Management model for biogas production from wastewater of natural rubber processing at community level

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Abstract

This study aimed to examine factors affecting the management of biogas production from wastewater of natural rubber processing at the community level, and to develop a management model. The methodologies consisted of a literature review on the factors affecting biogas management and the area based on in-depth interviews with three cooperatives of rubber sheet production in Songkhla Province. The data was summarized to find the key factors and criteria. These factors and criteria were prioritized using the analytical hierarchy process (AHP) to conclude the management model. As a result, there are five key factors including the environmental aspect, social aspect, health impact, economical aspect, and technological aspect respectively. In addition, collaboration with relevant sectors to prevent problems concerning biogas operation and maintenance, biogas funding, and the biogas utilization in the future must be promoted.

Keywords:

Management model, Waste-to-energy, Biogas from wastewater

1. Introduction

The economic growth and development, demands increasing and continuous energy consumption. According to B.P. [1], the total world energy consumption was 12,807.1 kiloton of oil equivalent (ktoe) in 2015, an increase of around 0.9% from 2014. In Thailand, the level of total primary energy consumption in 2014 was 2,053 thousand barrels per day (KBD) of crude oil equivalent, an increase of 2.5% from 2013. Moreover, the demand for natural gas, oil, lignite, hydropower, and imported electricity had increased by 66%, 1%, 21%, 3%, and 9% respectively [2]. The concept of "waste-to-energy" as a measure to reduce fossil energy use by utilizing waste includes biogas production from organic waste to substitute liquid petroleum gas (LPG), coal, wood, and fuel oil. The World Health Organization [3] has promoted biogas usage to replace biomass, in order to reduce vital health impacts from air emission produced by biomass combustion such as carbon monoxide, and particulate matters.

The process of natural rubber production at the community level such as rubber sheet production of the cooperative, especially in Songkhla province which had 89 rubber sheet production cooperatives, -the second highest number in Thailand [4], utilizes large amounts of water for rinsing, cleaning and overall processing as shown in Figure 1. Formic acid which is added for natural rubber coagulation [5][6], is the cause of acidic wastewater of a pH lower than 6. The process intensifies both the biochemical oxygen demand (BOD), and chemical oxygen demand (COD) at around 8,500 and 17,500 milligrams per liter respectively. At the same time, protein, glucose, fatty acid, and natural ingredients in rubber are released into the wastewater causing pollution through biodegradation and fermentation [7]. Biogas from natural rubber processing which is one of the waste-to-energy concepts, can be a wise alternative to reduce the environmental pollution and increase the waste-to-energy production from wastewater.

