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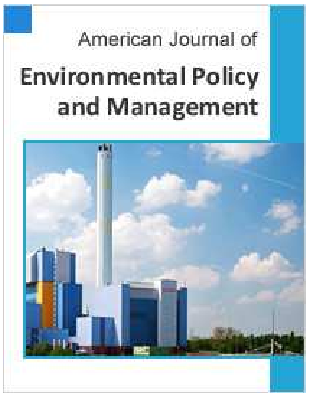

An Approach to the Design of Urban Simple Housing with Low CO2 Emissions Following Natural Disasters

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Abstract

In the last decade, many urban areas in Indonesia suffered from several large natural disasters. The magnitude of the disasters has destroyed many urban housing in a wide systemic scale. The implementation of recovery development presents an opportunity to achieve sustainable outcomes in terms of environmental, social, and economic impact long after the disaster. However, it also incorporates generation of CO2 emissions. There is a residential supporting environment system that influences generation of CO2 emissions. The various components of the system interact with each other to affect CO2 emissions into the air such as; the householder, houses, building material, parcels of land, building coverage, building layout, distance between buildings, density of buildings, and housing utilities. Qualitative research was implemented at Perumnas Griya Martubung I Housing, in Medan, in order to understand the interaction of these components, and to identify factors that influence the emission of CO2 in the residential area. This paper discusses about upgrading urban housing by creating low CO2 emissions residential in the urban area, an issue that has not yet been fully adopted particularly in the implementation of simple housing in Indonesia. This study raises issues that are not fully adopted by the general recovery development, particularly ideas on how to reduce emission of carbon dioxide produce from urban housing redevelopment initiatives. This study consists of four parts. The first part reviews about the interaction of natural disasters and residential development and presents an approach for a more holistic insight of residential impact of disaster. The second, it discusses CO2 emissions and the various components of the residential supporting environment system which play a direct or indirect part in producing CO2 emission in urban housing. The third, it presents a conceptual framework for creating low CO2 emissions urban housing. Finally, this study is to offer how CO2 emissions in simple urban housing can be reduced by controlling the components of residential supporting environment system.

1. Introduction

In the last decade, many urban residential areas in Indonesia suffered from natural disasters. Residential areas were destroyed by the magnitude of the disasters, in terms of both fatalities and damages. One effect of these disasters is actually opportunities for all local stakeholders to start the reconstruction of urban housing that promotes sustainability in various areas. The reconstruction presents a chance to encourage stakeholders to facilitate economic, social, and environmental development. Many believe that redevelopment process can have multiple benefits for local people such as: the use of local materials, reduced costs and increased effectiveness of recovery and policies. External assistance can be used to build and support local organizations to become more effective in starting sustainable developmental schemes. Local people can also identify goals, direct resources, and organize programs that have`continued environmental, social, and economic benefits.

In addition to the above opportunities, there is also a prospect to minimize the emission of CO_2 in the urban residential area. The CO_2 emission derived from the building material's manufacturing and distributions, and also the type of houses. By doing appropriate standards of reconstruction design , repair and land use, a recovery program can lower CO_2 emissions with the least risk. Moreover, long term urban housing problems can be resolved with residential reconstruction schemes. For example, the improving traffic circulation, increasing affordable housing stock for the poor, renewing public facilities, and stimulating the locals'participation can be accomplished through redevelopment projects. The above focus of renewal actions would necessitate a redevelopment planning which includes local efforts to influence the pace, location, type, density, design, and cost of redevelopment. Having locals effectively carry out the redevelopment initiatives already results in a significant resolution to achieve low CO_2 emissions in urban residential.

