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THE PLANNING AND DESIGN OF KAMPONG PAKUNCEN IN YOGYAKARTA BASED ON THE GREEN CONCEPT

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Abstract. This study aims to determine the green concept of a slum "kampong" with the green concept and carbon footprint approach based on daily activities, building materials and fuel consumption as well as to deliver the concept of renewable energy. The carbon footprint is the measure of total amount of carbon dioxide gas emissions directly or indirectly caused by daily main activities and accumulation of products used daily. It is the case study of Kampong *Gampingan-Pakuncen*, Yogyakarta. This kampong is known as a densely populated kampong located in the city centre not far from *Malioboro*, the centre of commercial and business districts in Yogyakarta City. The employed methods were the quantitative-comparative method between carbon footprint of existing and planning condition and the quantitative approach of renewable energy. The results showed that the carbon dioxide concentration of Kampong *Pakuncen* in the existing condition is 1,712.767 tonnes CO_2/month while the total amount of carbon dioxide concentration of the design is 1,293.785 tonnes CO_2/month, hence 24.462% carbon dioxide concentration reduction. To save energy consumption in daily activities, it is proposed that water wheel as micro-hydro power should be used for electricity.

Keywords: carbon dioxide concentration, slum, city kampong, sustainable, renewable energy, comparative method.

Introduction

Indonesia is the fourth most populous country in the world having a large percentage of the younger and productive generation. With the unstable nature conditions due to frequent disasters, there are many slums in Indonesian cities, and this phenomenon, furthermore, reflects poverty. Slum villages in urban areas called "slum kampong" have become the concern of the Indonesian Government that already created the Kampong Improvement Program (KIP) to solve this problem until 2016. In 2016, the government through the Ministry of Public Works and Public Housing has issued the RP2KPKP program, the national program of Action Planning for Preventing and Improving the Quality of Urban Slum Settlements, continuing the KIP to eradicate slum in Indonesian kampongs and villages (Ministry of Public Works and People Housing, 2016a, 2016b). In connection with the low carbon eco-district movement initiated by the Indonesian Government, the Ministry of Public Works and People Housing has scheduled several pilot projects in order to create villages without slums based on low carbon concept. One of the pilot projects that has become the focus in the Low Carbon Eco-District (LCED) program is Kampong Gampingan-*Pakuncen, Yogyakarta*. The kampong is located in the eastern side of the *Yogyakarta* City, close to the famous *Malioboro* street area. The socio-cultural condition of this kampong is traders and urban people living within the downhill land and building leasing system done by the landowners. The problem is that there are slummy housing, poor sanitation, and dense and poor infrastructures. Meanwhile, residents refuse to move because of some reasons related to their employment and their poor condition. Slum improvement is developed with the concept of low carbon to reduce and prevent carbon dioxide emissions that trigger global warming. Some studies on low carbon concept villages have been discussed several times, but no study has discussed how the concept of low carbon is applied significantly to urban villages with calculations related to the carbon footprint and adjusting densification of slum housing or verticalization as well as the utilization of renewable energy.

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The concept of low carbon city by Chao and Li who displayed the city model of new eco-city of Tianjin in China (Cao & Li, 2011). The integrated development of Tianjin's eco-city economy, society, population, natural resources and environment with the urbanists' characters was approached with the concept of low carbon. Although their paper stated that the low carbon city concept was inevitable due to the solution of the urban bottleneck development and opening the opportunity of industry to get commercial activities in cities, there was no calculation of the carbon footprint of the Tianjin city yet. The similar study has been discussed by Su et al., in which they focused on the viewpoint of how to explore the low carbon city concepts to be implemented in subsequent development in cities (Su, Chen, Xing, Chen, & Yang, 2012). In their paper, they have not discussed the real calculation of carbon footprint in cities to ensure how to reduce it regarding the low carbon concepts implementations.

Unlike those studies above, Tan et al. developed low carbon city (LCCI) framework to evaluate the rank of low carbon level of 10 cities in the world (Tan, Yang, & Yan, 2015). The results showed that the low carbon level of cities in Asia and America were lower than that of the European cities due to fewer activities regarding the use of fuels and variables of good environment and good infrastructures. Similarly to Tan et al., study, several studies also discussed the low carbon concepts in several cities in the world (Jiang, Chen, Xu, Dong, & Kennedy, 2013; Ruan, Cao, Feng, & Li, 2017; Webb, Hawkey, & Tingey, 2016). Not only for the new-big cities like Tianjin, the low carbon concepts were also applied for the low density medium city, as stated in Bengers' research (Benger, 2014). He studied the CO_2 emission towards the spatial explicitement through the whole city of Adelaide, a southern Australian city which poorly responds to the development concept of low carbon cities although there is a huge amount of renewable energy and many good government policies of environment aspects (Benger, 2014). The paper stated that the amount of carbon emission was in line with the houses' dimension, the number of rooms, number of vehicles used in daily activities, and the distance of public transportation to the daily destinations. The calculations were only focused on the carbon emission regarding the people and activities in their households, but the carbon footprints material has not been discussed yet.

Many studies discussed the theory and concepts of low carbon city development, but they have not explicitly discussed the calculation of the carbon footprint and how to reduce the carbon footprint related to the design and planning of the eco-city concepts (Mulugetta & Urban, 2010; Williams, 2016; Xie, Gao, He, & Feng, 2016). Williams, for example, discussed correlation between the low carbon city concepts and the regime change. The paper observed the urban transitional experiment ability to change the development done by the regime that has been stucked in the city. This paper also proposed the macro policy related to the low carbon concepts. Cultural concepts such as zero carbon can influence development regime in different viewpoints, but it needs to produce a new development model which was relevant to the context of development regime. The integrated approach structures and practices would be much more difficult to be implemented in the whole historical and geographical contexts. The same macro policies have been discussed in many references regarding the low carbon concepts in city developments (Ge, Luo, & Lu, 2017; Jenssen, König, & Eltrop, 2014; Moriarty & Wang, 2014).

Issuing the low carbon concepts is not only declaring the micro to macro policies which presents improving rurals, villages and cities, but it also proposing the efforts to alter the natural energy and waste management. The study conducted by Bong, et al. discussed composting the organic waste from the daily activities as an effort to enhance the green and sustainable environment (Bong et al., 2017). The paper aimed to highlight the economic and environmental impacts of composting process on the crude palm oil plantation, palm oil mills and the society who implemented the composting of organic waste. The interesting result was that a potential GHG emission around 71.64% from the composting process could be obtained. Based on these theoretical reviews of low carbon concept, this paper highlights the concept of low carbon kampong based on planning of densification, calculation of low carbon and the effort to reduce carbon dioxide concentration based on carbon footprint calculations through the design on renewable energy. The efforts have never been discussed in many studies related to the low carbon concepts implementation towards the slum villages around the world.