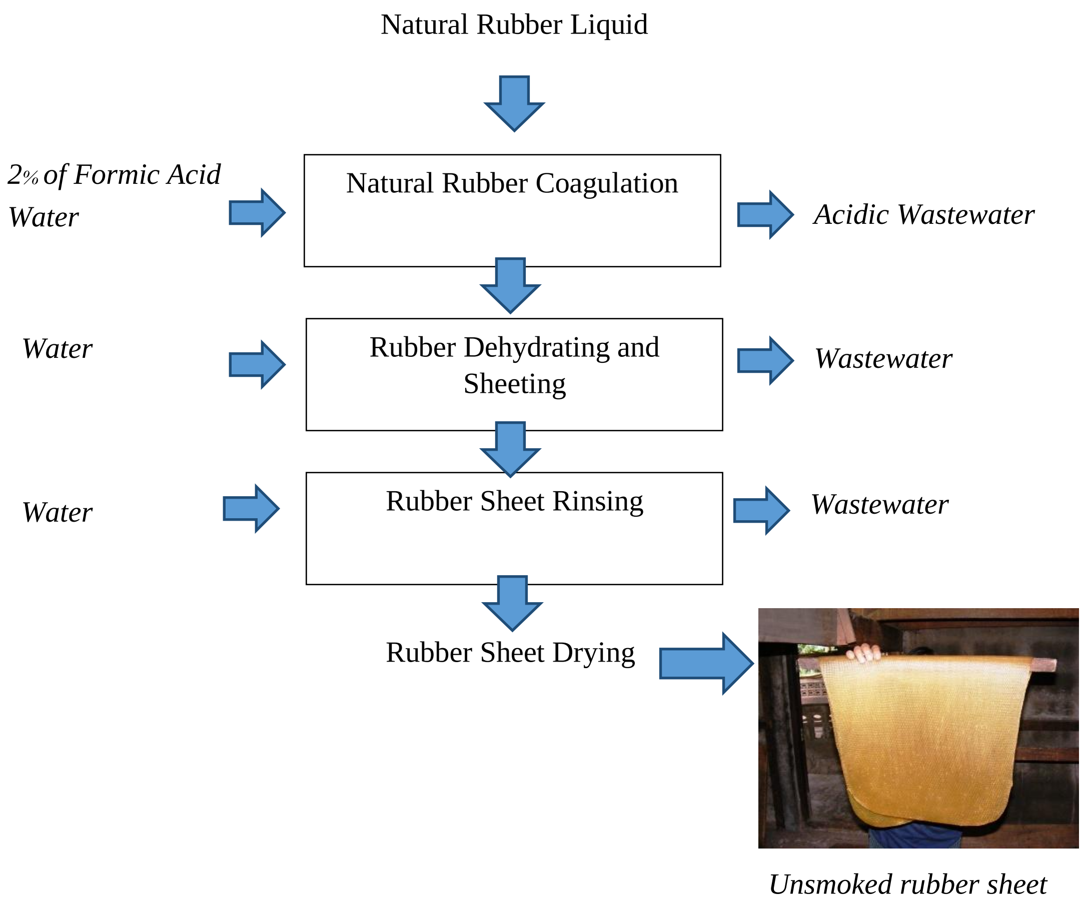

Fig. 1 The process of natural rubber processing at community level.

However, Boon & Templeton [3] stated that the lack of budget and knowledge for the management of biogas production was the crucial obstacle to the success and future of biogas production and management from natural rubber production. A suitable management model may provide a solution to the said obstacle to acquiring an alternative renewable energy source as well as reducing waste and environmental contamination. Hence, there are two main objectives of this research: 1) to examine the management factors affecting the biogas production from wastewater of natural rubber processing at the community level; and 2) to develop a management model for biogas production from wastewater of natural rubber processing at the community level.

2. Methodology

The conceptual framework for this study is shown in Figure 2. Concept of biogas production management derived from a literature review was analyzed in terms of economic al, environmental, social, technological and health impacts. The observations were carried out in Songkhla province at the 3 production cooperatives which were Yoong-Thong, Klong Kauo Rang, and Baan Yang Ngam Cooperatives of Rubber Sheet Production. Biogas technology was supported and transferred from the Energy Policy and Planning Office (EPPO) and the Prince of Songkhla University and they were successful for biogas production. Moreover, their managers were interviewed about the main reasons for biogas production, supporting agencies and subsidy for biogas production, biogas technology, and the advantage and the obstacle for biogas production. Data on management of biogas production of for each cooperative was collected and analyzed. An analytical hierarchy process (AHP method) [8][9] was adopted and calculated by the (1) equation and then was used to improve and complete a management model by 7 experts (see in Table 1) to investigate significant factors for wilder implementation of the natural rubber processing at the community level.

