

A Study on The Energy And Water Circulating System Shift by The Eco-systems of Buildings

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SUMMARY

The issue of sustainability has been prevailed not only in building industry but also all other industries. It has been raised that the concept of green building system should be taken into account for the design of buildings. This study is to understand characteristics of the green building system and find the solution of urban problems. Now, over 60% people all over the world live in urban areas, and their communities continue to expand. Pollution and other hazards also tend to accumulate in urban areas. Accordingly, the problems of urban environment are true microcosms of environmental afflictions happening on a global scale. Most of urban problems are caused by human and their buildings. This study was conducted by two ways. One is assessment of energy, and the other is water cycle. Energy and water is also typical factors of urban problems. To solve the urban problems, we must change or shift the wrong circulating systems on (buildings) micro scale. The object building is a recently designed as an environmental-friendly building in Korea that has eco-systems. (as earth-berm, thermal labyrinth, concrete core cooling, soil energy, water-recycle, etc.) Furthermore, comparing eco-system to normal system, difference of energy saving between eco-system and normal system were analyzed by calculation of exergy-entropy of the energy and water cycling system. Consequently, control of micro-environment (the consumption-discharge balance of the energy and the water) in buildings is a key of urban problem solution

INTRODUCTION

A city has been rapidly developed due to progress of Industrialization, so population in it is has been increased. We call it urbanization, and it has been making environmental problems more and more serious. More than 60% of people all over the world are living in urban areas, and all of them try to keep expanding their own area, so a lot of buildings are concentrated in it. Moreover, the people and buildings keep spending water and energy, and it makes excessive shifting or problems of circulating system. Accordingly, the roles of it for sustainable development became new and important issues and. Energy and water circulating systems are causes or effects from urban problems, so the aim of this study is to reduce unstable circulating system and to control the factors that cause urban problems as green building system is applied in a building unit. In brief, the purpose of study is to solve environmental problems of urban area indirectly through buildings.

METHODS

A circulating system in terms of urban area was estimated through technologies of green building, and plans for improving it were made indirectly for the purpose of this study. First of all, problems of urban ecology and environment were organized, and the problems about

water circulating system were found. Second, the energy and water shifting/circulation in a building were analyzed according to green building technologies. For this, a building that green building method had been applied was chosen, and the building was analyzed through the applied systems previously. Third, the energy/water circulating system that the green building system was applied was compared and analyzed with the energy/water circulating system that it wasn't applied. Finally, improving effects of energy and water shifting systems were proven through third step for the unstable building.

THEORIES

(1) Energy Circulating System

Exergy is originated from energy with the process of material dissolution as all materials in universe are controlled by the second law of thermodynamic. It is also existed in kinetic energy and any other dynamics because most of it is a kind of kinetic energy or dislocating energy that is related with restoration. Exergy is one of energy resources, and an element made by energy production is entropy. Equation (1) is the relationship between exergy and entropy.

$$\text{Consuming Exergy} = \text{Producing Entropy} \quad (\text{Inflowing Energy} = \text{Exhausting Energy}) \quad (1)$$

If the equation (1) doesn't work, the amount of error should be made up from other energy, so the energy shifting can be sequentially unstable.

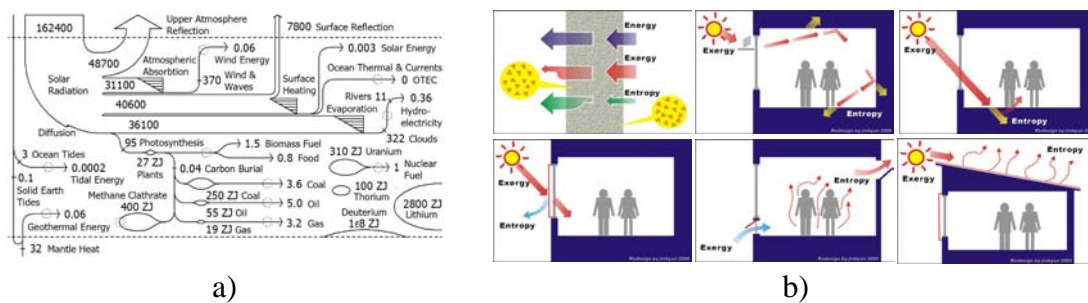


Figure 1. Exergy-Entropy Circulation a) Shifting on The Earth, b) Shifting in A Building

