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International Journal of GEOMATE, Oct., 2019 Vol.17, Issue 62, pp. 92- 100 ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2019.62.91544 Special Issue on Science, Engineering & Environment RAINWATER HARVESTING AND ELECTRICITY SAVING ON HOUSEHOLD SCALE Tri Budi Prayogo1 and Gatot Eko Susilo2 1 Water Resources Engineering Department, Brawijaya University, Malang, Indonesia 2 Civil Engineering Department, The University of Lampung, Bandar Lampung, Indonesia *Corresponding Author, Received: 21 Jan. 2019, Revised: 13 Feb. 2019, Accepted: 28 Feb.

2019 ABSTRACT: Rainwater harvesting (RWH) is an effort to utilize rainwater for various purposes, especially to meet domestic water needs. Research on this paper will look at RWH as an effort to save electricity on a household scale. The RWH method used in this study is Rooftop Rainwater Harvesting (RRWH). The research location is Natar area, a sub-district in Southern Lampung, Indonesia. A simulation involving daily rainfall data, the rooftop area of the building, number inhabitants, reservoir capacity, and volume of water demands per capita, will be undertaken to find Supporting Capacity of RWH.

The simulation is applied for the houses with type 45, 60, and 70. Inhabitants of every house in this simulation are assumed 5 persons with water demand per capita of 70 liters per day. The results show, by applying RWH and using 3 or 4 years old pumps, in the wet year's houses type 45 can save electricity of 43.1%, 46.7%, and 49.5%, in a year for reservoir sizes of 2, 3 and 5 m3, respectively. With the same condition, houses type 60 and 70 can save electricity of 53.9%, 58.0%, 62.8%, and 57.6%, 63.3%, 68.7%, respectively. When analyzed from its nominal value, it seems that the KWh value of electricity savings from RWH applications is not large.

But if the value is multiplied by the number of houses in a city, the electricity savings made will be significant. The advantage of saving electricity produced in wet years is 1.4 to 1.6 times from the ones produced in dry years. Keywords: Rainwater, Harvesting, Saving, Electricity, Household

INTRODUCTION Energy is a resource produced by nature to make human life easier. Therefore, human life is never separated from energy needs. Energy needs will continue to increase along with advances in technology created by humans. The revolution of energy needs in the world began when there was an industrial revolution in England in the 18th century.

Industrial machines created require large amounts of energy. The increase in the world population is another cause of rising energy demand. Many countries in the northern hemispheres consume a lot of energy to survive from fierce winters (Morison 2018). Meanwhile, in the wealthy Arab States, energy is used to convert sea water into fresh water (Dawoud and Al Mulla 2012). In developing countries like Indonesia, energy is widely used for various purposes such as lighting and industry (Surahman et al. 2016). Large dams are built to generate electrical energy. On the other hand, oil, coal, and natural gas exploitation is increasing from year to year (Diana et al. 2015).

Based on information and predictions of the National Energy Board (DEN), Indonesia's national primary energy demand in 2013 is equivalent to 3.6 million barrels of oil per day. This number will continue to double by 2025 by 7.5 million barrels of oil equivalent per day. By 2050, the national primary energy demand will _increase to 18.7 million barrels of oil equivalent per day (Detiknews 2016). The main source of energy at this time is still dominated by oil and gas that can meet the national energy needs of about 50%.

Indonesia is still very dependent on oil and gas, whereas the source of energy is a non-renewable energy source that will sooner or later be reduced or exhausted (BPPT 2018). In developing countries, energy needs are growing very rapidly from year to year. Rapid population growth and intensive urbanization lead to increased energy demand along with food and shelter needs. In general, developing countries at this time have difficulty in meeting energy needs due to an imbalance between demand and supply (Barnes and Floor 1996, Kammen and Kirubi 1998).

Poor planning in managing energy is another cause of the increasing energy demand in these countries (Mohamed and Yashiro 2013). Households are the most consuming sector in developing countries. In these countries, the use of traditional fuels such as firewood, charcoal, and agricultural wastes to meet the energy needs are still largely found, especially in rural areas (FAO 2007). The fear of future energy crisis threats has been felt by many people. Although it is not clearly known the year of its inception, the symptoms of the energy crisis have begun since today.

