

Eco-friendly toilet for sustainable wastewater management in tourism area

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Abstract. Indonesia has implemented sustainable tourism through many programs and ecotourism is one of the issues that most talked about. Ecotourism in Indonesia defined as activities of responsible traveling in intact areas or in areas which are named according to the role of nature. The presence of sustainable tourism should be minimum negative impacts, both on the environmental resources and on social culture local values. The tourism carrying capacity has been influenced by numerous factors of the environmental properties and tourist motivation in the ecotourism locations. One of the keys in environmental properties is sanitation facility as now tourist has voiced concern over the hygiene and quality of the facilities. In tourism area, sometimes with lack of fresh water, a huge amount of fresh water is needed for the sanitation system often caused by the wasteful use of water habit that still done by many tourists. In terms of eco-efficiency, this paper focuses on eco-friendly design in an environmentally manner and analyzing wastewater management an eco-friendly toilet in tourism area. The concept of eco-friendly toilet is maximizing the recycling cycle of water, rain water, and wastewater for later reuse in accordance with the needs of water use in the sanitation system.

1 Introduction

Indonesia is the largest archipelago country in the world with a total population of around 269.6 million people placing Indonesia as the fourth most populous country in the world, consisting of more than 17,000 islands, 300 different native ethnicities, and 742 different languages and dialects. The peak of activity in the most developed provinces, such as Jakarta, Bali, Yogyakarta, and several places in Indonesia became the main concern of the tourism sector in Indonesia [1]. Ecotourism in Indonesia is determined as a responsible tourism activity both in all areas especially in natural areas. Ministry of Tourism and Creative Economy Republic of Indonesia reported that ecotourism has an important role in the field of tourism in Indonesia which means that ecotourism has an impact on employment and the achievement of income to thereby provide incentives in the preservation of natural areas, to increase public awareness about many products and

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services by natural and biological resources and to respect the traditions of an area, and to reconcile economic and environmental issues and provide examples of movements for sustainable development.

One form of tourism that is close to the principle of preserving nature and the environment is called ecotourism. Regina and Soemarno reported that Indonesia must apply five basic principles of ecotourism, i.e.: (1) support programs related to nature conservation, (2) also taking part in the role of the local community in ecotourism activities, (3) the tourism community is expected to get economic benefits, (4) preserving the social values, traditional cultural and religious communities of the local area, and (5) comply with regulations related to tourism and nature conservation [2, 3]. On the contrary, ecotourism can have a negative impact on natural resources and the environment around it if it is poorly managed [4-6]. The most important factor in developing tourist attraction is the carrying capacity which has been influenced by several factors of the environmental properties and tourist motivation in the ecotourism locations. One of the keys in environmental properties is sanitation facility as now tourist has voiced concern over the hygiene and quality of the facilities.

The current sanitation infrastructure in developed countries requires a secure, easy, hygienic, and eco-friendly. Basically, conventional basic water sanitation facilities meet all the requirements but pay little attention to environmental efficiency [7]. The inefficient flush technique because to flush the small amount of excreta requires quite a lot of fresh water [7]. In tourism area, sometimes with lack of fresh water, plenty of fresh water is needed for the sanitation system. Nowadays, many sustainable sanitation system designs with less water consumption, solid and liquid excreta separation method, re-processing methods of excreta, and greywater reusing method which could close the loop of the cycle to overcome the challenges.

The problem that often occurs for proper waste treatment in ecotourism areas is that most of the toilets are directly connected to the septic tank without further treatment. While waste treatment is considered less efficient compared to septic tanks because it is constrained in terms of poor maintenance and management as well as inappropriate operations that will add new problems [8]. One system that emerged to succeed the sustainable water and sanitation management program was later known as the Eco-Toilet system [8]. The concept of eco-friendly toilet is maximizing the recycling cycle of water, rain water, and wastewater for later reuse in accordance with the needs of water use in the sanitation system. some types of eco-toilet have separate disposal systems for urine and feces so that further processing for solid and liquid excreta is also separated [8].

