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Comparison of Environment Impact between Conventional and Cold Chain Management System in Paprika Distribution Process

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ABSTRACT

Pasir Langu village in Cisarua, West Java, is the largest central production area of paprika in Indonesia. On average, for every 200 kilograms of paprika produced, there is rejection amounting to 3 kilograms. This resulted in money loss for wholesalers and wastes. In one year, this amount can be approximately 11.7 million Indonesian rupiahs. Recently, paprika wholesalers in Pasir Langu village recently are developing cold chain management system to maintain quality of paprika so that number of rejection can be reduced. The objective of this study is to compare environmental impacts between conventional and cold chain management system in paprika distribution process using Life Cycle Assessment (LCA) methodology and propose Photovoltaic (PV) system in paprika distribution process. The result implies that the cold chain system produces more CO_2 emission compared to conventional system. However, due to the promotion of PV system, the emission would be reduced. For future research, it is necessary to reduce CO_2 emission from transportation process since this process is biggest contributor of CO_2 emission at whole distribution process.

Keywords: LCA, environmentally friendly distribution, paprika,cold chain, PV system

1. Introduction

The demand pull created by an agro-industrial enterprise stimulates businesses well beyond the closest links with its direct input suppliers and product buyers; a whole range of ancillary services and supporting activities in the secondary and tertiary sectors of the economy are also positively impacted. Because of the generally perishable and bulky characteristics of agricultural products, many agro-industrial plants and smaller-scale agro-processing enterprises tend to be located close to their major sources of raw materials (FAO and UNIDO, 2009). In addition, the boycott due to poor quality of agriculture products such as rotten and overripe one, etc commonly occurs and becomes a major problem in distribution process of agriculture products.

This condition also happens for paprika. In Indonesia, paprika is categorized as valuable vegetable. Pasir Langu village in West Java province is the largest central production of paprika in Indonesia. The boycott of paprika is occurring in a retailer side because of rotten one. In average, for every 200 kg paprika the rejection number is 3 kg and it is likely to be equal to IDR 45,000. That is, the paprika wholesalers would lose their money of

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approximately IDR 11,700,000. The aspects due to paprika not only caused the financial loss for both farmers and wholesalers but also produce the waste.

Therefore, the paprika wholesalers in Pasir Langu village develop the cold chain management system to maintain paprika quality recently. Cold chain is a logistic system that provides a series of facilities for maintaining ideal storage conditions for perishables from point of origin to the point of consumption in the food supply chain (Global Agrisystem, 2005).

The cold chain refers to the transportation system which is managed by the temperature sensitively. That is, we consider the supply chain due to cold energy and refrigerated packaging and the logistics to secure the integrity of the product shipment (Rodrigue et al., 2009). A cooling process of fresh fruit and vegetables before processing them removes heat around them, and that would inhibit decay and help maintain moisture content, sugars, vitamins, and starches, while the quick freezing of processed fresh fruit and vegetable maintain the quality, nutritional value, and physical properties for extended periods (Baldwin, C. J., 2009).

On the other hand, due to the promotion of cold chain management system, that is, the system, which requires electricity for pre-cooling and storage in cold circumstance and fossil fuel for refrigerated transportation, would generate more CO_2 emission compared to the conventional one. The impact of agriculture on the environment is an extremely important issue since the ecological influence for natural resources is already overstrained. In general, the agricultural impact on nature is well known and the agricultural environmental indicators have been developed for national monitoring systems. Thus, the efficient methods to comprehend the agricultural impacts on the environment indicators with sustainable factors are significantly required (Haas et al., 2000).

Therefore, the objectives of this study are to propose the cold chain management system and estimate CO_2 emission against the conventional one by using LCA methodology. In addition, in order to abate its impact, we propose the advanced system of paprika distribution process with PV system. The result from this study would be contributed to the development of cold chain management system so as to keep environmentally friendly condition and to maintain the paprika quality.

2. Method

2.1. LCA Methodology

LCA is a technique that aims at addressing the environmental aspects of a product and their potential environmental impacts throughout that product's life cycle. The term product refers to both goods and services. A product's life cycle includes all stages of a product system, from raw material acquisition or natural resource production to the disposal of the product at the end of its life, including extracting and processing of raw materials; manufacturing; distribution; use; re-use; maintenance; recycling; and final disposal (i.e., cradle-to-grave) (UNEP, 2009).

