Preliminary Design of Eco-City by Using Industrial Symbiosis and Waste Co-Processing Based on MFA, LCA, and MFCA of Cement Industry in Indonesia

Nova Ulhasanah and Naohiro Goto

***Abstract*—Cement Company in a city in Indonesia is taken as a case study in this study which its production process system was evaluated by material flow analysis, life cycle assessment, and material flow cost accounting. The cement company is the biggest company in the city which makes the company has substantial influence of the city's economy, society and environment. This study was aimed to propose the new system design of cement production as a preliminary design of eco-city by industrial symbiosis that involves many elements inside and outside the city in order to establish the cement production sustainability in Indonesia. The scope of this study is all activities inside the company, from raw material extraction until the product packaging process. Several problems are detected faced by the cement company such as limitation of limestone reserve, CO_2 emission, high energy consumption, cement kiln dust, dust emission, several diseases, and others related to cost, social, and environmental aspects. If the company keeps this system on, it will harm the environment, human health, even affects the company's income. Therefore, the new system proposal which is selected from several scenarios is needed to embody the sustainable development.**

***Index Terms*—Material flow analysis, life cycle assessment, material flow cost accounting, cement kiln dust.**

I. Introduction

Since the industrial revolution, waves of innovation have shaped how people work and live. People's needs for food, transportation, communication, housing, health and entertainment are met largely by manufacturing, and about a fifth of global income is generated directly by the manufacturing industry, and nearly half of household consumption relies on good from industrial processes. During the 19^{th} and 20^{th} centuries, developed countries relied on manufacturing to reduce poverty and improve the quality of life of their growing populations. Today, developing countries are counting on industrial to do the same for them [1]. The role of industrial sector showed a higher contribution in developing country like Indonesia. This is proved from the very significant achievement of economic growth by an average of 7% per year during 1970s to the 1990s which is caused by rapid movement of the industrial sector in Indonesia [2].

One of the strategic industries in Indonesia is cement industry. The improvement in the country's economic condition in 2010 has boosted the development of the Indonesian cement industries. Work in a number of infrastructure and property projects shelved earlier has been resumed. Many people build and renovate houses with the improvement in the people's welfare. Therefore the capacity expansion by cement industry is planned to keep pace with growing demand that follows the country's economic growth [3].

However, at the same time cement industry is facing growing challenges in conserving materials and energy resources, as well as reducing its CO_2 emissions [4]. The cement industry is one of the industrial sectors which consume the greatest amount of energy in the world and it has occupied a significant place among the other sectors in the last decade [5] which is consumes approximately 12-15% of the total industrial energy used [6] . According to the researchers, the world cement production has been increasing 50% during this period. If this cement production rises at about the same ratio, the energy consumption and costs will increase relatively in this sector [5].

Increased public awareness of the threads posed by global warming has led to greater concern over the impact of anthropogenic carbon emissions on the global climate. The current level of carbon dioxide (CO_2) in the atmospher is approaching 380 ppm [7], [8]. If there is no drastic market, technological, and society changes, CO_2 concentrations are projected to increase to over 800 ppm by the end of the century [7]. Amounting to around 7% of worldwide CO_2 emissions is sourced from cement industry (one of the most significant source of anthropogenic emissions of CO_2) [9]. Furthermore, the involving of massive raw material quarrying, other gases emission (NO_x, SO_2, etc), dust emissions, and other problem in cement industry have a considerable impact for the environment [10].

Due to the contradiction impacts of existence of cement industry, this study was aimed to propose the design of a new system of cement production as a preliminary design of eco-city that involves many elements inside and outside the city in order to establish the cement production sustainability in Indonesia.

II. Methodology

This study is a case study of Cement Company in a city in Indonesia by using material flow analysis (MFA), life cycle analysis (LCA), material flow cost accounting (MFCA), waste co-processing, and industrial symbiosis (IS). The cement company is the biggest company in the city which makes the company has substantial influence of the city's economy, society and environment.

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The authors are with Toyohashi University of Technology, Japan (e-mail: novaulhasanah@gmail.com)

MFA is a systematic assessment of the flows and stocks of materials within a system defined in space and time which connects the sources, the pathway, and the intermediate and final sinks of a material [11]. The data and results of MFA can be used in LCA and MFCA. LCA is a tool to assess the environmental consequences of a product from cradle to grave and may be performed on both products and processes. For globally significant products such as cement, environmental LCA is a valuable tool for improving our understanding of the environmental hazards posed by a product's life stage which also allows cement producers to optimize the manufacturing process by reducing adverse environmental impacts [12]. And according to Curran (1996) [13], LCA is a tool to assess the environmental consequences of a product from cradle to grave which can produce results at the level of the interventions (emissions, extraction of natural resources), at the level of impact categories (global warming, toxicity), at the level of damage to endpoints (human health, material welfare), or at the level of one single indicator. Afterwards, MFCA is a technique for measuring the cost of a production process in both physical and monetary units [14] [15] and for estimating room for cost reduction in each process. It is a technique for visualizing process costs including material, energy, system, and waste costs as a positive product cost and negative product cost (loss cost) on the basis of process yield [16].

Eventually, waste co-processing and IS will be solution for those three analysis's results (MFA, LCA, MFCA) and combined to build preliminary design of eco-city in Indonesia. The eco-town concept is originally focused on the individual system related to the 3R (Reduce, Reuse and Recycling), but now have expanded to include Eco industrial parks and industrial symbiosis to focus on collective areas and become part of the eco-city concept, to focus on overall urban planning and urban ecosystem, civil society and greening of cities [17].

