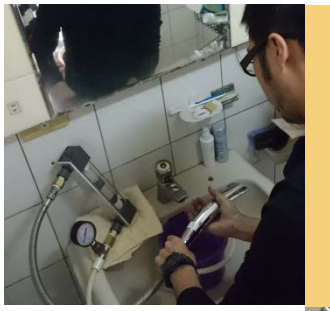
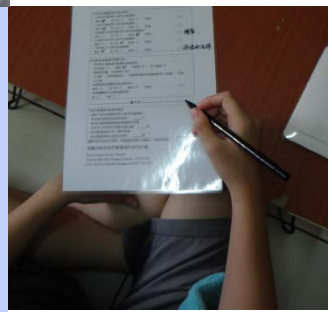
Energy saving assessment by domestic hot water supply system



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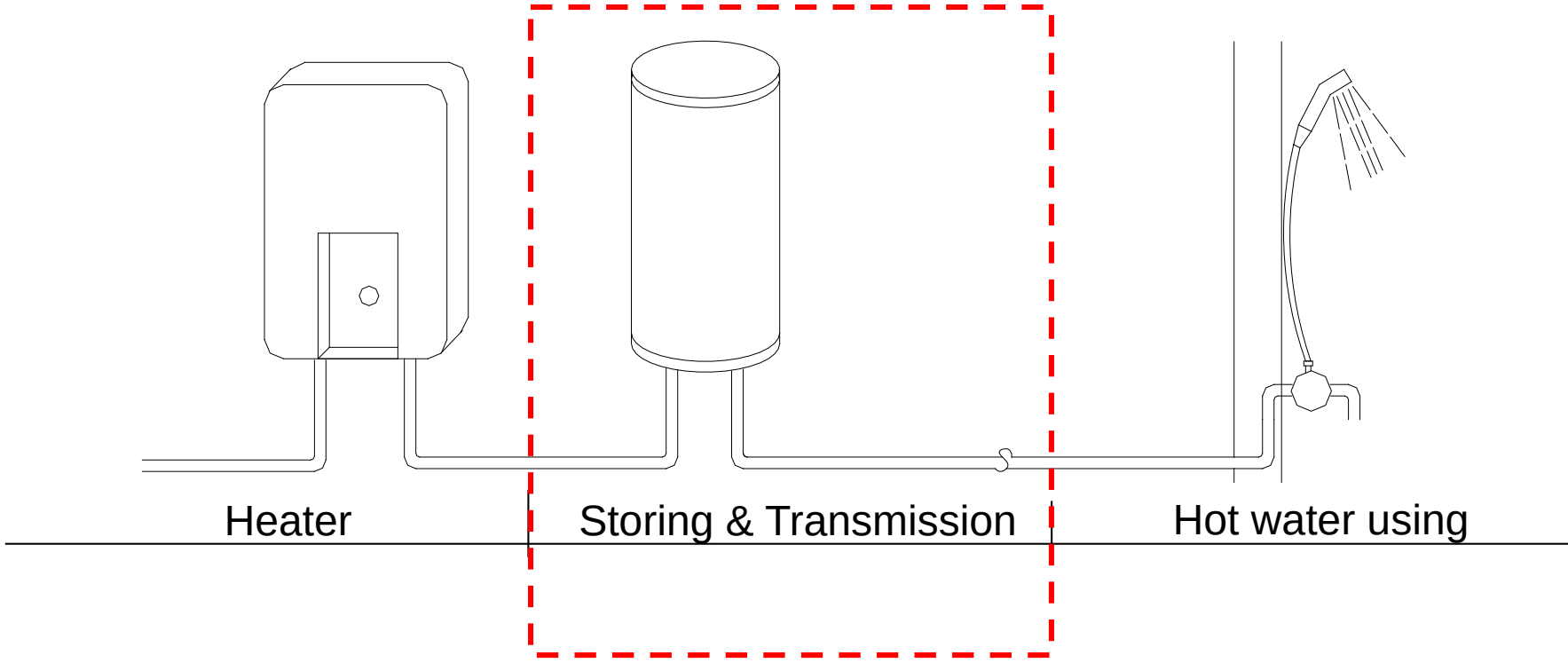
Introduction

