Environmentally Friendly Energy-Based Park for Carbon-Neutral at Universitas Pertamina

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Abstract. In line with Universitas Pertamina's vision of a green livable campus, parks are an important point in its implementation. The purpose of this study was to design a carbon-neutral park with combination of chosen alternative energy source installation and vegetation that has been proven to absorb CO2. Method of this research is quantitative-descriptive comparing three energy sources include solar energy, methane energy, and waste heat energy. Through the analytical hierarchy process (AHP) method, the chosen energy source is solar energy which are superior in terms of land requirements, investment costs, reduction in electricity consumption and CO2 emission, and ease of construction. Installing solar panels in the park can reduce CO2 as much as 67334.5 MT CO2/year with additional CO2 reduction from vegetation, namely golden photos, snake plant, Syzygium myrtifolium, and garden croton (228 ppm/day, 318,207 kgCO2/year, 42,624 KgCO2/year, 125m/day).

Keywords: Green Livable Campus, Alternative Energy, Carbon-Neutral, Solar Energy, Park.

1 Introduction

Extreme weather conditions such as drought, heat waves, heavy rain, floods and landslides becoming more frequent, in the entire world which is claimed to be caused by climate change. In addition, rising sea levels, ocean acidification and loss of biodiversity are also other consequences of the rapidly changing climate. In December 2019, the European Commission presented the European Green Deal, its flagship plan that aims to make Europe climate neutral by 2050. This target will be reached through the European Climate Law that sets climate neutrality into binding EU legislation [1]. In Indonesia itself, Indonesia's Minister of Energy and Mineral Resources (ESDM) Arifin Tasrif has revealed several long-term strategies for achieving the carbon neutral or net-zero emissions target in the energy sector by 2060 [2].

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Becoming carbon neutral typically starts by being more efficient, so there are less emissions being produced. Once emissions are reduced, carbon neutral status is usually achieved through one, or a combination of reducing carbon emissions to zero, through changing energy sources and balancing carbon dioxide emissions through carbon offsets [3]. Strategy to implement those combinations can be realized by creating a carbon-neutral park. Through vegetations and installment of renewable energy, parks can be used as a solution for those who have not been able to reduce carbon emissions to minimize the worsening of climate change [3].

Park is an area that has space for various conditions, including location, size or area, climate, and other special conditions such as the specific purpose and function of the park development [4]. In general, parks are used as symbols and have many uses including for exercising, playing, relaxing, and other activities [5]. However, nowadays in some areas, many parks have not run according to their function, one of which is at Universitas Pertamina, so it is necessary to rejuvenate the park so that the park can be used according to its function. Universitas Pertamina is one of the campuses located in South Jakarta which has open space that has not been utilized properly. Therefore, in order to support long-term strategies for achieving the carbon neutral, also in line with the University's goal of implementing education for sustainable development, carbon-neutral park was design in this research. This research aims to designa carbon-neutral park as an effort to reduce the carbon footprint at Universitas Pertamina as well as calculate the potential for reducing carbon footprint from the carbon-neutral park design.

2 Methods

The form of research in this paper is quantitative-descriptive where the secondary data were used to design a carbon-neutral park by comparing three (3) alternative designs of renewable energy sources to be installed in the park. Analytical Hierarchy Process (AHP) method was employed to choose the best design of the three alternative designs of renewable energy. The chosen alternative was then combined with several vegetation that has been proven to be able to absorb CO2 well according to previous research.

The placement of the selected renewable energy along with its vegetation was arranged in a design drawing using sketch up on a land dimension of 27 m x 9 m. This land was chosen because it is located in front of the main building, namely the rectorate building which is the entrance gate to Universitas Pertamina. The placement of supporting facilities such as garden chairs, lights, walkways, and so on was determined based on aesthetic and comfort aspects. The alternative renewable energy determined in this research were solar energy by solar panel, biomass heat by gasifier, and biomass gas by biodigester.

2.1 Solar Energy by Solar Panel

Characteristic of the selected solar panels are monocrystalline solar panels due to their higher efficiency compared to polycrystalline solar panels, which is around 15%-20%. Specification of the monocrystalline solar panels used in this research are peak power 320 W, module efficiency 19.18%, nominal operating cell temperature 42oC, alpha P-0.387%/oC [6][21][22][23][24]. To calculate the amount of electricity produced by monocrystalline solar panels, data on solar thermal potential (kWh) and duration of solar radiation in Jakarta are needed. Jakarta has 6.5862 hours duration of solar radiation averagely in 2020 (54.885%

duration of solar radiation on percentage scale), while the potential for solar heat on the island of Java is 2.0 kWh – 6.4 kWh [6][21][22][23][24].