Entropy is made by consumption of exergy in buildings, and energy moves to outside through the envelope of the buildings to be stable state. Generally, the shifting from exergy to entropy can be explained by four processes: ① Supply of exergy ② Consumption of exergy ③ Production of entropy, and finally ④ Giving entropy off. Buildings consume exergy like electricity and fossil fuel and give off entropy. It affects on the surrounding of the buildings. For example, if it increases, the temperature around the buildings will increase, and many kinds of environmental problems will be caused like green house effect in terms of global environmental system. Accordingly, exergy has to be consumed as less as possible to minimize the environmental effects.

(2) Water Circulating System

Inconsiderable development and excessive paving destroy the water circulating system which is the basis of ecological function. The paving, that water doesn't permeate, has covered more than 70% of an urban area, and 73% of urban area is changing to desert. They are the main reason that functions of eco-system and amenity are lost. In 2002, surface water was increased as much as 483 mm/year (that was 5.3 times of 1962's one) on the other hand the groundwater was decreased as much as 107 mm/year (that is 60% of 1962's one). Moreover,

flow of groundwater that goes to watercourses or rivers and shows reversing acting, so urban areas often have overflow and heat island and are accelerated to desert fast. This situation can be resolved through the recovering water circulating system before spaces of urban areas are considered. Accordingly, the alternatives that can recover the water circulating system are necessary with controlling water circulation about water consumption and release and spontaneous generation.

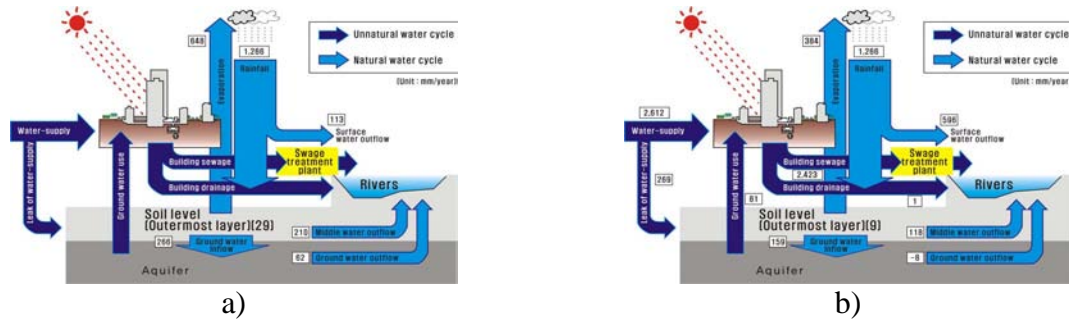


Figure 2. Changes of Water Circulating System at Seoul a) in the 1962', b) in the 2002'.

CASE STUDY : THE APPLIED SYSTEM OF THE OBJECT BUILDING

(1) Analysis of The Object Building

A campus center in E university which is still constructing now was selected for this study to analyze energy and water circulation in it according to the application of green building system. It was planned as a building in earth berm with 6 stories' basement. The building will be better than any buildings on the ground if it can take enough daylight and ventilation in terms of energy saving, thermal comfort, and residential space. HVAC(or machine and equipment) of the building is based on the energy saving, operating cost, and environmental load as reduction of primary fuel consumption such as enough utilization of regenerative performance and various using of water resources like groundwater and dewatering.

Table 1. Summary of The Object Building And Its Building Service System

Project	E University Campus Center	Site Location	Seoul, Korea
Structure	RC + SS	Total Floor Area	About 70,000 m ² / Basement with 6 Stories
Services	A. Academic : small class room, auditorium, computer lab, seminar room, 24hr reading room, student gallery, theater, recreation, offices. B. Commercial: fitness, academic shop, cafeteria, restaurant, etc. C. Parking Lots		
Cooling	Hot Water Absorption Chillers + Heatpump Type Chillers		
Heating	Co-generation System + Heatpump Type Chillers + Hot Water Boiler		
Ventilation & Air Conditioning	Vairable Air Volume + CCC(Concrete Core Cooling) + CHR(Cooling Heating Radiator)		
Green Building System	Thermal Labyrinth, Geothermal Energy, Water Recyle System (groundwater, dewatering and rain water)		