Reconstruction schemes are part of urban housing development dynamics, and they happen in conjuction with the increase of infrastructure demand due to redevelopment needs. The dynamics of residential life and redevelopment programs are a complex interaction system that is associated with the production of CO_2 emission (Siahaan, et.al. 2012; Puslitbangkim, 2007). The overcoming methods of recovery initiatives, however, has been focused on short term support, with little relation to long term sustainable development, local roles and capacities, as well as diverse social, economic, and cultural conditions. The common assumption so far sees local people as having limited capacity to cope with redevelopment programs and to participate effectively in recovery programs. However, what is needed is a greater understanding of community needs and capacities. Furthermore, how such understanding can be put into practice is also important to know.

This paper raises issues that are not fully adopted by the general recovery development, particularly ideas on how to reduce emission of carbon dioxide produced from urban housing redevelopment initiatives. This paper consists of four parts. The first part reviews the interaction between natural disasters and residential development, and presents an approach for a more holistic insight of the residential impact of disaster. The second part discusses CO_2 emissions and the various components of the residential supporting environment system that play a direct or indirect part in producing CO_2 emission in urban housing. In the third part of the paper, a conceptual framework is presented for creating urban housing with low CO_2 emissions. Finally, this paper offers conclusions on controlling components of residential supporting environment system to reduce CO_2 emissions in urban housing.

2. Definitions

There are many examples that can define the word "recover". An economic recession is followed by an economic recovery. Complex social conflicts are followed by a period of economic and social recovery. Defining development recovery is crucial to the process of recovery because different definitions lead to different objectives. Those affected by a disaster event, and want to return to the condition that they had known before, define recovery as "…. getting back to normal". Yet others see in these disasters opportunities for change (Anderson, 1990). Given that physical properties and infrastructure must be replaced anyway, there is some argument that the devastation can change a society towards a different direction of development that may ultimately generate better outcomes (Siahaan and Nababan, 2009).

3. CO_2 Emissions and Residential Development

In Indonesia, urban residential hazards are not only caused by one-off events like earthquake, land slides or cyclones, but also by physical changes in the form of restoration, renovation, or reconstruction of the housing.The physical changes are part of housing development dynamics, and it happen alongside the increase of infrastructure demand due to the growth and development of the housing residents' needs. The production of CO_2 emission to air is associated with the complex interaction of house alterations and the dynamics of residential life (Puslitbangkim, 2007; Suhedi, 2007; Siahaan et.al, 2012). This emission of CO_2 is not merely caused by the process of construction, but also by the whole aspect of utilizing the space in residential areas. (Jabareen, 2006).

The emission of CO_2 produced by a housing is closely related to activities that use non-renewable energy resource. The greater each activity's dependency on energy usage, the greater the emission of CO_2 produced by an urban housing's implementation system (Zubaidah, 2007). Therefore, through utilization and regulation of space, an urban housing with low CO_2 emission can substantially be created. Nevertheless, the processes of a land development for housing, construction, house alterations, and finally house demolitions are also processes that vastly damage the environment, especially related to the CO_2 emission produced (Priemus, 2005).

I take as study case Griya Martubung I Housing in Medan, where the livelihood activities of its residents rely on every resource in and around the housing areas. Qualitative research conducted to gain knowledge about the various components of the design of housing related to CO_2 emissions generation. Each component is investigated by conducting in-depth interviews, observation, and discussion of the various stakeholders. From the analysis of the components obtained knowledge that the generation of CO2 emissions is influenced by the interactions the various components of a residential supporting environment system. The linkages between various components of the system play a direct and indirect part in producing CO2 emission, as can be seen in activities involving space utilization, as well as the regulation in housing implementation and living in Griya Martubung I, Medan.

4. Creating Low CO2 Emissions of Urban Housing

Observation done from December 2011 until February 2012 on house alterations at Griya Martubung I Housing shows that as many as 89% of houses type 29 have gone through various alterations on elements such as flooring, walls, roof, as well as windows, doors, and poles. Generally, small house types as type 29 and type 36 at Griya Martubung I Housing have more tendency to go through alterations than bigger house types as type 54. Both small types go through alterations because the space they provide no longer supports residents' need of activities. Moreover, house alterations happen because residents desire to separate the function of rooms available.