Through calculations and conversions between the average duration of solar radiation (6.59 hour/day), the solarthermal potential (taken the average number: 4.2 kWh) can be seen in the electrical energy produced by solar panels in one year, which is 10,097 MWh. If nine (9) monocrystalline solar panels are installed (according to the dimension of land that will be used as a park), the energy that can begenerated is 90,873 MWh. For this alternative budget plan, it is estimated at 68 million IDR including the panels, poles, set of cable, batteries, solar charger controller, inverter, installation fee and tax.

2.2 Biomass Heat by Gasifier

According to data from Rahman and Ridhosari (2019), organic waste generation produced by the Universitas Pertamina is 10 MTCO2 (food waste 8.9 Mt/year, leaves 1.1 Mt/year). In this alternative, the organic waste is utilized to produce biogas by Biomass Power Plant (gasifier technology). Every 1 kg of waste briquettes or biomass briquettes used as gasifier fuel will produce biomass gas with a volume of 2.185 m3 or the equivalent of 0.75 kWh of electricity [8][25].

By assuming the density of organic waste is 250kg/m3 [8], it is found that approximately 19 kg of waste briquettes are produced which will produce 14.25 kWh of power when burned with a gasifier. This alternative budget plan costs 66 million IDR including reactor, installment fee and tax.

2.3 Biomass Gas by Biodigester

The next alternative is a biodigester, a method that can process organic waste into biogas. In this method, the existing waste is put into a biodigester to be processed into biogas by biological conversion [26][27][28][29]. The calculation of organic waste into biogas is carried out where 1 MT of organic waste is equivalent to 403 kWh [9]. By a total of 10 MT of organic waste, produce energy about 4030 kWh. This alternative budget plan costs 32.5 million IDR including land clearing, stirrer, biogas storage bag, organic waste shredder, reactor, installment fee and tax.

2.4 Analytical Hierarchy Process (AHP)

Determination of alternatives in solving the problem of a systematic case can use the AHP method or analytical hierarchy process. AHP is a method for solving complex situations into several components in a hierarchical arrangement. AHP is done by giving a subjective value about the relative importance of a variable. This method sets the variables that become the highest priority to get the results and goals to be achieved. The main thing in AHP is to have a functional hierarchy in which the main input comes from human perception. Priority can be determined based on the importance of the criteria that we have set [10]. In this research, the steps to employ the method are:

a. Criteria weight assessment

   The weight assessment is based on criteria determined based on the level of importance. Level of importance 1 means as important as the others, 3 means moderate importance over the others, 5 means strong importance over the others, 7 means very strong importance over the others, 9 means absolute importance over the others and 2,4,6,8 means the value between two adjacent values [20]. In this problem, there are 3 alternatives that are used with the criteria of interest being assessed, namely the area, investment costs, electricity & CO2 and also the ease of construction. These criteria will be given points based on urgency or level of importance. Based on the level of importance, the CO2 reduction criterion is a criterion with high importance with a weight of three (3) because it is based on the objective of the problem, which is to reduce CO2 as one of the efforts to reduce the carbon footprint at Universitas Pertamina. For area, investment costs, and ease of construction have the same level of importance which is one (1). The levels of importance are then inputted to paired comparison scale table and getting values of RI (Ratio Index) of 0.9, CI (Consistency Index) of 0.0052, and CR (Consistency Ratio) of 0.057. When the CR value ≤ 0.1, the weight assessment is consistent and acceptable [20].

b. Area criteria assessment

After determining the weight of the existing criteria, the next step is an assessment of the area. The area is compared between 3 predetermined alternatives. The level of importance between area of alternative 1, 2, and 3 has been decided by making an area criteria value interval. There are 8 importance intervals with 6.230 difference. Alternative 1 need 0.16 m2, alternative 2 need 20 m2, and alternative 3 need 50 m2. Therefore, alternative 1 has seven (7) weight of importance compared to alternative 3, and 3 weight of importance compared to alternative 2. The levels of importance are then inputted to paired comparison scale table and resulting RI 0.58, CI 0.019, and CR 0.033. When the CR value ≤ 0.1, the weight assessment is consistent and acceptable.