(2) Applied Green Building System (Eco-system)

- Thermal Labyrinth (Air Soil Duct)

Inside soil of earth berm keeps the temperature constant during a whole year. It is one of the ground characteristics, and it can be used for the energy saving systems through preheating and precooling of outside air to Air handling unit. A double layer wall is used as an air soil

duct for the building in earth berm due to the characteristic and architectural necessity, and it plays a role of cool (or hot) tube system. It decreases load of outside air by $\Delta 11\text{ }^{\circ}\text{C}$ ($-11\text{ }^{\circ}\text{C} \rightarrow 0\text{ }^{\circ}\text{C}$) during winter and by $\Delta 7\text{ }^{\circ}\text{C}$ ($31\text{ }^{\circ}\text{C} \rightarrow 24\text{ }^{\circ}\text{C}$) during summer, so operating cost and the size of machine can be possibly decreased.

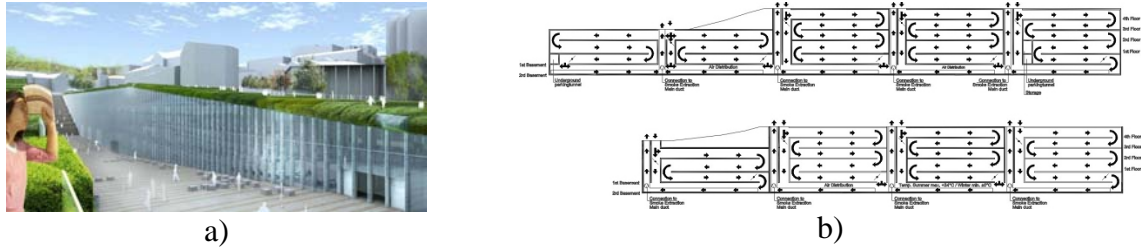


Figure 3. a) A Building View, b) Thermal Labyrinth in The Object Building

• Geothermal Energy

Pipes are installed on slab of floor to use geothermal energy, and air cooling source is made through the heat exchange with geothermal heat source. The air cooling source is supplied to CCC (Concrete Core Cooling) for 24 hours. After thermal solution (water) is passed by the pipes, the temperature of it is estimated to be around $12\text{ }^{\circ}\text{C}$, and it has heat exchange again until it has $17\text{ }^{\circ}\text{C}$ before it is supplied to CCC.

• CCC(Concrete Core Cooling)

It is a system that controls surface temperature of ceiling, wall or floorboard for residents to be comfortable more than they are with all-air system by cooling radiation even though indoor temperature is over comfort zone. Moreover, water is used as a thermal mass, so the amount of air volume (of AHU) is decreased. Accordingly, duct size can be reduced, delivering (fan) energy can be saved, cooling or heating peak time can be moved during a week, and thermal storage system of concrete (mass) can be combined.

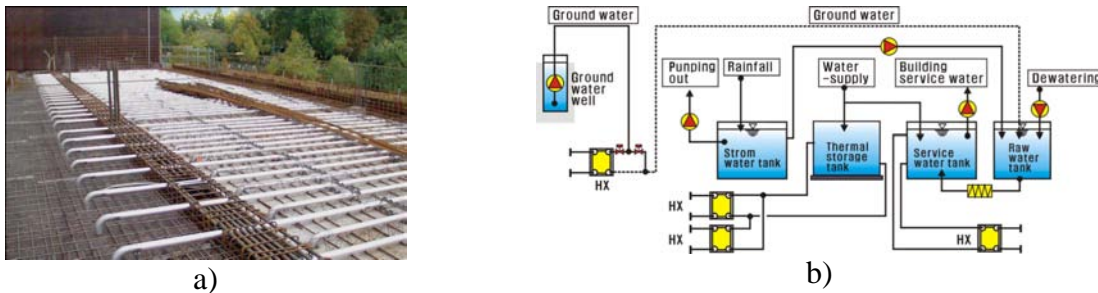


Figure 4. a) CCC (Concrete Core Cooling), b) Recycling of Water Resource

• Recycling of Water Resource

Groundwater with around $15\text{ }^{\circ}\text{C}$ is supplied with 80 ton (8.5 ton/h) per day not only as service water for a building but also as a cooling resource by constant water temperature during a year. The idea about it is to apply heating and cooling system to CCC that cooling source is necessary for 24 hours and to use chilled water, water source, and service water (for washing and gardening). In other words, Groundwater, dewatering, and rainwater are collected in raw water tank, and they get water treatment. After that, the water is used to Re-Cooling. Rainwater is collected in storm water tank during a long spell of rainy weather, and it is usually used for chilled water source, city water for building and landscaping. Dewatering of 150 ton is estimated to be produced.

