IOP Conference Series: Materials Science and Engineering

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To cite this article: A Prasetyadi and A Koonsrisuk 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **886** 012039

Minimization of Energy and Water Cost for the Main Building of Suranaree University of Technology Hospital (SUTH)

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Abstract

Hospitals consume a significant amount of energy and water. Energy and water are intertwined in a way that an improvement of one can worsen the other one. However, as the water price was relatively cheaper in comparison to energy, several studies paid their attention to the minimization of energy usage of the building only. In this research, a study of energy and water for the main building of Suranaree University of Technology Hospital (SUTH) was conducted in order to find the minimum cost of energy and water of the building using proposed a new method namely variables pair. The investigation showed that a single meter of electricity usage as the only energy consumption of the building was applied. Meanwhile, water usage was composed of tap water, flush water, and distilled water. Therefore, a method to determine the cost of energy and water was proposed. A variables pair in a form of (water usage, electricity consumption) was used in the proposed method to determine the cost of energy and water for the main building. Several water-saving options were proposed and examined. It was found that the water and electricity consumptions in the form of variables pair were (82.9 m^3/day, 26.3 kWh/day) for a current system, while they were (82.9 m^3/day, 21.2 kWh/day) for an option without water regeneration with minimum energy. Meanwhile, they were (82.9 m^3/day, 24.4 kWh/day) for a system with water supply tanks allocated at the rooftop and 8th floor of the main building, instead of using only one supply tank installed at the rooftop as in the current system. A system that collects the condensed vapor of the HVAC system and then uses it, had consumptions of (77.3 m^3/day, 16.3 kWh/day). Applying the current cost of energy and water at 4.5 Baht/kWh and 10 Baht/m^3 respectively it was found that the cost of water could be reduced up to 10.2% with water regeneration. The water cost contributed 7.1% cost reduction, while the energy part was 38.2%. It shows water volume saving is more significant than the energy of water processing saving. The proposed method could separate process and cost parts, therefore it is easy to handle and provides a broader perspective of the saving strategy.

Keywords: Energy and water nexus, energy cost, water cost, energy and water conservation

1. Introduction

Energy and water become the main factors in building conservation. Intensities of energy and water usage portray the building conservation level [1] in addition to the cost. The more efficient a building is, it consumes less energy or water and has less metric intensity. Energy and water usage over space and over inhabitants are two main metrics that people usually use for evaluating the building. Codes [2, 3] and benchmarking [4] are applied to set a standard of intensity. The codes also relied on planning the energy needs of an area or a country [3].

Energy and water conservation were investigated separately in many cases. The discussions only focused on conservation of energy or water neglecting the other. Domestic hot water was the main issue of energy-related to water [4] where the energy consumption of the hot water preparation was the single object of concern [5]. The system consuming a lot of water generating abundant energy requirement of the cycle was still far from discussing the water aspect of the energy. Even, about a system consuming abundant water such as a cooling tower, the discussion just focused on energy conservation [6]. Effectiveness of the evaporation cooling became the main issue of the proposal as minimum energy consumption and exergy destruction. Highly efficient energy consumption can aggravate the water usage of the building. In a broader view, the condition may imply the disadvantage of energy conservation.

Some studies about energy and water in a hospital have been performed. Some organizations and governments conducted a study about energy and water in hospital and produced benchmark [2,5,7]. Nevertheless, a deeper analysis of the measure for optimizing energy and water is still rare. Neural network method was applied for energy optimization in operational through forecasting the consumption [8]. Improvement of the intensity consumption by evaluation of energy and water usage was proposed in facilities audit by merit system approach [9]. A multi-objective approach using genetic algorithm was elaborated for optimizing CHP system in a hospital. It showed that a primary energy saving should be companied with payback analysis for economical optimum [10].