A study done by Afiaty (2003) shows that alterations to bigger types of houses such as type 54 are no longer affected solely by the need of room functionality, but also by the purpose of inner space aesthetics. CO2 emission produced by alterations to house type 54 is quite large due to greater need of material. Therefore, the various alterations and area extension to the house type certainly produces CO2 emission to air.

Furthermore, house alterations in the form of adding rooms or extension of building that differ from the house's original structure will change the existing building structure and material. Table 1 explains some underlying factors that may be controlled to reduce CO2 emission at Griya Martubung I Housing, Medan. The change of building structure and material produces CO2 emission to air. Efforts for reducing CO2 emission can be done only if every underlying factor of house alteration can be controlled.

One of the contributing factors of house alteration dynamics at Griya Martubung I is the number of householder, or the increasing number of residents in a house. More residents in a house certainly demands for a larger house area with more complex building scheme. In consequence, house alteration needs construction technology to condition the space, especially to handle ventilation, lighting, and house utility systems that become more complex with the addition of building area. The whole construction technology system affects energy utilization at residential areas, and certainly produces CO2 emission.

Meanwhile, to determine the minimum space requirements for each person that resides in a house, it is required to take into account the basic activities of the residents. Some of the activities are sleeping, eating, working, sitting, cooking, bathing, washing, and toilet activities. It is also required to take into account space for human movement, and all the furniture inside of a house. To obtain the minimum area for a house, the following are considered: the space area requirement per person, space area requirement per householder, building area requirement per householder, and lot area requirement per building unit. Table 2 shows a relationship matrix between a house with its residents and the house alterations done by the residents. According to Undang Undang Republik Indonesia No. 1 Tahun 2011, on Housing and Settlement Areas section 22 verse 3, the standard for a house's floor area is at least 36 (thirty six) square meter, with the assumption that the space area requirement per person is 9 (nine) square meter, and the average height of the ceiling is at least 2.80 m (Oktaviana, 2007).

One of the mechanisms for controlling housing development in urban areas is through authorization of a Building Erection Permission (BEP). BEP may be utilized in controlling housing with low CO2 emission.

Tabel 1. *Matrix of Factors of House Alterations.*

No.	Underlying Factor	Data	Reasoning	Restraining Factors
1.	Numbers of head of households	Data of the number of head of households at every block and field survey	If the number of head of household in a house increase, then the member of the family and need for room increase too	The Awareness that a house should be for one head of houseold needs to be developed and sociaized to members of community
2.	Average numbe rof residents between 4 and 5 people	Data of the number of head of households at every block and field survey	The bigger the number of residents, the bigger the number and area of rooms needed	House type does not conform to the number of family members. Type 29 for 3-4 family members, type 36 for 4-5 people, and type 54 for 5-6 family member
3.	The majority of residents work as civil officers (47 %) and private employees (42 %)	Field survey December 2010 – January 2011	A steady job gives opportunity to residents to do house alterations	Careful access to fundig for house construction/ repair even though there is a steady job
4.	55 % of residents have high school education	Field survey December 2010 – January 2011	The higher the residents' education level the bigger the awareness of need for rooms	High level of education affects the amount of income and the awareness to save enegy
5.	The majority of residents are 40-50 years old	Data of the number of head of households at every block and field survey	With the big number of residents in their productives age, horizontal activities among the residents become more intensive, and increase the need for social room among residents	Activity for productive ages are mostly outdoor activities. Awareness of social-cultural relationship among residents develop.

One of the difficulties that is usually faced by stakeholders in realizing urban housing with low CO2 emission is that there is not yet any BEP strategy in the form of regulations to develop the implementation of urban housing with low CO2 emission. BEP can actually be used to control residential supporting environment system through tight establishment of policy regulations on house alteration, so that any alterations made conform to: maintaining the line of buildings and streets (ROW), the distance between buildings, building density, Building Basic Coefficient/Building Floor Coefficient BBC/BFC, building plan, and the use of local material that is suitable for the local climate. Through tight practice of regulations, the use of daylight, sufficient ventilation, and the option of using low emission local material will definitely reduce the use of energy that produces CO2 emission.