c. Investment cost criteria assessment

The calculation of this criterion assessment uses interval limits to assess the existing weights. There are 8 importance intervals with 4.488.481,25 IDR difference. To perform the calculation, the higher cost has a lower importance, while lower costs have a higher level of importance. The intervals determined that alternative 1 has 7 weight of importance compared to alternative 3, and 2 weight of importance compared to alternative 2. The calculation obtained CI 0.033, RI 0.58, and CR 0.057. The calculation is consistent and subjective value for the criteria was accepted.

d. Electricity production and CO2 reduction criteria assessment

The calculation of this criterion assessment uses 8 interval limits to assess the existing weights with 6308,622 different. The intervals were then determined the level of importance of each alternative. The largest electricity & CO2 reduction get a higher importance value. Meanwhile, small electricity & CO2 get a lower level of importance. Alternative 1 has 6 weight of importance compared to alternative 3, and 7 weight of importance compared to alternative 2. The calculation is consistent and value for the criteria was accepted because the values of CI 0.002, RI 0.58, and CR 0.004.

e. Ease of construction criteria assessment

Ease of construction compared to the three alternatives. Calculation of the assessment of this criterion uses 8 interval limits to assess the existing weights, and 0.625 difference between intervals. Calculation of the ease of construction criteria is carried out in a range of 1 – 10 with 1 being the hardest and 10 being the easiest. The calculation got score CI 0.055, RI 0.58, and CR 0.094 which means the calculation is consistent and subjective value for the criteria is accepted.

2.5 The Selected Alternative

After calculating the AHP starting from the assessment of the weight of the criteria to the assessment of the criteria for the three alternatives, it can be concluded that the results of the chosen alternative. It is found that the highest weight is on alternative 1 of 0.777 which differs quite a lot from alternative 2 of 0.339. While the lowest is alternative 3 of 0.111. Based on these data, it can be determined that alternative 1 or solar panels is the most appropriate alternative to be applied to this environmentally friendly energy-based park project because it has the highest weight. The detail calculation can be seen in **Table 1.**

Table 1. Comparison results for three (3) alternatives.

						Criteria Over Criteria			
	Area	**Investment Cost**	**Electricity &CO_2**	**Ease of Construction**		0,304		**Weight**	
Alternative 1	0,767	0,642	1,225	0,767		0,388		**0,777**	**SOLAR PANEL**
Alternative 2	0,325	0,467	0,181	0,200	×	0,129	=	**0,339**	**BIO GASIFIER**
Alternative 3	0,087	0,074	0,183	0,181		0,179		**0,111**	**BIO DIGESTER**

3 Result

On the land of 27 m x 9 m area, the park contains 9 poles of solar panels, 3 charging stations for electronic devices, 3 sets of garden chair and table, 2 pergola and the chairs under, and park nameplate and nameplate on each type of plant. The detail top view, side view and front view of the park can be seen in Figure 1, Figure 2, and Figure 3 respectively.

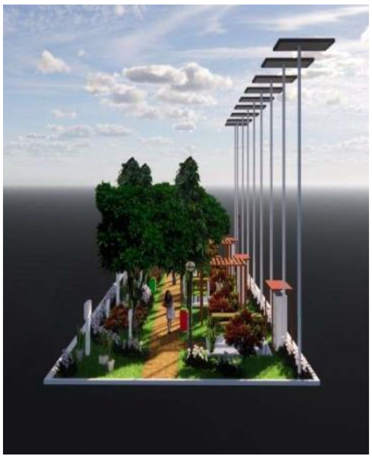

Fig. 1. Side view of carbon-neutral park of Universitas Pertamina.