Various measures have been suggested to reduce industry GHG emissions, ranging from energy efficiency to fuel switching to CO_2 sequestration. However among them, the utilization of waste as alternative fuels and raw materials (waste co-processing) is one of the best solutions as it is an innovative method to both reduce total CO_2 emissions and alleviate waste management pressure [18]. The cement Industry, for example, has a long history of utilizing various wastes as fuels and raw materials [19]. Moreover, IS offer an analytical framework for understanding how groups of firms corporate in the pursuit of competitive advantage to understand environmental, social and economic benefits and costs [20].

The scope of this study is all activities inside the company, from raw material extraction until the product packaging process which is shown in system and cement production process type of the company in Fig. 1 [21]. The main data in this study were obtained from the cement company itself by visiting the company for ± 1 month and enhanced with other data from various sources, afterwards calculated and analyzed by using MFA, LCA, MFCA. After all, the new systems were created based on the result by implicating many elements inside and outside the city including evaluation of the new system to get the best design in order to propose the preliminary design of eco-city in Indonesia.

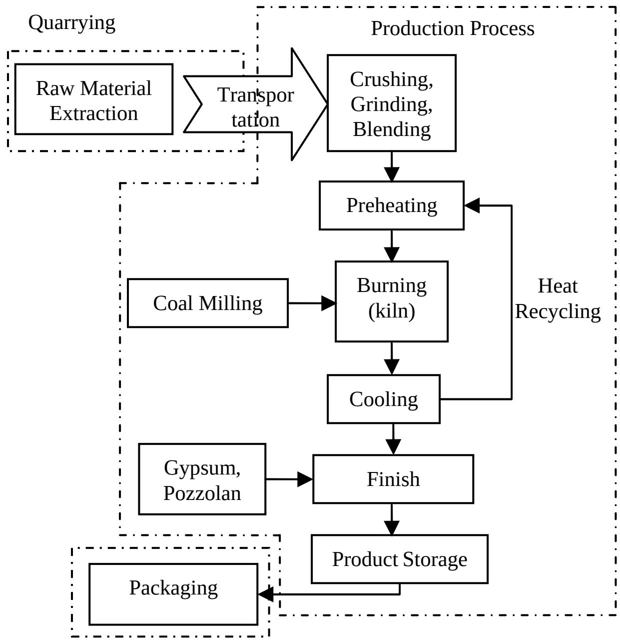

Fig. 1. Cement production process of the cement company

III. Result and Discussion

A. Material Flow Analysis

One of methods for environmental assessment is MFA [22] which has a main advantage to help identify waste of natural resources and other materials in the economy which would otherwise go unnoticed in the conventional economic monitoring system [23]. Hereafter, according to Daniels and Moore (2002) [24], MFA has emerged as the primary methodological framework across the different flow accounting approaches, offering the greatest scope for application, environmental accounting and for system analysis tools. It is a tool for the measurement and prediction of environmental pressures from the use of materials in an economy [25].

To analyze the material flow of Cement Company, knowing the cement production system is required. From fig. 1 can be seen that the system is divided into 3 major steps [26]. Those are:

- Quarrying Process

  Mining activities include limestone mining by delay blasting process and silica mining by ground flaking process, transporting by dump truck to dumping point (toward loading area), transporting by dump truck to crusher and crusher car II, afterwards materials are eventually brought to factory by using belt conveyor. Meanwhile other raw materials are obtained by purchased from third parties by using dump truck [21].
- Production Process

  The cement company used two types of process which is dry process and wet process from the beginning. However started in year 1999, the wet processing was not done anymore except for a few special types of cement. The activities in this step include:

  1) Raw material grinding in raw mill

All of raw material is mixed in raw mill in certain proportion by using recycled hot gas from kiln which works in centrifugal way with fan pulling in optimum temperature 290°C. There are three rooms in raw mill which are drying chamber to dry all raw material by hot gas, compartment I to grind coarse materials by using ball mill, compartment II also to grind material but for fine materials by using ball mill (ball mill in compartment I is bigger than ball mill in compartment II). The raw mix (raw material that has been fined by raw mill) will be filtered and come to separator where the fine material will be continued to blending silo for homogenizing process and course material will come back again to the raw mill (compartment II). The homogenizing process in blending silo is really important to get appropriate material composition and reduce fluctuation in the quality of raw mix, because performance of kiln will be disrupted if the materials are not homogeneous [21].

2) Fuel preparation in coal mill

In this step, coal will be mashed exactly like the process in place for raw material in raw mill. Eventually, the fined coal will be fed to kiln and injected together with air through burner [21].

3) Burning in kiln

The first step in kiln is raw mix preheating until temperature 500°C. The raw mix after preheating will go to kiln and dust in hot gas (330°C) will be directed toward gas conditioning tower which will reduce the temperature reaching 120°C. The temperature reduction in gas conditioning tower is done because electrode serves as dust catcher will work well under temperature of 120°C. After the preheating process, raw mix will undergo a calculation process which is CO_2 release process and oxide form (CaO and MgO) of carbonate compounds, incandescent process reaching temperature of 1100° – 1450°C, cooling process by planetary cooler which sprinkle the clinker (burned raw mix) in order to contact as much as possible to air and cooling water system that is installed in outlet planetary cooler [21].

