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REQUIREMENTS ANALYSIS OF GEOTHERMAL ENERGY-BASED COLD STORAGE: CASE STUDY IN INDONESIA

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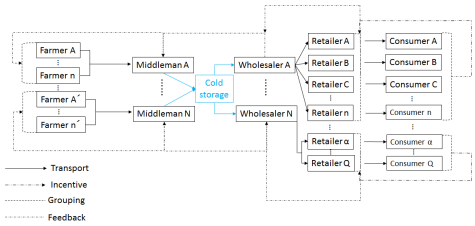
Graphical abstract



Abstract

This article presents the results from a viability analysis of geothermal energy-based cold storage for food supply chains in Indonesia. In this study, it was assumed that middlemen used cold storage as part of the supply chain. Gatekeepers were chosen based on three criteria: place, people, and prospect; and the gatekeepers, thus chosen from different societal groups, were then interviewed to validate outsiders' assumptions. Finally, results were categorized into four interest classifications: technical, economic, environmental, and social.

Keywords: Geothermal energy-based cold storage; food supply chain

1.0 INTRODUCTION

Renewable energy is regarded as an important factor for development due to the growing environmental concerns associated with global warming [1]. In particular, geothermal energy has been regarded as an emerging energy resource. This is due to the low life cycle carbon dioxide (CO_2) emissions of geothermal energy (13 grams per kilowatt-hour (g/kWh)), which is lower than wind power and solar power. Conversely, the capacity factor of geothermal energy is 45%-90%, which is higher than both wind and solar power [2-3]. because of these reasons, the geothermal energy production in Indonesia has reached 11,765 megawatts (MW) and it is being utilized by a range of institutions.

While global geothermal energy distribution is heterogeneous, Indonesia is considered a promising location for promoting this energy source as approximately 40% of total available geothermal energy contained within the earth's crust is released in the Indonesian archipelago and neighboring areas [4]. In recent years, Indonesia has achieved average annual economic growth of around 6%, supported by healthy domestic demand [5]. For this reason, Indonesia experiences an uncharacteristically high number of power outages each year. In response, the country's government has formulated a large-scale power generation plan known as the "Crash" program. The second phase of this program places emphasis on developing renewable energy sources such as geothermal energy.

However, there are many problems associated with geothermal energy utilization elsewhere in the world which promoters have failed to communicate to Indonesian residents [6]. It is important for geothermal energy promoters to consider these problems as a basis for developing more effective geothermal energy utilization. In Indonesia, research has already been undertaken with regards to geothermal energy. As per the results of these surveys, researchers showed that geothermal energy can be utilized for operating cold storage to reduce food waste in the

supply chain [7]. Furthermore, a previous Indonesian study demonstrated a consumer preference for tomato and chili as an incentive for installing cold storage [8]. However, the preferences of other societal groups, such as farmers, were not discussed. Therefore, this study discusses the following research questions (RQ).

RQ1: What kinds of food supply chain can be expected in this study?

RQ2: How can the requirements of geothermal energy-based cold storage (GEBCS) be analyzed as an element of the food supply chain?

RQ3: What are the requirements for installing GEBCS in Indonesia?

2.0 FOOD SUPPLY CHAIN MODEL

GEBCS should be considered in the context of the food supply chain, as it has the potential to be instrumental in reducing food wastage. With regards to the Indonesian food supply chain, there are five main societal groups: farmer, middleman, wholesaler, retailer, and consumer [9-10].

Farmers produce food products, with middlemen gathering these products to sell on to wholesalers or retailers. In Indonesia, farmers form groups for the purpose of managing their work efficiently [9]. Sometimes, middlemen also join groups with farmers. Middlemen then distribute products to wholesalers, exporters, and retailers [10]. Any of these groups may reject these products if they do not meet certain quality criteria. There are three main rankings for quality: A rank, B rank, and C rank. If middlemen consider a food product to be of low quality, they tend to distribute it to traditional markets at low prices.

It is better to install cold storage for high quality products rather than low quality products, as keeping the quality of products high ensures high product value and people have a willingness to pay (WTP) for high quality products [8]. Therefore, due to their reliance on cold storage, exporters and/or wholesalers will be examined in this study.

In Indonesia, cold storage has historically been underutilized and food demand will increase as a result of population growth [9-11]. Therefore, as a first step, domestic wholesalers are examined. Wholesalers distribute products to retailers, who reject products which do not meet certain quality criteria. Lastly, consumers purchase and use food products (Figure 1).