Tourism toilets are defined as a public lavatory for tourists who are mainly engaged in tourist activities which is an important component of tourism public services, not only to meet the basic physiological needs of tourists, but also enhance the quality of tourist experience tourism [9]. Fresh water resources are one of the important factors that are highly dependent on tourism so that the impact of the availability and quality of water resources is quite high on tourism [10]. Indonesia does not have any special toilet revolution program, according to Sunarsa and Andiani [11] 62% of public toilets in Indonesia are still wet and dirty, the cleanliness of public toilets in Indonesia was ranked 12th worst of 18 countries in Asia that means tourist awareness in using water wisely is still lacking and not in every tourist site has abundant water resources sometimes the management of tourist sites forced to provide water reserves so that visitors' water needs for sanitation are met. Low public awareness also plays a role in poor sanitation in toilets in tourist sites. In Indonesia, even though there are already local policies regulating public toilet fees, until now there are still illegal levies on the use of public toilets. This is also one of the causes of ineffective sanitation system maintenance.

According to Gössling [10], in the tourism sector the percentage for domestic scale water use is typically below 5 percent but if the location has a high enough number of tourists it can reach 40 percent and the water resources at the tourism site are usually limited. When calculating the value of water consumption, it will be seen clearly the difference in value in tourism with domestic water use because the use of water in tourism will increase along with the increasing number of tourists and the intensity of water use for activities around the tourist area. Therefore, in terms of eco-efficiency water use in toilet program, this paper focuses on design and analyzing wastewater management an eco-friendly toilet in tourism area. Eco-friendly toilet is designed in an environmentally friendly manner, by having a roof that is made in such a way as to facilitate the flow of rainwater to be accommodated and can be reused.

2 Method

2.1 Sustainable wastewater management

To conduct a study of sustainable wastewater management, a holistic approach is needed that considers the environmental impact and costs of the system to be used. Experts and policy makers often use cost / benefit analysis to choose a wastewater system. In the case of the treatment system selection, several indicators are used, including waste disposal to water bodies, the amount of sludge produced, the use of electrical energy, hazardous materials, as well as the investment, operational and maintenance costs used. In this research, sustainable wastewater management is analyzed through an efficient approach to water use through a recycling system. Recycling of wastewater is done using biological wastewater treatment, which can save electricity and chemicals. through research conducted by Petter et al. [12], it is known that the use of recycled wastewater can reduce the use of clean water up to 50%.

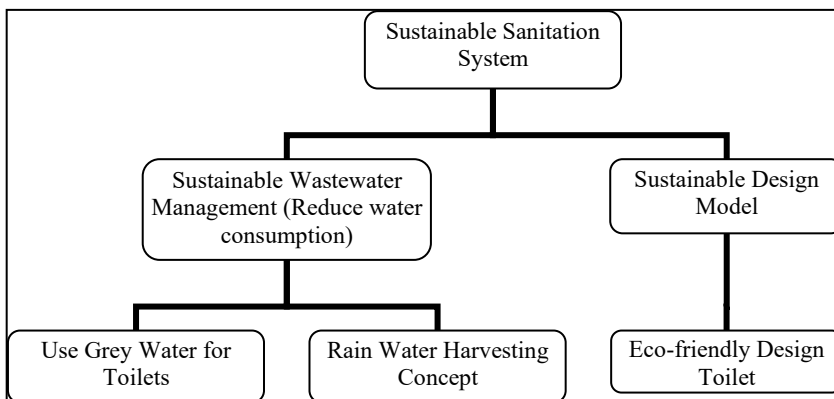


Fig. 1. Methodology flow chart (Author's Analysis, 2020)

From Fig. 1, it can be seen the research variables used. Water consumption in public toilets is an independent variable because it has the effect of changing other variables, but does not depend on other variables. Water consumption will affect the needs of sanitation system design. Sustainable sanitation system becomes the dependent variable because with uncontrolled water consumption, a sustainable sanitation system is needed to overcome this problem. The eco-friendly toilet design acts as a control variable that can be used to determine the effect of implementing a sustainable sanitation system.