The most well-known application of LCA can compare the total environment impact of a product or service with an alternative (comparable) product or service. LCA is often considered as a tool that provides the answer to the question of which product has least environmental impact (Horne et al., 2009).

The tasks with suppliers and supply chain issues are rapidly increasing as an important strategic consideration. Traditionally, enterprises manage suppliers in order to optimize the supply chain, the flow of information, the materials and funds, and the logistics of supply and distribution, minimize cycle times and costs in order to integrate processes and functions for the supply chain. A life cycle management framework is for the improvement which is continuous and based on a full system or a life cycle perspective; thus, the supply chain management practices are an entry gate for a life cycle management (UNEP, 2004).

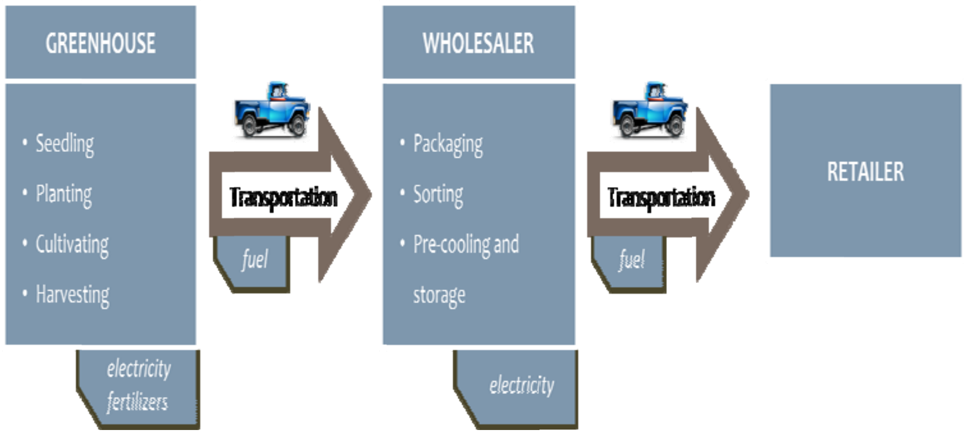

Fig. 1. System Boundary of Paprika Distribution Process in Pasir Langu Village

A LCA methodology was used to analyse distribution process of paprika in Pasir Langu village. The system boundary of paprika distribution process in Pasir Langu village is shown in Fig. 1. In the distribution process, there are four main processes such as cultivation, transportation from greenhouse to wholesaler, packaging, and transportation from wholesaler to retailer. Based on these conditions, the CO_2 emissions from our proposed systems were estimated and the environmental impact was argued.

2.2. Scenarios and Data Collection

In this study, there are three scenarios of calculating CO_2 emission both for conventional and cold chain management system. These scenarios are based on the differences of distance from greenhouse to wholesaler and from wholesaler to retailer. First scenario is calculating the farthest distance, second scenario is calculating the nearest distance and third scenario is calculating the average distance.

The data collection was conducted through an interview, a field observation, and a review of secondary data. The interviews in Pasir Langu village were conducted with key workers from paprika business such as farmers and wholesaler in order to clarify the factors on paprika distribution process in the life cycle stage. The field work regarding paprika distribution process in Pasir Langu village was implemented in April to September 2011. The observations include the site visits to paprika's greenhouse and wholesaler. Secondary data was collected by websites, books, national and international journal.

3. Result and Discussion

3.1. LCA Conventional System

A LCA methodology in this study was used to calculate the CO_2 emission from four main processes at paprika distribution system in Pasir Langu village (see Fig. 2). Eq. (1) was used to calculate CO_2 emission.

$$ECO_{2\,j} = \sum A_i \text{ x} \quad (1)$$

where, A_i energy input of i-th energy source (electricity, fertilizers, and fuel), FE_i is the i-th specific emission factor. The suffix of j is represented as the elements of cultivation, transportation from greenhouse to wholesaler, packaging, and transportation from wholesaler to retailer, respectively. There are three scenarios for estimating CO_2 emission based on the differences of distance both in transportation from greenhouse to wholesaler and transportation from wholesaler to retailer.