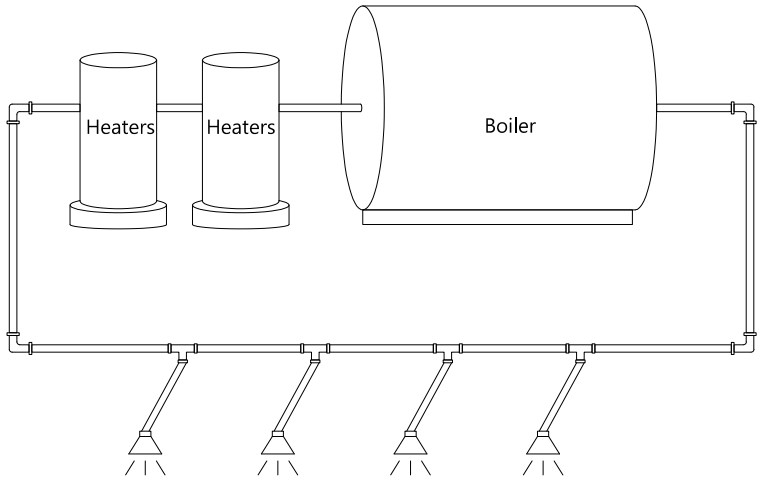
Hot water demand and energy consumption are the main considerations in Eco-Life, also involved with Carbon dioxide reduction





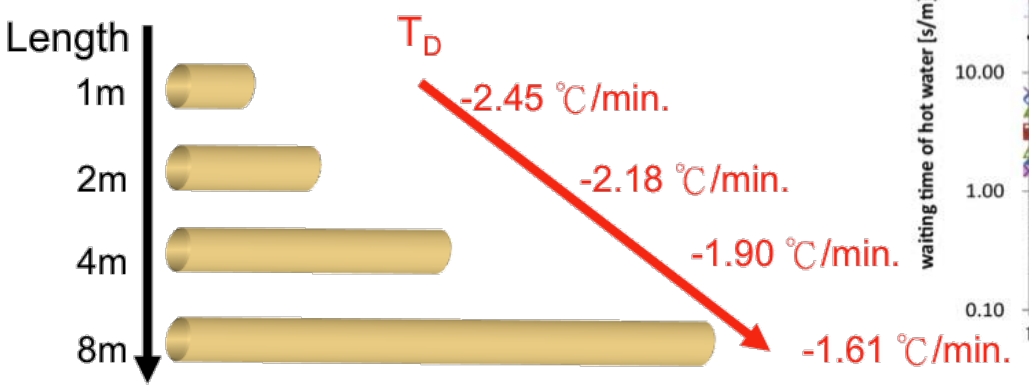
Introduction

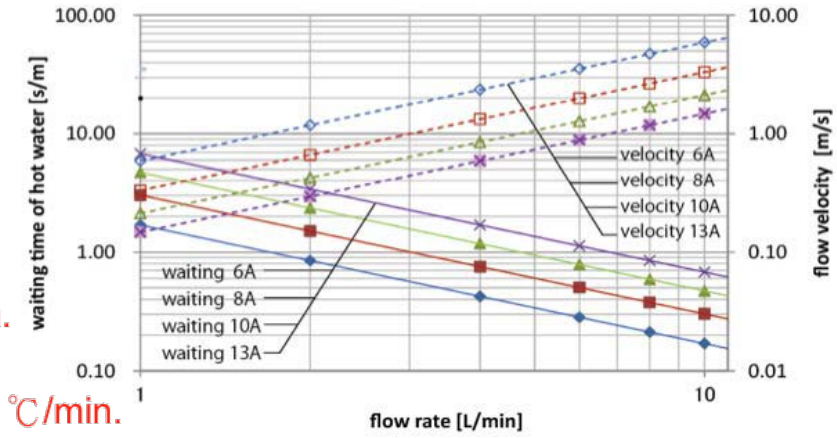
- The investigation is about the unsuitable temperature of hot water remain inner transmission pipes to waste water before showing.
- Central hot water piping systems are used in large lodging buildings (e.g. hotels, dormitories, etc...) for comfort and convenience.



