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 Prayogo[1] and Gatot Eko Susilo[2]

[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 m^3, 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*

1. 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.

2. 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:

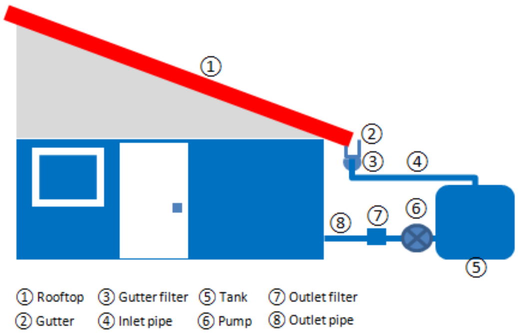

Fig. 2 Rooftop Rainwater Harvesting (RRWH) system

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):

$$S_t = S_{t-1} + I_t + O_t \quad for\ 0 \leq S_t \leq S_{max} \qquad \textbf{(1)}$$

where:

- S_t is the volume of water in the reservoir for day t (m^3)
- S_{t-1} is the volume of water in the reservoir for day t-1 (m^3)
- I_t is the total inflow for day t (m^3)
- O_t is the total outflow for day t-1 (m^3)
- S_{max} is the maximum storage capacity of the reservoir (m^3)

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

Total inflow for day t is calculated as follows:

$$I_t = c \times R_t \times A \times 1000 \qquad \textbf{(2)}$$

where:

- c is the runoff coefficient of the roof, assumed 0.8–1.0 (Fewkes, 1999)
- R_t is rainfall in the day t (mm)
- A is an area of the roof (m^2).

The outflow for day t is calculated using the formula below:

$$O_t = n \times D \qquad \textbf{(3)}$$

where:

- 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.

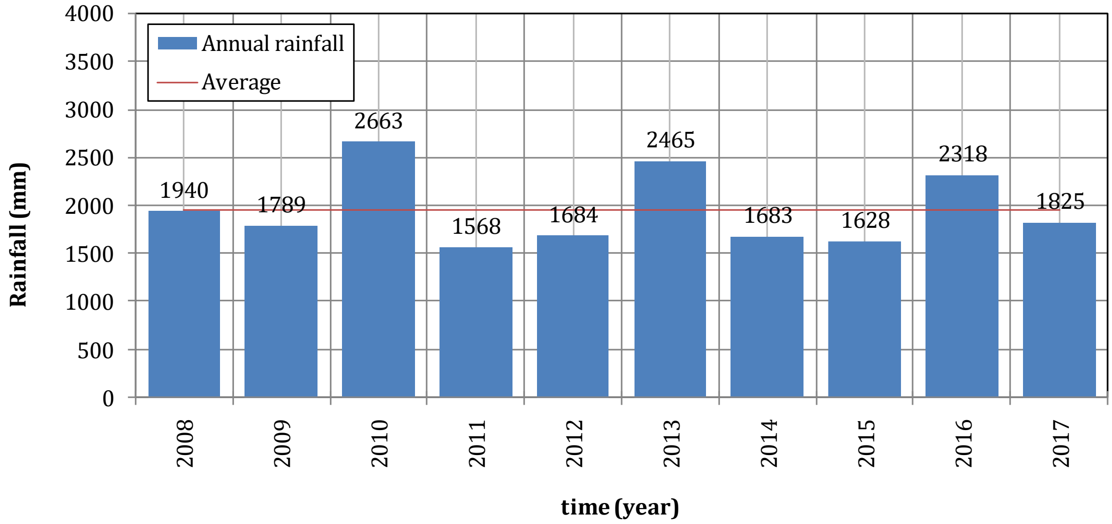

Fig. 3 Annual rainfall data from rain gauge at Radin Inten II Airport

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.