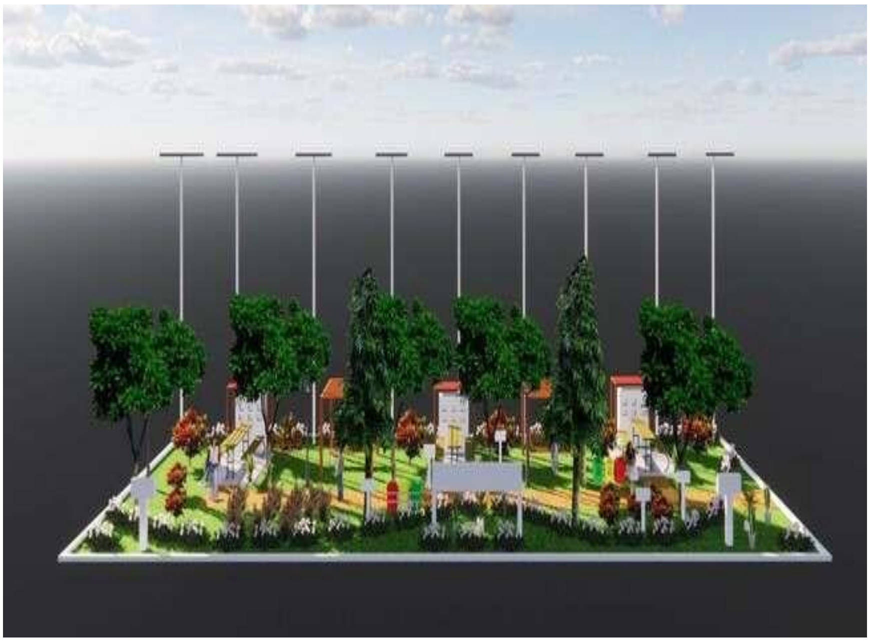

Fig. 2. Front view of carbon-neutral park of Universitas Pertamina.

Fig. 3. Top view of carbon-neutral park of Universitas Pertamina.

The vegetation of the park was determined by the ability of these plants to absorb carbon emissions, aesthetic factor, and price. Based on several literatures [11] [12] [13] [14] [15] [16] [17] [18] [19], there are 8 type of plants that are proven to have good ability to absorb CO2, including: golden photos (sirih gading), snake plant (lidah mertua), syzygium myrtifolium (pucuk merah), garden croton (puring), sanseivera (sirih belanda), caesalpinia pulcerrima (kembang krucutan/bunga merak), Bauhinia variegata (daun kupu-kupu), phaseolus vulgaris (kacang merah). The plant of golden photos has ability to capture CO2 about 228ppm/day (7 thousand IDR) while sanseivera 113 ppm/day (15 thousand IDR), snake plant 318.207 kgCO2/year (price 8 thousand IDR), bauhinie variegata 0.364 kgCO2/year (35 thousand IDR), syzygium myrtifolium 6619 kgCO2/year (10 thousand IDR), caesalpinia pulcerrima 42624 kgCO2/year (price 15 thousand IDR), garden croton 125 ppm/day (price 30 thousand IDR), and phaseolus vulgaris 120 ppm/day (price 50 thousand IDR). Based on those comparison, 4 plants were selected to be planted in the Universitas Pertamina’s carbon neutral garden which are golden photos, snake plant, syzygium myrtifolium, and garden croton.

3.1 The Selected Plants

Garden croton (puring) is a plant that has the best leaves in absorbing elements of lead (Pb/tin/lead) and carbon dioxide scattered in the open air, which is 2.05 mg/liter Apart from being a pollutant absorbing plant, croton is also used as an ornamental plant because of its beautiful variety of patterns and colors, medicinal plants (fever reducing and laxative) and a symbol of peace and public welfare. This plant can grow very well around wells/water sources, so the roots will improve water quality by absorbing the excess phosphorus contained in the water [11] [12] [13] [14] [15] [16] [17] [18] [19].

Syzygium myrtifolium (pucuk merah) are ornamental plants that are popular in Indonesia so that their presence can be easily found in pots planted on roadsides, both in urban areas and in villages. The unique thing about syzygium myrtifolium is that the tips of the young leaves are reddish orange. This plant is still included in the same family as the clove plant. If you pay attention, the shape of the crown and leaves is very similar to a clove plant [11] [12] [13]

[14][16] [17] [18] [19]. Syzygium myrtifolium are a concern because their presence can absorb CO2 pollutants of 42,624 Kg CO2/year.

In addition to its unique shape, snake plant (lidah mertua) is able to provide clean air for the room it occupies because this plant can absorb more than 107 pollutant elements in the air, one of which is carbon dioxide. Snack plant contains the active ingredient pregnane glycoside which functions to reduce pollutants into organic acids, sugars, and amino acids so that the pollutant elements become harmless to humans. It is proved that one strand of snake plant can absorb about 0.938 mg/hour of formaldehyde [11] [12] [13] [14] [15] [16] [17] [18] [19].