1. Materials and methods

This research used both qualitative and quantitative approaches covering four stages starting with the initial observation on the kampong including determining the kampong's administrative area, interviewing the key persons of inhabitants, and conducting visual observation. The poor condition of Kampong *Pakuncen* was presented using the descriptive method. In the second stage, the Focus Group Discussion (FGD) was held involving inhabitants, government representation, academicians and researchers. In this stage, the spatial planning was developed based on suggestion and advices obtained from the FGD. Furthemore, the presentation regarding the draft of spatial planning was presented in front of inhabitants' representatives, researchers and members of the previous FGD. On the other hand, the technological aspects in the third stage, such as the carbon footprint and renewable energy were described in different ways.

The quantitative method used was the comparative method between carbondioxide concentration of existing condition and that of the planning condition. The calculation of carbondioxide concentration was done with equations based on the references to calculate the Primary Carbon Footprint (PCF), Secondary Carbon Footprint (SCF) and Material Carbon Footprint (MCF) in order to obtain the Total Carbon Footprint (CF) of the Kampong

Pakuncen. Refer to studies, there has been modification to identify and to approach the carbon dioxide concentration from the carbon emission through calculating the difference of ground floor area between existing and planning condition (Astari, 2012; Seo & Hwang, 2001). The equations of PCF (Primary Carbon Footprint) were calculated based on the fuel used by inhabitants for daily activities such as cooking and artificial lighting. The survey data were found that 90% of household used 12 kg LPG (liquid petroleum gas) and only 10% of them used crude oil or kerosene for daily activities. For the next step, the Secondary Carbon Footprint was derived from the amount of electric energy which was used as much as 450 KWh for each house and the MPC (material carbon footprint) could be calculated from the model of 21 sqm house model with various kinds of wall, red brick, concrete brick and stone representing materials used on housings in kampong *Pakuncen*. The equations of the carbon footprint is described on Equation 1-3 (Seo & Hwang, 2001; Sudjono & Yudhi, 2011).

$$P_{ey} = F_{cy} \times EFCO_2 \times NCF_{LPG}. \quad (1)$$

The P_{ey} is the total CO_2 emissions, F_{cy} is the consumption of CO_2 emissions in kg, EF CO_2 is the emission factor of LPG 17.2 gram carbon/month, NCF_{LPG} is the net weight of 48.852 MJ/kg LPG. Furthermore, the calculation of PCF when a household uses the crude oil/kerosene as much as 20 liters/month is (noted that 1 liter kerosene is equal to 0.8 kg kerosene) (Seo & Hwang, 2001).

$$B_{ey} = EF_{kerosene} \times FC_{kerosene} \times NCV_{kerosene}. \quad (2)$$

The B_{ey} is total the CO_2 emissions, $Ef_{kerosene}$ is the emission factor of kerosene 19.4 gram Carbon/MJ, $Fc_{kerosene}$ is the kerosene consumption in kg, the NCV kerosene is 44.75 MJ/kg. For the Secondary Carbon Footprint (SCF), the assumptions use the type of plant and fuel where the factor values CO_2 emissions of 586.32 tonnes CO_2/GWh or equivalent to 0.000586 tonnes CO_2/KWh. Calculation for power consumption 1 household/month is as much as 450 KWh (Seo & Hwang, 2001).

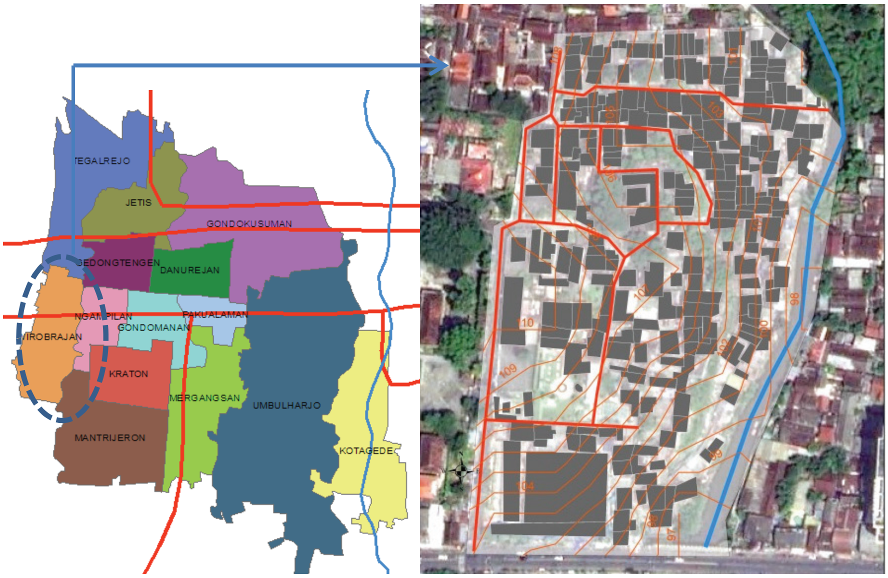
$$\mathrm{EF} = \mathrm{SCF} \times \mathrm{NCF} \times \mathrm{CEF} \times \mathrm{Oxid} \times 44/12. \quad (3)$$

The EF is CO_2 emission factor, the electrical consumption in mass unit/MWh. SFC; furthermore, stands for Specific Fuel Consumption while NCV stands for Net Calorivic Volume (the energy content) per mass unit or fossil fuel volume (TI /tonne fuel). CEF stands for Carbon Emission Factor (tonne CO_2/TJ), and Oxid means oxidation factors.

For the renewable energy concepts, calculations and descriptions were described by considering references related to the topics of waste water management, energy, electricity, and solar potential which are available abundantly in the pilot project due to the tropical climate region. Similar to the previous FGD, the second FGD on the last stage discussed the final design and planning of the Kampong *Pakuncen* as a low carbon kampong covering spatial planning, mapping of the renewable energy, verticalization of housing in the river bank, and the communal facilities needed by inhabitants for better future. To make clearer the description of the stages in this study, Table 1 shows the actions of the four stages and the data collection which were obtained in this research.

Table 1. The Stages of study, the data collection and data analyses

Stage of study	Technique of Data Collection	Aims of the data inventory	Method of Analyses
First stage	Visual Field Observation	To collect the physical and non physical data in correlation with content of space, activities and circulation	Descriptive and Spatial Mapping Analyses
	Interview	To have the problem and demographic data regarding number of inhabitants in age, gender, and fuel use.	
Second stage	Focus Group Discussion	To receive the inhabitants needs, aspiration and hope as well as to enrich the planning and design idea of the green concept of the kampong.	Descriptive Analyses
	Exploring the Spatial Concept		Spatial Mapping Analyses
Third Stage	Survey Data	To obtain the daily fuel used by inhabiyany	Content Analyses
	Calculation of Carbon Footprint and carbon dioxide concentration	Calculate the difference of total ground floor area before an after the housing densification through verticalization.	Quantitative Analyses
	Theoritical Review	Collaborating the theory of renewable energy and green concept to the factual condition and constrain in the field study	Descriptive and Comparative Analyses
Fouth Stage	Focus Group Discussion	Delivering the concept to the inhabitants, government and having feedback again from them to improve the planning and design.	Descriptive and Spatial Mapping Analyses
	Final Concept, Planning and Design	To obtain the green concept of the kampong and determining the renewable energy system.	Spatial and conceptual analyses



(a) (b)

Figure 1. (a) The map of Yogyakarta; (b) The map of Kampong Pakuncen

Located in the city center of Yogyakarta, Kampong *Gampingan-Pakuncen* has been chosen as a pilot project due to its high density population who lives in poor condition and lives near the River Winongo on the eastern side. Kampong Pakuncen is a kampong in subdistrict Wirobrajan, District Wirobrajan, Yogyakarta City. The kampong consists of four neighborhood units (RT stand for *Rukun Tetangga*), the smallest group of houses including 30-100 households depend on the size of kampong area which has perimeter at least 4 Ha.