Responding to this situation, many people in different countries are doing energy saving movements and are looking for new renewable energy sources (Pedraza 2012). People begin to take advantage of the wind, ocean waves, and sunlight and convert them into electrical energy that can be stored and converted into other forms of energy (Alrikabi 2014). Energy savings started from large industrial scale up to small household scale.

Rainwater harvesting (RWH) is a technique of collecting and storing rainwater on the natural or manmade reservoir before being lost as surface runoff (Wikiversity 2018, Oweis et al. 2018). RWH is basically to meet for domestic water supply (JeanCharles, 2007). Moreover, by applying RWH groundwater exploitation and flood discharge from rain can be reduced. Another benefit that might not be considered is the energy savings gained by applying RWH. When taking groundwater from deep wells, electricity consumption arises to drive the water pump.

Sometimes the electrical energy for the pump is quite large and costly. With the application of RWH, electrical energy for pump water operations can be eliminated up to a certain amount. This paper will examine the electrical energy savings gained from the application of RWH on a household scale. Supporting Capacity of RWH in this research will be estimated from the simulation of RWH implementation. The amount of electrical energy that can be saved by a household that implements RWH can be predicted from the simulation. Research Methodology 2.1

Location of The Study The location of this research is the Natar area, a sub-district in Southern Lampung, Indonesia. It is closed to Bandar Lampung City, the capital of Lampung Province. This area is a rural area that develops into urban areas. The area of

Natar is 213.77 km2 with a population of 150,000 in 2016. Two decades ago most of the population of Natar were farmers cultivating agricultural land. At present most of the population are workers in the formal and non-formal sectors (Wikipedia, 2018). Because changes in land use from agricultural areas to residential areas, the presence of water sources continues to decrease in this area.

Some parts of the Natar began to experience dryness in the dry season lately. The drinking water company has not yet reached Natar while the water supply from Sungai Sekampung which is on the Natar border which the government plan has not yet been implemented. Meanwhile, in Natar there is the main airport in Lampung Province. The need for water in Natar in the future is very large. Therefore rainwater harvesting is a method that must be _considered to overcome or reduce water scarcity in the future. / Fig. 1 Location of the study 2.2 Methodology and Data The RWH method used in this study is Rooftop Rainwater Harvesting (RRWH).

RRWH is a method to collect rainwater through the roof of a building and store it in a reservoir for later use for various purposes (The Constructor 2017, NEPCAT 2018). The system of RRWH is presented below: Fig. 2 Rooftop Rainwater Harvesting (RRWH) system A simulation involving daily rainfall data, the rooftop area of the building, number inhabitants, reservoir capacity, and volume of water demands per capita, will be undertaken to find Supporting Capacity of RWH. Supporting Capacity of RWH is the number of days that domestic water can be supplied by rainwater collected.

For example: if a house has a Supporting Capacity of RWH of 50%, this means that in one year there are 365 x 50% or 182 days that domestic water can be replaced or supplied by rainwater (Susilo 2018a). The fluctuations of water volume in the reservoir are calculated using following formulas (Kastaghir and Jayasurya 2010, Kahinda et al. 2010, Susilo et al. 2011, Susilo 2015, Susilo 2018b, Susilo 2018c): _ where: _(2)

/ where: _(1) _c is the runoff coefficient of the roof, assumed 0.8–1.0 (Fewkes, 1999) Rt is rainfall in the day t (mm) A is an area of the roof (m2).

St is the volume of water in the reservoir for day t (m3) St-1 is the volume of water in the reservoir for day t-1 (m3) It is the total inflow for day t (m3) Ot is the total outflow for day t-1 (m3) _The outflow for day t is calculated using the formula below: where: _ (3)

Smax is the maximum storage capacity of the reservoir (m3) Maximum storage capacity (Smax) is basically the dimension of the reservoir. Value of Smax is constant and unchanged during the simulation. St-1 at the beginning of the simulation is assumed = 0, meaning the volume of water in the reservoir is 0. If St is greater than Smax, the volume of water in the reservoir is considered Smax and excess water will be spilled out from the reservoir.