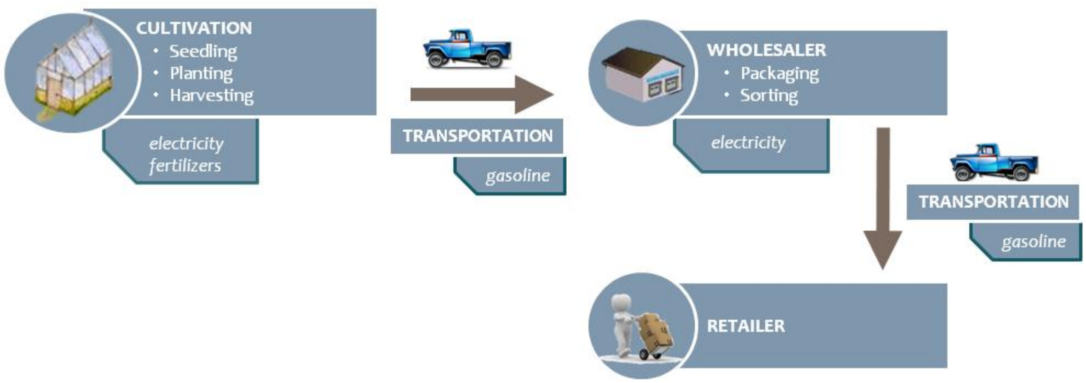

Fig. 2. Paprika Distribution Process: Conventional System.

(1) Cultivation

According to the farmers' interview, the greenhouse area was assumed to be 1000 m^2, in which 4,000 paprika plants can be plant. A cultivation period of paprika per one cycle would require 8 months or 32 weeks. Every paprika plant consists of 5 step harvesting processes and 3 pieces of paprika with average weight of 150 g would be yielded in each process. That is, the annual average yields for every 1000 m^2 greenhouse would be 9,000 kg.

A cultivation process consists of two main processes, seedling and planting. Both seedling and planting processes was done in the same greenhouse, so for electricity and fertilizers usage was calculated as one unit for both processes. In the paprika cultivation process, the following factors are necessary; charcoal husk as a media planting, poly bags which are made by plastics, water, seed, pesticides, fertilizers, and electricity which uses for some equipment of a pump and a lamp operation. From those inputs, the indirect CO_2 emissions of fertilizers and electricity should be considered and the rests are ignored.

The farmers in Pasir Langu village generally use "AB Mix fertilizers" which consists of N, P, and K in cultivation process and the annual consumption is 960 kg/yr. Also, they have to pay IDR 200,000 in average on electricity fee of 5 greenhouses to government electricity company (PLN). Using the data from the government electricity company, we estimated the average electricity consumption of 87.91 kWh/yr for each greenhouse. Here, note that the price per kWh is IDR 455 and the annual electricity consumption is 703.297 kWh in the total. Table 1 is shown factor emission for each variable. Based on those data, the CO_2 emissions of both consumption of electricity and fertilizers are 2.098 gCO_2 per paprika and 3.2 gCO_2 per paprika, respectively. Using Eq. (1), the total CO_2 emission from cultivation process is 5.298 gCO_2 per paprika.

Table 1. Factor Emission

No	Variable	Factor Emission
1	Electricity[1]	0.179 $kgCO_2$ / kWh
2	Fertilizers[2] (N,P,K)	0.2 $kgCO_2$ / kg fertilizer
3	Gasoline[3]	2.31 $kgCO_2$ / L
4	Diesel[3]	2.68 $kgCO_2$ / L

*sumber : ([1]Suhedi, F., 2005), ([2]Asdeputi KLH, 2009), ([3]Gratimah, R., 2009).

(1) Transportation from greenhouse to wholesaler

In average, a truck with 1 ton capacity goes to 10 greenhouses for collecting paprika every day. The load capacity is 50 kg due to the limitation of space. The farthest distance is 1.5 km, the nearest is 0.5 km, and the average from greenhouse to wholesaler is 0.95 km, and it is assumed that the frequency of truck is 4 operations of 0.5 km case, 3 ones of 1 km case and 3 ones of 1.5 km case every day. The fuel consumption of the truck is 15 km/L. Using Eq. (1), the CO_2 emissions of transportation from greenhouse to wholesaler for the farthest, the nearest, and the average distance are 0.693 gCO_2 per paprika, 0.231 gCO_2 per paprika, and 0.439 gCO_2 per paprika, respectively.