Introduction

- To evaluate energy consumption and hot water temperature drop in piping, Lee et al. utilized simplified empirical equations and figured out the hot water temperature drop from 60℃ to 40℃ inner 13A stainless pipe is around 10 minutes.
- The previous studies only discussed with the individual hot water non-circulating system temperature drop and energy consumption. Morooka and Ichikawa al provided the flow velocity and waiting time of hot water

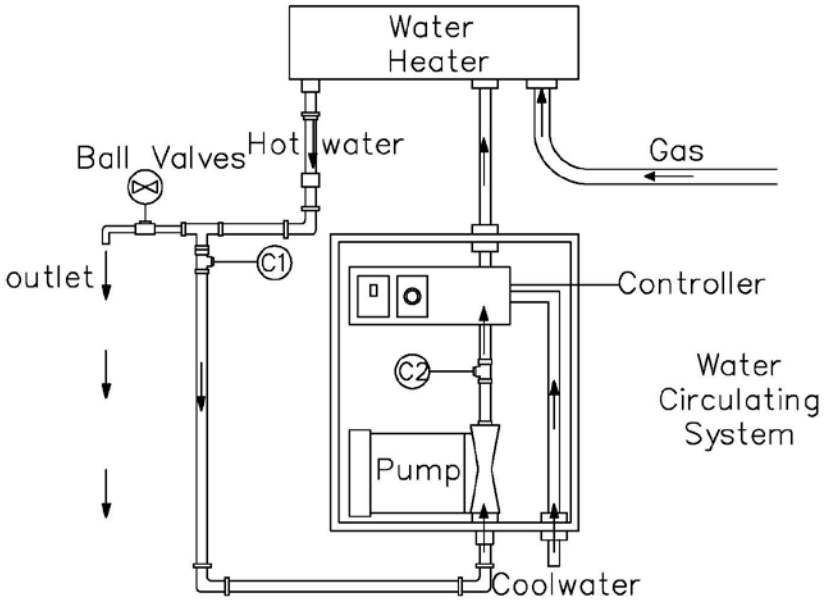




∗ S. Morooka, N. Ichikawa, M. Ichinose, M. Ogami, T. Akibayashi, Reconsideration of the “Conduit Header System” in the Cold and Hot Water Supply Piping System.

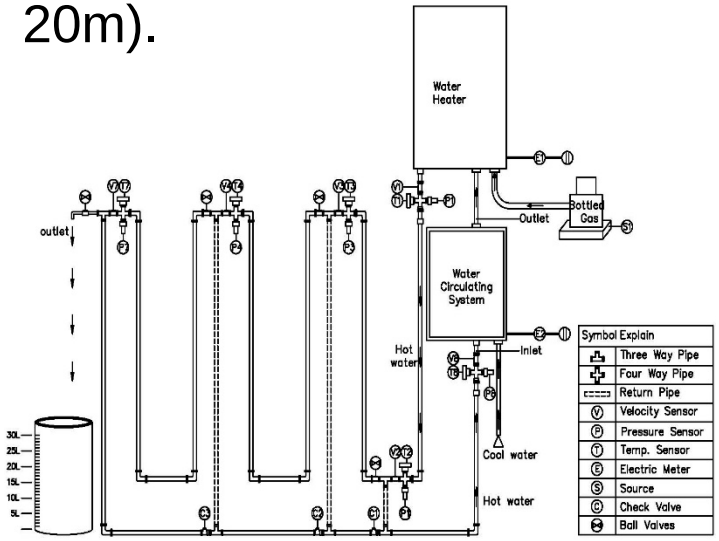
Transmission Part

- One circulated water pipe with a check valve setup before ball valves (faucets) to connect with transmission pipe for recycling and reheating the temperature dropped hot water in the intelligent hot water circulation system.
- Based on investigation of hot water pipe lengths in Taiwan, the average length is around 6.5m (the shortest is 0.5m, the longest is 20m) in the residential buildings (apartments and houses).



Transmission Part

- This study focuses on hot water saving via shower periods in residential building in Taiwan, to discuss with using behavior, clean performance and comfort sensation by users for analyzing the water demand and water saving improvement.
- The efficiency of the pump and heater are also considered for the design. In this experiment, air temperature, water temperature, flow velocity, pressure, circulator energy consumption (including electronic control and pumping), heater, and gas consumption were measured in various pipe lengths (1m, 2m, 4m, 8m, 16m, and 20m).