Strategy for optimizing two different materials can be categorized into 2 main approaches. The first method is projecting to one of the forming material and the second is projecting to another material. The 1st category includes mapping water to energy and vice versa. In analyzing the energy and water of the wind power generation, water was nominated into energy [11]. Then analysis was conducted in the energy unit. The reason for the method was that the water cycle needs energy. Therefore, the energy can be used as water metric. The economical unit [12] and CO_2 [13] evaluation belong to the 2nd type of the method. The economical unit was determined in fixed cost unit or its derivations. CO_2 was applied in order to trace the green-house impact which is mostly presented in CO_2 accumulation equivalence[14]. The 1st method can be applied if the interrelation between both materials can be determined clearly. In other words, it can be said that the interrelation has fixed relations. The advantage of this method is its adaptability for another comparison and parameters existence. The contra of the 1st type is the inability to determine the policy direction while the price of the material is unstable, the material is irrelevant, or the amount is insignificant. The 2nd type method cannot be adapted when the economic states are changing and may mislead in term of non-economic purposes. However, the second method is very practical and useful.

Purpose determines the way of energy and water interconnected. LCA (*life cycle analysis*) was applied for calculating the intensity of wind power [11]. NEA (*network environmental analysis*) was applied to show the interdependency [11] as an alternative to input-output analysis methods. The Input- output analysis was applied to understand the impact of the broader system by inter-sectoral interdependence [15]. It implies that there is not any single strategy being able to depict both economic and environmental basis thoroughly. Optimization on economy often has to cross the environmental issue that an adjustment of the economic structure should be conducted to save the environment [16]. Integrating a heat exchanger network can neglect the economical aspect of investment [17]. The optimization in the environmental aspect sacrifices cost of the system. According to extreme value theorem, it can be guessed that the optimum condition range boundaries are the environmental condition and the cost minimization.

Some methods have been proposed for integrating energy and water in industries. Wang and Smith [18] proposed a method advancing pinch method for water allocation problem of the contaminant system. They searched for optimum wastewater treatments number and capacities. This work has been improved by Kuo and Smith [19] for multiple treatment case. Both methods were based on the graphical approach and had assumptions of a single contaminant system and steady-state system [20]. The advancement of water and heat problem of integration does not yet cover the problem of mechanical which comes from a combination of static and dynamic conditions as mechanical generates a driving force of the mass flow. The driving force problem is more dominant in low quality thermal flow as the thermal aspect becoming less significant.

The aims of this article are to propose a method of energy conservation considering water factors in a building and to propose a method for evaluating the energy of water system using paired variables consisting of energy consumption and water usage. The proposed method fits the hospital main building problem categorized as low-quality thermal system. A modification of a commonly used composite curve is proposed and called as pair variables. Energy evaluation of water was calculated as an important part of energy optimization. Therefore, mapping of energy and water flow and its energy projection became the main part of this work. A new method separating the process and material parts were developed. Some options of reconfiguring water streams were presented. Finally, the cost of water was provided as an evaluation.

To meet its aims, the article is composed of 4 sections. It is started with setting the problem in the introduction as the first section, then it is followed by the method as the 2nd. The method has two main parts. The first part is about presenting the energy and water pair variables model. The second focuses on applying the variables pair approach for energy and water in SUTH main building. This part consists of strategy in estimating water usage in hospital, energy estimation of the system and streams of energy and water. Evaluation of energy consumption of the water flow is proposed as the third section followed by some advancement options. The last section shows the conclusion of the work.

2. Methods

The method is presented in two main parts. The first part discusses the variables pair method. This method consists of steps to represent the problem into energy and water variables pair model until the minimum energy condition reached as an ideal condition without any reuse and regeneration. The problem as mentioned in Kuo and Smith [19] is used to show the case method. Comparison of the result is presented to show the fitness of the proposed model into the existing method. Following the first, the application of the energy and water at the water network of the SUTH main building is presented.

2.1. Energy and water variables pair model

A description of the water allocation problem can be done using requirement diagram a shown in Table 1. The diagram consists of a stream number, flow-rate, and concentration. The stream number designates the streams of the problems. The flow-rate indicates the amount of each stream. The concentration shows the amount of the contaminant over the mass of water at the respective inlet stream. The concentration of the contaminant released to the environment was 30 ppm [19].