A group of 4-10 RTs becomes an RW (community units, stands for *Rukun Warga*) depend on the area of either kampong or village refer to the Indonesian government. RT which stands for *Rukun Tetangga* is the institution formed through local community consultations in the framework of government services and community defined by the head of village or kampong called Lurah (The Indonesian government, 2007, 2015) In this study, actually having more than 12 RWs, the RW 11 in Kampong *Pakuncen* had been selected as the object of the researh. This RW as object parameter has four RTs covering RT 48, RT 49, RT 50 and RT 51. Further illustration of the kampong location can be seen in the Figure 1.

2. Results and discussions

The pilot project of Kampong Gampingan-*Pakuncen* is delimited by Jalan (street) Prof. Amri Yahya in the west, *Jalan* Achmad Dachlan in the south, and the *Winongo* River in the east. Actually there are two other rivers in Yogyakarta city, *Code* and *Gajahwong* rivers, the *Winongo* river has an important role to this kampong. In the southern part of the kampong, lies the Secret Garden coffee shop, the garbage center point and the local market. Most of the pathways within the kampong are narrow with limited vehicles access to be passed in two directions (see Figure 1b). The river is dirty with lots of garbage thrown by inhabitants sporadically. From the observation conducted by researchers, the data regarding the kampong condition and the expectation of inhabitant are described in Table 2.

The poor conditions of infrastructures and components listed in Table 2 are described in Figure 2. The narrow concrete street in western side of Kampong *Pakuncen* can be only accessed one way with motorbikes (see Figure 2a). The similar conditions are seen in Figures 2b and 2c that describe lack of spaces between housing and the river. For these problems, there should be an access for motorbikes or other vehicles along the river so the connectivity among parts of kampong can be easily accessed by the inhabitants. The next figure (see Figure 2d) shows a shortage of drinkable water when the kampong only has limited number of communal wells providing clean water, the water closets without septic tanks, and the grey water is directly disposed to the river.

As a number of studies argued about slum and poverty in city (Astuti, 2009; Rolfes, 2010; Widhianthini, 2017), becomes a prolonged polemic. Some studies argued about the government policies to eradicate poverty in towns and cities (Sankhe et al., 2010; Sugranyes & Mathivet, 2010; The Shack Dwellers Federation Of Namibia, 2009), the rest studies talked about the community approaches based on upstream acts (Abdelhalim, 2010; Frisch, 2012). During a coupled of decades, scientists of urban design discussed slum housings and solutions to make the urban area better. For example, the urban acupuncture concepts were proposed in studies such as: slum housings in hillside of Morros dos Prazeres Favela, Rio de Janeiro (Frisch, 2012; Lerner, 2014), revitalization of the Cheonggyecheon river in Seoul, South Korea, Shibuya Crossing in Tokyo, Japan (Lerner, 2014), and many other in parts of worldwide spaces. The urban acupuncture concept was then proposed covers accessibility, public open spaces, self aided housings for low income, and waste management including trash and garbage (Harjoko, 2009; Shidan & Qian, 2011).

Continuing on the discussion about the bad condition in the kampong Pakuncen, refer to those studies, the improvement should be divided into several solutions covering low carbon footprint and adjusting the housing densification, renewable energy system and solar energy following consideration that the Yogyakarta has a tropical climate with an adequate solar radiation and rain water. The discussion about the concepts will be explained in the next subheadings.

The solution and efforts to improve the kampong were discussed based on the components listed in Table 2 starting from sanitation and waste, clean water, electricity, river bank and environment. The schematic renewable energy is needed in the next chapter to describe the strategy in accommodating inhabitants' needs regarding the components and its implementation in the Kampong *Gampingan-Pakuncen*. The improvement program always needs community participation to realize the strategy and development, so the kampong will be able to grow based

(a) (b) (c) (d)

Figure 2. The real poor condition of Kampong Gampingan-Pakuncen: (a) The western access on the narrow concrete street; (b) The lack of space between the housing and the river; (c) A street al.ng the river is needed for vehicle access; (d) Limited communal wells serving limited drinkable water for inhabitants

Table 2. Kampong conditions and expectation of inhabitant in kampong Gampingan-Pakuncen

The components of the kampong	General condition	Expectation from inhabitants
Sanitation and waste	– Inhabitants' bad behavior in littering at the River Winongo. – Large number of rats due to bad sanitation. – Water closets and toilets are not equipped by septic tank. – Insufficient black water and grey water sanitation.	– Having garbage collecting center in several points. – Having waste management system to reduce rats and having a better life with recycling system. – Having a better drainage system.
Clean water	– Limited number of wells where drinkable water is available. – Communal wells do not have infiltration tanks, hence grey water flowing directly to the river. – Unhealthy condition of communal wells.	– More communal wells which serve sufficient drinkable water. – Having communal sanitation able to serve 80-90 household waste. – Having sanitation with adequate dimension to contain rain water in order to prevent flood.
Electricity	– Difficulity in paying electricity budget due to low income. – The inhabitants' desire to reduce the budget of daily electricity needs.	– Energy alternative from solar or water from the River Winongo.
River bank	– No space between the housing and the river.	– Having pedestrian space between the housing and the river.
Environment	– Highly densly populated condition without green open spaces that bring the healthy atmosphere. – No communal space for meeting and hanging out. – No land consolidation and no adjusting densification. – No recreation area for the community.	– Having several spots of green open spaces for better living and healthy environment. – Having a building for meeting and sport activities. – Solution of vertical housing to adjust densification and to add more open spaces.

on the community demands and can be supported by the local government that also involves third parties who have purposes in developing the kampong. The kampong Pakuncen lies in the Wirobrajan Sub-district, Yogyakarta city. Actually the Wirobajan subdistrict has more than 50 RTs (Central Bureau of Statistics, 2017b, 2017a), but focussing on the pilot perimeter, this study was limited on observation in the RW #11. The RW 11 has four RTs bordering the Winongo river and the inhabitants live in poor condition as mentioned in the previous explanation. The following data on Table 3 are demographic data presenting the number of population and the percentage of population based on ages.

The data shown in Table 3 and Figure 3 describe that the inhabitants of kampong Pakuncen are 75% under 50 years old and at least 50% of population are under 30 years old. It can be concluded that the dominant group within the population is the young generation and it will be potential factor for the kampong improvement based on the community participation.