(2) Packaging

The packaging process is doing at wholesaler in Pasir Langu village. The packaging house, in average, has to pay IDR 150,000 per a month for electricity. Therefore, assuming that price per kWh is IDR 455, the average electricity consumption per a month for packing and sorting them is 329.67 kWh per a month, that is, 10.989 kWh per a day. In one day, the packaging house can receive around 500 kg paprika in order to be sorted and packed. Thus, using Eq. (1), the total CO_2 emission from packaging process is 0.590 gCO_2 per paprika.

(3) Transportation from wholesaler to retailer

The wholesaler distributes paprika for export and local market through retailer and directly to the traditional market. For the export market, there is the case that paprika from Pasir Langu village is export to Singapore. The paprika for local market is distributed through local distributors who distribute to restaurants and/or supermarkets. The wholesaler has to send paprika three times per a week for each market. The distance from Pasir Langu village to exporter is 60 km, and that of local distributor is 20.4 km and that to the traditional market has 29 km. Thus, the total distance from wholesaler to retailer is 36.467 km in average. The Wholesaler sends the products of 100 kg to 400 kg to exporter. Those of 200 kg to 500 kg for local distributor, and of 100 kg for traditional market are delivered. In the distributing paprika to retailer, a truck is required 15 km/L of gasoline. This 1 ton’s truck has an average load weight of 233.3 kg paprika for each trip. As we mentioned before, there are three scenarios to calculate CO_2 emission based on the distance from wholesaler to retailer. Using Eq. (1), the CO_2 emissions from transportation process from wholesaler to retailer for each scenario are 5.940 gCO_2 per paprika, 2.020 gCO_2 per paprika, and 3.610 gCO_2 per paprika, respectively. As a result, the total CO_2 emissions at paprika distribution process for each scenario are shown in Table 2.

Table 2. CO_2 Emission in gCO_2 per paprika at Paprika Distribution Process: Conventional System

Process	Farthest Distance	Nearest Distance	Average Distance
Cultivation (Seedling and Planting)	5.298	5.298	5.298
Transportation (from greenhouse to wholesaler)	0.693	0.231	0.439
Packaging	0.590	0.590	0.590
Transportation (from wholesaler to retailer)	5.940	2.020	3.610
TOTAL CO_2 Emission from whole system	12.521	8.139	9.937

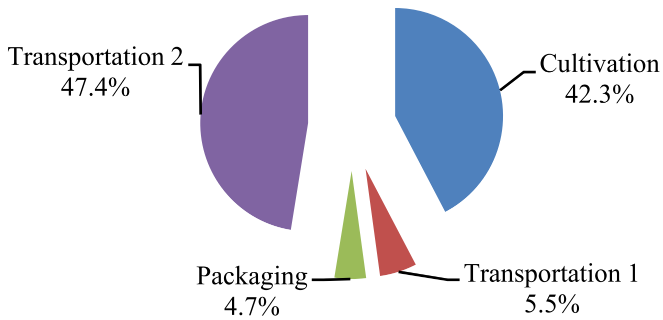

Fig. 3. Percentage CO_2 Emission of the farthest distance at Each Process: Conventional System.

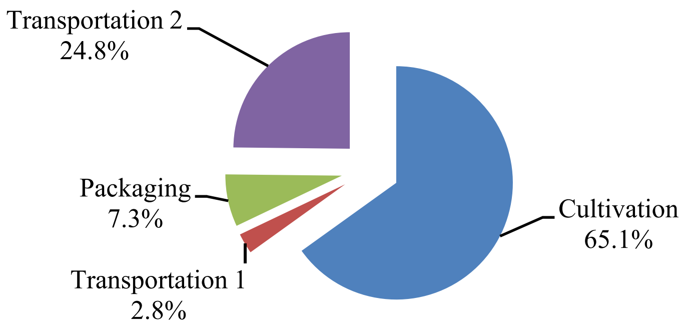

Fig. 4. Percentage CO_2 Emission of the nearest distance at Each Process: Conventional System

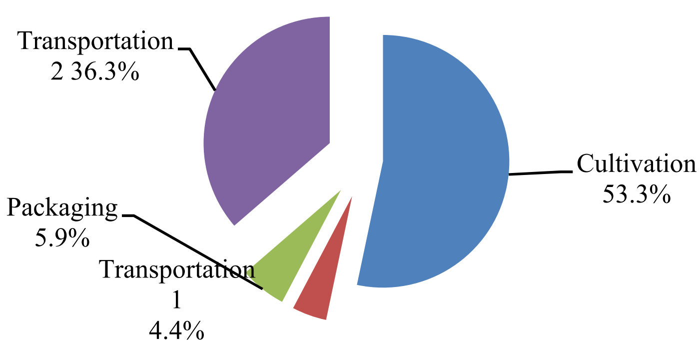

Fig. 5. Percentage CO_2 Emission of the average distance at Each Process: Conventional System.