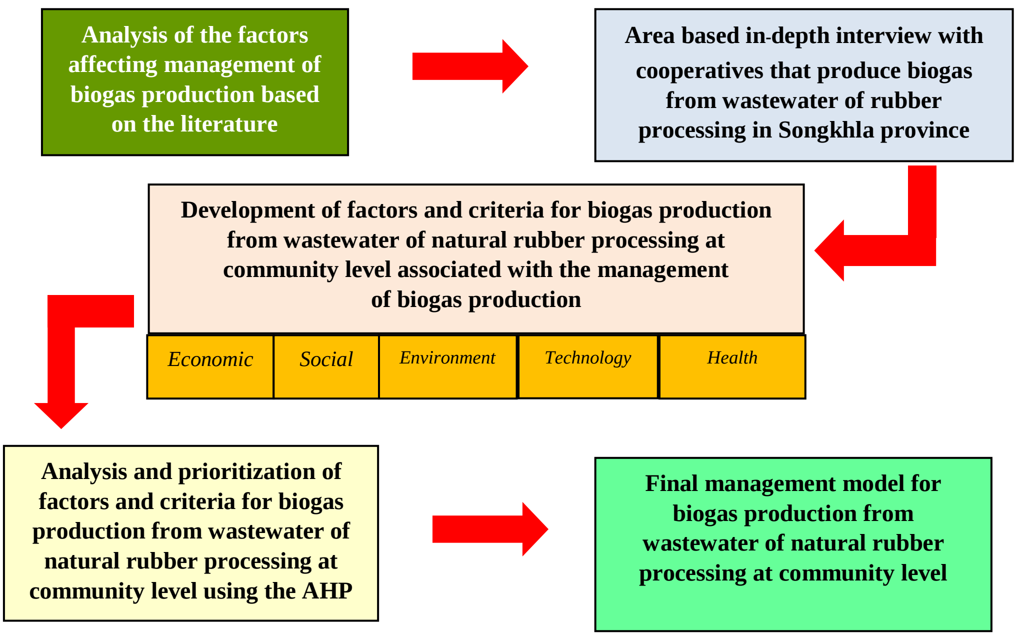

Fig. 2 The conceptual framework.

$$R_{AHP} = \text{Max}_i \sum_{j=1}^{N} a_{ij} w_{ij} \quad \text{for } 1,2,3,\ldots,M$$ ----(1) *the AHP equation* [9]

Where:

$\boldsymbol{R}_{AHP}$ is the criteria weight score for prioritizing of factor and criteria, $\boldsymbol{N}$ is number of decision factor, $\boldsymbol{a_{ij}}$ is the actual value of the i^{th} factor in terms of the j^{th} criterion, and $\boldsymbol{w_j}$ is the weight of importance of the j^{th} criterion

For Example

	Criteria			
Factor	*C1=0.20*	*C2=0.15*	*C3=0.40*	*C4=0.25*
F1	25/65	20/55	15/65	30/65
F2	10/65	30/55	20/65	30/65
F3	30/65	5/55	30/65	5/65
Sum	65	55	65	65

When the AHP equation is applied on the this example data;

F1= (25/65)x0.20 + (20/55)x0.15 + (15/65)x0.40 + (30/65)x0.25 = 0.34
F2= (10/65)x0.20 + (30/55)x0.15 + (20/65)x0.40 + (30/65)x0.25 = 0.35
F3= (30/65)x0.20 + (5/55)x0.15 + (30/65)x0.40 + (5/65)x0.25 = 0.34

Therefore, the best factor (in the maximization case) is F2 (because it has the highest AHP score; 0.35). Moreover, the following ranking is derived: F2 > F1 > F3

Table 1 List of experts.

Interviewer	Title/ Positions
Dr. Tarntip Settacharnwit	Expert in renewable energy policy, Department of Alternative Energy Development and Efficiency (DEDE).
Dr. Watcharee Chonchamrat	Expert in biogas technology and design, Energy of Environment Foundation (EFE)
Dr. Routerudee Chotikawin,	Expert in environmental Health , Faculty of Public Health, Burapha University
Dr. Nittaya Pasukphun	Solid waste management, waste utilization, and wastewater treatment School of Health Science, Mae Fah Luang University
Dr Yanasinee Suma	Expert in Wastewater treatment School of Health Science, Mae Fah Luang University
Mr. Chaiwat Pollap	Expert in biogas production process Energy Research Institute, Chulalongkorn University.
Mr. Sirm Doungdech	Expert in community Biogas technology and management, Head of Ratchaburi's Community Energy Volunteer, Ratchaburi province

3. Result and Discussions

3.1 Factor affecting biogas production management

According to literatures related to biogas production management, there are five groups of factors that management of biogas production can affect on these factors as follows[10][11][12][13]: 1) *Economical factors* are the factors related to cost and economic benefits including capital cost, net present value (NPV), maintenance cost, fuel cost, end of life cost, and emission cost; 2) *Social factors* are the factors associated with the biogas acceptance and quality of life in the community including involving various stakeholders, social acceptance, relevance to the national energy policy, job creation, and social benefit; 3) *Environmental factors* are the factors related to the effects or impacts on the environment including land requirement, environmental pollution, impact on ecosystem, and consumption of resources; 4) *Technological factors* are the factors related to the main technique and operation for biogas production including satisfaction of need, maturity, availability, reliability, easiness, safety, and efficiency; and 5) *Health impact factors* are the effects of biogas production on human health including insect and rodent protection, reducing exposure to products of incomplete combustion, sanitation of waste management, and reducing pathogen concentration.