Table 1. The requirement diagram of the allocation problem [19].

stream number	flow-rate (t/h)	concentration (ppm)
1	20	800
2	30	400

3	50	200

To find minimum concentration removing in water allocation problem, a composite curve is generated to complete the requirement diagram. The concept of composite curve bases on the assumption that the overlapping processes can reduce the total water streams. The composite curve is managed to find a minimum. The gradient of the slope represents the rate of a contaminant over the water flow rate. The higher the gradient means less water need for each contaminant rate. The optimum condition can be found as a line connecting output requirement and pinch point. This line should only cross in single point or equal to any line without crossing the rest. The more complex a system is, the more difficult to find the pinch point is. A thorough examination has to be done to find the minimum. Various algorithms can be applied to compare the gradients in order to find the minimum. An example of a composite curve of the problem from Kuo and Smith [19] is shown in Figure 1.a.

There are two main metrics of the composite curve method showing that conservation of contaminant is the base of requirement. The first is the capacity of the wastewater treatment that is represented by the flow rate of contaminant (X-axis). The second is the removal range (Y-axis). Higher capacity and range represent a higher cost [18]. Therefore, minimization is an effort to reduce cost in term of the capacity of wastewater treatment and the removal range. The ideal range shows a minimum single range of wastewater treatment that can be used for the system.

Based on these metrics, the variables pair composed of energy and water flow rate is proposed to exchange the removal range and flow rate. The removal range limits the contaminant mass removed in a specific flow rate. The difference in the contaminant between input and output determines cost linearly. The flow rate in addition to limiting the capacity of the system also determines cost in a linear way. Then, it can be inferred that cost constraint can be exchanged with another function that is linear to the cost. The relations can be formed mathematically as shown in (1).

$$\forall C(x,y) \wedge E(x,y) \rightarrow \exists C(x,E),\ x,y \mid x,y \in R \tag{1}$$

In order to minimize the wastewater treatment, the variables pair uses energy and flow rate as its components as shown in Figure 1 b. The X-axis is accumulative stream flow rates and Y-axis is energy consumption over cost factor. The requirement diagram presenting the streams can be changed easily. The slopes of the requirement diagram representing the contaminant flow rate that should be removed are used for calculating the flow of the water. Accumulation of the contaminant water needs can be plotted to Y-axis. The X-axis of the variables pair diagram is calculated from the stream of contaminant.

Energy represents the cost of the system for specific flow rates. These variables pair directly shows cost represented by energy need and the stream to handle at the same time. The energy is directly proportional to the contaminant flow rate at a composite curve. The stream is an additional feature that shows the input of the system. Minimum of the system can be found trough accumulating the stream and its required energy. This number becomes the limit of the system. The gradient shows the capacity of the treatment to remove the contaminant. The higher is the gradient, the more its ability to remove the contaminant.

Minimization procedure can be done by selecting a probable sequence of the streams and its energy requirement. The strategy of the minimizing is applied for reducing the flow rate as much as possible to minimize the overcapacity of the removal contaminant. Combination of some streams can be done as long as the combination of specific streams should be less than the gradient of the maximum targeted. The maximum stream should also be considered.

Adjustment of the variables should be done for a different case. Accumulative water flow rate can be changed to be accumulative water usage. The accumulative energy for the system can be transformed to be accumulative energy.

2.2. SUTH Energy and Water System

Suranaree University of Technology Hospital (SUTH) main building is the center of the SUTH activities which has 11 stories plus 1 ground level. This building is functioned for clinics, wards, emergency, operation rooms, office and support system. It becomes the center for employees and visitors. The building is equipped by centralized HVAC with 3 x 250 TR chillers, 2 x 1.25 MW electricity system substations, and 1.10 MW back up power generator and 30 minutes batteries. The building has a tap water system operating 2 x 30 kW pump, and provides water heaters with total power electricity power need 234 kW.

Energy and water usage of the SUTH main building was recorded daily for maintenance. The data consisted of building daily water and electricity consumption as the only energy type of the building. The electricity energy usage was measured by a meter at the electricity control cubicle on the ground floor. The water meter for the building was located before the groundwater tank supplying the system the tap water for the system.