4) Finish milling in cement mill

In this step, the temperature of clinker has to be kept in safe range which is 110°C – 125°C to prevent dry and wet clogging. Furthermore, clinker, gypsum, and pozzolan are fed to cement mill and undergo two steps of grinding in compartment I and compartment II like in raw mill process. Finally, the cement product is fed to separator which conveys the fine cement to cement silo and returns the rough part to cement mill [21].

- Cement Packaging

Cement is filled into sacks of cement consisting of 6 sheets of kraft paper and inside is covered by 1 sheet of polypropylene paper [21].

Based on the three years collected data (year 2008, 2009 and 2010), the cement company extracts 7 types of raw materials to produce cement. Those are limestone, the most widely used material which is about 79.9%, silica about 9.4%, clay about 3.6%, pozzolan about 2.8%, gypsum about 2.4%, copper slag about 1.5%, and iron sand about 0.4%. Moreover, coal, diesel fuel, gasoline, and electricity are also used in the company, not as raw material but as an energy sources. Related to cost categories, from all of used energy sources, the cement company used coal about 52.5%, electricity about 35.11%, diesel fuel about 12.35%, and gasoline about 0.04%.

Limestone, as a main raw material used by the cement company has extracted about 7.45x10^6 Mt in the year 2008, 6.91x10^6 Mt in year 2009, and 7.19x10^6 Mt in the year 2010. The amount of used limestone per year is not very fluctuating and tends to be constant which is 7 million Mt/ year average. Furthermore, other raw materials (auxiliary materials) like silica, clay, pozzolan, gypsum, copper slag and iron sand are used not very significant amount. Fig. 2 shows the trend of limestone used by "A" company based on the three years data.

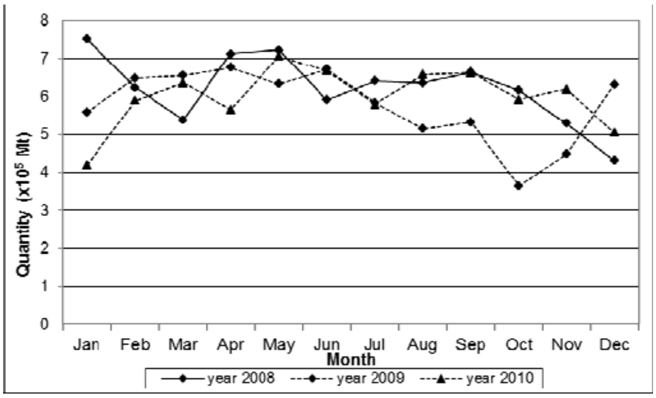

Fig. 2. Use of limestone of "A" company from 2008 to 2010

In order to see the condition of the production process comprehensively, process efficiency measurement is needed which input and output has to be a balance. Input of all raw materials of the cement company is 9.03x10^6 Mt in 2008, 8.64x10^6 Mt in 2009, and 9.30x10^6 Mt in 2010. Meanwhile, output in the form of products is 5.86x10^6 Mt in 2008, 5.36x10^6 Mt in 2009, and 5.67x10^6 Mt in 2010. From that calculation, it is known that the cement company loses about 3.17x10^6 Mt material in 2008, 3.28x10^6 Mt material in 2009, and 3.64x10^6 Mt material in 2010. The process efficiency calculation can be expressed using basic standard efficiency formula for energy, but can be used to determine the product efficiency calculation in Eq. (1) [26].

$$\eta = \frac{P_{out}}{P_{in}} \tag{1}$$

where η is efficiency, P_{out} is power output, and P_{in} is power input. Based on the formula in of Eq. (1), process efficiency of the company can be determined by change P_{out} to be product, and P_{in} to be input, and make the percentage. Therefore, the process efficiency of the cement company is 65.7% % in 2008, 62.5% in 2009, 61.4% in 2010 and loss about 34.3% materials in 2008, 37.5% materials in 2009, 38.6% materials in 2010. If we take the average amount, from 100% input raw material, only 63% become product, and 37% is gone (material loss). However, if we take monthly amount, the company reached the highest level of process efficiency on December 2008 which was 81.1% and the lowest material loss of 18.9% but reached the lowest process efficiency on September 2010 which is 49.4% and the highest material loss of 50.6%. Detail of process efficiency of "A" company every month once with material loss is shown in Table I.

TABLE I: PROCESS EFFICIENCY AND MATERIAL LOSS OF "A" COMPANY PER MONTH

Month	Process Efficiency (%)			Material loss (%)		
	Year 2008	Year 2009	Year 2010	Year 2008	Year 2009	Year 2010
January	58.1	60.7	64.0	41.9	39.3	36.0
February	65.8	59.2	53.3	34.2	40.8	46.7
March	67.8	66.7	63.3	32.2	33.3	36.7
April	58.1	56.0	63.1	41.9	44.0	36.9
May	61.0	63.4	52.9	39.0	36.6	47.1
June	69.4	57.5	56.5	30.6	42.5	43.5
July	64.4	63.4	70.0	35.6	36.6	30.0
August	66.2	68.4	63.4	33.8	31.6	36.6
September	61.3	58.6	**49.4**	38.7	41.4	**50.6**
October	63.6	68.6	64.4	36.4	31.4	35.6
November	71.4	67.2	61.6	28.6	32.8	38.4
December	**81.1**	60.1	75.0	**18.9**	39.9	25.0
Average	**65.7**	**62.5**	**61.4**	**34.3**	**37.5**	**38.6**
Efficiency		**63**			**37**	

Material loss in the cement production process is detected as cement kiln dust (CKD) and dust emission (if material attached to the equipment during production process is assumed to be zero). CKD is fine particulates of unburned and partially burned raw material that become entrained in the combustion gases which are captured by particulate control devices [12]. In order to find amount of CKD produced by the company, dust emission quantity is needed. Dust emission or emitted total dust (ETD) is obtained from three sources, which are form chimney at the factory, all activity related to cement production process around the company, and all activity related to quarrying process. By using combined law between Boyle's law and Charles's law Eq. (2) and Eq. (3) [27] and assumption that condition is in standard temperature and pressure (STP), the amount of dust emission can be determined.