Total inflow for day t is calculated as follows: _n is the number of building inhabitants D is water demand per capita per day If the reservoir volume on day t is greater than 0 then that day is considered as the day whose water demand has been fully supplying by rainwater. Rainfall data for the simulation is daily rainfall data obtained from Radin Inten II Airport. The period of the data is 10 years, from the year 2008 to 2017. The description of the annual rainfall data is presented below.

4000 3500 3000 2500 2000 1500 1000 500 0 time (year) Fig. 3 Annual rainfall data from rain gauge at Radin Inten II Airport The annual average of the rainfall data is 1956.4 mm.

Based on this value then the data is grouped into several classes: A dry year if the annual rainfall is less than 85% of average data A normal year if the annual rainfall is between 85% and 115% of average data A wet year if the annual rainfall is greater than 115% of average data By the classification, three groups of data have been derived: _Dry years: 2011 and 2015 ? Normal years: 2008, 2009, 2012, 2014, and 2017 ? Wet year: 2010, 2013, and 2016 Each group will be simulated in order to find the value of their Supporting Capacity of RWH. The value of Supporting Capacity of RWH will be multiplied by the use of electricity used for pumping the water in the household.

The saving of electricity per year for every type of house will be derived from this calculation. The electricity saving will be given in KWh value and Rupiah value. Results and Discussions Simulation Results The simulation is applied for the houses with type 45, 60, and 70. These types of house are the house with a building area of 45, 60, and 70 m2, respectively. The effective area of rooftop for each _type is 36, 48, and 56 m2. Inhabitants of every house in this simulation are assumed, 5 persons. The water demand per capita is assumed 90 liters per day.

This is based on the regulation issued by Dirjen Cipta Karya (Division of Ministry of Public Work) in 1996. The maximum capacity of the reservoir used in the simulation is 2.0, 3.0, and 5.0 m3, as available in the market. Below are the simulation results for each type of house with various dimensions of the reservoir:

Table 1. Supporting capacity of RWH for type 45 house _ _ _Smax = 2 m3 _Smax = 3 m3 _Smax = 5 m3 _ _No. _Year _Status _Supporting Capacity _# of Supporting Day _Supporting Capacity _# of Supporting Day _Supporting Capacity _# of Supporting Day _ _1 _2008 _Normal _37.2% _136 _37.7% _138 _37.7% _138 _ _2 _2009 _Normal _32.8% _120 _35.2% _129 _36.9% _135 _ _3 _2010 _Wet _53.8% _197 _57.7% _211 _60.1% _220 _

_4 _2011 _Dry _29.5% _108 _31.1% _114 _33.1% _121 _ _5 _2012 _Normal _30.9% _113 _32.2% _118 _33.3% _122 _ _6 _2013 _Wet _41.8% _153 _45.6% _167 _47.8% _175 _ _7 _2014 _Normal _28.7% _105 _31.1% _114 _33.3% _122 _ _8 _2015 _Dry _31.4% _115 _32.2% _118 _32.2% _118 _ _9 _2016 _Wet _41.5% _152 _45.6% _167 _49.7% _182 _ _10 _2017 _Normal _35.5% _130 _36.9% _135 _37.4% _137 _ _Source: calculation Table 2.

Supporting capacity of RWH for type 60 house _ _ _Smax = 2 m3 _Smax = 3 m3 _Smax = 5 m3 _ _No. _Year _Status _Supporting Capacity _# of Supporting Day _Supporting Capacity _# of Supporting Day _Supporting Capacity _# of Supporting Day _ _1 _2008 _Normal _45.9% _168 _50.0% _183 _50.0% _183 _ _2 _2009 _Normal _41.8% _153 _46.4% _170 _51.4% _188 _ _3 _2010 _Wet _66.7% _244 _71.3% _261 _76.2% _279 _ _4 _2011 _Dry _36.3% _133 _42.1% _154 _45.4% _166 _ _5 _2012 _Normal _40.4% _148 _42.6% _156 _44.5% _163 _ _6 _2013 _Wet _52.7% _193 _56.6% _207 _62.3% _228 _ _7 _2014 _Normal _39.6% _145 _42.9% _157 _46.4% _170 _ _8 _2015 _Dry _38.5% _141 _41.5% _152 _45.9% _168 _ _9 _2016 _Wet _52.2% _191 _56.8% _208 _61.5% _225 _ _10 _2017 _Normal _44.3% _162 _48.4% _177 _50.8% _186 _ _Source: calculation

Table 3.