3. Results and Discussions

3.1. 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 m^2, respectively. The effective area of rooftop for each type is 36, 48, and 56 m^2. 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 m^3, 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*

No.	Year	Status	S_{max} = 2 m^3		S_{max} = 3 m^3		S_{max} = 5 m^3	
			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

No.	Year	Status	S_{max} = 2 m^3		S_{max} = 3 m^3		S_{max} = 5 m^3	
			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*

No.	Year	Status	S_{max} = 2 m³		S_{max} = 3 m³		S_{max} = 5 m³	
			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		
			S_{max} = 2 m³	S_{max} = 3 m³	S_{max} = 5 m³	S_{max} = 2 m³	S_{max} = 3 m³	S_{max} = 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

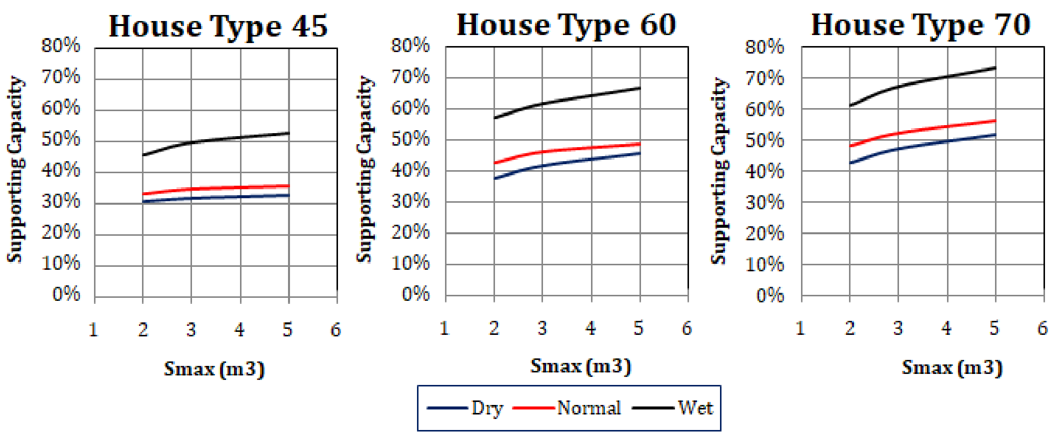

Fig. 4 Average Supporting Capacity of RWH for each type of house

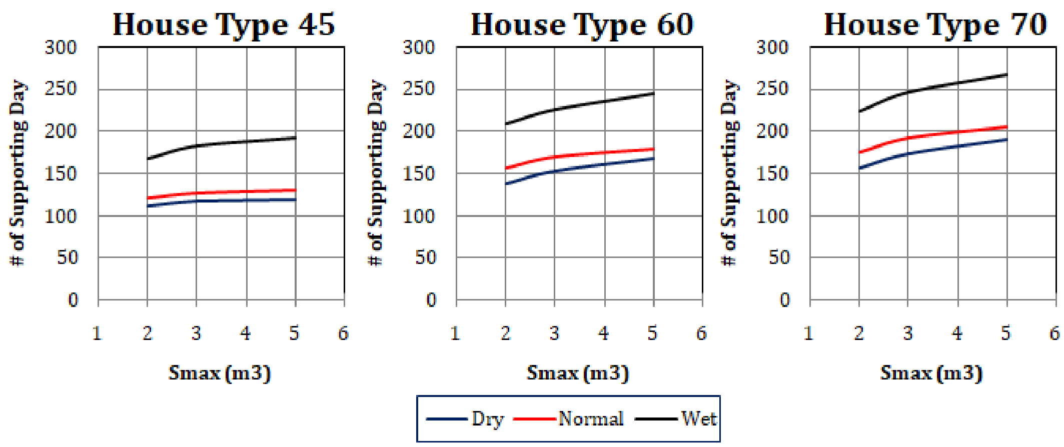

Fig. 5 Average # of Supporting of RWH for each type of house

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].