Tabel 2. *Matrix of House Residents and House Alterations Correlation.*

Underlying Factors	Effects to Home	Alterations done by Residents
Quality of building material generally low and not conforming to any standards	Shorter age building material resulting in recurrent need for changing, and low quality of construction	House residents do repairs by changing the building material (restoration)
Design of house does not conform to the preference and need of residents	• Low quality of building structure • Unsufficient room • Decline of comfort inside of house	• Do renovation to change house stucture • Redesign by repositioning certain room functions such as the kitchen, bathrooms. • Adding rooms and extending house • Redesign of windows, ventilation etc.
Implementation of house construction does not conform to building standards	• Bad quality of house • Residents desire for a new house structure	House reconstruction, by building a titally different house from the original (former house structure)

The renovation of a building always requires a cost for implementation and buying various building material. From observation and interview, it is acknowledged that in general, the residents of Griya Martubung I Housing renovate their houses in stages. The renovation process is usually done two or three times after the residents occupy for a couple years. The process is done in such a manner because of limited funds, causing residents to adjust the available funds with their needs. Figure 1 illustrates the relationship scheme between house residents' income with the building material and CO2 emission produced from the house alteration. The residents' financing capacity varies and comes from diverse sources.The various types of financing sources for house alterations affects the end result of house alterations.

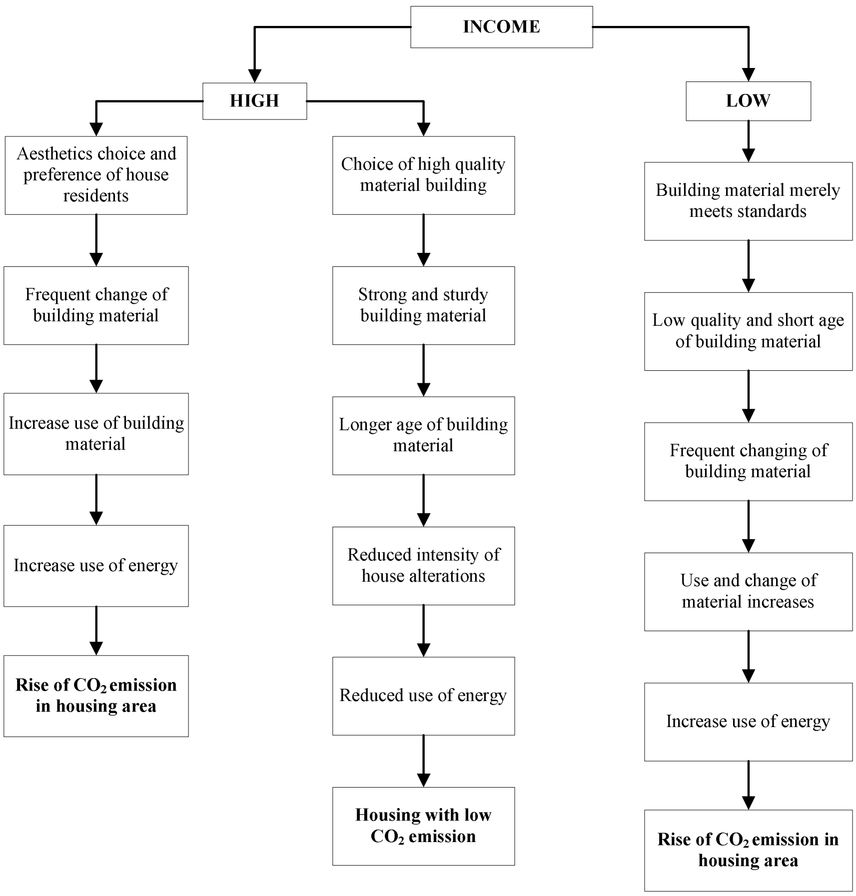

Figure 1. *Diagram of Resident's Income, Choice Building Material and CO2 Emission.*