3.2 Biogas production from wastewater of natural rubber processing based on in-depth interviews

From the in-depth interviews and observations in the target areas of Songkhla Province, it was clearly seen that there were 4 main elements of biogas digestion for treatment of the unsmoked rubber sheet wastewater comprising of screening pond, equalization pond, anaerobic digestion pond, and reclamation pond as shown in Figure 3. The intensive pollutants contaminated and bad odor from the wastewater could be reduced by the mechanism of anaerobic digestion of microorganism. Therefore, the biogas or methane (CH_4), the main byproduct generated by the anaerobic digestion process, could be utilized for heating in the process of smoked rubber sheet to prevent a sprouting of mold or fungi on the rubber and it could reduce nearly 30% of the cost of fuel for the smoke rubber sheet. Moreover, there were several ways for biogas utilization; for instance, cooking, heating process, and supporting the electricity supply in the community. The biogas production from the unsmoked rubber sheet wastewater, however, could not be conveyed for other households because it had a lower pressure compared with biogas produced from other organic matter sources such as livestock manure. In addition, it might significantly be a failure of biogas production if the operators lacked knowledge and good operation control of biogas production. Furthermore, it had a higher cost for maintenance and operation than a normal aerobic oxidation pond for wastewater treatment in the natural rubber processing.