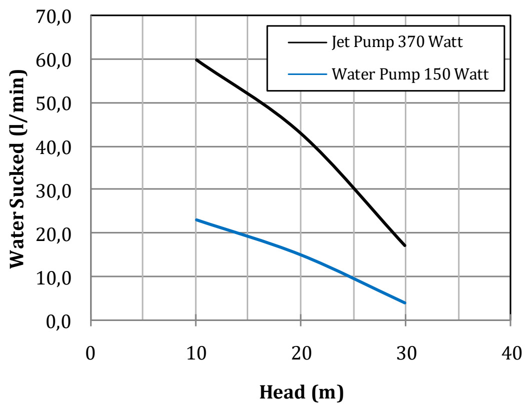

Fig. 6 The capacity of the jet pump and ordinary water pumps in new condition

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)		
			S_{max} = 2 m³	S_{max} = 3 m³	S_{max} = 5 m³	S_{max} = 2 m³	S_{max} = 3 m³	S_{max} = 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)		
			S_{max} = 2 m³	S_{max} = 3 m³	S_{max} = 5 m³	S_{max} = 2 m³	S_{max} = 3 m³	S_{max} = 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		
			S_{max} = 2 m³	S_{max} = 3 m³	S_{max} = 5 m³	S_{max} = 2 m³	S_{max} = 3 m³	S_{max} = 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.

4. 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 m^3. 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.

5. 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.

6. REFERENCES

[1] Morison, R. (2018) Europe’s Cold Weather Will Keep Going Into April, https://www.bloomberg.com/news/articles/2018-03-29/cold-start-to-april-awaits-in-europe-after-double-dose-of-chill. Accessed October 14, 2018.

[2] Dawoud, M.A. & Al Mulla, M.M. (2012) Environmental Impacts of Seawater Desalination: Arabian Gulf Case Study. International Journal of Environment and Sustainability, 1(3), 22–37.

[3] Surahman, U., Maknun, J. and Krisnanto. E. (2016) Survey On Household Energy Consumption of Public Apartments in Bandung City, Indonesia. Proceeding of 8th International Conference on Architecture Research and Design (AR+DC), Surabaya, Indonesia, November 1-2, 2016.

[4] Diana, C., Sorin, M., Mirela, I., Laura, M., & Sabina, I. (2015) Creating Competitive Advantage in Coal Mining Industry in Romania: A New Challenge. Procedia Economics and Finance, 23, 428–433.

[5] Detiknews. (2016) Krisis Energi, Tantangan Besar di Masa Depan, https://news.detik.com/adv-nhl-detikcom/d-3349429/krisis-energi-tantangan-besar-di-masa-depan. Accessed October 14, 2018.

[6] BPPT. (2018) Energi terbarukan, solusi krisis energi masa depan, www.bppt.go.id/profil/organisasi/sekretaris-utama/40-berita-bppt-3/berita-teknologi-informasi-energi-material/433-energi-terbarukan-solusi-krisis-energi-masa-depan. Accessed on October 14, 2018

[7] Barnes, D.F. & Floor, W.M. (1996) Rural Energy in Developing Countries: A Challenge for Economic Development1. Annual Review of Energy and the Environment, 21(1), 497–526.

[8] Kammen, D.M. & Kirubi, C. (1998) Poverty, Energy, and Resource Use in Developing Countries: Focus on Africa. Annual Review of Energy and the Environment, 21(1), 348–357.

[9] Mohamed, F.K. & Yashiro, T., (2013) Realising Sustainability in the Tropics. Proceeding of SB 13 Singapore.

[10] Food and Agricultural Organization (FAO). (2007) Forests and Energy in Developing Countries. Forests and Energy Working Paper 2, Rome, Italy.

[11] Pedraza, J.M. (2012) The Current and Future Role of Renewable Energy Sources for the Production of Electricity in Latin America and the Caribbean. International Journal of Energy, Environment and Economics, 20(5),1–65.

[12] Alrikabi, N.K.M.A. (2014). Renewable Energy Types. Journal of Clean Energy Technologies, 2(1),61–64.