Transmission Part

$$Q_{1i} = (t_n \times v_n)_i \quad (1)$$

$$Q_{2i} = Q_{1i} - (A_p \times L_p)_i \quad (2)$$

Table 1 Water demand and energy consumption in the non-circulation system

Pipe Length	Period time	Wasted water (Q_2)	Heated water (Q_1)	Gas Consumption (S_{ni})	Heater power
m	*sec.*	*l*	*l*	*g*	*Wh*
1	20	3.4	3.5	9.1	1.8
2	25	3.6	3.8	11.2	2.2
4	35	5.8	6.3	15.3	3.1
8	50	7.7	8.8	21.4	5.8
16	80	12.3	14.5	34.0	7.1
20	90	14.3	17.0	39.8	8.0

Table 2 Energy consumption in the circulation system

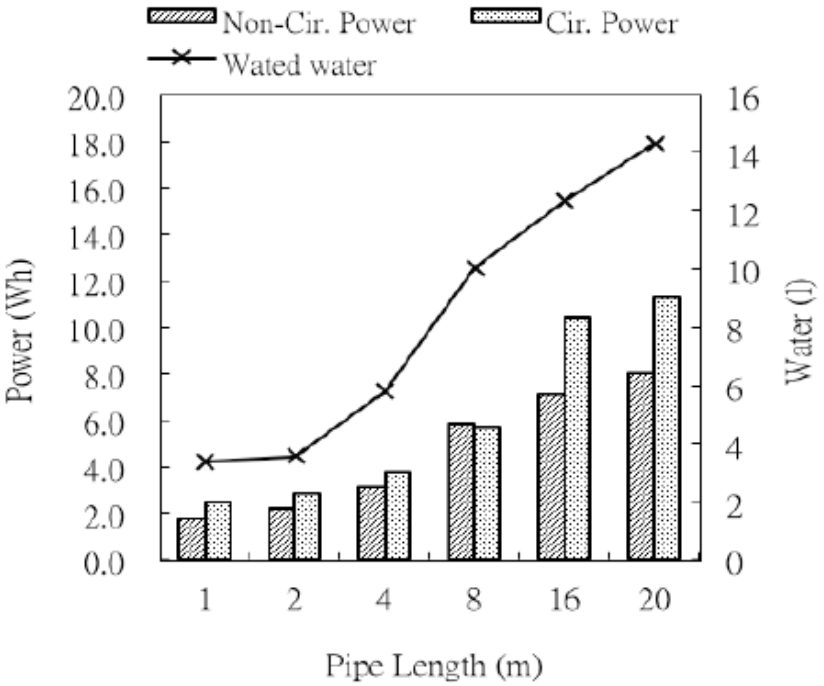
Pipe Length	Circulation Period time	Gas Consumption(S_{ci})	Heater Power(E_H)$_{ci}$	Circulator Power(E_R)$_{ci}$	Total Power
m	*sec.*	*g*	*Wh*	*Wh*	*Wh*
1	13.0	8.8	1.2	1.3	2.5
2	15.0	10.2	1.3	1.5	2.8
4	20.0	11.9	1.8	2.0	3.8
8	30.0	16.6	2.7	3.0	5.7
16	55.0	25.8	4.9	5.5	10.4
20	60.0	31.0	5.3	6.0	11.3