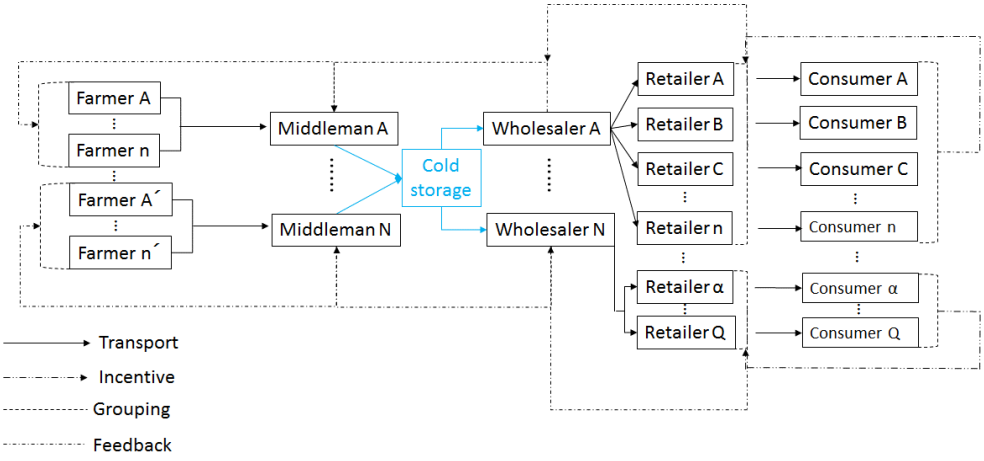


Figure 1 An Indonesian food supply chain model

3.0 RESEARCH METHODOLOGY

3.1 Data Collection

In order to understand requirements regarding the food supply chain with cold storage, data collection should first be undertaken. In general, there are two methods of data collection: quantitative methods and qualitative methods [12]. With regards to quantitative methods, results must be presented based on quantitative data such as statistics. However, in the case of the food supply chain, presenting only quantitative results is of limited value. This is because each societal group has different requirements relating to the food supply chain due to different locations; these can be classified as geographical problems. Therefore, qualitative methods should also be employed in this study.

Next, in order to gather data from societal groups, the research methodology should be clearly defined. Methodologies include interview, observation, and focus group discussion [13]. In this study, interview is chosen as the primary research methodology in this study.

Conducting interviews in all the societal regions of Indonesia is beyond the scope of this study, therefore representative target regions have been chosen. Table 1 shows the chosen societal groups and interview locations for the study. These have been chosen based on previous studies [14]. In this study, consumers have not been interviewed as this has been documented in a previous study [8].

Table 1 Target interview locations for societal groups

Societal group	Place
Farmer	Pangalengan
Middleman	Pangalengan
Wholesaler	Bandung
Retailer	Bandung, Jakarta

3.2 Research Steps

3.2.1 Determining Gatekeeper and Interview Methodology

Knowledge distribution within societal groups is unequal, therefore it is important to interview those people who have sufficient access to knowledge regarding a certain societal group; these people are herein referred to as "gatekeepers" [13]. To choose a gatekeeper, criteria should be defined. According to a previous study, three factors should be regarded as gatekeeper criteria; place, people, and prospect [15].

"Place" is defined by strong ties with living and/or working locations. People who have a strong connection to a "place" tend to provide extensive information regarding local rules and/or histories of that place, which are typically unknown to non-locals.

"People" refers to the interaction of people in their local area. To quantify this criterion, questions regarding for the roles of other people in local development should be asked. If they answer the questions regarding local development in detail, including providing problem scenarios and corresponding solutions, this means they fulfill the gatekeeper criterion of "people". Through "people" and "place", non-local researchers can demonstrate whether gatekeeper candidates are knowledgeable regarding current affairs in their locality. Furthermore, to gauge local interest in future development, "prospect" should be explored. If interviewees show an interest in future development in the area, gatekeeper candidates can be considered to have "prospect".

Following these questions, a process of categorization should be undertaken. People who have "people and place" or "people, place, and prospect" are treated as gatekeepers [15].

After gatekeepers of each societal group have been chosen, their opinions regarding the subject matter must be revealed. This is primarily achieved by asking the following question:

"We want to install geothermal energy-based cold storage as part of the food supply chain. What are your thoughts on this?"