Data assumption is carried out through library studies, analysis and reviews to produce simulation models so as to get quality data. The data obtained is then processed, analyzed and synthesized to achieve optimum conditions for managing the resilience of water supply and wastewater management at the eco-friendly toilet. In this paper, the calculation of the potential for recycled water comes from rainwater sources and domestic wastewater sources that come from the use of clean water. For the analysis of rainwater as a potential for raw water, it is done by calculation effective rain data in tourism area. Effective rain calculated by looking at the amount of rain, catchment roof area, and collection efficiency based on the design of eco-friendly toilet.

$$\text{Rain Water Harvesting (RWH)} = [(\text{Roof Area} + \text{Roof Container}) \times \text{Amount of Rain}] - \text{Evapotranspiration} \quad (1)$$

For the potential of used water, the amount of used water in eco-friendly toilet refers to the amount of clean water used and the completeness of existing sanitation infrastructure in tourism area that usually around 60-80% of the total clean water consumption. Furthermore, tourism growth is one of the key factors that must be considered in planning wastewater management. The increasing rate of tourist gives impact to the addition of infrastructure facilities that support the needs such as sanitation infrastructure. The method used in the sustainable wastewater management includes, preparation of design and general plans to achieve criteria and service standards in tourism area and then analyze potential water sources from the design of the sanitation system.

2.2 Eco-friendly toilet

In terms of providing sanitation systems, there are still many people who have not yet received proper domestic waste treatment because most of the existing sanitation is directly connected to the septic tank, where maintenance of the septic tank is not running optimally. This condition does not only occur in the residential environment, but also in tourist areas which are actually visited by many tourists both domestic and abroad, so that it will indirectly affect the good name of a country's domestic waste management. Problems are often encountered due to poor sanitation systems in tourist attractions, such as the spread of infectious diseases through water, the appearance of foul odors, and the contamination of ground and surface water sources. One of the paradigms that can emerging the problems between water management and sustainable sanitation is the sanitation system with source separation, known as the Eco-Toilet System (ETS).

The concept of ETS basically does not need water for flushing and draining feces into the septic tank, even in some configurations it does not allow the use of water and soap, so that in some field applications, the ETS type has a separate channel between urine and excreta. The perception on the concept of ETS is an important issue in applying the system in the field, because it cannot be denied, in this case in Indonesia, it is still very difficult to change people's habits to not use water when defecating. Based on research conducted by Jonathan et al. [8], ETS user interest can be increased by education and promotion of the ease of use and function of ETS in accordance with a combination approach between Technology Acceptance Model and Theory of Planned Behavior. The benefits of the new ETS are considered important if water conservation has already been introduced. Therefore, the ETS approach is applied through domestic waste management where the output from the management is expected to reduce the use of clean water, by implementing a wastewater recycling system. In this research, a study will be conducted related to the ETS approach through waste treatment technology to create sustainable domestic waste management.

3 Results and discussion

3.1 Design of eco-friendly toilet in tourism area

In the field of sanitation, technology can be either water-based or composting-based systems [13]. In water-based systems, potable water, rain water, or grey water can be used as a choice of water source for flush and for the treatment can use various methods such as wastewater treatment (conventional or portable) [14], septic tanks [15], constructed wetlands [16], or eco-machines [17]. In developed countries, potable water-based systems are still widely used with conventional wastewater treatment systems or even with septic tanks, which is why many sanitation technologies have adopted the same concept regarding human waste treatment [13]. Compost toilet is a composting-based sanitation system better known as composting toilet, dry toilet, biological toilet, bio-toilet, or waterless toilet [18]. The toilet itself and composting tank are the two main components of composting toilets [13]. In addition, there are fans and ventilation pipes to remove any odor which is another part of the composting system [13]. In the composting system, less water or even no water is needed to dispose the waste. Toilets in the composting system are similar to conventional toilets where the waste collectors that have been collected in the composting tank will be aerobically digested.

The concept of sustainable toilets in Fig.2 is designed by maximizing the water recycling cycle, namely rainwater and reuse of grey water and black water which will then be used according to the needs of toilet water use. The roof design of eco-friendly toilet in Fig. 2 is made in such a way as to facilitate the flow of rainwater to be accommodated and can be reused. The research approach water-based systems toilet since the composting toilets is still not common in Indonesia and composting toilets have not been permitted for some areas that have conditions such as land that is considered unsuitable for treatment and direct disposal of waste in the area, the unavailability of clean water services for the surrounding area so that the surrounding community uses deep ground water, and in flood-prone areas.