Table 3. Number of population in Kampong *Pakuncen*

Areas	Families	Inhabitants
RT 48	97	299
RT 49	78	258
RT 50	83	287
RT 51	66	199
Total	324	1.043

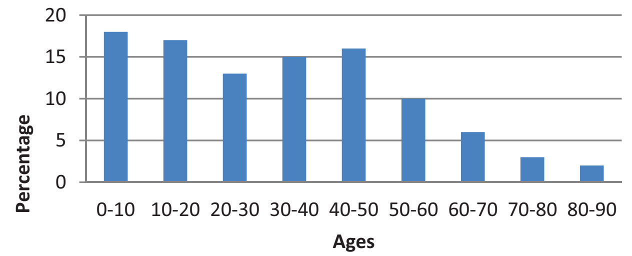


Figure 3. The age percentage of Kampong Pakuncen population (organized from the kampong data)

2.1. Low carbon footprint and adjusting the densification

According to the field observation, the kampong Pakuncen can be separated into two zones, the upper zone in the western part and the lower zone in the eastern part which is delimited by the Winongo river. The upper zone has housings in better condition than that of the lower zone which extend until the cliff next to the river. As the lower zone has housing with poor condition and lack of bordering spaces to the river, this densely populated zone should be adjusted on their densification by verticalization (see Figure 4b). The verticalization of housing is implemented in order to make some green public open spaces and to widen the circulation, access and the streets within the kampong. Adjusting the densification becomes very important for the kampong, because it will give more green open spaces and landscape area (Mapes & Wolch, 2011; Smith, Clayden, & Dunnett, 2009). Furthermore, the verticalization concept should be applied as green as possible. Due to the previous research of modular housing was made of waste and there is consideration about the constraints in the field, it was proposed that the housing in the lower zone was in modular-vertical ways (Setyowati & Pandelaki, 2018).

The verticalization of housing is not only to reduce the density but also to reduce the carbon dioxide concentration because the more the green open spaces, the more

(a) (b)

Figure 4. (a) The existing ground floor area; (b) The planned ground floor area after verticalization

the oxygen produced in the kampong. The calculation of the carbon footprint in Kampong Pakuncen used the carbon footprint model of 21 m^2 house type shown in the next Table 5. The activities and the building materials used were assumed as they were in 21 m^2 housing with three different types of materials; namely, red bricks, concrete hollow brick and stone. The total building floor area was calculated from the existing map of the Kampong Pakuncen while the planned total floor area after verticalization was calculated from the planned map following the existing map to predict the carbon dioxide concentration. The calculation of Carbon Footprint was based on the type 21 m^2 house as the model house with the assumption that each house was occupied by 4 people (parents and two children). Based on the calculation, the houses' carbon footprint per sqm is 96.118 kg/sqm Furthermore, the ground-building floor area of the kampong in existing condition and planning condition were 16,895.530 sqm and 12,536.480 sqm respectively (see Figure 4 and the next Table 6). Due to the calculation result of carbon footprint per square was 96.118 kg CO_2/ sqm, the calculation of the total carbon footprint at Kampong Pakuncen in both existing and planned condition were 1.623.964.550 kg CO_2 and 1.204.981.390 kg CO_2 respectively. Finally, in connection with those results, it can be concluded that the planning and design of Kampong Pakuncen can reduce the carbon dioxide concentration as much as 24.460 % (see Table 6):

The calculation of carbon dioxide concentration could be approached by the calculation of the carbon footprint in Kampong *Pakuncen* consists of the primary carbon footprint (PCF), the secondary carbon footprint (SCF) and the material carbon footprint (MCF). The primary and secondary carbon footprints are caused by the energy from LPG (Liquid Petroleum Gas) or kerosene for daily cooking and electricity respectively. Meanwhile the material carbon footprint is the use of building materials for houses in the kampong (Seo & Hwang, 2001).

The primary carbon footprint can be calculated based on the data that 90% of households (292 houses) use 12 kg LPG and only 10% of households (32 houses) use crude oil or kerosene for cooking and other daily activities (see Table 4). The calculation of the primary carbon footprint (PCF) for one house per month when a household consumes 12 kg LPG (Seo & Hwang, 2001).

Based on the Table 4, that total amount of households used the LPG is 292 households, while only 32 households used the crude oil or kerosene. Refer to these data, the Primary Carbon Footprint can be calculated as:

$$P_{ey} = F_{cy} \times EFCO_2 \times NCF_{LPG}$$
$$P_{ey} = 12kg \times 17.2 gramsCarbonMJ \times 48.852 MJ / kg$$
$$P_{ey} = 10,083 gramsCarbon / household \ / month$$
$$P_{ey} = 0.010083 \ tonnes\ Carbon / household \ / month. \quad (4)$$

The EF CO_2 is the emission factor of LPG 17.2 gram carbon/month, NCF_{LPG} is the net weight of 48.852 MJ/kg LPG. Furthermore, the calculation of PCF when a household uses the crude oil/kerosene as much as 20 liters/month is described in Equation (5) which is noted that 1 liter kerosene is equal to 0.8 kg kerosene (Seo & Hwang, 2001):

$$B_{ey} = EF_{kerosene} \times FC_{kerosene} \times NCV_{kerosene}$$
$$B_{ey} = 16kg \times 19.4 gramsCarbon / MJ \times 44.75 MJ / kg$$
$$B_{ey} = 13,890.4 \text{gramsCarbon / household \ / month}$$
$$B_{ey} = 0.013890 \text{ tonnes Carbon / household \ / month}. \quad (5)$$

The $EF_{kerosene}$ is the emission factor of kerosene 19.4 gram Carbon/MJ, $Fc_{kerosene}$ is the kerosene consumption in kg, the NCV kerosene is 44.75 MJ/kg. For the Secondary Carbon Footprint (SCF), the assumptions use the type of plant and fuel where the factor values CO_2 emissions of 586.32 tonnes CO_2/GWh or equivalent to 0.000586 tonnes CO_2/KWh. Calculation for power consumption 1 household/month is as much as 450 KWh (Seo & Hwang, 2001):

$$EF = SCF \times NCF \times CEF \times Oxid \times 44 / 12$$
$$Emission\ CO_2 = EF \times Electricity$$
$$Emission\ CO_2 = 450 KWh \times 0.000586 tonnesCO_2 / KWh$$
$$Emission\ CO_2 = 0.2637\ tonnesCO_2 / household / month. \quad (6)$$

These results present the total of secondary emissions from the use of electricity as much as 0.2637 tonnes of CO_2/household/month. The further discussion is about the material carbon footprint (MCF) using the house with 21 sqm type to find out the average MCF per sqm for the floor area. The model of the house consists of a 9 sqm

Table 4. Total amount of households used daily fuel and type of house wall per RT

RT*	Households	Type of daily fuel used		Type of house wall construction		
		LPG	Kerosene	Red-Brick	Hollow concrete brick	Stone
48	97	87	10	50	42	5
49	78	70	8	44	30	4
50	83	74	9	45	31	7
51	66	61	5	33	25	8
Total	324	292	32	172	128	24

Note: *RT stand for Rukun Tetangga, a group of 30–100 households depend on the size of kampong or village area (The Indonesian government, 2007, 2015).

bedroom, a 9 sqm living room and a 3 sqm toilet. In connection with the material types of the housing, it can be categorized in three types as described in Table 5 below:

Table 5 deals with the results in Table 4, both tables describe three types of house walls used in kampong Pakuncen. Refer to the Table 4, number of houses with red brick walls, hollow concrete and stone are 172, 128 and 24 units respectively. To simplify the calculation of the material carbon footprint (MCF), Table 5 describes the average MCF in both per household and per square meter. As a result, the average MCF in the village is 2.0185 per household or 0.0961 per sqm (see Table 5).