To gather accurate information, interviewers cannot push their opinions. This means that open-ended questions should be used throughout the interview process [16]. If societal group members ask questions which the interviewers do not know the answer to, interviewers must take the question under consideration and seek to avoid potentially inaccurate answers. In such an instance, interviewers should involve a third party to provide local people with correct information. After information is gathered from societal group members, it should be processed. To do this, a question and answer map is a useful tool [16].

3.2.2 Interest Categorization

Following completion of interviews for each societal group, interests should be categorized for the purpose of assisting mutual understanding. In general, interests can be categorized into four areas: technical, economic, environmental, and social. Additionally, each area has both theoretical variables and operational variables [16]. Theoretical variables are defined as the detailed categorizations of each interest area. Operational variables are the interview findings, and can be assigned to each theoretical variable.

The "technical" category has three theoretical variables: functions, time and difficulty, and features. "Functions" are the necessary processes which have to be added to GEBCS for successful integration into the food supply chain. "Time and difficulty" relate to

limitations, which negatively influence existing conditions. Lastly, "features" denote existing and future requirements, which should be incorporated into GEBCS for the food supply chain.

In the case of "economic" interests, there are three theoretical variables: investment, operation, and income. "Investment" represents how much societal groups can invest in GEBCS, and any subsequent requirements for outside investment. For example, many previous geothermal projects have received outside investment from trading companies and government institutions [17]. Despite this, additional financial support for GEBCS should be considered later in the process due to the subjective nature of information obtained from societal groups. "Operation" represents operational and maintenance costs associated with GEBCS for food supply chain. Lastly, "income" represents the projected future income generated by using GEBCS in the food supply chain.

Next, there are three theoretical variables relating to the "environmental" interest category: emission, reusability, and degradability. "Emission" is defined as the environmental impact caused by GEBCS in the food supply chain. It includes criteria such as carbon dioxide equivalent (CO_2eq), water pollution, and land use change. "Reusability" is the potential reusability of GEBCS in the food supply chain. It should be noted here that in the food supply chain system without GEBCS, there are many materials which are not reused, such as for transportation. Lastly, degradability dictates that GEBCS for food supply chain must be installed by utilizing as many degradable materials as possible.

The "social" interest category is seen as an important aspect for promoting empowerment. It can be divided into three theoretical variables: knowledge, perception, and fear. "Knowledge" relates to some of the current techniques/activities/relationships between people or societal groups. "Perception" denotes expectations of local people for GEBCS.

4.0 RESULTS AND DISCUSSION

4.1 Gatekeepers

Based on the previous explanation regarding research methodology, gatekeepers were chosen. These results are presented in Table 2. The table shows via binary digits (0 or 1) that six farmers, three middlemen, two wholesalers, and one retailer were chosen as interviewees. As a result of the interviews, four farmers, one middleman, two wholesalers, and one retailer were chosen as gatekeepers.

Concerning the number of gatekeepers, it is of course better to interview as many gatekeepers as possible as this will provide a more representative analysis of the different social groups. However, it is often difficult for the outsiders to find sufficient numbers of local people who agree to conduct an interview. Furthermore, gatekeepers can influence local people. Therefore, it is considered acceptable that there is only one gatekeeper per societal group. Concerning Gatekeeper D of Table 2, this person can play a role in both the farmer and middleman societal groups.

Table 2 Gatekeeper determination matrix

Societal group	Gatekeeper No.	Place	People	Prospect
Farmer	**A**	**1**	**1**	**1**
	B	**1**	**1**	**1**
	C	**1**	**1**	**0**
	D	**1**	**1**	**0**
	E	0	1	1
	F	1	0	1
Middleman	**D**	**1**	**1**	**0**
	G	0	0	1
	H	1	0	0
Wholesaler	**I**	**1**	**1**	**0**
	J	**1**	**1**	**0**
Retailer	**K**	**1**	**1**	**1**

4.2 Interest Categorization

Table 3 provides a summary of gatekeeper interviews conducted as part of this study, categorizing the stated requirements of each gatekeeper with regards to GEBCS.

Concerning "general" interests, there are four operational variables. All of these variables were expressed as requirements for GEBCS by the farmer (F) and middleman (M) societal groups. "Capacity of cold storage" represents the volume of products in cold storage, which can be stored at any one time. "Type of operation source" denotes the types of fuel used for geothermal energy utilization, such as steam or electricity [3]. Different fuel source utilization for geothermal energy results in variations in performance and efficiency. "Available area" represents the concern that space requirements for installing cold storage can be an impediment for its utilization. Lastly, "target products" represents the products which were chosen for this study. In this case, tomato and chili were chosen as target products. There are, however, a range of other food products which could be studied with regards to GEBCS.