To calculate the energy of water usage, estimation of water usage of the building activities were conducted. The activities of the building involving water usage are sanitary, medical activities, cafeteria and HVAC. Gardening and food preparation are excluded from the counting as they were held by other building and had its own meter. Sanitary system water usage was estimated by combining a proportion of employees and patient water usage. The medical activities were estimated from some medical treatments and their patients. The HVAC water usage was estimated from the simulation of the centralized HVAC system of SUTH main building. The cafeteria usage was assumed as the rest of the water usage of the building.

Energy intensity of the water was calculated from the ideal condition that becomes the benchmark (named: *benchmark*), current condition operation (named: *current*) and 2 options as an enhancement (named: *option 1* and *option 2*). The ideal condition (*benchmark*) takes place when every system uses water without any regeneration or reuse in minimum energy processing. The *current* was the operation condition as the data were taken. It used a single water tap tank on the rooftop. *Option 1* is a proposed condition when there were 2 tap water tanks. They were the current water tap tank for supplying floor 5th – 11th and additional water tap tank in floor 8th for supplying the ground floor until floor 4th. *Option 2* is proposed retrofit by installing a system to collect condensed water from HVAC.

As the building is multistory one, the heights of the level determine the ideal potential energy of water. Additional energy intensity was added as a specific quality of water needed. The HVAC needed to soften water for chiller water and medical activities needed RO water. Domestic hot water is excluded as a limited number of inpatients which are the main hot water consumers.

2.2.1. HVAC water

HVAC water usage was determined from the make-up water needed for centralized HVAC of SUTH main building with a temperature setting 24°C and relative humidity 50% using simulation in TRNSYS as shown in previous work. The temperature setting was chosen as it provided reasonable result compared to sampled data condition in 2017. The simulation also reported that the HVAC system consumed 1.8 GWh of electricity in a year. The result represents 56% of the electricity consumption of the building in the same year. Total evaporated make up water for the HVAC in a year was 8,506 m^3, which is equal to 23.3 m^3 water per day on average.

Water usage of the HVAC consists of make-up water and blow-down water. The make-up water is defined as the amount of water compensating evaporated water at cooling tower. Therefore, the make-up water keeps the condenser water is always equal. Amount of make-up water is equal to the amount of evaporated water for cooling. In addition, keeping an equal amount of water, the cooling tower also needs to maintain the mineral concentration of water is acceptable. Assuming that soften water and hard water have the conductivity 50 µS/cm and 300 µS/cm respectively, the blow-down water can be calculated as Equation (2). Therefore, the HVAC water usage is presented in Equation (3). It shows that the water of HVAC is a function of the water evaporated at simulation.

$$V_{bw} = \frac{V_m}{5}.V_{cdw} \tag{2}$$

$$V_w = V_m + V_{bw} \approx \frac{6}{5} V_m \tag{3}$$

2.2.2. Sanitary water

Sanitary water consists of water for flushing, water for showering and water of hand washing. According to the type of water contacts with a human, it is clear that water of flushing does not have contact with a human. The water for showering and hand washing is considered to have indirect contact with a human because it does not go directly into the human body system. The water for flushing can be relatively low quality in term of medical requirement. The water for showering and hand washing can be tap water quality with bacteria colony less than 150 fcu/cm^3 [21].

Sanitary water for flushing was determined from a number of inhabitants and their times staying at the hospital in a day. The inhabitants of the hospitals are employees, outpatients and inpatients. The employees were assumed to stay in the hospital for 8 hours. The outpatient stays at a hospital on an average of 2 hours. The inpatient category lived 24 hours in hospitals. The flushing water equation is shown in Equation (4).

$$W_f = \sum C_i N_i t_i \tag{4}$$

In a similar way, water for handwashing and showering was calculated using Equation (4). The difference was the coefficients. The coefficients for flushing water, hand washing, and showering were 50.4 l/day, 29.8 l/day, and 69.6 l/day respectively [22]. The number of daily inhabitants is provided in Table 2.

2.2.3 Medical activities water

Medical activities water is the water used for medical activities such as lubricating at the dentistry clinic, operation and hemodialysis. The other water types were neglected due to the minimum amount. Medical activities water is determined by a coefficient of water usage and patient number assumed as activities. The equation of the medical activities water is presented in Equation (5).

$$W_m = \sum C_m N_m \tag{5}$$

There were some clinics which had significant water usage per patients. They were the operation room, delivery room, dental clinics, and hemodialysis unit. The coefficients of those clinics were 100 l/patient, 100 l/patient, 2 l/patient, and 200 l/patient in respective sequence for the preceding units. The water of hemodialysis and dental clinics was distilled water. While the other clinics used tap water mostly for the hand washing.