Since its establishment in 1995, a big number of house alterations have been made at Griya Martubung I Housing Medan. The reason for the alterations is that the residents needed to extend the area of rooms available. The house owner performs alterations to be able to support indoor activity needs of the house residents. Other than the need for room addition, relatively bad building material quality is also one of the underlying factors of house alterations. Table 3 shows some factors that relate with building material changes in correlation with house residents. There are a couple reasons for house residents changing the building material of their house. The reason of material change by residents of Griya Martubung I Housing is mainly because the quality of building material does not yet conform to the residents' preferences, and because of the age of the building material. The whole alteration done needs energy that causes increase of CO2 emission.

The quality of environment at urban housing with low CO2 emission rate depends on the spatial characteristics of the housing, as it is a variable that influences the housing area's physical environment quality level. The housing's spatial characteristics are determined by the form and area of house lots, form and plan of houses, building density, allocation and area of green open space, crowdedness and connectivity of the housing area's road system, including the position and location in the geographic coordinate system.

In general, the building plan at Griya Martubung I Housing conforms to the road pattern which is dominated by a grid pattern forming a 90^o intersection. This house arrangement pattern has the tendency of maximizing land exploitation in order to get as many house lots as possible. The house arrangement pattern for the lots of houses types RSh 29 and RSh 36 is in parallel with the roads that have various Building Line (BL), in accordance with ROW. Therefore, the house lot size becomes smaller and the house structure is coupled, the building plan in parallel with the roads, and one side of the houses have side borders. This results inair flow and daylight entering the house only through the front and back sides of the house. On the other hand, the ROW and BL at the blocks of houses type RSh 29 and RSh 36 are relatively small, giving the potential of lessening the continuity of air circulation outside and inside the house. This house arrangement pattern will certainly produce CO2 emission since the houses will need energy to condition the inner rooms.

Tabel 3. *Matrix of Material Change and House Residents.*

No.	Underlying Aspect	Response	Effect on CO2 Emission
1.	Length of time residing	House Area extension and building material change because 82% of residents have occupied their houses for more than 10 years	House area extention will result in CO2 emission rise at Griya Martubung I Housing Medan
2.	Buildig Structure	Since establishment in 1995 , up untill 2009, 52 % of houses have gone through building structure alteration in the form of building renovation and reconstruction	CO2 emission produced is 4,161,837 kg-C
3.	Authorization process for altering a house	There is not yet any authorization procedure to do house alteration or emissions.	Difficulty to control the pace of house alterations
4.	Houses that violate building border line	As many as 21% of houses at Griya Martubung I Housing violates the building border line	Difficulty to control house alteration, due to lack of implementation supervision
5.	Development employing professionals	Most houses do not employ architect service to do house alteration	Building experts' will help determine the residents needs
6.	House extension	Extentions of houses type 29 and 36 are done because the existing rooms are no longer sufficient to accomodate more than 4 residents	Because of many room additions and extensions made, houses type 29 and type 36 produce much CO2 emission

Increased indoor activity needs is an aspect that also drives house residents to do adjustments to their house's structure and size. As many as 94% from a total of 611 units of RSh 29/75 houses at Block I and Block II Griya Martubung I Housing, Medan, have changed through house restoration, renovation, or reconstruction. This also applies for houses type RSh 36/84 at Block VII and Block IX, of which 87% out of a total 605 house units located at both blocks have been restored, renovated, and reconstructed.