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \tag{2}$$

$$\frac{P_{eks} V_{eks}}{T_{eks}} = \frac{P_{STP} V_{STP}}{T_{STP}} \tag{3}$$

where P_{eks} is existing pressure condition, V_{eks} is air volume of the measurer (high volume sampler (HVS)), T_{eks} is existing temperature when the measurement done, P_{STP} is pressure in STP condition (final condition), V_{STP} is volume in STP condition (final condition), and T_{STP} is temperature in STP condition (final condition). Then obtained that the highest amount for dust emission is from chimney which is about 189.9 kg in 2008, 199.7 kg in 2009, and 240.5 kg in 2010, then followed by dust emission from all activity related to quarrying process which is about 88.7 kg in 2008, 103.4 kg in 2009, and 108.3 kg in 2010, and the lowest amount is from all activity related to cement production process which is 0.09 kg in 2008, 0.07 in 2009, and 0.06 in 2010. Therefore, ETD of the cement company is 278.6 kg in 2008, 303.1 kg in 2009, and 348.8 kg in 2010 which means that the cement company produce 569 mg ETD/Mt product in 2008, 685 mg ETD/Mt product in 2009, and 750 mg ETD/Mt product in 2010 or averagely the company produce 668 mg ETD/Mt product every year. Even though the ETD amount is very a few, but dust emission is contained in air which can be inhaled by human causing various diseases.

Based on the amount of ETD, the amount of CKD can be determined by calculation between material loss amount and ETD amount as Eq. (4).

$$\text{CKD} = \text{Material loss} - \text{ETD} \tag{4}$$

From the equation, amount of CKD can be obtained that 3.17×10^6 Mt in 2008, 3.28×10^6 Mt in 2009, and 3.64×10^6 Mt in 2010.

The cement company uses 3 kinds of energy sources, which are coal, diesel fuel, gasoline, and electricity. Coal is used 9.09×10^5 Mt in 2008, 8.84×10^5 Mt in 2009, and 9.26×10^5 Mt in 2010, or 9.06×10^5 Mt per year averagely. Diesel fuel is used 3950.9 Mt in 2008, 4228.2 Mt in 2009, and 3610.7 Mt in 2010, or 3929.9 Mt per year averagely. Gasoline is used 19.7 Mt in 2008, 19.9 Mt in 2009, and 13.7 Mt in 2010, or 17.8 Mt per year averagely. While the electricity consumptions is 5.67×10^5 Mwh/year.

Another output produced by the cement company is CO_2 emission and gas emission. The emission is obtained from fuel combustion (diesel fuel and gasoline) (2.8%), coal combustion (38.1%), and calculation process (59.1%). Gas emission amount can be determined by equation (2) and (3) while CO_2 amount can be determined as equation (5) and (6):

$$\text{Total } CO_2 = E_g + E_d + E_c + E_p \tag{5}$$

$$E_p = E_{clinker} + E_{loss\ CKD} \tag{6}$$

where E_g is CO_2 emission caused of gasoline, E_d is CO_2 emission caused of diesel fuel, E_c is CO_2 emission caused of coal, and E_p is CO_2 emission caused of process (calcination). If we compare to clinker production, CO_2 emission goes up averagely every year, which are 0.834 Mt CO_2/Mt clinker in year 2008, 0.861 Mt CO_2/Mt clinker in year 2009, and 0.870 Mt CO_2/Mt clinker in the year 2010. And for gas emission, the company carries out the measurement in 2 sites which is in kiln chimney and surrounding the company area every 6 months per year that measure several gas type such as NO_2, SO_2, CO, O_3, H_2S, HC, Pb. From the measurement is discovered that NO_2 SO_2 has high amount compare to others. The cement company emit for NO_2 about 2 kg in 2008, 1 kg in 2009, and 0.9 kg in 2010, for SO_2 about 2.1 kg in 2008, 0.9 kg in 2009, and 0.8 kg in 2010, for CO about 0.071 kg in 2008, 0.065 kg in 2009, and 0.047 kg in 2010, for O_3 about 4×10^{-4} kg in 2008, 2×10^{-4} kg in 2009, and 2×10^{-4} kg in 2010, for H_2S about 0.033 kg in 2008 also 2009, and 0.022 kg in 2010, for HC about 0.005 kg in 2008 also 2009, and 0.004 kg in 2010, for Pb about 1×10^{-5} kg in 2008 also 2009, and 4×10^{-6} kg in 2010. The material flow balance diagram for 1 ton cement of the cement company is shown in Fig. 3.