Supporting capacity of RWH for type 70 house _ _ _Smax = 2 m3 _Smax = 3 m3 _Smax = 5 m3 _ _No. _Year _Status _Supporting Capacity _# of Supporting Day _Supporting Capacity _# of Supporting Day _Supporting Capacity _# of Supporting Day _ _1 _2008 _Normal _50.5% _185 _57.7% _211 _59.6% _218 _ _2 _2009 _Normal _47.5% _174 _52.5% _192 _57.7% _211 _ _3 _2010 _Wet _71.0% _260 _77.6% _284 _83.9% _307 _ _4 _2011 _Dry _42.3% _155 _47.3% _173 _53.0% _194 _ _5 _2012 _Normal _45.4% _166 _48.6% _178 _51.6% _189 _ _6 _2013 _Wet _56.0% _205 _62.6% _229 _68.3% _250 _ _7 _2014 _Normal _47.0% _172 _49.7% _182 _53.6% _196 _ _8 _2015 _Dry _42.6% _156 _47.0% _172 _50.5% _185 _ _9 _2016 _Wet _56.3% _206 _61.5% _225 _66.7% _244 _ _10 _2017 _Normal _49.2% _180 _52.7% _193 _57.1% _209 _ _Source: calculation Results above can be summarized into: Table 4.

Supporting capacity of RWH for each type of house No. _ House Type _ Status of the Year _Average Supporting Capacity _Average # of Supporting Day _ _ _ _ _Smax = 2 m3 _Smax = 3 m3 _Smax = 5 m3 _Smax = 2 m3 _Smax = 3 m3 _Smax = 5 m3 _ _1 _House type 45 _Dry _30.5% _31.7% _32.7% _112 _116 _120 _ _ _ _Normal _33.0% _34.6% _35.7% _121 _127 _131 _ _ _ _Wet _45.7% _49.6% _52.6% _167 _182 _192 _ _2 _House type 60 _Dry _37.4% _41.8% _45.6% _137 _153 _167 _ _ _ _Normal _42.4% _46.1% _48.6% _155 _169 _178 _ _ _ _Wet _57.2% _61.6% _66.7% _209 _225 _244 _ _3 _House type 70 _Dry _42.5% _47.1% _51.8% _156 _173 _190 _ _ _ _Normal _47.9% _52.2% _55.9% _175 _191 _205 _ _ _ _Wet _61.1% _67.2% _73.0% _224 _246 _267 _ _Source: calculation Fig.

4 Average Supporting Capacity of RWH for each type of house

/ Fig. 5 Average # of Supporting of RWH for each type of house

3.2 Calculation of Energy Saving Generally, Indonesia households in the urban area get domestic water by taking water from deep well-using the jet water pump. The jet pump used is usually run with 370 Watts of electricity. The depth of the well is ranged between 30 to 40 m. The water obtained then is stored in the reservoir on an elevated place. For daily use, water flows from reservoir gravitationally.

For households that apply RWH, the pump used is an ordinary water pump with electricity running at 150 Watt. This pump serves to send water from the reservoir for various purposes at home. This is because usually the reservoir for RWH installation is located above the ground surface. Moreover, even though a household has implemented RWH, it still has to have two pumps, a water jet pump and an ordinary water pump. The jet pump is used during the dry season or when the reservoir is not filled with rainwater. The ordinary water pump is used when the reservoir is filled with rainwater.

The capacity of both water pumps in the new condition is presented below (Putra 2015). In fact, after 3 or 4 years the efficiency of the water pumps will decrease considerably due to engine conditions. Based on field experience, jet pump efficiency is usually only 30 to 40% (depending on the pump brand). While ordinary water pumps still have an efficiency of an average of 80%. The electricity price per KWh set by the State Electricity Company (PLN) is 1467.28 IDR Indonesian Rupiahs (IDR) (PLN 2018). Based on the number 3 above, the total water requirement for each house which is occupied by 5 people is 350 l / min.