2.3. The energy of water usage

The energy of water usage is depended on the type of water usage and clinic position. The clinic position implies a minimum energy need for pumping. The types of water usage determine the energy intensity of water processing. The energy of tap water usage was assumed to consists of water distribution only which was depended on story. Soften water was assumed to have single-phase RO water processing. The intensity of this activity is 0.36 kWh/m^3 [23]. The RO water was assumed as double stage RO water processing which has 0.47 kWh/m^3 [23] of energy intensity. The hot water is assumed to be proportional to the number of patients and became part of water showering or hand washing. The hot water of consumption per patient per day was assumed to be 11 liters. The energy needed for the hot water was assumed to heat to 65°C from 25°C as the average of the water temperature with 4.2 kJ/kg°C heat capacity. Therefore, the energy of the water according to the type can be calculated according to Equation (6).

$$E_{wt} = \sum C_t W_t \tag{6}$$

The water usage can be broken down into story energy-water requirement. Every story has a different function and water usage. Some stories only need tap water; other stories might need all type of water. It also has a different level that determined the energy of tap water. Therefore, the water usage of stories can be calculated by Equation (7).

$$W_s = W_{fs} + W_{ds} + W_{ms} \tag{7}$$

The energy of the water at a story was composed of energy for distribution which was proportional to the amount of story tap water consumption, and energy according to the function. Therefore, energy for water in every story could be calculated by Equation (8).

$$E_{ws} = C_s W_s + C_{ms} W_{ms} + C_{hs} W_{hs} \tag{8}$$

The HVAC water was calculated as additional water. It was settled at the rooftop, therefore the energy of the HVAC was assumed as much as the tap water energy for 11th story. The processing of the HVAC water was in accordance with Equation (6) with energy intensity as a single step RO. Energy for HVAC was calculated as energy for make-up water and blow-down and calculated as Equation (9).

$$E_{HVAC} = (C_{11} + C_{SO})(V_m + V_{bw}) \tag{9}$$

After usage, the water was sent to the wastewater treatment before going to the environment. The intensity of water treatment at the building is 0.344 kWh/m^3. Except for the water evaporated at a cooling tower, the water from the hospital was treated at the facility. Then the water treatment needed energy as shown in Equation (10).

$$E_{WT} = C_T (W - V_m) \tag{10}$$

The energy of the water was calculated as an accumulation of energy of water processing for water, energy for distribution and energy for wastewater treatment. Accordingly, energy necessity of the water at the building was calculated using Equation (11).

$$E_W = \sum E_{ws} + E_{HVAC} + E_{WT} \tag{11}$$

2.4. Energy and water cost

Energy usage and water amount could be presented as variables pair as there were energy and water at the same time in every process cycles. Amount of water in a specific time (could be assumed as flow rate) was projected into X-axis. The Y-axis projection was used for energy usage of the water. The ordered pair variables can be done in every step of the system. The cumulative becomes the system of water and energy variables pair.