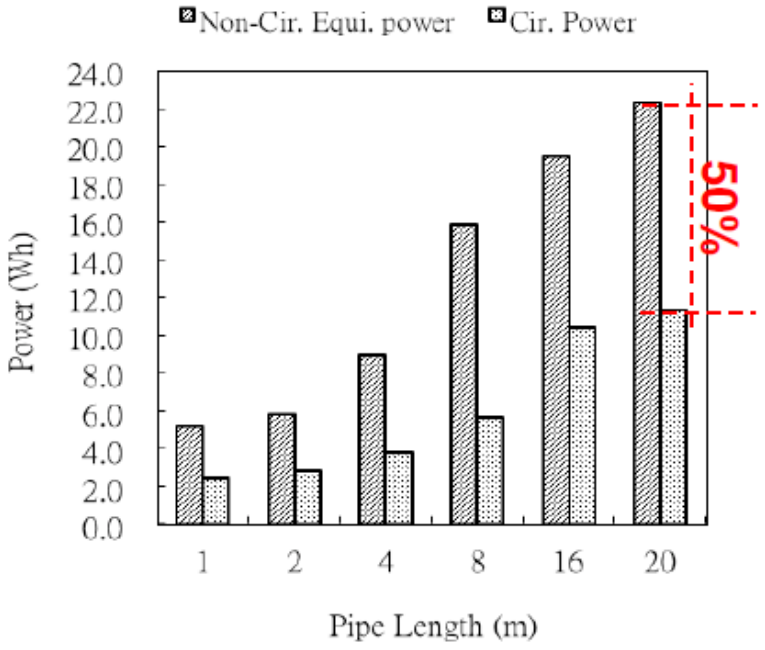
Transmission Part

- The volume of wasted water is measured and converted to electric equivalent power, then added to the heater power consumption, the results show the total energy consumption of the non-circulation system is 50% higher than the energy consumption of the circulation system

$$E_{\mathrm{P}} = (Q_{1i} - Q_{2i}) \times \theta_W + (E_H)_{ni} + S_{ni} \times \theta_S \quad \text{kWh}$$

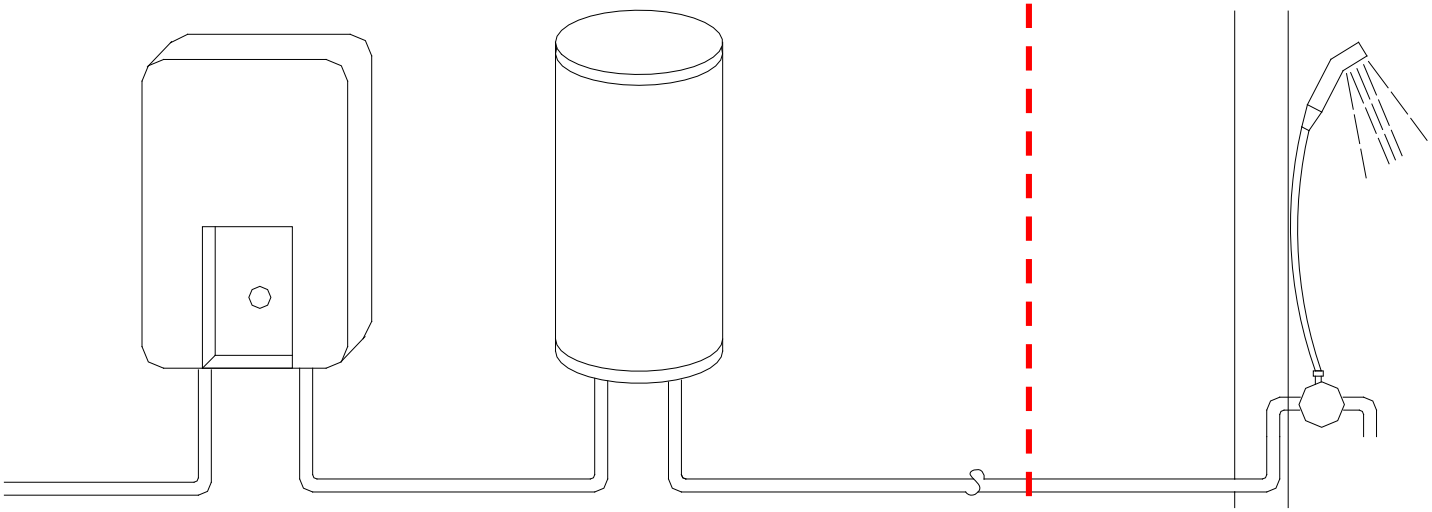
$$E_{PWS} = (Q_{1i} - Q_{2i}) \times \theta_W + (E_H + E_R)_{ci} + S_{ci} \times \theta_S \quad \text{kWh}$$