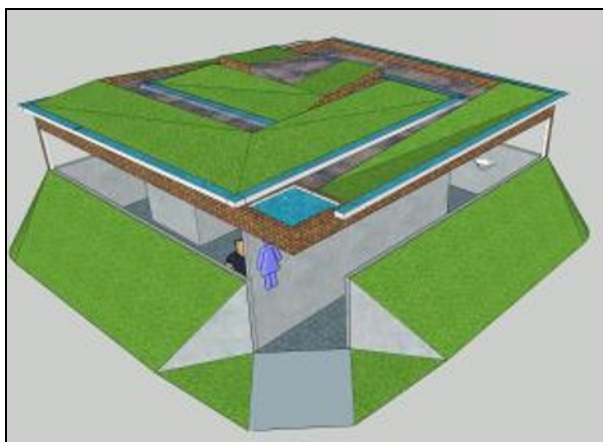


Fig. 2. Design of eco-friendly toilet. Source: Indonesia Water Institute, 2020.

The term of eco-friendly indicates that the product that used on the design has a positive impact or at least not have a negative impact on the environment. Eco-friendly products are renewable, recyclable, and do not harm the environment when we use them. Based on the details design in Fig.3, the eco-friendly toilet has a roof area about 52.64 m² with installation of vegetation on the walls and also the roof is intended as a catchment of

rainwater and dew which is common, especially tourist sites in forest or mountainous areas. This design consists of 2 area of toilet, namely women restroom area and men restroom area. Furthermore, there is a room for nursing, disabled restroom, and also for janitorial things in this eco-friendly toilet. This eco-friendly toilet is using local materials such as wood, sand, brick, and also natural vegetation in the area. In addition, the use of sunlight will be maximized as a source of natural lighting during the day. The open eco-friendly toilet design also aims to maximize air circulation inside the toilet so the odors will be reduced.

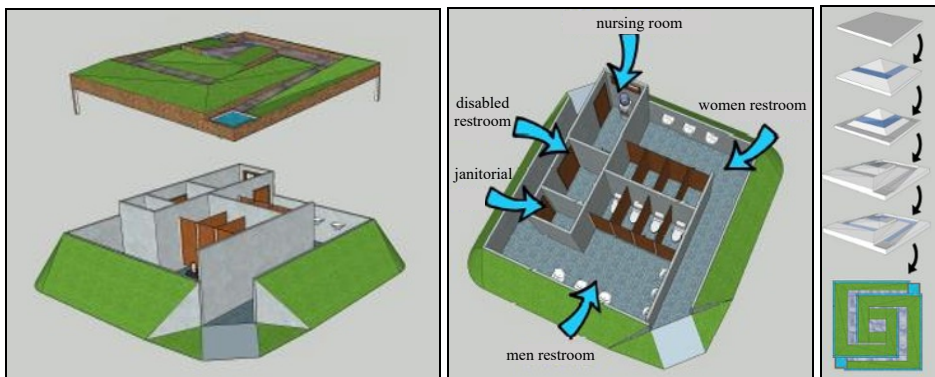


Fig. 3. Details design of eco-friendly toilet. Source: Indonesia Water Institute, 2020.

3.2 Wastewater management in eco-friendly toilet in tourism area

Sustainable sanitation system is the main concept of eco-friendly toilet design which is focused on processing sewage separately and can then be reused for flushing and plants. In this paper, it is planned that water consumption for flush will be reduced by the application of a water recycling system using treated wastewater (grey water) as a flushing media. Conventional toilets, which are still commonly in regular use, waste as much water about 14-15 liters for flushing, 10 liters for sink, and 5 liters for urinal. The standard water requirements for sanitation facilities refers to Indonesian National Standard (SNI) number 03-7065-2005. Consuming that much of water is not a sustainable way of living. Nowadays, there are many technologies that water conservation friendly such as dual-flush toilets that offers either a side lever toilet handle or dual system above the tank for single flush or dual flush so users can use water wisely.