Furthermore, the BL at blocks of houses type RS 36/135 and RS 54/153 varies between 4 m and 6 m in accordance with the house type's block location. Block III, Block IV, Block V, and Block VIII are combinations of houses type RS 36 and RS 54. The four blocks' ROW varies between 8 m and 10 m. At these four blocks, only 73 units of houses out of a total 1241 house units still maintain their original structure as in their original design. Unlike houses type RS 54/153 that are located at the combination blocks, 21% of houses type RS 54/153 located at Block VI, Block X, Block XI, and Block XII have not gone through alterations, compared with 3% at the combination blocks. Meanwhile, the ROW of the four latter blocks is between 10 m and 12 m. Figure2 shows the location of the house type's block.

The arrangement of distance between buildings in an urban housing determines the level of health, security, and comfort of its residents. The distance between buildings at Griya Martubung I Housing has a pattern typical of regular simple housings, where the distance between houses is only at one side of the houses. Figure- 3 and figure 4 show typical building patterns of houses type RS 36/135 and type RS 54/153 in Griya Martubung I.These kind of patterns do not give maximum sunlight and air circulation, nor fire hazard prevention. In addition, the distance between the houses and the road should take into account the distance of the house's fences, so that the length of the house's front yard is enough to let sunlight and fresh air flow in, as well as to place plants for shielding and filtering dust and noise.

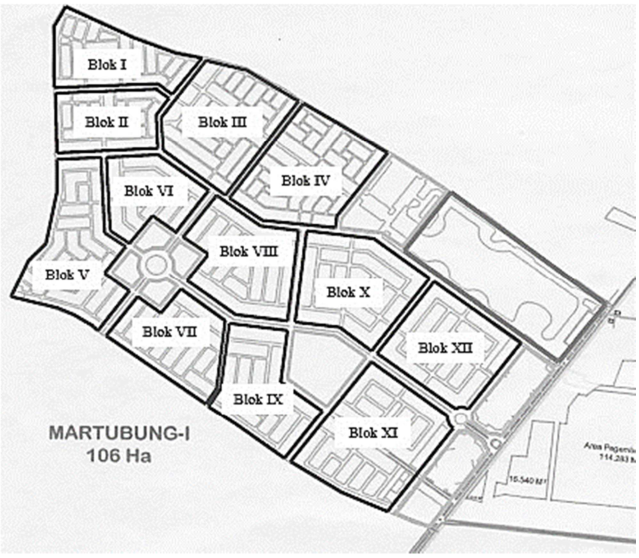

Figure 2. The house type's block location.

In general, the house orientation is intended for anticipating the effects of excessive sunlight and heat. Hence, the problem is how great the influence of building orientation is on the building's ability to restrain heat at ideal and non-ideal orientations of houses at Griya Martubung I Housing. The orientation referred to in this study is orientation in relation to a building's openings' positions, where the position and exterior of the openings will affect the amount of solar radiation entering the building. This implies that the area and position of openings affect a building's ability to restrain heat. For residential houses, generally the orientation does not face merely one direction, but numerous directions. The houses at Griya Martubung I Housing usually face two directions, i.e. the front and back side. This housing plan will certainly produce CO2 emission, because the houses will need energy to condition the inner rooms.

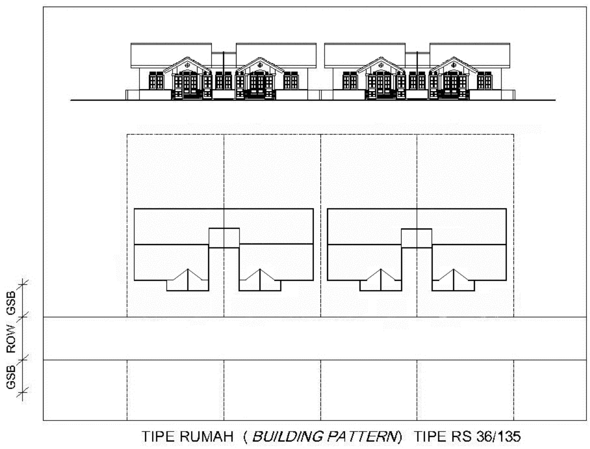

Figure 3. Building pattern of housing type RS 36/135.