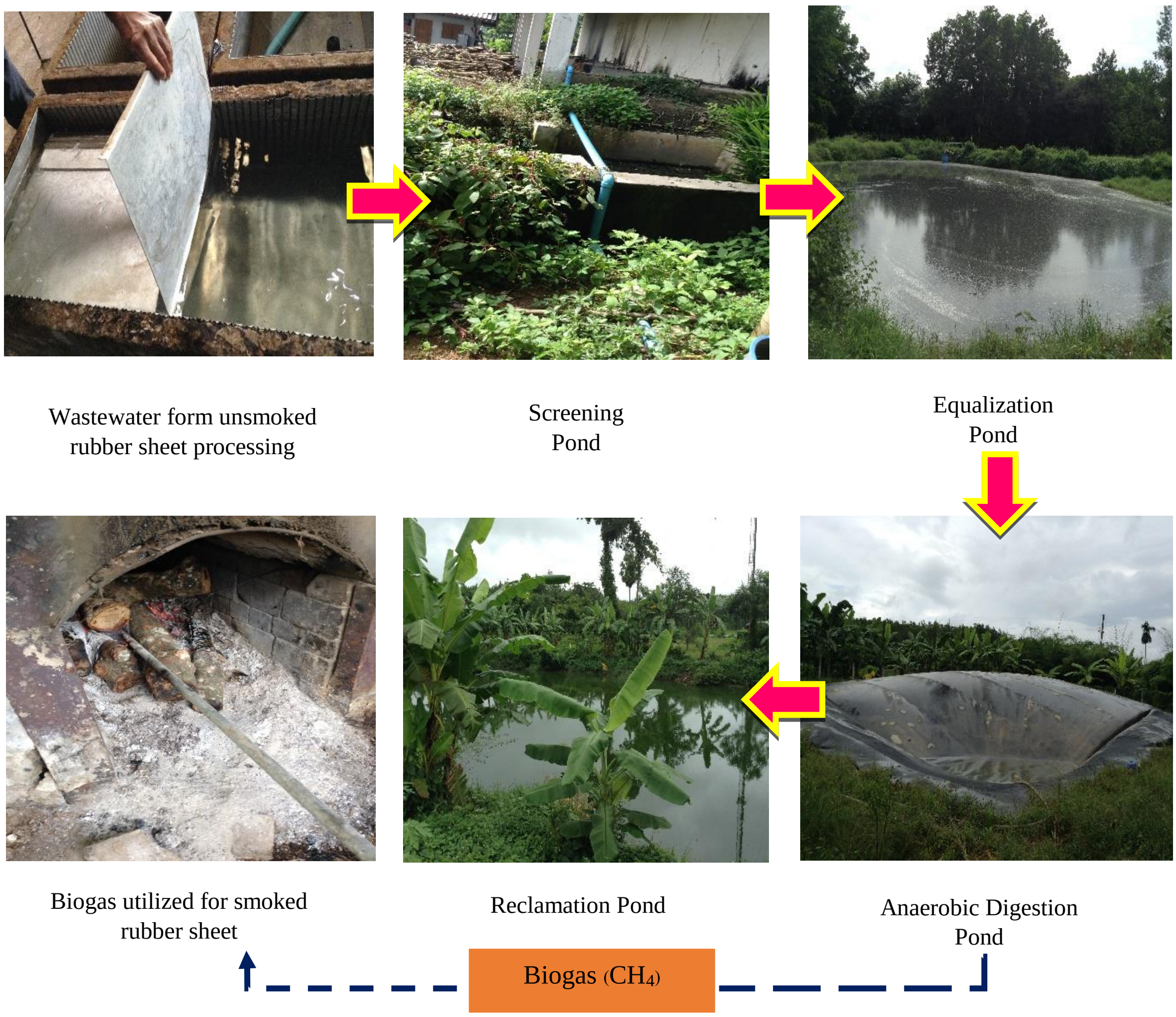

Fig. 3 Biogas production process from wastewater of unsmoked rubber sheet processing.

3.3 Factors prioritization using the AHP

To examine the significance of factors related to the biogas production from wastewater of natural rubber processing at community level including economic, social, environmental, technological, and health impact factors, the AHP analysis was adopted to prioritize key factors weights (FW) and the criteria weights (CRW) of the factors affecting this management model [8][9]. As can be seen in Figure 4, the environmental factors had the highest weight (factor weight = 0.220); while, social factors, health impact factors, economical factors, and technological factors had factor weights lower than that of the environmental factors which were 0.201, 0.197, 0.193, and 0.186 respectively. In addition, the priority weight as can be seen in Figure 5 indicated that there were three main criteria of biogas production from natural rubber processing at the community level which could provide a basis for the upper level of priority weighting including the environmental criteria (range of score = 0.051-0.059), the health impact criteria (range of score = 0.049-0.053), and the social criteria (range of score = 0.029-0.049) respectively. The main reason why the environment factors were the most significant factors relied on the fact that they encompassed several vital aspects such as environmental pollution that environmental impact such as SO_2, NO_2, wastewater, and solid waste that could affect human health and the ecosystem, and the consumption of resources [13]. The social factors, especially the social acceptance, were the other significant factors for implementation of renewable energy development. This is in accordance with Ruggiero, Onkila, & Kuittinen [14], who stated that if the positive impact from the renewable energy project was illustrated in the community, it could receive acceptance from the local people. In addition, the collaboration among related sectors including the government, intermediate organizations, and local community has been addressed as an important element in mobilizing renewable energy management. For the health impact, Bagge et al [15] concluded that there were a lot of pathogens within the organic matter used for biogas production that could affect human health, such as *Escherichia coli*, *Enterococcus* spp., Coliform bacteria, *Salmonella* spp. Hence, it implies that sanitation for waste management is the best way to reduce the chance of infection from microorganism to protect human health [16].

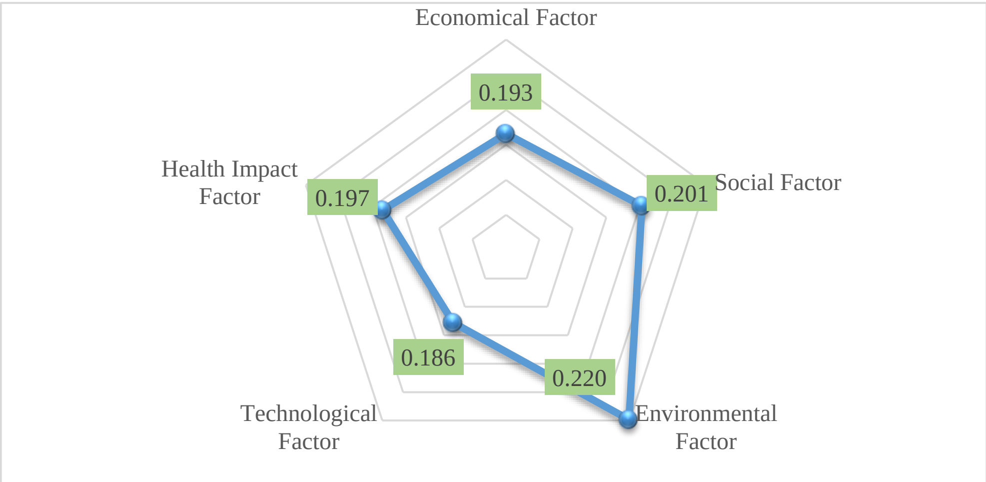

Fig. 4 Factor Weights using the AHP method.