If it is assumed that a house has a deep well with a depth of 35 m, it will take 32.65 minutes to get that amount of water or need 0.54 x 0.370 KWh or about 0.20 KWh per day. If this _electrical power is multiplied by the electric power tariff, the house concerned requires funds of around 295.42 IDR every day. This means within a year a house without RWH requires around 107.827,51 IDR. For households that implement RWH, water pumps are usually used to raise water at an average of 3.0 m. Based on the pump capacity graph, the time needed to pump 350 liters of water is 13.05 minutes. Electricity needed is: (13.05 / 60) X 0.150 KWh or 0.08 KWh. The price of electricity is 47,88 IDR. Thus, households that implement RWH require a cost of 47,88 IDR per day to meet their water needs.

The costs needed a year are the sum of [(365 - # of Supporting Day) x non RWH electricity costs] and [#of Supporting Day x RWH electricity costs]. 70,0 60,0 50,0 40,0 30,0 20,0 10,0 0,0 0 10 20 30 40 Head (m) Fig. 6 The capacity of the jet pump and ordinary water pumps in new condition The following tables show the costs that must be incurred by a household with RWH application and the benefits derived from the application of RWH. Each price is calculated using the Indonesian Rupiah.

Table 5 Electricity costs and financial saving for households applying RWH with new pumps condition No. _ House Type _ Status of the Year _Cost with RWH Application per year (IDR) _Saving of RWH Application per year (IDR) _ _ _ _ _Smax = 2 m3 _Smax = 3 m3 _Smax = 5 m3 _Smax = 2 m3 _Smax = 3 m3 _Smax = 5 m3 _ _1 _House type 45 _Dry _80,226.9 _79,113.0 _78,246.6 _27,600.6 _28,714.5 _29,580.9 _ _ _ _Normal _77,924.8 _76,439.6 _75,449.4 _29,902.7 _31,388.0 _32,378.1 _ _ _ _Wet _66,406.0 _62,857.9 _60,217.5 _41,421.5 _44,969.6 _47,610.0 _ _2 _House type 60 _Dry _73,914.7 _69,954.0 _66,488.5 _33,912.8 _37,873.5 _41,339.0 _ _ _ _Normal _69,409.5 _66,092.4 _63,765.6 _38,418.1 _41,735.1 _44,062.0 _ _ _ _Wet _56,009.3 _52,048.7 _47,428.0 _51,818.2 _55,778.8 _60,399.5 _ _3 _House type 70 _Dry _69,335.2 _65,127.0 _60,918.9 _38,492.3 _42,700.5 _46,908.6 _ _ _ _Normal _64,409.2 _60,498.0 _57,181.0 _43,418.3 _47,329.5 _50,646.5 _ _ _ _Wet _52,461.3 _46,932.9 _41,734.6 _55,366.2 _60,894.6 _66,092.9 _ _Source: calculation Table 6 Electricity costs and financial saving for households applying RWH with 30% of jet pump efficiency and 80% of ordinary water pump efficiency No. _ House Type _ Status of the Year _Cost with RWH Application per year (IDR) _Saving of RWH Application per year (IDR) _ _ _ _ _Smax = 2 m3 _Smax = 3 m3 _Smax = 5 m3 _Smax = 2 m3 _Smax = 3 m3 _Smax = 5 m3 _ _1 _House type 45 _Dry _256,301.2 _252,139.2 _248,902.2 _103,123.9 _107,285.8 _110,522.9 _ _ _ _Normal _247,699.8 _242,150.6 _238,451.1 _111,725.2 _117,274.5 _120,974.0 _ _ _ _Wet _204,662.2 _191,405.6 _181,540.2 _154,762.9 _168,019.4 _177,884.8 _ _2 _House type 60 _Dry _232,716.8 _217,918.8 _204,970.5 _126,708.2 _141,506.3 _154,454.6 _ _ _ _Normal _215,884.0 _203,490.7 _194,796.8 _143,541.0 _155,934.4 _164,628.2 _ _ _ _Wet _165,817.3 _151,019.3 _133,754.9 _193,607.7 _208,405.8 _225,670.1 _ _3 _House type 70 _Dry _215,606.6 _199,883.7 _184,160.7 _143,818.5 _159,541.4 _175,264.3 _ _ _ _Normal _197,201.5 _182,588.4 _170,195.1 _162,223.5 _176,836.6 _189,230.0 _ _ _ _Wet _152,560.7 _131,905.1 _112,482.7 _206,864.3 _227,519.9 _246,942.3

