake Tondano area. Finally, phase 4 takes place at Manado State University in Tondano and is intended to validate the proposed PLB.

Fig. 1. Research protocol applied.

2 Results

In this research, PLB scenario developed simple technology that can be applied around the area near Lake Tondano. Scenarios use anaerobic digester technology with a capacity of 3 m³ of biomass in 1 (one) digester, output and financial investment required. Economic analysis was made to determine the exact financial requirements of this scenario (see Table 1). The scenario (modular system) requires an investment of Rp 2.7 billion, has a DPP of only two months and IRR equals a staggering 590.10%. From a purely economic perspective, scenario 2 is favorable over scenario 1 because it is very feasible

Table. 1. Economic Analysis.

Characteristic	Scenario
Required investment (Rp) ^a	2.659.314.240
Annual income (Rp) ^a	16.372.933.637
Annual costs (Rp) ^a	680.250.107
Cash flow (Rp) ^a	15.692.683.529
Net present value after five years (Rp) ^{a; b}	57.287.033.446

^a Currency exchange rate of \$1 = Rp13.514,95.

^B Discount rate of 9,7% [12].

As argued in the problem statement, the scenario is applied not just a financial decision. Technical aspects, environmental issues and social issues should also be

considered. To do so, sixteen criteria were formulated to ensure proper assessment of the scenario. The assessment matrix presents these criteria as well as scenario scores on each criterion (see Table 2). Based on observations from Table 2, it can be stated that the utilization of PLB offers full-time employment (excluding administrative and management functions) to Lake Tondano area. Using 4.5% of water hyacinth in the lake, it has a non-continuous energy generation capacity of only 8.5kW, but produces 887 tons of liquid organic fertilizer and 591,300 tons annually. In addition, a relatively small investment is required and it provides four full-time workers (excluding administrative and management functions) and sixteen part-time jobs (one day per week) to the area. To determine which scenarios are most appropriate for the Lake Tondano area, the scores are calculated on the basis of technological precision. Thus, scenario 2 is most applicable in the area of Lake Tondano, offering a lucrative business opportunity with relatively low investment costs, scalable technology, and social benefits to the area.

Table 2. Assessment of scenario.

	Criteria	Scenario
Economic and technical aspects	Low investment and operational costs	++
	Easily expandable system	++
	Reliable energy supply to PLN	-
	Understandable technology	+
	Create social value: pay proper salary	+
	Can withstand weather conditions	+
	Ease of implementation	+
Environmental matters	Utilise all water hyacinths	-
	Low environmental impact	++
	No loss of natural habitats	0
	Environmental best practice	+
Social issues	Stakeholder acceptance	++
	Community involvement	+
	Set an organisational standard	++
	Low transportation inconvenience	+
	Low impact on area's aesthetics	+

3 Conclusions

The results of this study presents a PLB scenario that can be applied as a solution to the problem of water hyacinth in Lake Tondano. After the assessment, which considers the economic, technical, environmental and social aspects, the proposed scenario uses a modular system from the factory in Bandung. This scenario can be realized from the government budget or CSR funds available for bioenergy production. The advantage of this scenario is that it will offer the possibility of a profitable business with relatively low investment costs, measurable technology, and social benefits to Lake Tondano area.

Based on the assessment, this study is described in the design specifications and the implications of realizing the PLB. First, with scenario implementation, 12 ha of water hyacinth in Lake Tondano will be

utilized. To do so, a floating floating hyacinth will be drawn near the shore. This allows the workers to harvest the water hyacinth in an easy way. The area will be given a barrier that wraps 12 ha of water hyacinth to ensure that water hyacinth can not drift. The border can be built similar to the protective border around the fish farm made of bamboo. Secondly, a number of options can be considered to control the remaining hyacinths in Lake Tondano, namely:

3.1 Harvesting

Increase the frequency of cleanup activities from the government and PLN into a sustainable cleaning program. The introduction of a sustainable cleaning program will, most likely, reduce labor costs and needs as hyacinth is harvested as soon as the first signs of new plant growth are detected. But the problem statement says that the water hyacinth seeds have spread remained active for six years and will regenerate the new hyacinth [4]. Thus, it should be emphasized that sustainable solutions to the problem of water hyacinth can only be achieved on long-term horizons. Increased frequency will ensure that lake conditions will increase dramatically over the years;

3.2 Instalation

Installing additional modules may increase PLB's proposed capacity, which in turn, will increase the amount of used hyacinth and economic benefits to the area. This of course will require additional investment;

3.3 Food Stock

The remaining hyacinth can also be used to feed the livestock [2]. High protein levels make it an excellent source of food for chickens, cows, goats and sheep;

3.4 Handycraft

The remaining hyacinth can be used for handicraft production. Research in this case has been done by dr. Joudie Lucky and dr. Hanny Anapu from Sam Ratulangi University in cooperation with North Sulawesi Provincial Government Research and Development institute;

3.5 Compost

Instead of using water hyacinth as a biomass source as proposed in this policy, the remaining hyacinth can be directly applied as compost [2]. This will require less investment and technological skills than if implementing PLB.

If desired, researchers can provide additional information that can be used to educate people in the Lake Tondano region about the possibility of application of water hyacinth. In addition, empowering communities to use water hyacinth can lead to additional business opportunities in the area.

Finally, researchers want to emphasize the need for government control over water hyacinth if the government will allow the realization of PLB. Because once the first PLB is realized and people with close relationships with investors see the economic benefits, it is likely to emerge that the other party wants to realize the PLB as well. This can lead to the development of parties who want to take advantage of water hyacinth, which threatens the long-term sustainability of the solution. To prevent this from happening, local authorities must control the level of water hyacinth in Lake Tondano. For example by issuing permits of use to interested parties.

References

1. Kamagi, M., *Policy brief: water hyacinths for energy independency and food security*, Manado, ID.(2014)
2. Gunnarsson, C.C. & Petersen, C.M., Water hyacinths as a resource in agriculture and energy production: a literature review. *Waste management*, 27(1), pp.117–29. (2007)
3. Abdelhamid, A.M & Gabr, A.A Evaluation of Water hyacinth as feed for ruminants Archives of Animal Nutrition 41 (7), pp 745-756 (1991)
4. Lee, B.,Insects for controlling water weeds. *Rural Research*, 105, pp.25–29. (1979)
5. McKendry, P., Energy production from biomass (Part 2): Conversion technologies. *Bioresource technology*, 83(1), pp.47–54. (2002)
6. Sharma, B. et al., Biomass supply chain design and analysis: Basis, overview, modeling, challenges, and future. *Renewable and Sustainable Energy Reviews*, 24, pp.608–627.(2013)
7. Gold, S. & Seuring, S., Supply chain and logistics issues of bio-energy production. *Journal of Cleaner Production*, 19(1), pp.32–42.(2011)
8. Mafakheri, F. & Nasiri, F., Modeling of biomass-to-energy supply chain operations: Applications, challenges and research directions. *Energy Policy*, 67, pp.116–126. (2014)
9. Sianipar, C.P.M. et al., Seven Pillars of Survivability: Appropriate Technology with a Human Face. *European Journal of Sustainable Development*, 2(4), pp.1–18.(2013)
10. Cambero, C. & Sowlati, T., 2014. Assessment and optimization of forest biomass supply chains from economic, social and environmental perspectives – A review of literature. *Renewable and Sustainable Energy Reviews*, 36, pp.62–73.(2014)
11. Martinot, E. et al., Renewable Energy Markets in Developing Countries. *Annual Review of Energy and the Environment*, 27(1), pp.309–348.(2002)
12. Griffin, J.M. International Cost of Capital. *Yale School of Management*, p.14. Available at: <http://faculty.som.yale.edu/johnggriffin/intl/notes/Lect 14 Ccap.pdf>. (2014)