The percentage of CO_2 emission from the farthest distance (see Fig. 3) shows that transportation from wholesaler to retailer is the highest CO_2 emission (47.4%), while that of CO_2 emission from the nearest distance and the average distance (see Figs. 4 and 5) shows that cultivation process is highest CO_2 emission (65.1% and 53.5%). The emissions of gasoline and fertilizers usage are attributed to the highest CO_2 emission.

3.2. LCA Cold Chain Management System

Next, the cold chain management system (see Fig. 6) is assumed to be implemented in Pasir Langu village in order to maintain the quality of paprika and reduce the boycott products. Since December 2011, the cold storage was built in Pasir Langu village. The cold storage is equipment in cold chain. The cold storage is a box made of insulated walls, ceiling and floor that fitted with an insulated door. It is kept at a pre-set temperature by refrigeration machinery. In this system, the refrigerated transportation will be used to carry paprika from wholesaler to retailer.

In the cold chain management system, pre-cooling and storage are required to be done in cold storage. This process is done at wholesaler after packaging process. The facility area of cold storage in Pasir Langu village is 24 m^3 and that is able to store 2,700 kg of paprika for 7 days. At that time, the electricity consumption to operate the cold storage is 54.601 kWh per a day, that is, 382.204 kWh per a year. Using Eq. (1), the CO_2 emission from pre-cooling and storage is 3.801 gCO_2 per paprika.

On the other hand, since the refrigerated transportation is also required to carry paprika from wholesaler to retailer in order to keep temperature condition of paprika, the quality of paprika can be maintained. Based on interview, the fuel consumption for refrigerated transportation is 4 km/L or 0.25 L/km, so total fuel consumption for one trip from wholesaler to retailer is 10.05 L. Using Eq. (1), the CO_2 emission of the farthest, the nearest, and the average distance are 25.843 gCO_2 per paprika, 8.787 gCO_2 per paprika, and 15.707 gCO_2 per paprika, respectively.

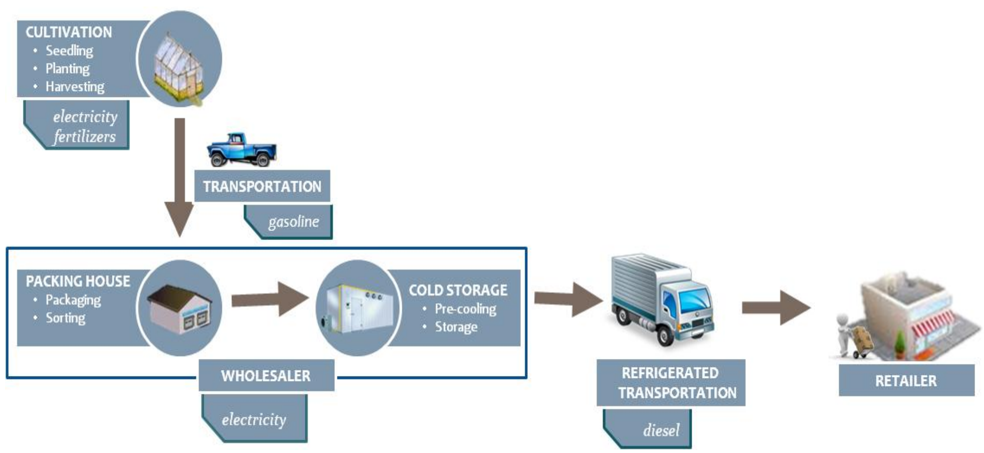

Fig. 6. Paprika Distribution Process: Cold Chain Management System.