The choice of golden photos (sirih gading) as vegetation in the park is that this plant is able to absorb CO2 in the air at 228 ppm/day. In addition, this plant is able to absorb toxins and provide a supply of oxygen to the surroundings. This plant can also help with respiratory problems and calm psychological conditions so that we can feel calm near this plant [11] [12] [13] [14] [15] [15] [17] [18] [19]. Picture of the selected plants is shown in Figure 4.

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

Fig. 4. The Selected plants; (a) Garden croton (puring), (b) Syzygium Myrtifolium (pucuk merah), (c) Snake Plant (lidah mertua), (d) Golden Photos (sirih gading).
Source: [11] [12] [13] [14] [15] [16] [17] [18] [19].

3.2 Budget Plan

In this research, capital expenditure (CAPEX) and operating expenses (OPEX) of the carbon neutral park design were calculated. CAPEX spends about 309 billion IDR include site cleaning fee, cost of purchasing solar panels, batteries and installment, total garden work and supporting accessories, and tax. For OPEX, the carbon-neutral park needs about 180 billion IDR/year include operating expenses, maintenance expenses, and tax.

4 Conclusion

From the park design project based on environmentally friendly energy, it can be concluded several things. At the beginning of the design, there were 3 (three) alternatives to support this project, the alternatives include solar panel, bio-gasifier, and bio-digester. After selecting alternatives using the AHP (Analytical Hierarchy Process) method by calculating the potential for CO2 reduction from the electricity generated, investment costs, area and ease of construction, alternative solar panel was selected which then began with designing. AHP method is also show that application of solar panel (alternative 1) would get much higher success rate than bio-gasifier and biodigester. The solar panels are designed on an area of 27 x 9 meters by utilizing all parts of the land that can be used. After the final design has been determined, it is followed by making a comparison table of vegetation that can reduce CO2 and the budget plan needed for an environmentally friendly energy-based park project (309,618,100.00 IDR). Based on the results of the comparison of vegetation, the plants selected were garden croton (puring), syzygium myrtifolium (pucuk merah), snake plant (lidah mertua), and golden photos (sirih gading).

References

[1] News European Parliament. What is carbon neutrality and how can it be achieved by 2050? [Internet]. News European Parliament; 2021 June 24 [cited 2022 March 18]. Available from: https://www.europarl.europa.eu/news/en/headlines/society/20190926STO62270/what-is-carbon-neutrality-and-how-can-it-be-achieved-by-2050.

[2] VNA. Indonesia outlines strategies for meeting carbon neutral target by 2060 [Internet]. Jakarta: Vietnam Plus; 2021 June 8 [cited 2022 March 18]. Available from: https://www.europarl.europa.eu/news/en/headlines/society/20190926STO62270/what-is-carbon-neutrality-and-how-can-it-be-achieved-by-2050.

[3] Simple Energy. What is carbon neutral, and how does it affect my energy use? [Internet]. Simple Energy; 2022 [cited 2022 March 18]. Available from: https://www.simplyenergy.com.au/blog/what-is-carbon-neutral-and-how-does-it-affect-my-energy-use.

[4] Andini D. Revitalisasi objek wisata taman balekambang Kota Surakarta [Thesis]. Surakarta: Universitas Sebelas Maret; 2011.

[5] Artiani GP, Siswoyo SD. Optimalisasi ruang terbuka hijau berupa taman energi baru terbarukan sebagai upaya pemanfaatan lahan kosong di lingkungan kampus (Studi Kasus Kampus Stt-Pln, Jakarta). Konstruksia. 2020;11(1):1-10.

[6] Fachri MR, Sara ID, Away Y. Pemantauan parameter panel surya berbasis arduino secara real time. Jurnal Rekayasa Elektrika. 2015;11(4):123-128.

[7] Deputi Bidang Klimatologi Badan Meteorologi, Klimatologi, dan Geofisika. Informasi iklim untuk sektor energi [Internet]. Badan Meteorologi, Klimatologi, dan Geofisika; 2021 [cited 2021 November 30]. Available from: https://iklim.bmkg.go.id/publikasi-klimat/ftp/brosur/Leaflet%20Matahari.pdf.

[8] Sundadjaya SD. Pembangkit listrik tenaga biomassa briket sampah. Inisiatif listrik kerakyatan. Jakarta: Penerbit jurusan teknik mesin STT-PLN; 2016.

[9] Ridhosari B., Rahman, A.: Carbon footprint assessment at Universitas Pertamina from the scope of electricity, transportation, and waste generation: Toward a green campus and promotion of environmental sustainability. Journal of Cleaner Production, 2020;246.