ENERGY CIRCULATION IN THE OBJECT BUILDING

(1) Comparison with Scheme of Cooling/Heating Plants

A campus center in E university has experimental green building systems, and they are organically interconnected each other. Also, most of the exterior walls are faced on earth berm, so envelop and solar loads can be reduced. The peak load of cooling is about 4,200 kW(1,200 usRT), and the peak load of heating is about 4,000 kW in case of the building, so more than 20% reduction of loads is estimated compare to above ground buildings, and the capacity(size) of cooling/heating plant is decreased. Energy circulating system in the building was compared and analyzed with the case that eco-systems were not applied. Exergy consumption and entropy release were converted into the amount of TOE and CO₂ as a concept of energy input and output.

Table 2. Heating/Cooling System (of Eco-system and Normal System)

Sources		Eco-system			Normal System		
Cooling		App.	Capacity	kW(usRT)	App.	Capacity	kW(usRT)
1	Geothermal Energy	Y	120(34)		N	-	
2	Groundwater & Dewatering	Y	30(9)		N	-	
3	Thermal Labyrinth	Y	325(92)		N	-	
4	Hot Water Absorption Chillers	Y	950(270)		Y	950(270) x 3ea	
5	Electric Chiller	Y	745(212)		Y	745(212) x 3ea	
6	(Water) Thermal Storage Tank	Y	2,010(527)		N	-	
Total Cooling Capacity		4,180(1,144)			5,085(1,446)		
7	Cooling Tower	Y	3,628		Y	3,628 x 3ea	
8	Dry-cooler	Y	500		Y	500 x 3ea	
Heating		App.	Capacity	kW(kcal/h)	App.	Capacity	kW(kcal/h)
1	Geothermal Energy	Y	300(258,000)		N	-	
2	Thermal Labyrinth	Y	412(354,300)		N	-	
3	Co-generation(Waste Heat)	Y	500(430,000)		Y	500(430,000)	
4	Heatpump Type Chiller	Y	960(825,600)		Y	960(825,600) x 2ea	
5	Hot Water Boiler	Y	872(750,000) x 2ea		Y	872(750,000) x 3ea	
Total Heating Capacity		3,916(3,367,900)			5,036(4,331,200)		

Notes) The difference of heating(cooling) capacity is the difference of load saving between a building on the ground and a building under the earth.

(2) Calculation of Energy Consumption and Release in Building

The full load equivalent hour was use for the calculation of energy consumption for heating and cooling in the building.

Table 3. Boundary Condition for Exergy-Entropy Calculation (in The Object Building)

Full Load Equivalent Hour (hour/year)			
Cooling	273	Cooling Period (90 days : June 15 – September 15)	
Heating	294	Heating Period (150days: November 1 – March 30)	
Carbon Exhausting Coefficient of Energy Sources			
Sources	Calorific value	Carbon Exhausting Coefficient (TC/TOE)	
Gas	11,000 kcal/N m ³	0.637	
Electricity	860 kcal/kWh	0.787	
			Combustion
			0.995
			-

Notes) Operating: 10 hours for every weekday, 6 hours for every Saturday, and no operation on every Sunday
a) TC: Ton Carbon(10³ Carbon) b) TOE(Ton of Oil Equivalent) 10⁷ kcal

For the energy circulation in the building, exergy and entropy was calculated as the amount of TOE and CO₂ release. The consumption of exergy was 561.75 TOE for the case that the eco-

system had been applied and 653.95 TOE for the case that normal system had been applied. Also, release of entropy was 974.51 Ton-CO₂ in former case and 1,202.10 Ton-CO₂ in the latter case. As a result, when the green building systems was applied, exergy was reduced by 14% and entropy was reduced by 19% in terms of energy flow and shifting.