Table 3. CO_2 Emission in gCO_2 per paprika at Paprika Distribution Process: Cold Chain Management System

Process	Farthest Distance	Nearest Distance	Average Distance
Cultivation (Seedling and Planting)	5.298	5.298	5.298
Transportation 1 (from greenhouse to wholesaler)	0.693	0.231	0.439
Packaging	0.590	0.590	0.590
Pre-cooling and storage	3.801	3.801	3.801
Refrigerated transportation (from wholesaler to retailer)	25.843	8.787	15.707
TOTAL CO_2 Emission from whole system	36.225	18.707	25.835

Thus, the total CO_2 emissions at paprika distribution process for cold chain management system for each scenario are shown in Table 3. The percentage of CO_2 emission from three scenarios (see Figs. 7, 8, and 9) shows that of transportation from wholesaler to retailer would be the highest CO_2 emission in the total process due to the high amount fuel of refrigerated transportation.

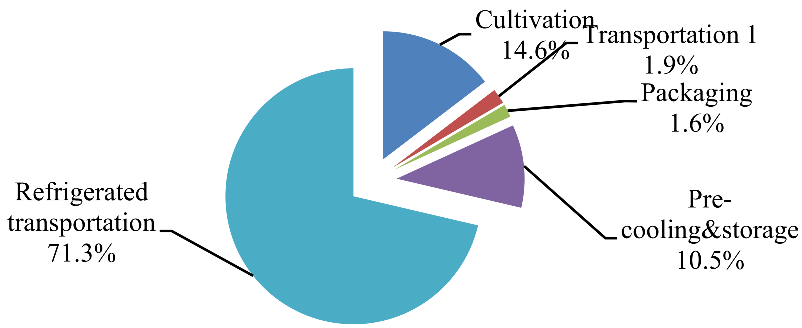

Fig. 7. Percentage CO_2 Emission of the farthest distance at Each Process: Cold Chain Management System.

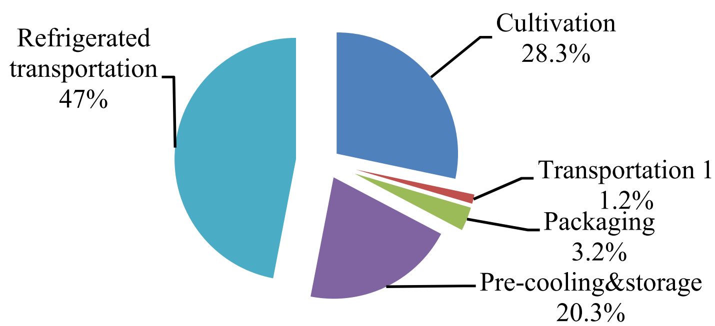

Fig. 8. Percentage CO_2 Emission of the nearest distance at Each Process: Cold Chain Management System
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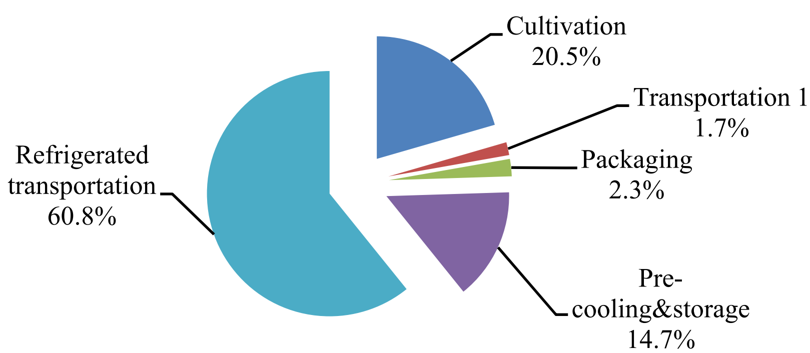

Fig. 9. Percentage CO_2 Emission of the average distance at Each Process: Cold Chain Management System.

3.3. PV System for Paprika Distribution Process

Next, it is an extremely important purpose to reduce CO_2 emission for the whole system. Here, the specific CO_2 emission of electricity in our target area (Indonesia) is very large due to much of fossil fuel consumption. However, there would be plenty of solar resource in Indonesia. Recently, the PV (photovoltaic) system would be generalized as one of countermeasure of CO_2 emission reduction. Also, this is one of promising system in the renewable energy ones. In the near future, the number of environmentally friendly system will be increased in any countries.

The PV system can convert directly sunlight dissociation energy to electric energy. The electric energy yielded by PV would be little influenced by the sunlight intensity, so that PV can produce electric energy which is equivalent to the received sunlight (Bien et al., 2008). The daily solar radiation data from NASA Surface Meteorology and/or Solar Energy website was used in this study. The average daily solar radiation in Pasir Langu village, Cisaura is 4.81 kWh/m^2/day.