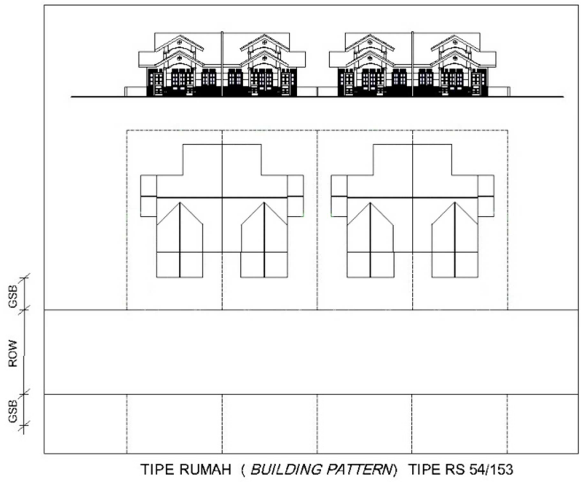

Figure 4. Building pattern of housing type RS 53/153.

Generally, there has not been any policy of housing planning that directly relates the distance between buildings with building density to decrease CO2 emission in the development of urban housings. However, the act or policy of developing urban housings have, directly or indirectly, already accommodate the steps to reduce CO2 emission. Some policies that relate with the steps of reducing CO2 emission in the development of urban housings are: regulations on building density; the establishment of certain conservatory area as urban forests, green channels, green open spaces, or town parks, demarcations, regulations on road networks; regulations of centers of activities; and even regulations on house lot areas. However, policy that directly relates with controlling CO2 emission in urban housing; such as control of building plan, control of public and social facilities' locations, control of public transportation, distance between buildings, control of household waste, control of gas waste caused by use of household utensils and instruments; has not yet been included in the documents of housing development, and should refer to policies in the related fields, such as transportation, environment, and energy.

Moreover, another aspect that has not been acknowledged is how far the plan policies have been implemented and what are the effects of the change to the housing environment condition, especially the emission of CO2. Experience of housing development practices generally addresses merely the aspect of correctness or distortion of space utilization, based on land usage that has been established before. Meanwhile, the change of utilization intensity that results in change of building density is rarely discussed. Consequently, its relation with CO2 emission controlling is not yet acknowledged.

Building density at urban housings is one of the aspects that causes inconsistency of housing landscape. With high building density which results in less open space, the speed of wind in housing areas is less than areas that are still open. This happens because the movement or flow of air at land surface is different than the movement of air at higher places (over land surface). The more dense the buildings in a housing area, the more dense the layer of air restrained, resulting in change of wind direction and speed. Furthermore, buildings will hamper or distort the movement of air and in the end cause thermal discomfort.

One of the ways to minimize thermal discomfort in urban housing areas with tropical climate is by optimizing the amount of air flow around and inside the buildings. Movement of air, or wind, happens when there is constant open space that does not interfere with the speed of the wind. Constant open space is available only when the building plan is not too dense, meaning that there is still space available between the buildings. According to the concept of building mass plan in tropical housings, open space or space in between buildings hold an important part in allowing air circulation or wind around the housing. Spaces between houses can be used to create cross ventilation, so that air may enter the houses, and the houses do not need electricity for air conditioning.

The building mass plan at Griya Martubung I Housing is intended for creating housing with low CO2 emission. Survey data shows that 23% of houses go through extension of house area as much as 2 to 2.5 times the house's former area. Moreover, 77% of houses; type 29, type 36, and type 54; have gone through extension of house area between 50% and 100%. This extension of house area has increased the building density at the housing, and causes thermal discomfort to residents due to air circulation and room lighting being hampered. To overcome this discomfort, the housing needs larger openings on the houses' exterior walls so that the air circulation and lighting can enter optimally.