Introduction

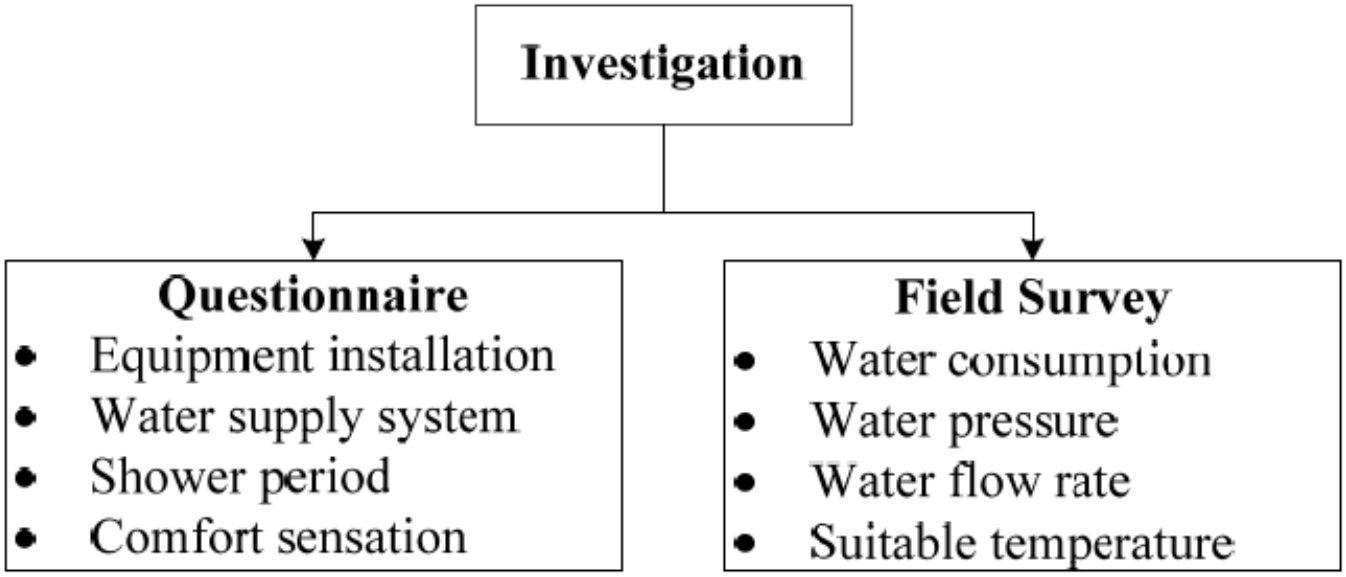
Hot water demand and energy consumption are the main considerations in Eco-Life, also involved with Carbon dioxide reduction



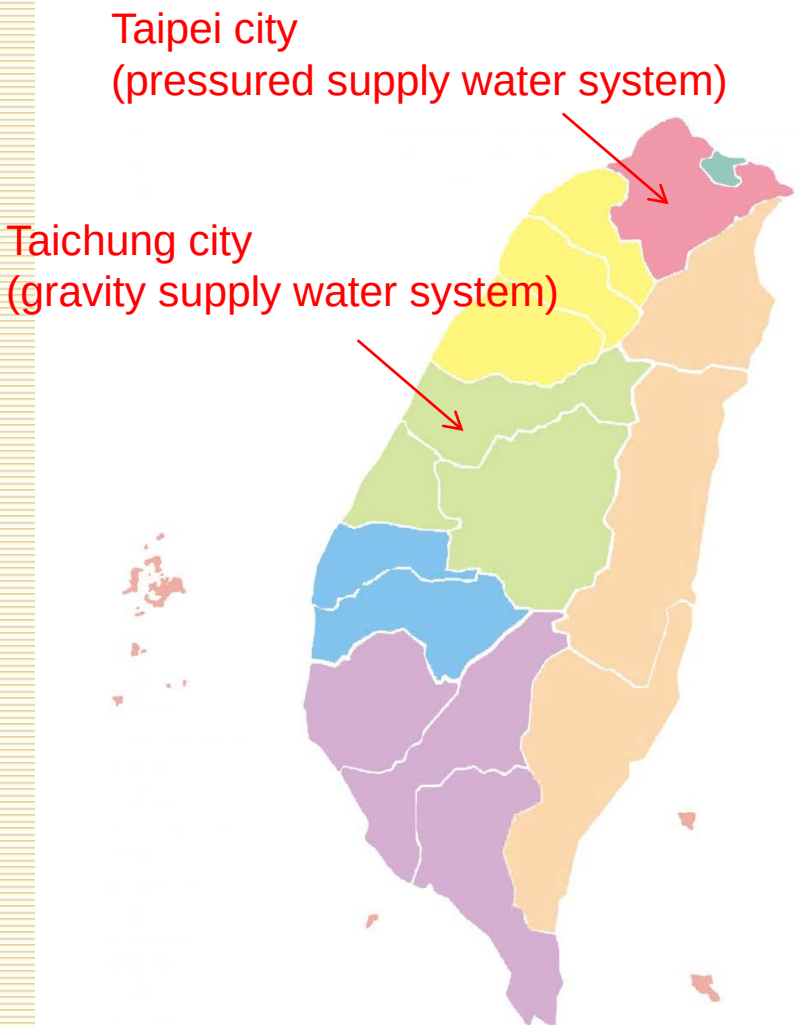
Heater	Storing & Transmission	Hot water using
Energy consumption of Hot water generating	Energy consumption of cooling by ambient temp.	Energy consumption via hot water demand