Table 1. Standard sanitation facility in toilet.

| No. | Facility | Number of Facilities | Water Use Standard (liter/person/day) | Average Tourist per Day | Total Water Needs (liter/day) |
|-------------------------------|-----------|----------------------|---------------------------------------|-------------------------|-------------------------------|
| 1. | Sink | 8 | 2 | 50 | 800 |
| 2. | Jet Spray | 9 | 2 | 50 | 900 |
| 3. | Flush | 13 | 4.5 | 50 | 2,925 |
| 4. | Urinal | 4 | 1 | 50 | 200 |
| Total Water Needs (liter/day) | | | | | 4,825 |

From Table 1, we can see the number of facilities is based on the design above. In this eco-friendly toilet, we will have 8 sinks (3 sinks in women area, 3 sinks in men area, 1 sink in disabled toilet, and 1 sink in nursing room), 9 jet spray (4 in women area, 4 in men area, and 1 in disabled toilet), 13 flush (7 in men area, 4 in women area, and 2 in disabled toilet),

and 4 urinal (3 in men area and 1 in disabled toilet). The water use standard is performed by adopted standard from SNI number 8153:2015 which stated for toilet seat or squatting that uses a flush tank or not, with a flush capacity does not exceed 6 liters. Adopted from US EPA, maximum water use for urinal is 4 L per flush and for faucet is 10 liters per minutes. For water conservation, the adopted regulations are still too high so we had some research on water-friendly toilet products that are available on Indonesia's sanitary market and in harmony with the concept of environmentally friendly design, we choose the most efficient products that can reduce toilet water use by 20-60 percent. The eco-friendly products use 2 liters per person for sink, average 2 liters per person for jet spray, 4.5 liters per flush, and 1 liter for urinal with assumption of an average 50 tourists per day, the calculation result based on the multiplication formula between number of facilities, water use standard, and average tourist per day per facility so we get the total water need for the toilets is 4,825 liters per day. Thus, the use of water can be saved up to 68%, when compared to using a plumbing tool as in regular use.

Table 2. Potential water sources for eco-friendly toilet.

| No. | Water Sources | Calculation of Water Potential | Total Water Sources Potential |
|-----|--|---|-------------------------------|
| 1. | Grey Water from Sink | - | 800 liter/day |
| 2. | Rain Water Harvesting | $52.64 \text{ m}^2 \times 2.00 \text{ m/year} = 105.28$ $105.28 - (20\% \times 105.28) = 84.224 \text{ m}^3/\text{year}$ $= 230.75 \text{ L/day}$ | 230.75 liter/day |
| 3. | Recycling of Waste Flushing Processed Wastewater | $70\% \times (900+2,925+200) = 2,817.5 \text{ L/day}$ | 2,817.5 liter/day |

Water conservation calculation is one of the important instruments for the sustainable toilet, by knowing the calculation of the water balance in an eco-friendly toilet can be later be used to ensure the used of sanitation facility. From the Table 2 calculation above, we can assume total water sources potential sequentially 800 liters per day from sink based on Table 1 total water need calculation, 230.75 liters per day from rain water harvesting that using equation 1 with the 52.64 m² roof area, 2 m amount of rain per year and 20 percent of evapotranspiration, and 2,817.5 liters per day from flushing that already processed at wastewater treatment plant that using an average 70 percent of the total clean water consumption from jet spray, flush, and urinal in Table 1.

Rain water harvesting is an alternative sustainable way for tourism area and it has a smaller water footprint. The concept is to utilize roofing system as the catchment area, then channels it into a gutter or line that will stream into the storage tank. For the rainfall value is obtained from the 2020 average rainfall data in Indonesia by value 2,000-3,000 mm/year so we used the average minimum for rain water harvesting calculation. We calculate evapotranspiration since the design is using vegetation with assumption 20 percent of rain will evaporated. Many factors influence the evapotranspiration, in the mountainous area which has cool temperature and cloudy, the effect of evapotranspiration is low.

Table 3. Water balance calculation for eco-friendly toilet.

| No. | Water Sources | Supply (liter/day) | Water Used | Demand (liter/day) | Supply – Demand (liter/day) |
|-----|---|---------------------------|------------------|---------------------|-----------------------------|
| 1. | Grey Water from - Sink - Rain Water | $800 + 230.75 = 1,030.75$ | Sink & Jet Spray | $800 + 900 = 1,700$ | (-) 669.25 |

| No. | Water Sources | Supply (liter/day) | Water Used | Demand (liter/day) | Supply – Demand (liter/day) |
|-------------------|---------------------------|--------------------|----------------|---------------------|-----------------------------|
| | Harvesting | | | | |
| 2. | Black Water from flushing | 2,817.5 | Flush & Urinal | 2,925 + 200 = 3,125 | (-) 307.5 |
| Total (liter/day) | | | | 4.825 | (-) 976.75 |