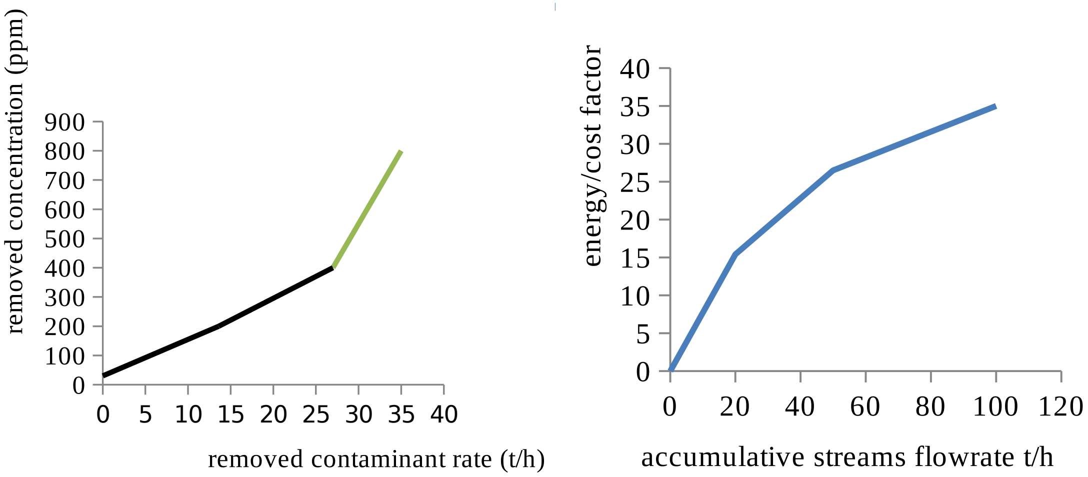
The variables pair can be transformed for other variables such as cost or CO$_2$ emission. The cost of energy and water can be calculated as a dot product of energy water paired variables and the respective cost prices. The total cost of energy and water can be considered as the summation of the water cost and energy cost. Equation (12) shows the cost of energy and water.

$$C_{EW} = \begin{bmatrix} f_{EC} & f_{WC} \end{bmatrix} \begin{bmatrix} E_W \\ W_s \end{bmatrix} \tag{12}$$

3. Results and discussion

Comparing the proposed method and the composite curve on the problem of wastewater treatment [18] provided a similar result. The composite curve gave 35 t/h contaminant removed capacity with 437.5 ppm contaminant rate at the water as the optimum condition in a single water treatment system with an unspecific removal factor. The new method in the other hand mentioned that the energy needed for removing the contaminant should be at least 35F; with F is the conversion factor connecting removed contaminant and the cost. The rate of contaminant removal shows the cost of the system [18]. Accordingly, F is a function that shows energy necessity for removing every ton contaminant. Assuming energy as the basic cost of the removal, the new method also easily shows the condition to reach that.

Specified remove factor of wastewater treatment means that the constraint depends on the structure. Basically, the established method and the proposed one can be applied in a similar way. The established method minimizes the area on the left of the graph. The X-axis shows the capacity which is related to the cost of the system. The present method minimizes the area under the graph with energy as the main factor. Comparison of the methods can be seen in Figure 1.



(a) (b)

Figure 1. a) The composite curve of Kuo and Smith problem [19], minimization can be considered as integration to the Y-axis. b) The ordered pair variables of the same problem, the minimization process has an area of integration to the Xaxis.

The hospital water usage of the SUTH main building was composed of tap water, RO water in exchange for distilled water. The RO choice was based on assuming a practical process. The water should not be kept for a long time in order to avoid contamination. This composition basically represents the quality of the water which also shows the energy necessity of water processing. In addition to the quality, as the building is multi-story, division of the water into floors requirements is also presented. Table 3 shows the story and its water requirement. Outpatients were assumed to stay 2 hours in the hospital during their visit. The employees were assumed to stay for 8 hours per day for 1 shift work.

Table 2. The daily building inhabitants (in person) and water usage (m^3) of the building.

Floor	Inhabitants			Tap Water	Flush	RO
	OP	IP	Staff			
Ground			53	14.53	0.89	
1	356.4		77	8.24	2.79	
2	141.2		34	3.76	1.16	0.32
3	126.6		38	3.88	1.17	0.25
4			20	0.99	0.34	
5	91.4		16	2.27	0.65	
6	0.5		16	0.96	0.27	

7			43	2.13	0.72	
8	62.5	7.6	13	7.55	0.86	3
9	4.0	18	21	3.77	1.28	
10	1.3	21.8	21	4.30	1.46	
11		13.6	11	2.57	0.87	
HVAC						27.96

The energy of water processing consisted of energy for tap water distribution, water processing to be RO or softening. The minimum pressure of the floor was 20 psi as compensation of the network pressure loss. Therefore floors 8th, 9th, 10th and 11th needed booster pumps. The additional energy for those floors should be provided. Table 2 shows the distribution of the energy coefficient for the floor and energy usage for water on every floor.