[13] Wikiversity. (2018) Rainwater Harvesting, en.wikiversity.org/wiki/Rainwater_harvesting. Accessed October 14, 2018.

[14] Oweis, T., Prinz, D. & Hachum, A. (2018) Water Harvesting: Indigenous Knowledge for the Future of the Drier Environments. International Center for Agricultural Research in the Dry Areas (ICARDA) Publication, Aleppo, Syria.

[15] JeanCharles, M. (2007) Rainwater Harvesting Systems for Communities in Developing Countries. M.Sc. Theses, Michigan Technological University, Michigan, USA.

[16] Wikipedia. (2018) Kabupaten Lampung Selatan, id.wikipedia.org/wiki/Kabupaten_Lampung_Selatan. Accessed on October 21, 2018.

[17] The Constructor. (2017) Methods of Rainwater Harvesting – Components, Transport, and Storage, https://theconstructor.org/water-resources/methods-of-rainwater-harvesting/5420/#2_Rooftop_rainwater_harvesting. Accessed on October 21, 2018.

[18] Nepal Conservation Approaches and Technologies (NEPCAT). 2018 Rooftop Rainwater Harvesting System, http://www.icimod.org/?q=10354. Accessed on October 21, 2018.

[19] Susilo, Gatot, E. (2018a) Pemanenan Hujan: Sumber Air Domestik Alternatif yang Mudah dan Murah. Prosiding Pertemuan Ilmiah Tahunan HATHI XXXV, Medan, Indonesia, 7–9 September 2018.

[20] Khastagir, A. & Jayasuriya, N. (2010). Optimal Sizing of Rain Water Tanks for Domestic Water Conservation. Journal of Hydrology, 381(3–4), 181–188.

[21] Kahinda, J.M., Taigbenu, A.E. & Boroto, R.J. (2010) Domestic rainwater harvesting as an adaptation measure to climate change in South Africa. Physics and Chemistry of the Earth, 32(15-18), 1050–1057.

[22] Susilo, G.E., Yamamoto, K. and Imai, T. (2011) The Identification of Rainwater Harvesting Potency in Supporting Freshwater Availability Under the Effect of El Nino. Proceeding IWA – ASPIRE International Conference, Tokyo – Japan, October 2–6, 2011.

[23] Susilo, Gatot, E. (2015) Experience in Rainwater Harvesting Application at Household Scale in Bandar Lampung, Indonesia. Proceeding of The 1st Young Scientist International Conference of Water Resources Development and Environmental Protection, Malang, Indonesia, 5-7 June 2015

[24] Susilo, Gatot, E. (2018b) Rainwater Harvesting as Alternative Source for Wudlu Water in Indonesia. Civil and Environmental Science Journal, 1(2):62–69.

[25] Susilo, Gatot, E. (2018c). Rainwater Harvesting as Alternative Source of Sanitation Water in Indonesian Urban Area (Case Study: Bandar Lampung City). Rekayasa Sipil, 12(1),21–26.

[26] Fewkes, A. (1999) The use of rainwater for WC flushing: the field testing of a collection system. Building and Environment, 34(6), 765–772.

[27] Ditjen Cipta Karya. (1996) Kriteria Perencanaan Air Bersih. Kriteria Perencanaan Ditjen Cipta Karya Dinas PU, Jakarta, Indonesia.

[28] Putra, Iwan, B. (2015) Menentukan Daya Listrik Pompa Air yang Tepat Untuk Pemakaian, http://esparindopump.blogspot.com/2012/11/menentukan-daya-listrik-pompa-air-yang.html. Accessed on October 22, 2018.

[29] Perusahaan Listrik Negara (PLN). (2018) Penetapan Penyesuaian Tarif Tenaga Listrik (Tariff Adjustment): Bulan April – Juni 2018, http://www.pln.co.id/statics/uploads/2018/05/Tariff-Adjustment-April-Juni-2018-1.jpg. Accessed on October 22, 2018.