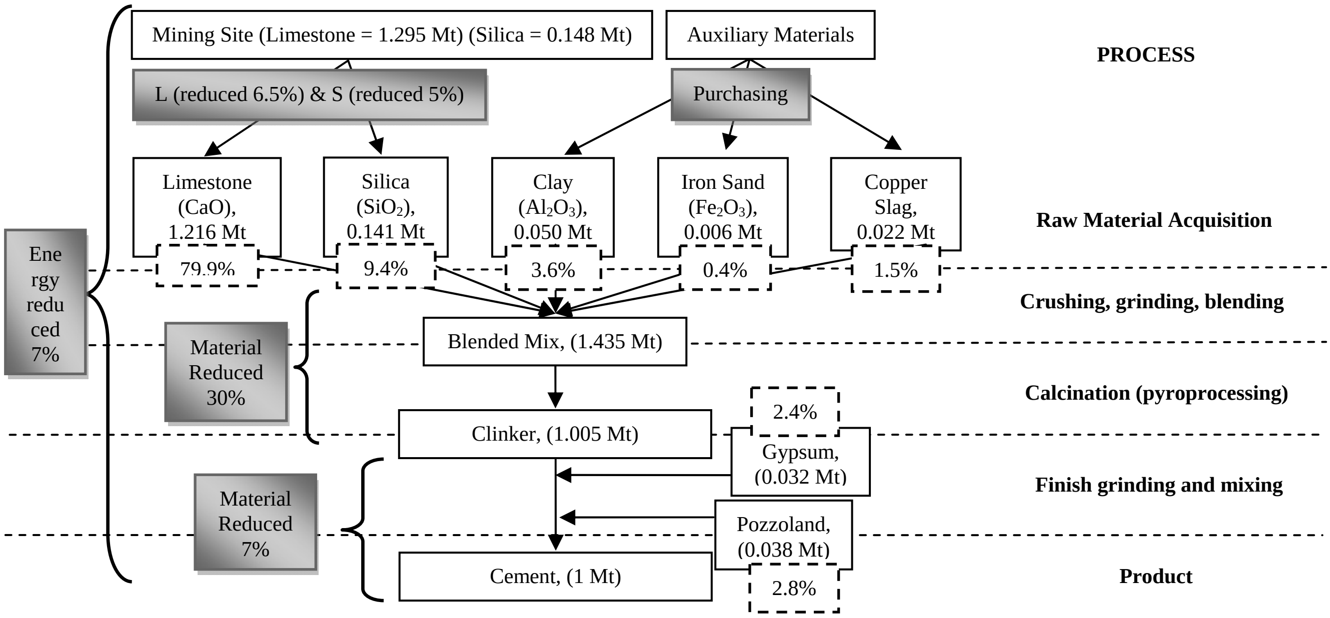

Fig. 3. Material flow balance diagram for production 1 ton cement

B. Life Cycle Analysis

The limestone consumption of the cement company is 7 million Mt/ year averagely while the natural resource reserve of limestone is just remains about 74 million Mt. If the company still continues the production process just the same way like before, the natural resource reserve of limestone might be exhausted approximately 10 years. Another way to keep the company running is using new land to be raw material quarry which automatically will reduce forest area (damaging the environment).

In term of process efficiency, the cement company's process efficiency is relatively low seen from CKD quantity as the biggest amount of waste. If we take comparison with clinker production, which is kiln product [8], the company produces about 24.9–114.3% CKD (by mass) of clinker production. That value is very high compared to CKD's amount of most cement companies in USA which is 15-20% (by mass) of clinker production [28]. This condition is exacerbated by the absence of recycling process for the CKD. For the ETD, many complaint form residents around the company's area about the emitted dust proved by direct interview with residents and view of a lot of amount piles of dust on the house's roof.

The detail potential impact that occurs in each process steps are also considered in this study which described in Fig. 4. Those are energy (fuel and electricity) and heat consumptions, dust emissions, gaseous emissions, loudness, land degradation, erosion, occupational accident, and blasting and fire.