Usage Part - Investigation

- To understand the shower comfort in water temperature, flow rate, water pressure and shower period are main impacts of shower water demand.
- This study invited about 40 households to participate this investigation with different showerheads in Eco shower (ES) and Investigated shower (IS) to compare the shower comfort of subjects in the same water supply pressure in each sample.



Investigation area



- This study totally investigated 44 households (includes 3 pre-test) in Taichung city and Taipei city for different water supply pressure area.
- The field survey are adopted the pressure meter, flow meter, timer and thermometer to measurement water pressure, flow rate, suitable water temperature and shower period.



Investigation

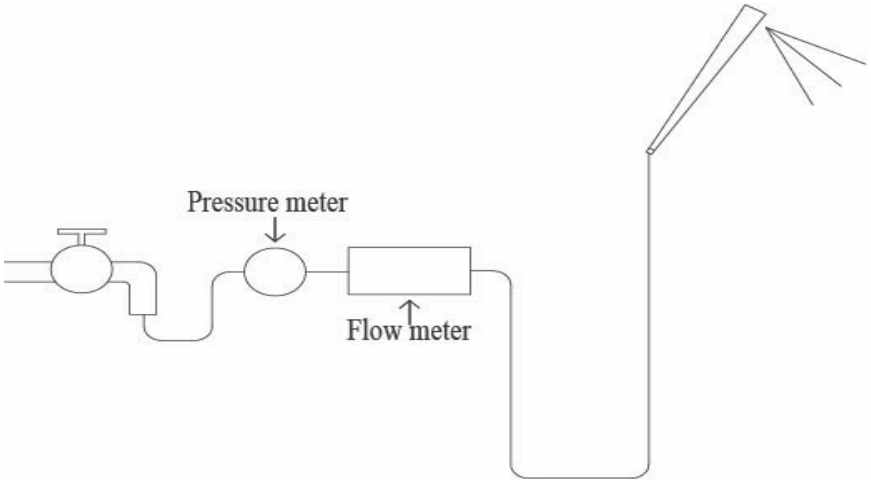
- 71 samples were investigated (33 in Taichung and 38 in Taipei) in 44 households.
- The 44 investigated shower head types (IS) and 1 Eco shower head type (ES) are show in these photos.

Eco showers (ES)

Investigated showers (IS)

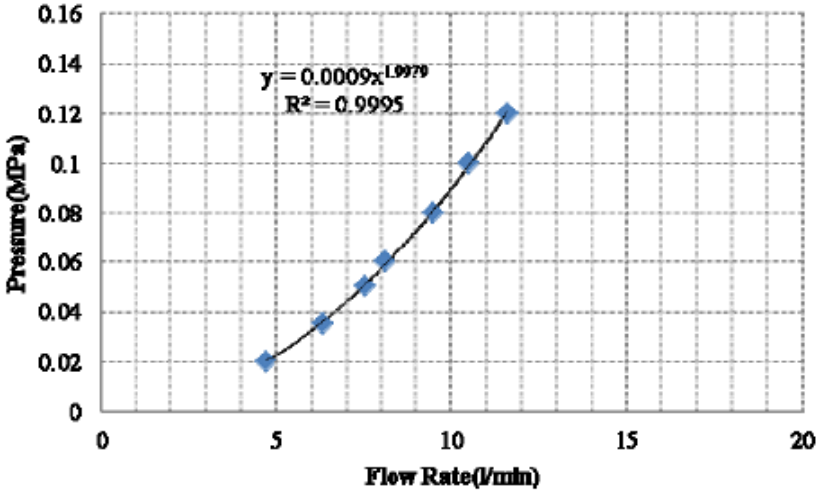


Measure device and installation



Water supply pressure cloud be checked by measured flow rate of Eco Showerhead

Water Pressure (MPa)	Flow Rate (l/min)
0.02	4.7
0.035	6.3
0.05	7.5
0.06	8.1
0.08	9.5
0.1	10.5
0.12	11.6