Table 4. The Amount of Exergy-Entropy Release (Between Eco-system and Normal System)

Sources	Energy Source	Eco-system			Normal System		
		Calculation	Exergy (TOE)	Entropy (TCO ₂)	Calculation	Exergy (TOE)	Entropy (TCO ₂)
Cooling							
Geothermal Energy ^{a)}	Non	(+32,760 kW)	-	-			
Groundwater ^{a)}	Non	(+ 8,190 kW)	-	-			
Thermal Labyrinth ^{a)}	Non	(+88,725 kW)	-	-			
Co-generation	Non	Waste Heat ^{b)} (+136,500 kW)	-	-	Waste Heat ^{b)} (+136,500 kW)	-	-
Hot Water Absorption Chiller	Gas	79.3 N m ³ /h x 273 h = 21,649 N m ³	22.73	53.09	79.3 N m ³ /h x 273 h x 3ea = 64,947 N m ³	68.20	159.29
	Elec.	6.0 kW x 273 h = 1,638 kWh	0.41	1.18	6.0 kW x 273 h x 3ea = 4,914 kWh	1.23	3.55
Electric Chiller	Elec.	239 kW x 273 h = 65,247 kWh	16.31	47.07	239 kW x 273 h x 3ea = 195,741 kWh	48.94	141.22
Water Thermal Storage ^{c)}	Elec.	239 kW x 624 h = 149,136 kWh	37.29	107.61			
Colling Tower	Elec.	30 kW x 273 h = 8,190 kWh	2.05	5.92	30 kW x 273 h x 3ea = 24,570 kWh	6.15	17.75
Dry-cooler	Elec.	37 kW x 273 h = 10,101 kWh	2.53	7.30	37 kW x 273 h x 3ea = 30,303 kWh	7.58	21.87
Heating							
Geothermal Energy ^{a)}	Non	(+88,200 kW)	-	-			
Thermal Labyrinth ^{a)}	Non	(+121,128 kW)	-	-			
Co-generation	Non	Waste Heat ^{b)} (+147,000 kW)	-	-	Waste Heat ^{b)} (+147,000 kW)	-	-
Heatpump Type Chiller	Elec.	272 kW x 294 h = 79,968 kWh	20.00	57.71	272 kW x 294 h x 2ea = 159,936 kWh	39.99	115.40
Hot Water Boiler	Gas	79.3 N m ³ /h x 294 h x 2ea = 46,629 N m ³	48.97	114.38	79.3 N m ³ /h x 294 h x 3ea = 69,943 N m ³	73.45	171.55
Dry-cooler	Elec.	37 kW x 294 h = 10,878 kWh	2.72	7.85	37 kW x 294 h x 2ea = 21,756 kWh	5.44	15.70
Co-generation ^{d)}							
Gas Turbine Generator	Gas	120 N m ³ /h x 7,860 h = 1,051,200 N m ³	1103.77	2578.04	120 N m ³ /h x 7,860 h = 1,051,200 N m ³	1103.77	2578.04
Waste Heat	Hot Water	Colling/heating (+4,380,000 kW)	-	-	Colling/heating (+4,380,000 kW)	-	-
Generate Electricity	Elec.	320 kW x 7860 h = 2,803,200 kWh	-700.8	-2022.28	320 kW x 7860 h = 2,803,200 kWh	-700.8	-2022.28
Total Exergy-Entropy			561.75	974.51		653.95	1202.10

Notes) a) (): No energy shifting due to spending of natural/surplus energy

b) Waste heat from cogeneration is calculated as a surplus in terms of heat resources.

c) Electric chiller is operated for 624 hours for cool water thermal storage system during nighttime.

(8 hours/day x 6 days/week x 13 weeks)

d) Co-generation is operated for 365 days/year

WATER CIRCULATION IN THE OBJECT BUILDING

(1) Comparison with Schemes of Water Recycling

The object building combines all water sources and redistributes them to maximize water utilization. It is to minimize water source waste and unnecessary sewage exhaust. Water

circulating system in the building were analyzed through same ways of the comparison with schemes of energy system of cooling/heating, and the annual consumption of city water and sewage were calculated with the concept of water sources consumption and release.