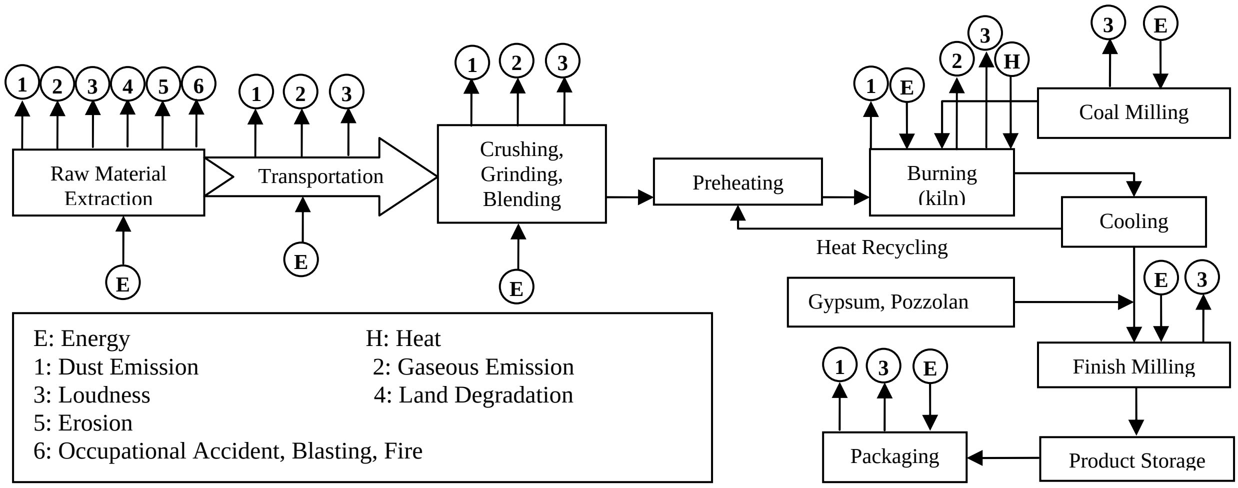

Fig. 4. Potential impact of each step of production process

Based on the medical checked up of all employee, detected that 17.44% employee is in very good condition, 50.31% in good condition, 17.9% in average condition, 4.94% in bad condition, and 9.41% in very bad condition. The detected diseases are common cold, cough, pharyngitis, diabetes mellitus, dyspepsia, dermatitis, febris (fever), arthralgya, hypertension. The medical check up is only done for the employee of the cement company, but there is no for the community around the company.

C. Material Flow Cost Accounting

Product cost, material; loss cost and waste and emission control cost are calculated in MFCA. In order to get product cost, material used is needed to be multiplied with purchase cost. Total cost of all material used (product cost) is 100.649 billion IDR/year averagely, however run into cost loss at 37% of the material used cost in the amount of 37.24 billion IDR/year average.

For energy consumption, the company spends about 268.128 billion IDR/ year yet runs in costly loss at 7% of the energy consumption cost of 18.769 billion IDR/year. Afterward, packaging paper consumption, the company spends about 499 millions IDR /year averagely and has cost loss of 5% of the packaging paper consumption cost of 24.9 million IDR /year averagely. Beside the materials, energy, and packaging cost, factories activities also need water to supply the employee need of working which spends about 136 millions IDR/ year [29].

For the waste and emission control cost, the calculation includes equipments machine depreciation cost (grate cooler, electrostatic precipitator) which spends about 9.545 billions IDR/year, employee safety cost (helmets, shoes, uniforms, masks, air plugs) which spends about 455 millions IDR/year, maintenance of emission control equipments cost (grate cooler, electrostatic precipitator) which spends about 57 millions IDR/year, internal personnel cost (salary for employee who work in factory and directly responsible to the environmental waste and emission control) which spends about 4.2 billions IDR/year, and remediation and compensation cost (the compensation of the not-maximum of farmer's field because of the contaminated water) which spends about 704 million IDR/year [29]. The detail data are shown in Table II along with the percentage between product cost, material loss cost, and waste and emission control cost.

TABLE II: DISTRIBUTION OF COST CATEGORY OF ENVIRONMENTAL DOMAIN

No	Environment-related cost categories	Total Cost (IDR)	Percentage (%)
1	**Product Cost**	**369,276,000,000**	**96**
	Raw and auxiliary materials	100,649,000,000	
	Packaging materials	499,000,000	
	Energy	268,128,000,000	
	Water	None	
2	**Waste and Emission Cost**	**14,961,000,000**	**4**
	Equipment Depreciation	9,545,000,000	
	Employees Safety	455,000,000	
	Maintenance of Emission Control Equipments	57,000,000	
	Internal Personnel	4,200,000,000	
	Remediation and Compensation	704,000,000	
	TOTAL	**384,237,000,000**	**100**
3	**Material Loss Cost**	**56,170,000,000**	**15**
	Raw and auxiliary materials	37,240,000,000	
	Packaging materials	25,000,000	
	Energy	18,769,000,000	
	Water	136,000,000	

D. Scenarios

Based on the evaluation of the cement production process's system by MFA, LCA and MFCA, several problems are detected that is faced by the cement company such as limitation of resource reserve (limestone), CO_2 emission, high energy consumption, CKD, dust emission, and others related to cost and environmental problems. If the company keeps this system on, it will harm the environment, human health, even affects the company's income. The new system is needed to embody the sustainable development. The new system utilizes several wastes from many industries, such as waste of rubber industry, municipal solid waste of the city which is directly used to be alternative energy (burn), and also waste of human secretory, waste of tapioca starch industry, waste of tofu industry and waste water of rubber industry that need to have a preliminary process to get biogas to be alternative energy. Those industries have difficulties in treating their wastes, so it is good to help them also the cement company itself to utilize the waste.

Therefore, we propose three scenarios involving many elements in and outside the city to make integrated system as a preliminary design of eco-city. The new systems utilize several wastes from various sources, such as waste of rubber industry, municipal solid waste of the city and other cities which is directly used to be alternative energy (burn), and also waste of human secretion, waste of tapioca starch industry, waste of tofu industry and waste water of rubber industry that need to have a preliminary process to get biogas to be alternative energy. Those industries have difficulties in treating their wastes, so it is good to help them also the cement company itself to get advantage from the waste. Those three scenarios are:

Scenario 1: basic scenario that is currently operated by the cement company which is shown in Fig. 1.

Scenario 2: the cement company system with industrial symbiosis efforts (waste co-processing method) by involving many elements inside the city, and also other improvement inside the company itself which is shown in Fig. 5.

Scenario 3: contain the design of scenario 1 and 2 which also involve elements outside the city.

Those three scenarios are compared and then make the best scenario which will be proposal of eco-city's preliminary design. Scenario 1 is exactly the same with the cement company's system which extracts a lot of raw materials and produce many wastes. There is recycling facilities and no IS efforts. While scenario 2 saves about 36.8% of raw material used, produce energy from alternative sources (wastes) that is obtained from inside the city and reduce the amount of waste which is CKD and CO_2. Furthermore, scenario 3 saves raw material in the same amount with the scenario 2, but produce more energy from alternative sources that is obtained from inside and outside the city. However, these both scenarios need the biogas plant construction cost (about the biogas plant maintenance is not considered in this study). The comparison of each scenario is shown in Table III.