Studies relating to simple house building models and calculation of CO_2 emissions have been carried out (Seo & Hwang, 2001; Sudjono & Yudhi, 2011). In their study, Sudjono dan Yudhi stated that the CO_2 emission is directly proportional to and in line with the area of the house, the type and volume of building materials and the complexity level of the construction process (Sudjono & Yudhi, 2011), while Astari observed Primary and Secondary Carbon Footprint in one settlement in Jakarta (Astari, 2012), furthermore Seo and Hwang studied lifecycle of residential building covering manufacture, construction process, operation and demolition (Seo & Hwang, 2001).

Table 5 shows that the 21 sqm houses in three types of material have their own MCF per household and MCF per sqm (see Table 5) and they have both average MCF per household as much as 2.0185 tonnes carbon and average MCF per sqm as much as 0.0961 tonnes carbon. Based on the results in the Table 6, then we can calculate the total carbon dioxide concentration of kampong Pakuncen either for the existing condition or for the planning one (Astari, 2012; Seo & Hwang, 2001; Sudjono & Yudhi, 2011). The Table 6 presents the carbon dioxide concentration derived from the carbon footprint of kampong Pakuncen both for the existing condition and for the planning condition. As presvioulу mentioned, that the total carbon footprint consists of PCF (primary), SCF (Secondary) and MCF (material carbon footprint). The calculation data that 90% of the households (232 houses) use LPG and only 10% of household (32 houses) use crude oil or kerosene were obtained by survey data on the Table 4. The final results show that total numbers of Carbon dioxide concentration (CF) of kampong Pakuncen both the existing condition and for the planning one are 1,712.767 tonnes/month and 1,293.785 tonnes/month respectively. Therefore, it can be concluded that there is carbon footprint reduction in Kampong Pakuncen as much as 24.462% (see Table 6).

2.2. Renewable energy concepts

Following the discussion regarding the green concepts of renewable energy in Kampong *Pakuncen,* below is the schematic diagram of the renewable energy implemented in the kampong consisting of rain water harvesting, solar energy, water wheels and communal sanitation calculation based on on the number of inhabitants (see Figure 5).

Figure 5 illustrates the renewable energy concept in the kampong *Pakuncen*. Due to the huge amount of rainy days in Yogyakarta city (Central Bureau of Statistics, 2017b), the rain water harvesting could be implemented, while the lots of population in the kampong means a big volume of solid waste (CH_4) is available to be recycled as

Table 5. The Average of MCF (Material Carbon Footprint) per sqm of floor area

House (sqm)	Wall types	MCF/ Households (T)	Average MCF/ Households (T)	MCF/ sqm (T)	Average MCF/ sqm (T)
21 sqm	Red-brick	2.0385	2.0185	0.0971	0.0961
	Hollow Concrete	2.0156		0.0959	
	Stone	2.0013		0.0953	

Table 6. Carbon Footprint of Kampong Pakuncen – existing and planning per month

Carbon dioxide Concentration – Existing Condition									
Houses	PCF (T)	Sub total	SCF (T)	Sub total	MCF/ sqm (T)	Ground Floor area (sqm)	Total MCF (T)	Sub Total CF (T)	TOTAL CF (T)
292	0.010	2.920	0.2637*	77.0004	0.0961**	15,226.836	1,463.573	1,543.493	1,712.767
32	0.014	0.445	0.2637*	8.4384	0.0961**	1,668.694	160.392	169.274	
Carbon dioxide Concentration – Planning									
Houses	PCF (T)	Sub total	SCF (T)	Sub total	MCF/ sqm (T)	Ground Floor area (sqm)	Total MCF (T)	Sub Total CF (T)	TOTAL CF (T)
292	0.010	2.920	0.2637*	77.0004	0.0961**	11,298.309	1,085.971	1,165.891	1,293.785
32	0.014	0.445	0.2637*	8.4384	0.0961**	1,238.171	119.011	127.893	
The difference of the CF (Carbon dioxide concentration) between the existing condition and the planning									418.982
The reduction percentage of carbon dioxide Concentration of Kampong Pakuncen									24.462%

(see calculation on the Equation 3) ** see the Table 5

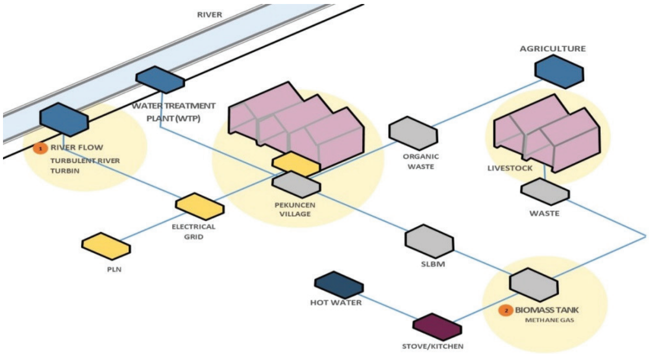


Figure 5. The schematic diagram of renewable energy in Kampong *Pakuncen*, Yogyakarta

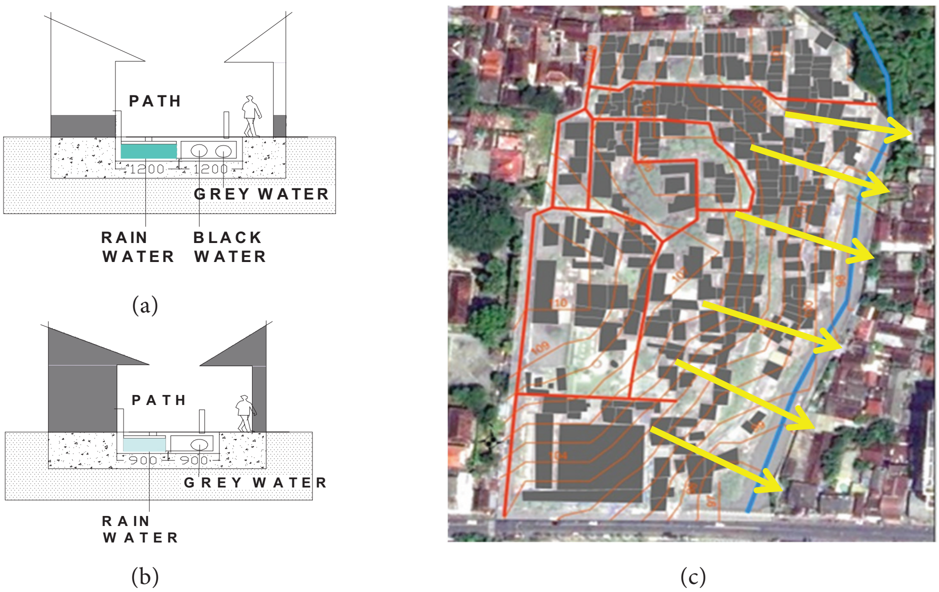
biogass energy in Communal Solid Waste Plant (*Sanitasi Lingkungan Berbasis Masyarakat* abbreviated as *SLBM*). Furthermore, the river has an important role as alternative energy of Microhydro energy which is explained in the next subheading.