Wind speed is needed for ventilation (for the health and comfort of house residents). For comfort, ventilation is useful for air cooling and preventing increase of humidity, especially in residential buildings. The need for ventilation depends on the number of people that occupies the building, and the function the building is intended for. A house needs to be at a position that crosses the direction of wind coming to cool the air temperature. The type, size, and position of window openings at the upper and lower part of the building also holds a part in increasing the effect of cross ventilation (movement of air) inside rooms, making it possible for the change of hot air and avoid increase of air humidity.

In general, for tropical areas such as at Griya Martubung I Housing, with average temperature of 23°C – 33°C and average humidity of 84% - 85%, building position that crosses the wind direction is more needed than that which crosses the sun radiation. This is because the solar heat can be dealt with the blowing wind, whether the wind blows due to the shape of the house's roof, or due to the design of walls and window openings. The amount of air circulation that enters a house depends on the speed of released wind, the direction of wind against the ventilation openings, the size of the ventilation openings, the distance between openings for air entering the room and openings for air leaving the room, also the density of buildings that may hold back wind from entering the house.

The density of buildings in a housing is the ratio between the area of buildings and the total area of the housing area calculated in presentation. According to *Dinas Pekerjaan Umum* (2002), the classification of building density is as follows: low density if the density is less than 40%; medium density if it is between 40% and 60%; high density if it is between 60% and 80%; and very high density if it is greater than 80%. With 89% of houses, from type 29, type 36, or type 54, having gone through building extension as much as 50% to 100% of their original area, Griya Martubung I Housing has grown and developed into a housing with high density.

The building density in the development of urban housing is expected to be able to create a compact urban area, therefore contributing to the creation of more efficient public transportation and the increase of public facilities procurement. However, with the high density ratio, small lots, and the use of houses' side border areas for further development, the air circulation becomes hampered and sunlight does not optimally enter houses. If the intensity of land use for house development increases, the need for electricity for lighting and air conditioning will certainly rise. This condition will certainly increase CO2 emission.

In relation with CO2 emission, the general approach for transportation in land use planning is usually done by distributing centers of activities, public facilities, and social facilities in proximity with housing, so as to reduce the operational distance of vehicles and ease residents to walk around the housing area. Route planning, the mode of public transportation, and the road networks generally should go with policies for urban housing planning. Building density can be used to reduce the need of transportation.

As many as 97% of Griya Martubung I residents use their own transportation mode daily. More specifically 11% use cars, and 86% use motorcycles as means of transportation to support their daily activities. From the correlation of distance, working area, travel time, and transportation mode used, it is shown that the residents of Griya Martubung I Medan work relatively far from their house, thus not using the mode of walking to support their activities. Walking is still common to do in daily life. However, as one determinant factor in reducing CO2 emission, it is a misfortune that the housing is not provided with pedestrian facilities that have capacity for walking activities, especially inside the housing area. Pedestrian facilities for pedestrians in Griya Martubung I are not yet provided.

5. Conclusions

The various components of residential supporting environment system such as; householder, houses, building materials, parcels of land, building coverage, building layout, distance between buildings, density of buildings, housing utilities; play a direct or indirect part in producing emission of carbon dioxide. Establishment of BEP as a housing reconstruction permit still needs to be utilized to control residential supporting environment system. By establishing a tight policy on a reconstruction permit, any changes made would conform to rules, policies and regulations of low CO2 emissions in urban housing.

This study shows that the emission can be kept low if the dynamics of Griya Martubung I Housing is maintained by controlling residential supporting environment system. Based on the components of the system, ideas on policy to reduce CO2 emission can be deduced. These include appropriate concepts on housing alterations schemes; affordable low-emitted construction technology system; establishment of rules and policy to use low-emitted local materials; distribution of centers of activities, public facilities, and social facilities in proximity with housing blocks; enforcement of the role of government and Perum Perumnas to control BBC, BL, distance between building, building density, available utilities; minimum area required to support activities, sufficient ventilation and the use of daylight to minimize the use of energy.

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