Table 3. The coefficients of energy water processing and energy necessity for the main building usage.

Floor	Ct (Tap)	Ct (RO)	Tap (kWh/d)	RO` (kWh/d)	Booster (kWh/d)
Ground	0.013		0.191		
1	0.026		0.217		
2	0.040	0.47	0.137	0.164	
3	0.053	0.47	0.180	0.133	
4	0.067		0.066		
5	0.080		0.182		
6	0.094		0.090		
7	0.107		0.229		
8	0.121	0.47	0.187	1.772	0.030
9	0.134		0.566		0.058
10	0.148		0.636		0.116
11	0.161		0.414		0.098
HVAC	0.173	0.36	5.705	10.044	

Accumulation of the energy for the water processing as the minimum without any reuse or regeneration can be shown in Figure 2. This condition is represented as an ideal condition as there is not any water reuse or regeneration and the water resource. At this condition, the energy for distribution of the water is considered as a minimum. The final water usage of this condition was 82.9 m^3/day consuming 21.2 kWh/day of electricity.

The current operation condition (*current*) has energy necessity higher than the ideal condition without regeneration (*benchmark*). The *benchmark* assuming the energy distribution is different for every story, while the *current* need single energy distribution as much as the eleventh story. The single water tower at the rooftop is the reason. The tap water is distributed from the rooftop tank. The current operation (*current*) has variables pair as (26.3 kWh/d, 82.9 m^3). *Option 1* of proposing a new water tower on the 8th floor to supply the ground up to 4th floors need less energy intensity for an equal volume of water. Regeneration strategy by collecting condensed water from the HVAC and use it can decrease the necessity for water by 8.6% and the energy for water usage by 39%. The ordered pair variables of the *option 1* and *option 2* are (16.3 kWh/d, 77.3 m^3/d). The reduction of energy comes from the collected condensed water from HVAC operation which is used for flushing.

This final water usage and energy necessity can be depicted into a vector-like of energy and water ordered pair variables as shown in Figure 3. The X-axis is water amount which is withdrawn or water usage and the Y-axis is energy usage. Figure 3 shows that water *option 2* have less water energy intensities than the current operation condition but higher energy intensity than the *benchmark*. It also mentions that *option 3* has less water and water energy intensity compared with *current* and *benchmark*. *Option 3* is more preferable for conserving energy and water.

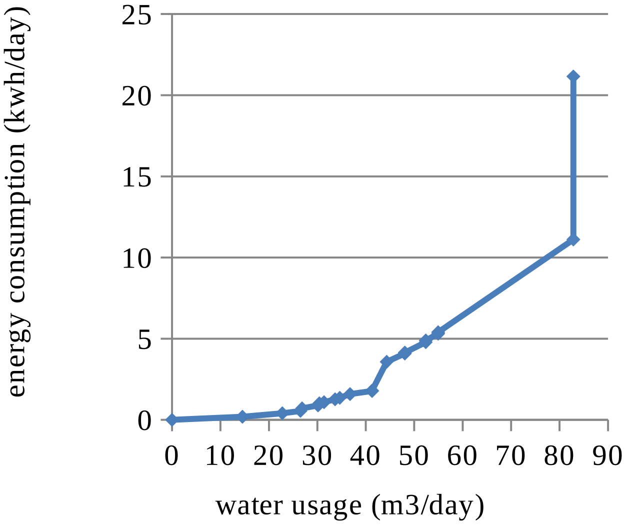


Figure 2. The accumulation of water usage and its energy for preparation is presented in variables pair approach.