Note: The consistency index (CI) is 0.00

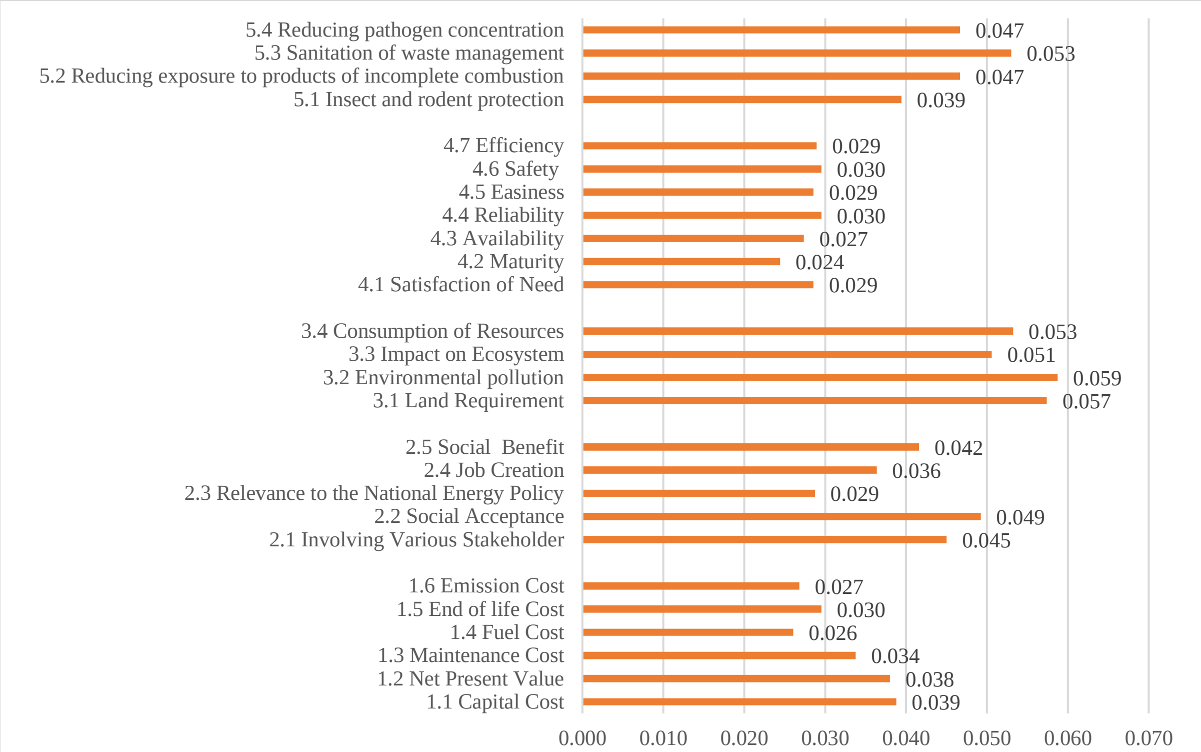

Fig. 5 Criteria weights using the AHP method
Note: The consistency index (CI) is 0.00.

4. Conclusion

Although the biogas production from wastewater from natural rubber processing can be used to reduce the environmental pollutant concentration and bad odor from the fermentation, the failure for biogas production from this wastewater may occur due to inadequate knowledge in biogas production maintenance and the insufficient funding for operation. To avoid this problem, the management model for biogas production from wastewater of natural rubber processing as can be seen in Figure 6 including the five key factors should be considered. The first priority factors are *environmental factors* consisting of criterion such as environmental pollution and land requirement. Secondly, the social factors, there are two main criterions including social acceptance and involving various stakeholders. The *health impact factors*, the third factors for this model, encompasses important criterion such as sanitation of waste management, reducing pathogen concentration, and reducing exposure to emission from incomplete combustion. The forth are *economical factors*, comprising of important criterion such as capital cost and net present value. The last factors are *technological factors* including safety, reliability, satisfaction of need, and efficiency of biogas technology. However, the collaboration among related sectors including the local administration, the environmental protection agencies, the owner of the natural rubber processing enterprise, and the alternative energy department must be promoted for sustaining the biogas operation and maintenance, biogas funding, and the wider utilization of biogas production. Moreover, the environmental complaints or environmental problems in the community such as bad odor from wastewater of natural rubber processing are the key issues which the owner of the natural rubber processing enterprise needs to manage to avoid objection from the community.