Water balance calculation is all about how supply can meet the demand. As we can see in Table 3 that water sources supply is come from grey water (sink and rain water harvesting) and black water (flushing) that will be processed at wastewater treatment then can be for the demand. The water demand for sink and jet spray is about 1,700 liters per day that will covered by grey water from sink and rain water harvesting although it is still deficit 669.25 liters per day. The water demand for flush and urinal is about 3,125 liters per day can be covered by recycling water from the wastewater treatment for about 2,817.5 liters per day but it is still deficit 307.5 liters per day. Thus, it can be concluded that the cycle of toilet water use has reached 79.76% of reclaimed water in other words only an additional supply of clean water is needed from another alternative source of raw water by 20.24% of the total water needs. Additional water supply can be obtained by purchasing water at the local water supply or management of tourism area has a water reserve tank.

Ecological, economic, and sociological aspects are some aspects that must be included in the perception of sustainability where it must be carried out in three different stages, the first stage is the local scale which includes hygiene and health aspects which are the daily main concern [12]. The second stage is the regional scale which is usually the occurrence of classic environmental problems in the span of months or even years and the last stage is global scale, which emphasizes sustainable systems on a long scale or in a span of decades or even centuries [12]. Wastewater from toilet has the biggest potential to be treated into recycled water that can be used as non-potable clean water supply. By utilizing recycled wastewater as another source of water supply, the amount of groundwater or surface water used can be minimized significantly. Wastewater from toilets and urinary will be treated to septic tank for the feces and wastewater mini plant that consist of primary settlement, biological treatment, and final settlement. The treated water can be reused as a flusher for toilets and urinary.

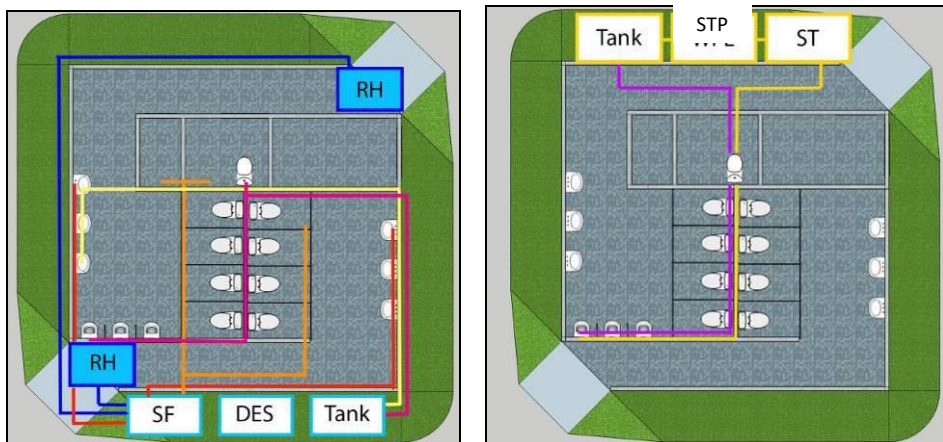


Fig. 4. Water and wastewater management for eco-friendly toilet. Source: Indonesia Water Institute, 2020.

The design of this eco-friendly toilet has water and also wastewater treatment facility. The water treatment facility is added to reused the water from wastewater treatment facility. Based on the design in Fig. 4, this eco-friendly toilet has rain water tank (RH) that used to be temporary rainfall collector. If we do not treat, the harvested rainwater can be used as a flusher for toilets or urinary, water plants, and as an additional reserve water for hydrant usage. Greywater from sink and the harvested rainwater will be treated at mini plant of water treatment which consists of filtration and disinfection system then the treated water will be used as clean water (for sink and jet spray).

4 Conclusion

The implementation of a sustainable wastewater treatment system is one form to reduce the proportion of water use in tourist toilets, several factors that influence include the water recycling system and energy efficiency. The proposed eco-friendly toilet design has aims to close the loop of water prints by paying attention to environmentally friendly conditions that have priority on water conservation and improving the efficiency of sanitation infrastructure and energy. With the energy efficiency, the eco-friendly toilet system can also economically reduce the cost of clean water consumption so that investment costs can be covered by the savings made.

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