Table 5. Schemes for Water Recycling (of Eco-system And Normal System)

Sources		Requirement	Production	Eco-system	Normal System
1	Service Water	Potable/Washing Water	220 ton/day	-	City Water + Grey Water Use
		Lavatory Water(Toilet)	330 ton/day	-	
2	Supply Water for Cooling Tower	6.8 ton/h	Scatteration		
3	Water for Gardening	100 ton/day	-		
4	Water for Firefighting	100 ton	-		
5	Groundwater	-	80 ton/day	Reusing for Grey Water	Undeveloping
6	Pumping Dewatering	-	150 ton/day		
7	Rain Water	-	22,700 ton/yr		

- notes) 1. Service water(ton/day) = 110ℓ/day-person x 0.1 person/m² x Occupancy area
 2. Cooling tower supply water(absorption chiller) = 567.3 m³/h(water for cooling tower) x 0.012(rate of scatteration)
 5,6. They get treatment before they move to city water tank, and after they move to city water tank, they are supplied to building.
 7. Rain water is calculated as monthly rainfall is multiplied by water catchment area (16,865 m²).

In terms of the water circulating, consumption and discharge were calculated to the amount of water supply (grey water) and sewage. Water supply was 98,328 ton/yr in case that a green building system had been applied and 187,341 ton/yr in case that the normal system had been applied. Also, the amount of sewage was estimated by 189,251 ton/yr in former case and 249,251 ton/yr in latter case. As a result, water circulating consumption was reduced by 48% and release of it was reduced by 24% when the green building system was applied.

Table 6. The Amount of Water Service Release (between Eco-system And Normal System)

Sources	Eco-system Calculation	Supply		Release	Normal System Calculation	Supply		Release
		City Water (ton/yr)	Grey Water (ton/yr)	Sewage (ton/yr)		City Water (ton/yr)	Grey Water (ton/yr)	Sewage (ton/yr)
City Water	550 ton/day x 6/7 ^{a)} x 365day = 172,071 ton/yr	98,328	-73,743	172,071	550 ton/day x 6/7a) x 365 day = 172,071 ton/yr	172,071	-	172,071
Water for Cooling Tower	6.8 ton/h x 273 ^{b)} h/yr = 1,856 ton/yr	-	-1,856	(1,856)	6.8 ton/h x 273 ^{b)} h/yr x 3ea = 1,856 ton/yr	5,570	-	(5,570)
Water for Gardening	100 ton/day x 12 day x 8 month = 9,600 ton/yr	-	-9,600	(9,600)	100 ton/day x 12 day x 8 month = 9,600 ton/yr	9,600	-	(9,600)
Water for Firefighting	100 ton (Store)	-	-100	-	100 ton (Store)	100	-	-
Ground water	80 ton/day x 6/7 ^{a)} x 365 day = 25,029 ton/yr	-	+25,029	-	Non	-	-	-
Dewatering	150 ton/day x 365 day = 54,750 ton/yr	-	+43,800	10,950	150 ton/day x 365 day = 54,750 ton/yr	-	-	54,750
Rain-fall ^{c)}	22,700 ton/yr	-	+16,470	6,230	22,700 ton/yr	-	-	22,700
Total Supply-Release		98,328		189,251		187,341		249,251

- notes) a) Building use : 6-days of One week(7-days) b) Cooling full load equivalent hour: 273 h
 c) 20% of it is discharged before they are supplied to stormwater tank / Collectable period (from march to october)
 () : Cooling tower supply water: scatterate in the air / Gardening water: ground inflow

RESULTS

First of all, energy and water source can be saved a lot when the green building system was applied. However, more important factor is to restrict excessive consumption and release of energy and water circulation in the building. In case of consumption in the building, and exergy was reduced by 14%, and the amount of city water was reduced by 48%. Furthermore, in case of release, entropy was reduced by 19%, and sewage was reduced by 24%. If exergy consumption and entropy release are reduced, bad influence around building area can be minimized, and further, the causes of environmental problems in an urban area can be reduced.