About waste of biogas production process (anaerobic digestion), carbon dioxide and the sludge will be conveyed to greenhouse (open up a new agriculture site near the company) as well as carbon dioxide emitted by cement factories. The green houses are expected to be managed by the company that can open a new job opportunity for communities while providing additional benefits to the company and conserve the environment. However, the biogas plant construction needs quite much money which is 48.13 billion IDR [30].

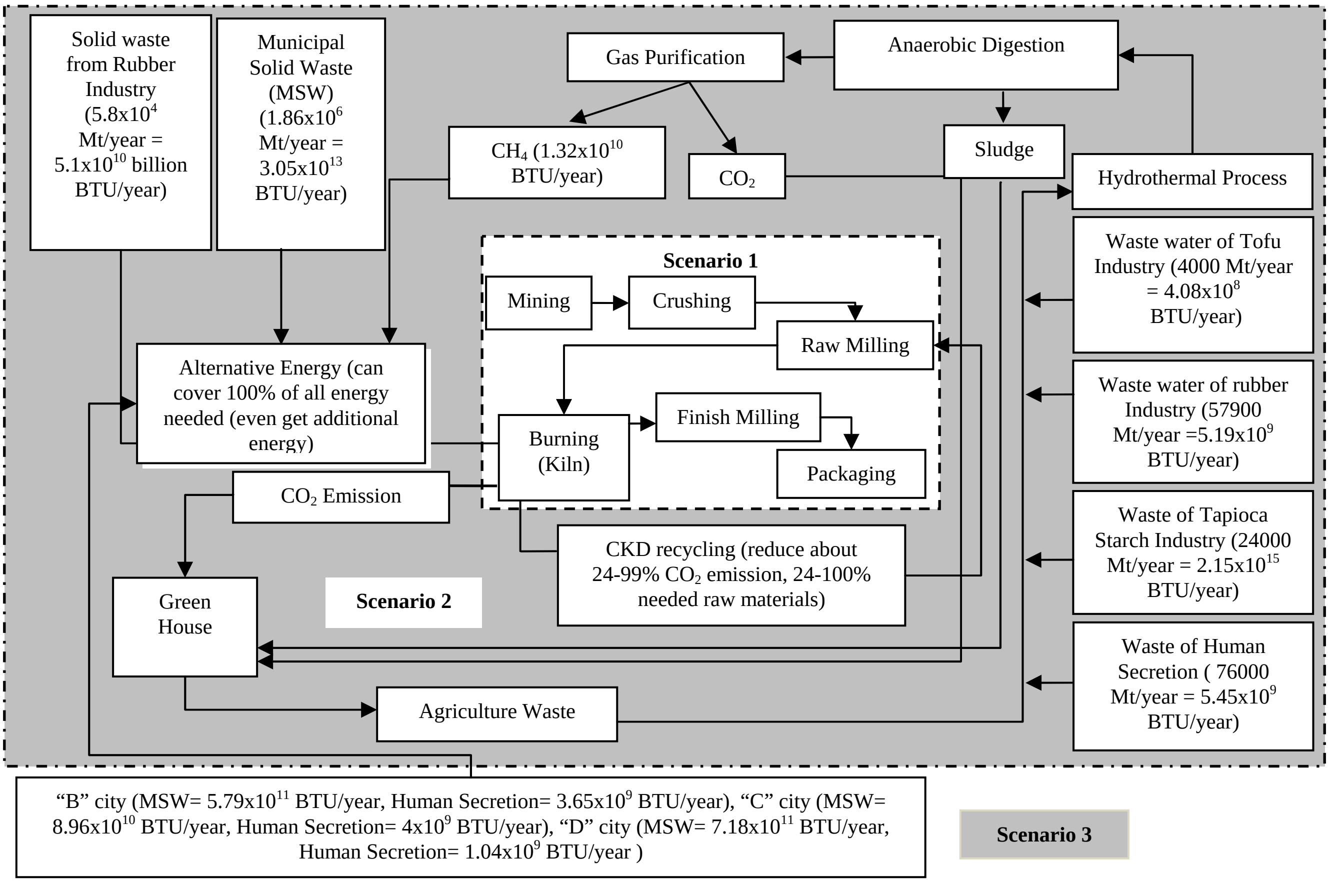

Fig. 5. Scenarios of design of alternative material exchange

TABLE III: COMPARISON OF EACH SCENARIO

No.	Activity	Scenario 1	Scenario 2	Scenario 3
1	Raw Material	Extract about $8.99x10^6$ Mt material/year. Spends cost about 100.649 billion IDR/year	Can save about 36.8% of raw material needed. Save about 37 billion IDR/year	Can save about 36.8% of raw material needed. Save about 37 billion IDR/year.
2	Energy	Consume energy about $2.28x10^{13}$ BTU/year (inside process). Spends cost about 152.624 billion IDR/year	Produce energy about $3.05x10^{13}$ BTU/year (surplus 24.1% than inside process's energy needed). Get surplus energy cost about 52.028 billion IDR/year. Only spends for a fuel fee of transportation process about 38,000 IDR/year	Produce energy about $3.19x10^{13}$ BTU/year (surplus 40.2% than inside process's energy needed). Get surplus energy cost about 61.390 billion IDR/year. Only spends for a fuel fee of transportation process about 315,500 IDR/year.
3	Waste	Produce CKD $3.36x10^6$ MT/year. Produce CO_2 $4.41X10^6$ MT/year.	CKD is recycled again to the process. Produce CO_2 about $8.04X10^5$ MT/year	CKD is recycled again to the process. Produce CO_2 about $8x10^5$ MT/year
4	Construction cost of new design	-	Need cost about 48.13 billion IDR for biogas plant construction	Need cost about 48.13 billion IDR for biogas plant construction
5	Additional Benefit	-	Get more benefit from the agriculture site and more residents can work and involve for the company	Get more benefit from the agriculture site and more residents can work and involve for the company