2.3. The drainage and waste water management system

Water is one of the most potential natural resources in Kampong Pakuncen. Not only because there are always heavy rainy days in rainy seasons, but there is also the Winongo river that serves primary water resource in the kampong. The water management system consists of drainage, grey and black water system, sewage treatment plant and rain water harvesting for drinkable water. The drainage system should be planned, and there are three types. The first is the primary drainage; that is the Winongo River as one of three potential rivers in Yogyakarta. The secondary drainage; moreover, was enlarged from its previous dimension that had 1.50 meters in depth and 1.20 meters in width flowing the grey and black water in separated concrete subdrainage (see Figure 6a). Meanwhile, the tertiary drainage will have 1.00 meters in depth and 1.00 meters in width flowing only grey water inside it (see Figure 6b). The large secondary drainage was arranged to support the largest hierarchy of roads and paths, whereas the smaller tertiary drainage was proposed following the lowest road hierarchy. The pattern of drainage flow arrangement can be seen in Figure 6c.

The low carbon concept for the drainage system in Kampong *Pakuncen* aims to reduce the number of rats, enlarge the dimension of drainage, and create the grey and black water waste management by making a communal sanitation system accommodating at least 80 households. The system should be implemented in the kampong because it can cut down the budget of Sewage Treatment Plant construction. To describe this water management system, below is the calculation of the system. Based on the number of inhabitants in Kampong Pakuncen, the Table 7 describes the total daily water consumption per day in Kampong Pakuncen. Refer to the standard of SNI Number 03-7065-2005 on Plumbing Planning System and Procedure (Standardization, 2005), the average consumption of daily water per inhabitant is 120 liters, so the total of daily water consumption according to the type of activities can be calculated in Table 8.

Reducing the dependence on clean water supply from the regional government, through city-owned water company (PDAM), Kampong *Pakuncen* will have water management system where the sources are from rain water



Legends:

Housings · space between housings · kampongs' streets · flow of drainage

Figure 6. (a) Secondary and (b) Tertiary Drainage systems; (c) The pattern of drainage flow in Kampong Pakuncen

and grey water produced from the daily activities; which is then processed by the water treatment system. The black water comes from the toilet can be calculated as the sewage treatment plants or as the Communal Solid Waste System (SLBM stands for *Sanitasi Lingkungan Berbasis Masyarakat*) and furtherly distributed in two groups, the area of RT 48 and 49 and the area of RT 50 and 51. The calculations of clean, grey and black water in the kampong (Table 9):

Refer to Jain, rain water is much cleaner than the grey water due to risk of infections. Although consisting several contaminant such as: dust, gases, living organism in the atmosphere and pollutant in the collecting tanks surface, the rain water harvesting is an appropriate alternative for clean water supply system (Jain, 2009). The most often gaseous content in rain water are nitrogen and oxygen. The increasing content of carbon and sulfur dioxide causes the acidity

Table 7. Total Water Consumption of Kampong *Pakuncen*

RT*	Households	Number of inhabitants	Water consumption (liters)	Total (liters/day)
48	97	299	120	35.880
49	78	258	120	30.960
50	83	287	120	34.440
51	66	199	120	23.880
Total	324	1043		125.160

*RT (Rukun Tetangga) is a smallest group of houses in the kampong containing 30-100 households depend on the size of area (The Indonesian government, 2007, 2015).

Table 8. Allocation of water per day in Kampong *Pakuncen*

Allocation	Type of Activities		Percentage (%)	Water used per day (liter)	Quantity (liter/day)
Grey water (GW)	a.	Taking a bath*	20	125.160	25.032
	b.	Doing laundry*	12	125.160	15.019
	c.	Doing dishes*	13	125.160	16.271
	d.	Washing hands*	8	125.160	10.013
	e.	Gardening*	6	125.160	7.510
	Sub Total				73.844
Black water (BW)		Toilet	35	125.160	43.806
Drinkable water (DW)		Drinkable water	6	125.160	7.510
Total water management = Subtotal + BW + DW					125.160

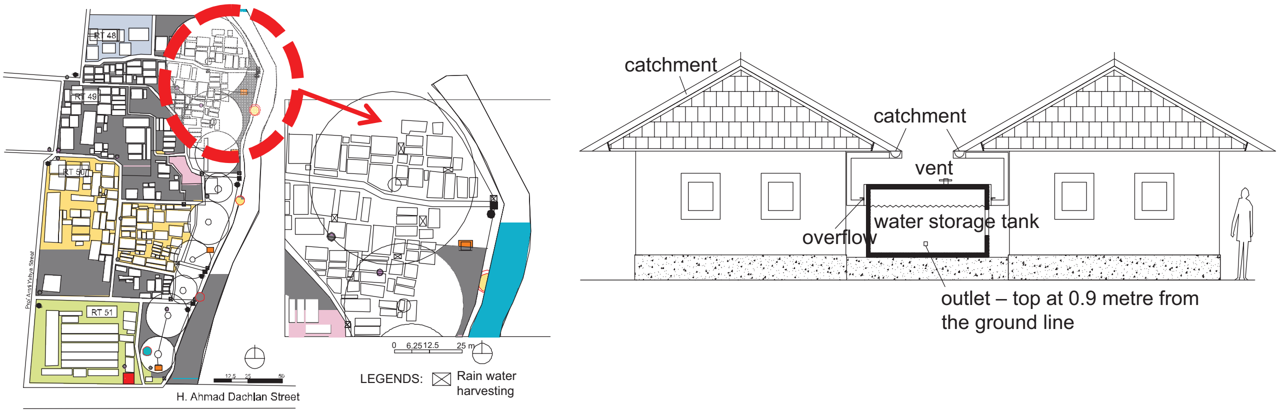
*The regulation of daily activities regarding grey water (Jain, 2009)

Table 9. Water management system of Kampong Pakuncen

Water management	Equation	Capacity (liters/day)	RT 48 and 49 (liters/day)	RT 50 and RT 51 (liters/day)
Grey Water	Grey water – (2% × grey water) = 73,844-1,476	72.368	38.647	33.721
Rain Water	= 31.000* × 0.298** = 9.238 m^3/month Rain water – (2% × rain water) = 307,933 – 6,159	301.774	161.158	140.616
Water Treatment Plant			161,158	140,616
Sewage Treatment Plant (Communal STP)	= Toilet waste – (2% × toilet waste) = 43.806 – 876	42.930	22.926 liters/day = 24 m^3 = 2 × 3 × 4 m^3	20.004 liters/day = 20 m^3 = 2 × 2,5 × 4 m^3
Drinkable water tank capacity	Drinking water – (2% × drinking water) = 7.510 – 150	7.360 liters/day	3.931 liters/day = 4000 liters	3.429 liters/day = 3500 liters
Grease Trap per 4 houses	Greased water – (2% × greased water) = 86***– 1	85 liters/day	90 liters/ 4 houses	