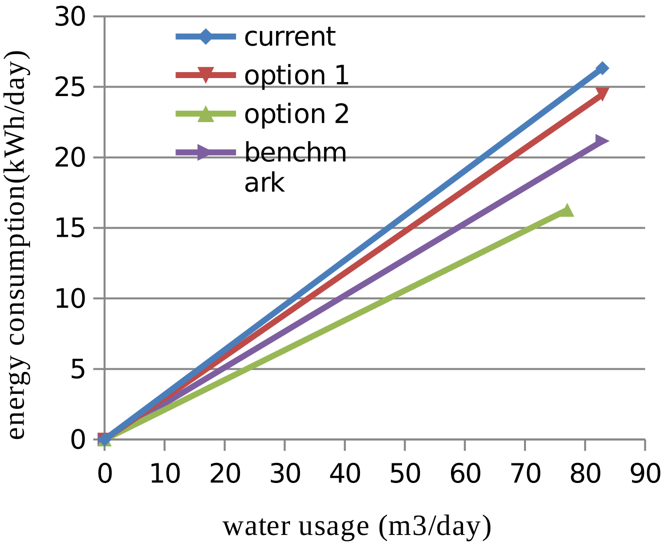


Figure 3. Vector-like representation of ordered pair variables that consist of water usage and energy consumption. The method also shows the energy intensity of the water as the gradient.

Cost of the water and energy can be calculated using Equation (12). As long as the price function of the water and energy is linear or exponentially progressive, cost of energy and water is proportional to the daily water usage and energy consumption. It can be inferred easily that *option 3* is the best. At the current prices, the daily energy and water consumption concerning water in SUTH main building can be seen in Table 4.

Tabel 4. Comparison of daily electricity and water cost (in Baht)

	cost of electricity	cost of water	total cost
current	829	118	947
option 1	829	110	939
option 2	770	73	844
benchmark	829	95	924

4. Conclusion

Managing water flow in SUTH main building can be used for conserving water and energy at the same time. Proposed option 1st, where the additional water tank should be built for supplying the ground until 4th floor, can reduce the energy of water by 7.1% without water usage reduction. The second proposed option which includes regeneration of the water from HVAC, can reduce the water usage by 7.1%. It also reduces the energy for water reduction by 38.2%. A similar pattern took place for water and electricity for water cost.

The variables pair can be used for minimizing the energy and water of the water usage at the SUTH main building. It shows the compatibility with composite curve method in water allocation problem and provides two variables that can easily be connected to the cost as the main variable for conservation.

Acknowledgments

The authors would like to express gratitude to SUT for providing the Postgraduate Scholarships for Foreign Students to the first author and the support for the conference. The authors also express their sincere thanks to the SUTH director, Dr. Niwatchai Namvichaisirikul, and the staff of the Engineering and Maintenance Department at SUTH, particularly Mr. Watcharin Singtana, Mr. Songkrit Jitpakdeebordin, Mr Chaleomkiat Kaewkurn, Mr. Prashya Suranachit, and Ms. Naphatthira Decheerawas.

Abbreviation and Variables

SUTH	Suranaree University of Technology Hospital	HVAC	Heating Ventilation Air Conditioning
LCA	Life Cycle Analysis	NEA	Network Environmental Analysis
RO	Reverse Osmosis	IOA	Input Output Analysis
GWh	giga watt hour	kWh	kilo watt hour
ppm	part per million	µS	micro siemens
V_{bw}	The volume of blow-down water	V_{m}	The volume of evaporated make-up water
V_{cdw}	The volume of condenser water	V_{w}	The volume of water for HVAC
W_{f}	water sanitary function	C_{j}	coefficient of function
N_{j}	number of people	t_{j}	time of staying at the hospital
W_{m}	water of medical function	C_{m}	coefficient of medical usage
N_{m}	number of patients	E_{wt}	energy for type of water processing
C_{t}	energy intensity of water processing	W_{t}	type of water volumetric flow rate
W_{s}	water usage of story	W_{fs}	sanitary water usage of story
W_{ds}	domestic water usage of story	W_{ms}	medical water usage of story
E_{ws}	The energy of water of story	C_{s}	The distribution coefficient of story
C_{ms}	medical water coefficient of story	W_{ms}	medical water of story
C_{hs}	coefficient of HVAC water condensed of story	W_{hs}	The volume HVAC water condensed of story
E_{HVAC}	The energy of HVAC water processing	C_{11}	coefficient of distribution for 11th floor
C_{SO}	coefficient of single-step RO	E_{WT}	energy for treating wastewater
C_{T}	coefficient of wastewater treatment	W	total water usage of the building
E_{W}	energy of water	C_{EW}	cost of energy and water
f_{EC}	The function of energy cost	f_{WC}	The function of water cost

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