Table 7. The Result of Energy and Water Circulating System

Sources		Eco-system	Normal system	Reduction
Energy	Supplied Exergy (TOE)	561	653	(-)14%
	Released Entropy (Ton-CO ₂)	974.50	1202.10	(-)19%
Water	Supplied Water (Ton/yr)	98,328	187,341	(-)48%
	Released Water (Ton/yr)	189,251	249,251	(-)24%

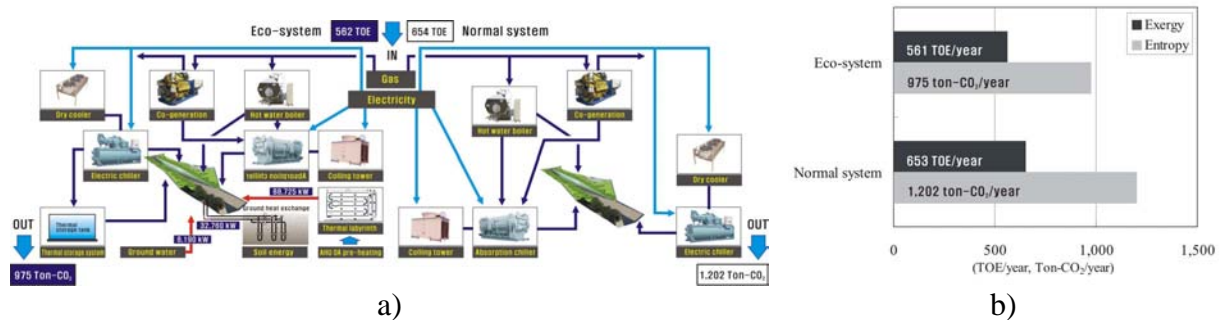


Figure 5. Energy Circulation in The Building. a) Flow Diagram, b) Result Graph

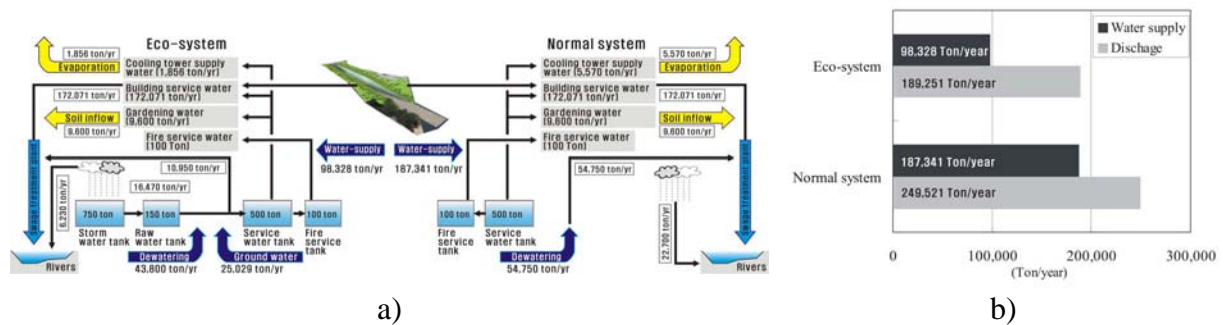


Figure 6. Water Circulation in The Building. a) Flow Diagram, b) Result Graph

CONCLUSIONS

The data in this study can be little different from the real data after the campus center in E university is constructed completely because the consumption-release calculation of energy and water circulation in this research is based on the (SD)plan of the building. However, to solve the problems of urban environment and eco-system, research of energy and water circulation in building with green building method and minimizing causes of problems is very important. There are four categories of the process about it.

- (1) As a human uses a building, circulation of energy and water is caused, and it has an effect on problems of urban environment.
- (2) All circulation systems have the process that is from consumption to release. It is from exergy to entropy in energy, and it is from water supply to sewage in water.

(3) Entropy and sewage can be controlled as green building system is applied and as the exergy and water supply are controlled in a building which is micro aspect. This method saves energy and minimized the environmental pollutants with improving circulating system that have excessive consumption and release.

(4) Primarily, matters' release from a building which can be environmental problems for urban area in terms of micro aspect can be reduced by controlling them in the building. In other words, the urban area and the eco-system can be recovered to stable circulating system is as macro environmental(urban) problems are solved with the removal of micro environmental problems in a building. Consequently, when a green building system is planned, the not only energy saving factors but also environmental factors have to be examined practically.

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