_ _Source: calculation If the saving is translated into KWh then the table becomes: Table 7 Electricity saving in KWh per year No. _ House Type _ Status of the Year _Electricity saving (KWh) for a new pump _Electricity saving (KWh) for an old pump _ _ _ _ _Smax = 2 m3 _Smax = 3 m3 _Smax = 5 m3 _Smax = 2 m3 _Smax = 3 m3 _Smax = 5 m3 _ _1 _House type 45 _Dry _18.8 _19.6 _20.2 _70.3 _73.1 _75.3 _ _ _ _Normal _20.4 _21.4 _22.1 _76.1 _79.9 _82.4 _ _ _ _Wet _28.2 _30.6 _32.4 _105.5 _114.5 _121.2 _ _2 _House type 60

_Dry _23.1 _25.8 _28.2 _86.4 _96.4 _105.3 _ _ _ _Normal _26.2 _28.4 _30.0 _97.8 _106.3 _112.2 _ _ _ _Wet _35.3 _38.0 _41.2 _132.0 _142.0 _153.8 _ _3 _House type 70 _Dry _26.2 _29.1 _32.0 _98.0 _108.7 _119.4 _ _ _ _Normal _29.6 _32.3 _34.5 _110.6 _120.5 _129.0 _ _ _ _Wet _37.7 _41.5 _45.0 _141.0 _155.1 _168.3 _ _Source: calculation

3.3. DISCUSSION When analyzed from its nominal value, electricity savings from RWH applications are not large. But if the value is multiplied by the number of houses in a city, the electricity savings made will be significant. The investment value of making an RWH installation is between 3 to 5 million rupiah. This amount may be very large when compared to the benefits of electricity savings obtained.

But for type 70 houses and above electricity savings due to RWH implementation can be significant. Especially if the dimensions of the reservoir can be enlarged, the value of electricity savings can be greater. So far space to place large reservoirs is the main problem for small houses, therefore, the value of electricity savings obtained is not optimal. The success of implementing RWH is strongly influenced by the rainfall that falls within the year. The advantage of saving electricity produced in wet years is 1.4 to 1.6 times from the ones produced in dry years. What we need to watch out for is the El Nino event. In strong El Nino and extreme El Nino years, annual rainfall will be more decreased.

It will affect the Supporting Capacity RWH value and minimize the benefits of electricity savings. However, El Nino events occur only once in 3 to 7 years, and not all El Nino events are strong El Nino or extreme El Nino. In addition to saving electricity for pumping water, the application of RWH is a good effort to save wasted natural resources, preserve groundwater, and control flood hazards. Unfortunately, the application of RWH has not been so popular in urban areas in Indonesia. Some swamp or peat areas have applied RWH for a long time to meet their domestic water needs.

However, there is no definite record that shows the number of people who apply RWH in Indonesia. CONCLUSION The relationship between the application of rainwater harvesting and energy savings on a household scale has been discussed. Some conclusions can be drawn from the research that has been carried out. The results of the research show that by applying RWH for wet years, type 45 houses that use pumps with ages 3 to 4 years can produce a supporting capacity of 45.7%, 49.6%, and 52.6% for reservoirs of sizes 3, 4 and 5 m3. This means that the electricity saved in a year is 43.1%, 46.7%, and 49.5%, respectively. With the same condition, houses type 60 can produce supporting capacity of 57.2%, 61.6%, and 66.7%, respectively, and can save electricity of 53.9%, 58.0%, and 62.8%, respectively. On the other hand, houses type 70 can produce supporting _capacity of 61.1%, 67.2%, and 73.0%, respectively, and can save electricity of

57.6%, 63.3%, and 68.7%, respectively.

When considered from its nominal value, electricity savings from RWH applications are not significant. However, if the value is multiplied by the number of houses in a city, the savings will be quite large. Acknowledgments I would like to express my special thanks of gratitude to Civil Engineering Dept., The University of Lampung and Ibu Eka Desmawati form BBWS Mesuji – Sekampung who always support me in all my rainwater harvesting research.

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