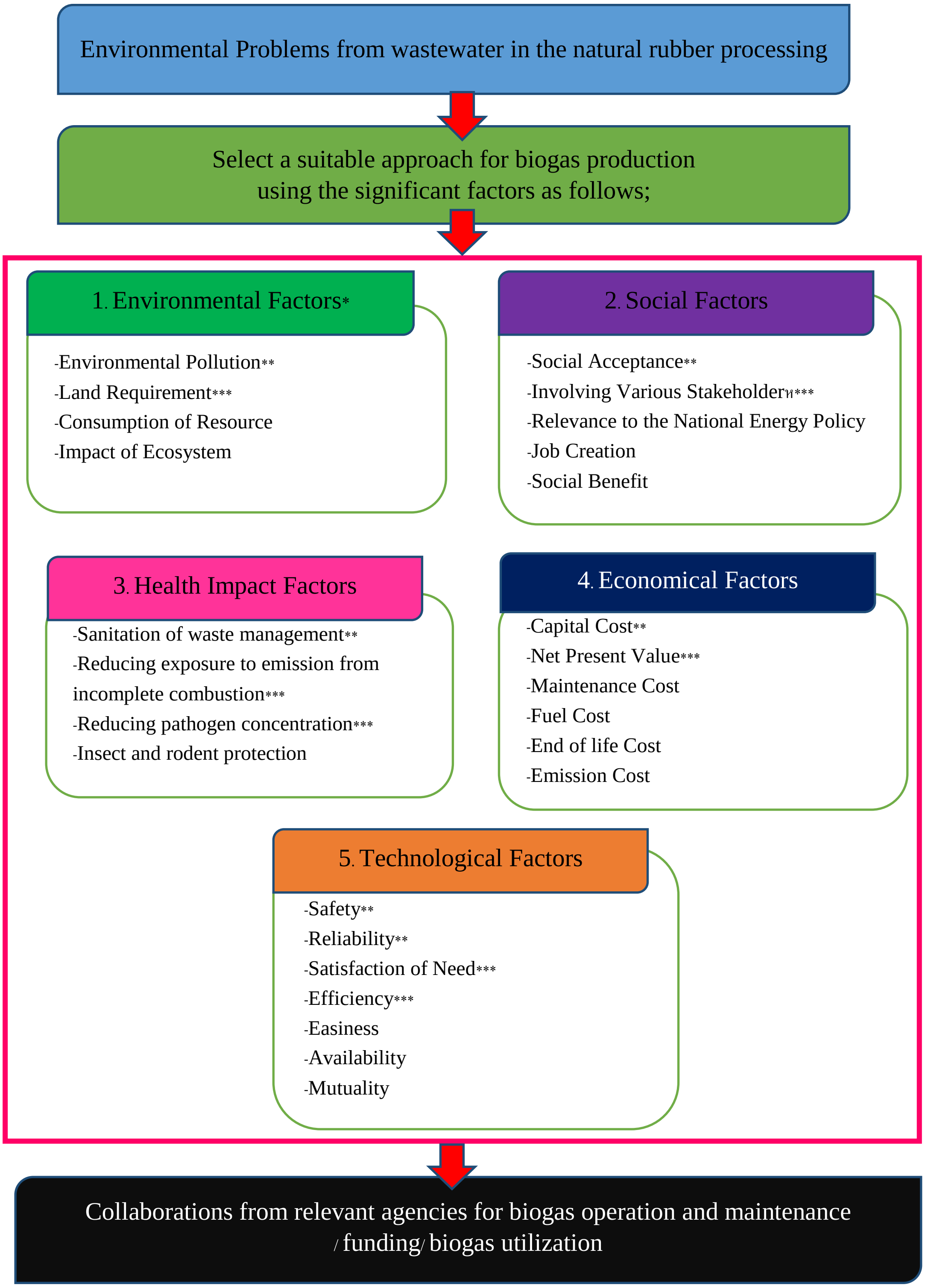

Fig. 6 Management model for biogas production from wastewater of natural rubber processing at the community level.
Note: * the main factors that had the highest weight score from AHP calculation
, * are the first and second orders between the criteria for each factor using AHP method

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