The objective in this scenario is to promote PV system installation in greenhouse, packaging house, and cold storage in order to mitigate CO_2 emission by decreasing electricity usage. This PV hybrid system with electrical grid of PLN without battery equipment is assumed to yield continuously so as to meet the supply of electric energy (Strong et al., 1993). Here, the PV system would supply the electricity of 30% and the rest electricity of 70% would be compensated by PLN. Eq. (2) was used to calculate the electricity demand (E_B) which would be supplied by PV system (E_A). Eq. (3) was used to calculate the total energy system (E_T). Due to Eq. (4), the capacity of PV system (CPV) whose factor adjustment is 1.1 was estimated, and the total number of PV module which should be installed to be supplied for energy demand in each process was estimated due to Eq. (5) (Bien et al., 2008). In this study, the capacity of PV module has 100 Wp at 24 V. Table 7 shows the performance results of PV module in the sub-process of cultivation, packaging, pre-cooling and storage, respectively.

$$E_A = 30\% \times E_B \tag{2}$$

$$E_T = E_A + (15\% \times E_A) \tag{3}$$

$$CPV = \left(\frac{E_T}{\text{Solar Radiation}}\right) \times \text{factor adjustment} \tag{4}$$

$$\text{Total PV Module} = \frac{CPV}{100 \text{ watt peak}} \tag{5}$$

Table 4. Performance Results of PV System Calculation

Data	Cultivation	Packaging	Cold Storage
Energy Demand (E_B)	2,930 Wh/day	10,989 Wh/day	54,601 Wh/day
Energy from PV (E_A)	879 Wh	3,296 Wh	16,380 Wh
Total Energy (E_T)	1,010 Wh	3,791 Wh	18,837 Wh
Capacity of PV (CPV)	231W	867 W	4,307 W
Total PV module	3	9	44

The utilization of solar energy by PV system causes very little environmental problem and provides no greenhouse effect (Jivacate et al., 1994). The solar energy supply due to a clean energy source does not emit pollutant substances including CO_2 gas during its operation. On the other hand, in LCA, the environmental load (ex. indirect factors of manufacturing and materials and so on) from another viewpoint might have to be considered (Battisti, R., & Corrade, A., 2003). However, we referred to the operation only, that is, assuming that PV system produces electricity, we treated the specific CO_2 emission of PV system as zero emission. As a result (see Table 5), the promotion of PV system in greenhouse, packaging house, and cold storage, will be able to reduce 1.947 gCO_2 per paprika from whole distribution process, that is, the percentage of 11.9 % from cultivation , 30% from packaging, and 30% from cold storage, respectively.

Table 5. CO_2 Emission in gCO_2 per paprika at Paprika Distribution Process: PV system

Process	Farthest Distance	Nearest Distance	Average Distance
Cultivation (Seedling and Planting)	4.669	4.669	4.669
Transportation 1 (from greenhouse to wholesaler)	0.693	0.231	0.439
Packaging	0.413	0.413	0.413
Pre-cooling and storage	2.661	2.661	2.661
Refrigerated transportation (from wholesaler to retailer)	25.843	8.787	15.707
TOTAL CO_2 Emission from whole system	34.278	16.760	23.888

4. Conclusions and Future Research

This paper has shown the calculation of CO_2 emission on paprika cold chain model using LCA methodology. Based on the result above, the CO_2 emissions from cold chain management system are approximately 2-3 times higher than a conventional system. In general, that would emit higher CO_2 gas; however, the advanced system with PV system would contribute environment aspect. Simultaneously, we would be able to secure the quality of paprika quality.

Therefore, it is important to make optimization model in cold chain management system to mitigate CO_2 emission. Proposing PV system for greenhouse, packaging house, and cold storage reduce CO_2 emission and/or probably maintain paprika quality.

As other system candidates for paprika cultivation system, Blue-Tower (BT) system also can be used in order to reduce the CO_2 emission. This is due to the biomass resources. In the previous research (Fukumoto et al., 2011). it was shown that in Japan, paprika was cultivated in greenhouse which requires electricity, thermal energy and CO_2 gas as growth agents. The CO_2 emissions from paprika conventional cultivation system of 2 ha to 4 ha were 582.4 to 573.9 gCO_2 per paprika, respectively. Inversely, due to promotion of BT-CGS (Blue-Tower-cogeneration) or BT-CGS (SOFC-HP) case in the paprika cultivation facility, it enables to mitigate CO_2 emission as shown in Tables 6 and 7.