Area of kampong; **Rainfall in Yogyakarta in meter cubic (Central Bureau of Statistics, 2017b)

*** Volume of grease coming from kitchen and washing dishes.



(a) (b)

Figure 7. (a) illustrates that the housing groups implementing rain water harvesting system are located in the RT #48. The rain water is captured by the roof in a gutter-shaped catchment equipment by gravitation. The water is then flowed to the water storage tank placed between housings. For the detail, the tank in the (b) has vent pipe to maintain water contents oxygen, overflow and outlet to drain water and distribute into destination needs (Jain, 2009)

and corrosiveness in rain water, therefore rain water plantation should be built not only to provide clean and drinkable water but also to reduce the dependency on PDAM (Government institution serving and providing clean water). Depend on the kampong area, refer to the Jain findings, the rain water harvesting could be implemented in the kampong with the system as seen in Figure 7.

2.4. Energy and electricity

Generally water resources that have previously been managed are not only limited to the process of reservoir only, but they can also be used as the alternative of clean water resources to meet the needs of people at Kampong Pakuncen (only after filtering). On the other hand, the water resources can also be utilized as one of the alternative raw materials for power plants by utilizing technology of Micro Hydro Turbulence Water Turbine/MHTWT. Potential power sources contained in the flow of the Winongo River can be calculated as follows:

Table 10 reveals the measurements of the discharge in the Winongo river in m^3 / second. Measurements of the water discharge from the river are carried out 3 times in a row. In these measurements the Cross Sectional Area had four points which observed the discharge as seen in Figure 8(a). In 3 measurements, the water debit at points A, B, C, D has average debit 0.875, 0.900, 1.050 respectively. And from all of the points, the average debit was 0.942 m^3 /second. Based on the study conducted by Bilgili et. al., this finding tend to be categorized as small-scales hydro power energy (Bilgili, Bilirgen, Ozbek, Ekinci, & Demirdelen, 2018). Depend on this result, the river debit could be obtained as following the calculations.

As the CSA is the Cross Sectional Area, so the calculation becomes:

$$\begin{aligned} \mathrm{CSA} &= 0.087 \times 0.7 \\ \mathrm{CSA} &= 0.061\ m^2 . \end{aligned} \tag{7}$$

Therefore, the water debit can be calculated as:

$$\begin{aligned} \mathrm{Q} &= 0.061 \times 0.942 \\ \mathrm{Q} &= 0.057\ m^3 \ / \ second \\ \mathrm{Q} &= 57\ liters \ / \ second . \end{aligned} \tag{8}$$

To make clearer the discussion, the Figure 8 illustrates the section of the river basin and the model of the Micro hydro energy Plant (see Figure 8 a and b).

Water elevation in the Figure 8 (a) has four points in different height consist of 7 cm (Point A), 10 cm (Point B) and 9 cm (Point C). The equation applied to calculate the water energy is presented below:

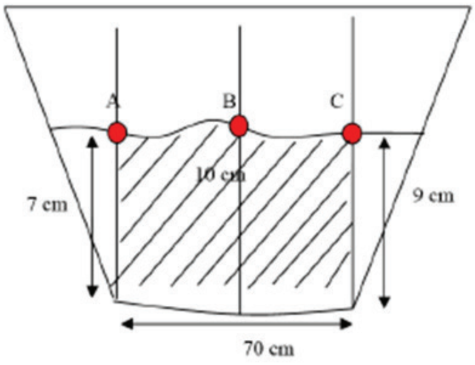
$$\mathrm{P} = \mathrm{Q} \times \mathrm{H} \times \mathrm{G} \times \mathrm{E} , \tag{9}$$

with P is power generated in Watt, Q is water debit in Liter/second, H is different level in meter, G is gravitation in 9.81 m/second and E is efficiency in 0.54 – 0.8. and:

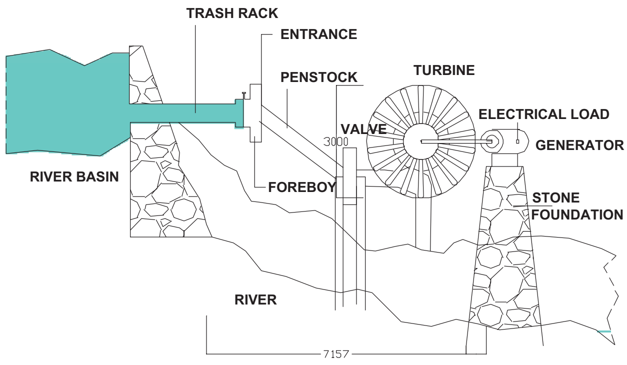
$$\begin{aligned} \mathrm{P} &= \mathrm{Q} \times \mathrm{H} \times \mathrm{G} \times \mathrm{E} \\ \mathrm{P} &= 57 \times 15 \times 9.81 \times 0.6 \\ \mathrm{P} &= 5{,}032.5 \text{ Watt} . \end{aligned} \tag{10}$$

Table 10. Average debit of the River Winongo

TRIALS	Point A	Point B	Point C	Point D	Average
1	0.500	1.000	1.500	0.500	0.875
2	0.600	1.000	1.500	0.500	0.900
3	0.600	1.500	1.500	0.600	1.050
Average Debit (m^3/second)					0.942



(a)



(b)

Figure 8. (a) Cross section of measurement of potential energy in the Winongo River; (b) The sample of the turbine that generates electricity for inhabitants

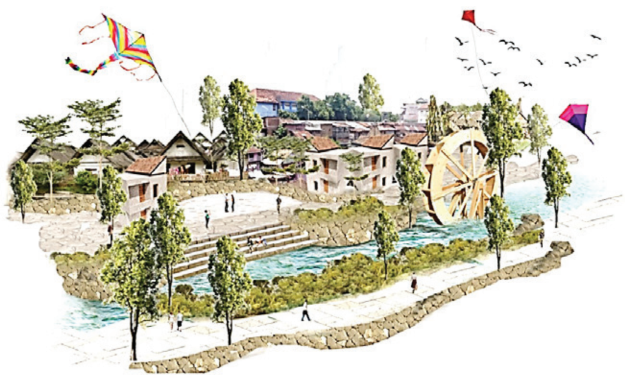
It is determined that the potential power in the Winongo river can be converted into energy as much as 10 times with the Small-scale Hydropower energy such as waterwheel (Bilgili et al., 2018), so it needs 3 units of waterwheels to accommodate the electricity need of inhabitants because the total electricity consumption of households in the kampong is 145,800 Watt as described in Table 11.