Next, with regards to technical interests, there are seven operational variables, belonging to 3 distinct theoretical sub-categories; "function", "time and difficulties" and "feature". Within the "function" sub-category, farmers and middlemen indicated interest in "storage temperature" and "humidity". This is due to the pivotal role these variables play in influencing food quality [18]. As per the "time and difficulties" sub-category, farmers and middlemen raised concern around "storage term" and "durability of

cold storage", both of which are affected by the type of cold storage utilized. Finally, concerning "features", there are three requirements for societal groups. The first, "countermeasure toward quality loss", should be considered as part of GEBCS implementation. This consideration includes both storing products and food loss in the food supply chain. "Product weight" and "product color" were regarded as operational variables.

With respect to the "economic" category, there are eight operational variables. Within the "investment" theoretical sub-category, "budget for cold storage", "financial support from outsiders", and "employment" were considered. "Budget for cold storage" signifies the amount that farmers and middlemen have to pay for cold storage. "Financial support from outsiders" is defined as outside financial support from non-local entities to farmers and middlemen for cold storage utilization. "Employment" refers to the potential employment salary that can be created/influenced by GEBCS as part of the food supply chain. Next, regarding "operation" as a theoretical variable, "maintenance" and "operation cost" should be considered. "Maintenance" represents the cost of cold storage maintenance. "Operation cost" is defined as the increase in operational costs resulting from implementation of GEBCS for food supply chain. Regarding "income", farmer, middleman, and wholesaler profits are considered as variables. This includes both direct and indirect profits. Lastly, "product price" was stated as an important consideration from all societal groups.

Regarding "environmental" interests, there are eight operational variables. Within the "emission" theoretical sub-category, "total environmental effect" was indicated as an important consideration by all societal groups. Emissions can be quantified as CO_2eq for common understanding. "Soil", "forest", and "water pollution" are considerations stated by both farmers and middlemen. These three variables count toward the "total environmental effect" based on either their preservation or destruction. Lastly, it is preferable to use "degradable material" from available local materials.

Finally, concerning the "social" theoretical sub-category, there are seven operational variables. "Available knowledge" and "information sharing" were highlighted by farmers and middlemen. "Available knowledge" refers to a person who has sufficient knowledge for implementing and maintaining cold storage and managing GEBCS for food supply chain. "Information sharing" represents the delivery of accurate information. Within the "perception" theoretical sub-category, "maintenance engineer" and "education program" were stated as required considerations for GEBCS by farmers and middlemen.

Table 3 Requirements categorization

Interest	Theoretical	Societal group	Operational
	General	F/M	Capacity of cold storage
			Type of operation source
			Available area
			Target products
Technical	Function	F/M/W	Storage temperature
			Humidity
	Time and difficulties	F/M/W	Storage term
			Durability of cold storage
	Feature	F/M/W	Countermeasure toward quality loss
			Product weight
			Product color
Economic	Investment	F/M/W	Budget for cold storage
			Financial support from outsiders
			Employment
	Operation	F/M/W	Maintenance
			Operation cost
	Income	F/M	Profit for farmer and middleman
		W	Profit for wholesaler
		F/M/W/R	Product price

Interest	Theoretical	Societal group	Operational
Environmental	Emission	F/M	Soil
		F/M/W/R	Total environmental effect
		F/M	Forest
			Water pollution
	Reusability	F/M	Duration of cold storage
			Duration of system
			Available material
	Degradability	F/M	Degradable material
Social	Knowledge	F/M	Available knowledge
			Information sharing
	Perception	F/M	Maintenance engineer
			Education program
	Fear	F/M	Vibration
		M/W	Delivery frequency
		M	Payment for products

5.0 CONCLUSION

This study presented the requirements associated with implementation of geothermal energy-based cold storage for the food supply chain in Indonesia, with the goal of minimizing food loss and adverse environmental impacts. In this study, it was assumed that middlemen used cold storage. Gatekeepers were then chosen based on three criteria: place, people, and prospect. After gatekeepers of each societal group were chosen, they were interviewed to validate outsiders' assumptions. Interview results were then categorized into four interest areas: technical, economic, environmental, and social. The results of this study should be incorporated into future design of GEBCS for the food supply chain in Indonesia.

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