Table 6. CO_2 Emission and Reduction (BT-GE)

Case name (Cultivation scale, BT-plant scale)	CO_2 Emission per a paprika (gCO_2 per paprika)	Rate of CO_2 Reduction (%)
GE-Case1 (2ha 15t)	104.6	82.0%
GE-Case1 (2ha 30t)	68.6	88.2%
GE-Case1 (2ha 60t)	98.9	83.0%
GE-Case1 (4ha 15t)	257.8	55.1%
GE-Case1 (4ha 30t)	93.2	83.8%
GE-Case1 (4ha 60t)	67.4	88.3%

Table 7. CO_2 Emission and Reduction (BT-SOFC-HP)

Case name (Cultivation scale, BT-plant scale)	CO_2 Emission per a paprika (gCO_2 per paprika)	Rate of CO_2 Reduction (%)
SOFC-Case1 (2ha 15t)	60.6	89.6%
SOFC-Case1 (2ha 30t)	68.5	88.2%
SOFC-Case1 (2ha 60t)	98.9	83.0%
SOFC-Case1 (4ha 15t)	92.1	84.0%
SOFC-Case1 (4ha 30t)	58.4	89.9%
SOFC-Case1 (4ha 60t)	66.9	88.4%

For future research, it is necessary to reduce CO_2 emission from transportation process since transportation is the biggest contributor of CO_2 emission in cold chain management system. The CO_2 emission reduction from transportation process can be done by switching solar system for refrigerated transportation. Also, we need to consider the scale merit, that is, we have to refer to the relationship between the scale of renewable energy system and that of cultivation from the viewpoints of environmental impact and/or the cost.

References

A Bridge to Sustainable Products", United Nations Environment Programme, Paris.

Asisten Deputi Urusan Data dan Informasi Lingkungan. (2009). *Emisi Gas Rumah Kaca dalam Angka.* Kementrian Negara Lingkungan Hidup Republik Indonesia.

Baldwin, C. J. (2009). *Sustainability in the Food Industry*. Wiley-Blackwell and the Institute of Food Technology.

Bien et al. (2008). Perancangan Sistem Hibrid Pembangkit Listrik Tenaga Surya Dengan Jala-Jala Listrik PLN untuk Rumah Perkotaan. *Journal Teknik Elektro* 8 (1): 37-56.

Battisti, R., & Corrade, A. (2003). Evaluation of Technical Improvements of Photovoltaic Systems through Life Cycle Assessment Methodology. *Journal Energy* 30: 952-967.

FAO and UNIDO. (2009). Agro-Industries for Development. CABI North American Office, USA.

Fukumoto et al. (2011). A Business Feasibility Study on a Paprika with Carbon Footprint Label. *Proceedings of EcoDesign International Symposium*.

Global Agrisystem. (2005). *Cold Chain*. Project Profiles, MP Agros.

Gratimah, R. (2009). *Analisis Kebutuhan Hutan Kota sebagai Penyerap Gas CO_2 Antropogenik di Pusat Kota Medan.* Fakultas Matematika dan Ilmu Pengetahuan Alam, Universitas Sumatera Utara Medan.

Haas et al. (2000). Life Cycle Assessment Framework in Agriculture on the Farm Level. *International Journal LCA* 5 (6): 345-348.

Horne et al. (2009). Life Cycle Assessment: Principles, Practice and Prospects. CSIRO, Australia.

Jivacate et al. (1994). PV Development in Thailand. *Solar Energy Materials and Solar Cells* 34: 57-66.

Rodrigue et al. (2009). *The Geography of Transport Systems, 2nd ed.* New York, Routledge.

Suhedi, F. (2005). *Emisi CO_2 dari Konsumsi Energi Domestik.* Pusat Litbang Permukiman.

Strong et al. (1993). *The Solar Electric House. Chelsea Green.* ISBN 0-963783-2-1.

UNEP. (2004). *Background Report for a UNEP Guide to Life Cycle Management: A Bridge to Sustainable Products.* United Nations Environment Programme, Paris

UNEP. (2009). *Guidelines for Social Life Cycle Assessment of Products.* United Nations Environment Programme, Paris.