Table 11. The Electricity consumption per day in Kampong Pakuncen

RT*	Households	Electricity consumption (Watt)	Total (Watt)
48	97	450	43.650
49	78	450	35.100
50	83	450	37.350
51	66	450	29.700
Total	324		145.800

Hydropower energy becomes the most popular renewable energy in the world because there is no fossil fuel burnt on its power plant (Ali et al., 2016). The example of large hydro energy plant is Three Gorges Dam in China which generates 22,500 MW electricity, Itaipu Hydro electric power located between Brazil and Paraguay which produces 14,000 MW and many others, however there are several constraints on providing the hydropower plants due to microbial decomposition of submerged forest during the reservoir construction process (Ali et al., 2016; Bilgili et al., 2018). In this case, the kampong Pakuncen has potential Winongo river as a micro-hydro power energy which is beneficial for at least the kampongs' inhabitants electricity need. In architectural point of view, the micro-hydro power energy plant could be an eye catching in the kampong scenery as seen in the Figure 9 a and b. Supported by public open space near the micro-hydro power plant, the sequence will be a beautiful attraction for people passing through.

The design of atmosphere surrounding the water wheel illustrated in Figure 9 is about the green concept of the kampong *Pakuncen*. The healthy environment with more green open spaces is the focus of this research. The vertical housings are adjusting the densification, giving a lots of open spaces, subsidizing the oxygen to the environment and reducing the low carbon emission. If there are more green open spaces, the environment will be healthier and more beautiful where the children can play comfortably, people will be able to hang out with their friends, fish and other water creatures could live and breath healthily.



(a)

(b)

Figure 9. (a); (b) The atmosphere of the water wheel surroundings

2.5. Solar energy

To reduce the expensive cost of the water wheels construction, the alternative energy possible to utilize in Kampong Pakuncen is the solar energy. Indonesia is known as the tropical country, so there is much solar energy that can be harnessed in this kampong. Refer to the Table 11, the electricity consumption in Kampong Pakuncen is 145,800 Watt/day or 145.8 KWh per day. Refer to Walsh et al. study that solar panel with textured glass, EVA encapsulant, polymer backsheets, and standard frames can produce the electricity of 10kWp. Depend on his study, for the kampong Pakuncen, to obtain 145.8 KWh, we should have at least 15 multiple modules (Walsh, Xiong, & Sheng, 2012). Meanwhile, refer to Haques' study, the typical area of a single solar cell is 225 cm^2. With 10% cell efficiency the maximum power generated would be 2.25 Wp (Haque, 2016). Solar PV modules are various energy modules, materials and shapes. According to Haque, these solar PV cell modules are connected to each other so as to form larger modules with higher power. Power between 3 Wp to 200 Wp can be given by solar PV cells for certain purposes. These modules can be connected to form arrays. Solar PV arrays can provide power ranging from a few hundred watts to several megawatts (Haque, 2016). Depend on those studies, the module of PV solar panel can be calculated as (Haque, 2016):

$$\begin{aligned}
&\text{PV panel dimension} = \left(145{,}800 / 2.25\right) \times 225\ sqcm \\
&\text{PV panel dimension} = 64{,}800 \times 0.0225\, sqm \\
&\text{PV panel dimension} = 1{,}458\, sqm \\
&\text{3 PV panels with dimension} = 486\, sqm\, each\,. \qquad (11)
\end{aligned}$$

Depend on the kampongs' size of perimeter, the panel dimension would be dispersed into three points with 486 sqm each as seen in the Equation (11) and the Figure 10.

The renewable energy concept previously discussed above should be implemented in Kampong *Pakuncen*, Yogyakarta. The drainage, waste water management, rain water harvesting, water wheels and solar panel location in the kampong can be seen in the Figure 10.

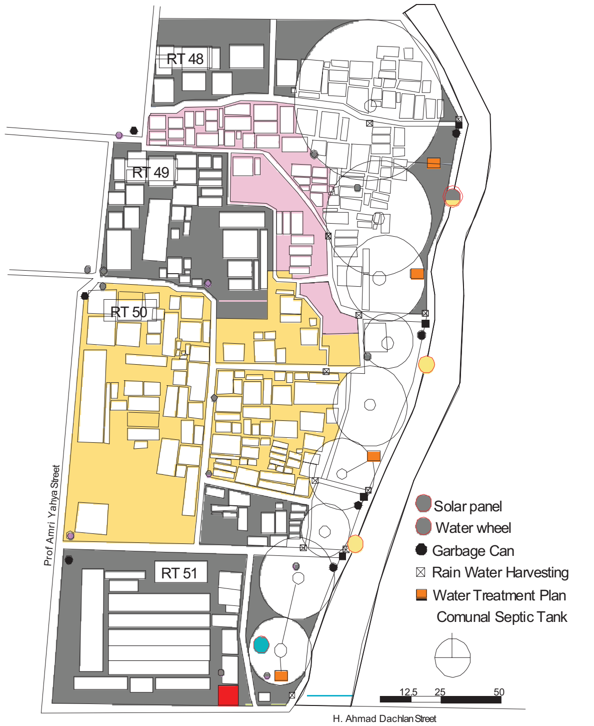


Figure 10. The sanitation, renewable energy and green concep of Kampong *Pakuncen*

Conclusions

By calculating carbon footprint, carbon dioxide concentration and adjusting the densification of housings, it was found that the carbon dioxide concentration reduction in Kampong *Pakuncen* was 24.462%. With the calculation of carbon footprint, it was known that the existing carbon dioxide concentration is 1,712.767 tonnes CO_2/month while the total amount of carbon dioxide concentration of the design is 1,293.785 tonnes CO_2/month. By adjusting the densification, the Kampong Pakuncen will have more green public open spaces that can bring more oxygen to the environment. The greener the open spaces in Kampong Pakuncen, the healthier its environment. Furthermore, the efforts and concepts of utilization of renewable energy can bring sustainable environment and encouragement to the kampong to be a green kampong because the use of natural energy for daily needs; particulary water and electricity, will reduce the kampong's dependence on the government energy supply companies like PDAM (for clean water supply) and PLN (for electric supply). Kampong Pakuncen; therefore, contributes to reduce the carbon emission because of the huge carbon emissions produced by PDAM and PLN. This study has limitation on that providing the detail of housing performances completely with the equal number of housings on their own wall type in correlated to the implementation on calculating the carbon dioxide emission. In addition, the more detail carbon emission calculation per housing model has not been obtained yet due to the obtaining the simple calculation of the carbon dioxide concentration. Further research would be needed to address those aims.

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Author contributions

Erni Setyowati led the team in the observation, interviewing the leader of inhabitants as well as in the Focus Group Discussion. She was assisted by Septana BP and Bangun IRH on term of realizing the design concept of the kampong. To explore the planning of the kampong intercorrelated to the urban scale point of view, Tiara RD should design the zonation of the kampung covering map of renewable energy, sanitation and vertical housing as well as the location of communal space in the centre of the kampong. As becoming an expert of green design, Subrata AKAU had responsibility to calculate the carbon footprint of the kampong. Her concentration is the building science and environments.

Disclosure statement

This paper has no conflict of interest, the third parties do not have any interventions on this work.

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