From Table III, about the comparison of each scenario can be concluded that the scenario 2 and 3 has each benefit for the economy, environment, and society. Actually, scenario 2 has enough to meet criteria of good design because can cover 100% of energy needed (even a surplus 24.1% of energy needed, the company can sell it or use it for other purposes), save the use of raw materials and reduce the production of waste (CO_2, CKD, etc.), but the scenario 3 is still needed to get the comparison and validation in order to achieve the best choice. Compare to scenario 2, scenario 3 has more benefit in the economic sector for the company itself, but for the social aspect is a little bit more difficult because it should get permission from other city's government and society that probably different with the city (the effort is more). Therefore, from the consideration above, it can be concluded that the chosen scenario is scenario 2.

IV. Conclusion

The increasing of many environmental problems's concerns, many countries are now seeking innovative approaches to reform their industries which no exception for Indonesia that is developing their industrial sector. IS characterizes relationships between businesses by analyzing their economic and environmental performance. By encouraging IS, industrial systems can minimize environmental impacts by mimicking the circular flow of energy and materials as demonstrated by natural ecosystems [31]. From the case of this cement industry in Indonesia, we can see the value of encouraging IS at the broader level by using MFA, LCA, MFCA of the cement industry. Furthermore, the new design of cement production system can be proposed as preliminary design of eco-city by involving various elements inside and outside the city. Eventually, this new design is expected to be implemented in real condition which will give benefit not only for the cement company itself, but also for the environment and society in order to achieve the sustainable development.

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Nova Ulhasanah was born in Padang, West Sumatera, Indonesia, on November 28th, 1986. She obtained her bachelor's degree of Environmental Engineering from Andalas University, Padang, West Sumatera, Indonesia on August 15th, 2009. She is currently a masters student of Environmental and Life Engineering from Toyohashi University of Technology, Toyohashi, Japan.

She have had internship in waste water treatment department, PT. Argo Pantes tbk (textile industry), volunteered of global exchange member for volunteer services overseas (VSO) and British Council (youth exchange between United Kingdom and Indonenesia), and worked as broadcaster in Star radio, Padang, West Sumatera, Indonesia. She has authored some publications including Effect of Various Concentration and Organic Material in Anaerobic Layer toward the Removal of Nitrogen Compounds of Rice Field Wastewater by Multi Soil Layering Method (Padang, Indonesia: Andalas University, 2009), Sustainable Cement Production of Cement Industry in Indonesia by using Material Flow Analysis (Nagoya, Japan: Proceedings of the International Symposium on EcoTopia Science (ISETS), 2011), Sustainable Cement Production of Cement Industry by MFA, LCA and MFCA as a Preliminary Design of Eco-City in Indonesia (Phuket, Thailand: . International Proceedings of Chemical, Biological, & Environmental Engineering. Biotechnology and Environment Management (IPCBEE), 2012), Preliminary Design of Eco-City in Indonesia by MFA, LCA, and MFCA of Cement Industry (Yokohama, Japan: Proceedings of Annual Meeting of Environmental Science Association, 2012).

She is currently research about new design of cement production as a preliminary design of eco-city.

Naohiro Goto was born in Tokyo, Japan on March 3rd, 1966. He obtained his bachelor's degree of Engineering from University of Tokyo, Japan, 1989, his master's degree of Engineering from University of Tokyo, Japan, 1991, and his doctoral degree of Sustainable Engineering from University of Tokyo, Japan, 1994.

He has worked as researcher in Research Institute for Innovative Technology for the Earth from 1994 until 1996, as researcher in Japan NUS Co., LTD from 1996 until 1998, as assistant professor in Toyohashi University of Technology from 1998 until 2000, and a in Toyohashi University of Technology from 2001 until now. He has authored some publications including Environmental Management System Based on Material Flow Analysis to Establish and Maintain Eco Town (Toyohashi, Japan; Journal of Industrial and Engineering Chemistry, 2005), A Method for Regional-Scale Material Flow and Decoupling Analysis: A Demonstration Case Study of Aichi Prefecture, Japan (Toyohashi, Japan: Resources, Conservation and Recycling, 2008), Net Greenhouse Gas Emission on Biofuel Production: A Case Study of BDF Production from Palm Oil in Indonesia (Toyohashi, Japan: Journal of ecotechnology research, 2009).

Prof. Naohiro Goto is currently a member of International Society for Industrial Ecology and Japanese Society of Environmental Science. He has achieved the Bronze Poster Award of International Conference on EcoDesign with title "Greenhouse Gas Balance on Life Cycle of Biodiesel: A Case of Palm Biodiesel Production in Indonesia" in 2008.