[10] Munthafa AE, Mubarak H. Penerapan metode analytical hierarchy process dalam sistem pendukung keputusan mahasiswa berprestasi (Studi kasus: STMIK CIC Cirebon). Jurnal Siliwangi Sistem Teknologi. 2017;3(2):192-201.

[11] Fascavitri A, Rachmadiarti F, Bashri A. Potensi tanaman lili paris (chlorophtum comosum), melati jepang (pseuderanthenum reticulatum, dan paku tanduk rusa (playtycerium bifurcatum sebagai absorben timbal (pb) di Udara. Lentera Bio. 2018;7(3):188-194.

[12] Heri: Puring dan Keunikannya. Tanaman Puring (Codiaeum Variegatum) sebagai Pendegradasi Polutan Menuju Lingkungan Sehat. 118-119 (2008).

[13] Artiani GP, Siswoyo SD. Optimalisasi ruang terbuka hijau berupa taman energi baru terbarukan sebagai upaya pemanfaatan lahan kosong di lingkungan kampus (Studi kasus Kampus STT-PLN, Jakarta). Jurnal Konstruksia. 2019;11(1):1-10. Doi: https://doi.org/10.24853/jk.11.1.1-10.

[14] Mahadi S. Tanaman sirih gading: Jenis, manfaat, dan cara merawatnya. Lengkap! [Internet]. 99.co; 2021 Mei 9 [cited 2021 November 30]. Available from: https://www.99.co/blog/indonesia/tanaman-sirih-gading/.

[15] Mudiana D, Eriyanti EE. Syzygium myrtifolium Walp. flowering stages and its visitor insects. Biodiversitas: Journal of Biological Diversity. 2021;22:3489-3496.

[16] Nida S. 10 Jenis tanaman lidah mertua yang cocok dijadikan dekorasi rumah. Brilio Belly; 2020 December 8 [cited 2021 November 30]. Available from: https://m.brilio.net/brilicious/wow/10-jenis-tanaman-lidah-mertua-yang-cocok-dijadikan-dekorasirumah-2012083.html.
[17] Rahman. Daun Tanaman Puring Efektif Seserap Timbal [Internet]. Hasil penelitian UII; 2008 [cited 2021 November 30]. Available from: http://langitlangit.com.
[18] Stover H. The sansevieria book. California: Endangered Spesies; 1983.
[19] Suryani T. Galeri Puring. Jakarta: Penebar Swadaya; 2008.
[20] Mulyono S. Riset Operasi. Jakarta: Universitas Indonesia; 2004.
[21] Oluwasayo BD. Design and construction of a solar car park [Thesis]. Nigeria: University of Ibadan; 2016.
[22] Vermaak L, Kusakana K. Design of a photovoltaic-wind charging station for small electric tuk-tuk in DRCongo. Renewable Energy. 2016;67:40-45.
[23] Aziz M, Oda T, Mitani T, Watanabe Y, Kashiwagi T. Utilization of electric vehicles and their used batteries for peak-load shifting. Energies. 2015;8:3720-3738.
[24] Ma T, Yang H, Lu L. A feasibility Study of a Stand-alone Hybrid Solar-windbattery System for a Remote Island. Applied Energy. 2014;121:149-158.
[25] Raj R, Vijayan V, Vivek K, Vishnudas RS, Venugopal P. Biogasifier. International Journal for Innovative Research in Science & Technology. 2016;2(12).
[26] Okwu MO, Olusegun D, Samuel, Omonigho B, Otanocha, Promise P, et al. Design and development of a bio-digester for production of biogas from dual waste. World Journal of Engineering. 2020;17(2):247-260.
[27] Rabbani EK, Peres S, Souto LM, Lopes AL, Soares DM. Project guidelines for construction of biodigester in poor communities. Journal of Geotechnical Engineering. 2017;22(3):955-974.
[28] Fernandes P, Firmo AL, Firmo B. Inventory of Methane Emissions from Municipal Solid Waste Management in Pernambuco State, Brazil. The Electronic Journal of Geotechnical Engineering. 2015;20(14):6009-6023.
[29] Rana IR, Ganguly R, Gupta AK. An Assessment of Solid Waste Management System in Chandigarh City. The Electronic Journal of Geotechnical Engineering. 2015;20(6):1547-1572.