Questionnaire

- The questionnaire for investigate is to ask the shower comfort, divided into three parts.

Part. 1 The water supply conditions in the residential building

1. What was the type of your dwelling?
2. How many floors does your residence have?
3. Which floor do you live?
4. What kinds of water supply system does your house have?

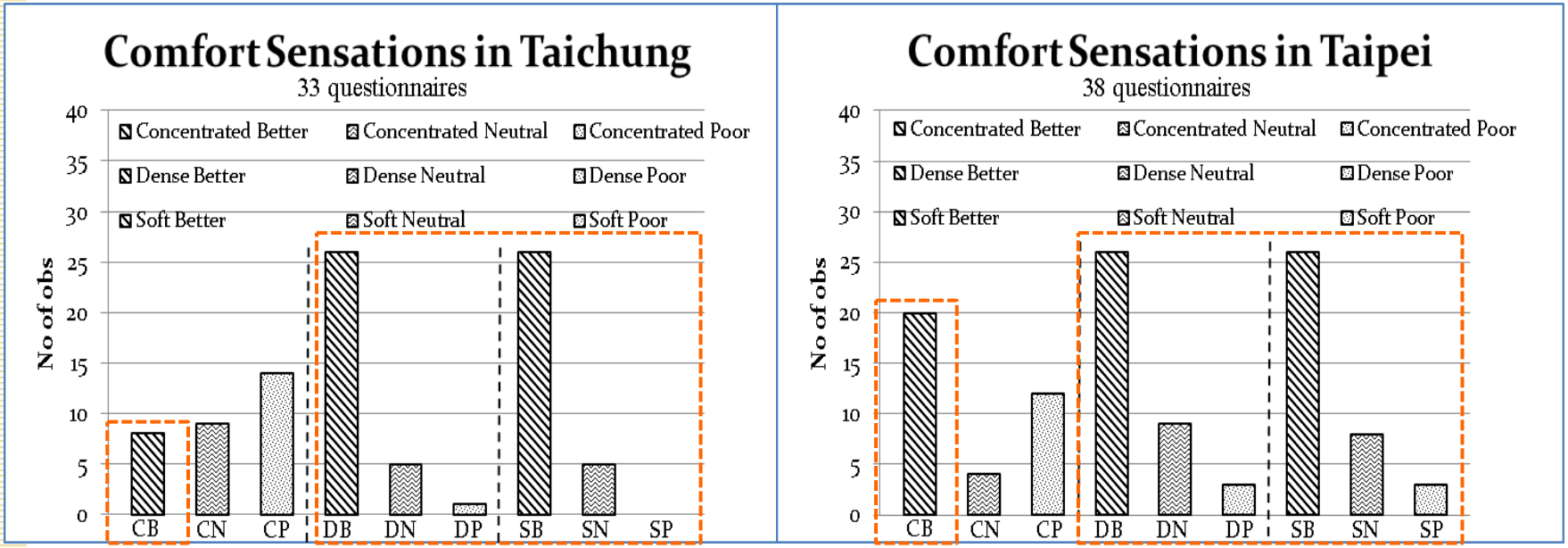
Part. 2 Shower comfort sensation of subjects

5. How well does the water flow "Soft Sensation" compared with your previous showerhead?
6. How well does the water flow "Dense Sensation" compared with your previous showerhead?
7. How well does the water flow "Concentrated Sensation" compared with your previous showerhead?

Part. 3 Measuring in water supply pressure, flow rate, temperature, and periods.

Measuring values / Shower Head type	Water pressure (MPa)	Flow rate (l/min)	Temperature (℃)	Shower periods (Sec.)
NS				
IS				
ES				

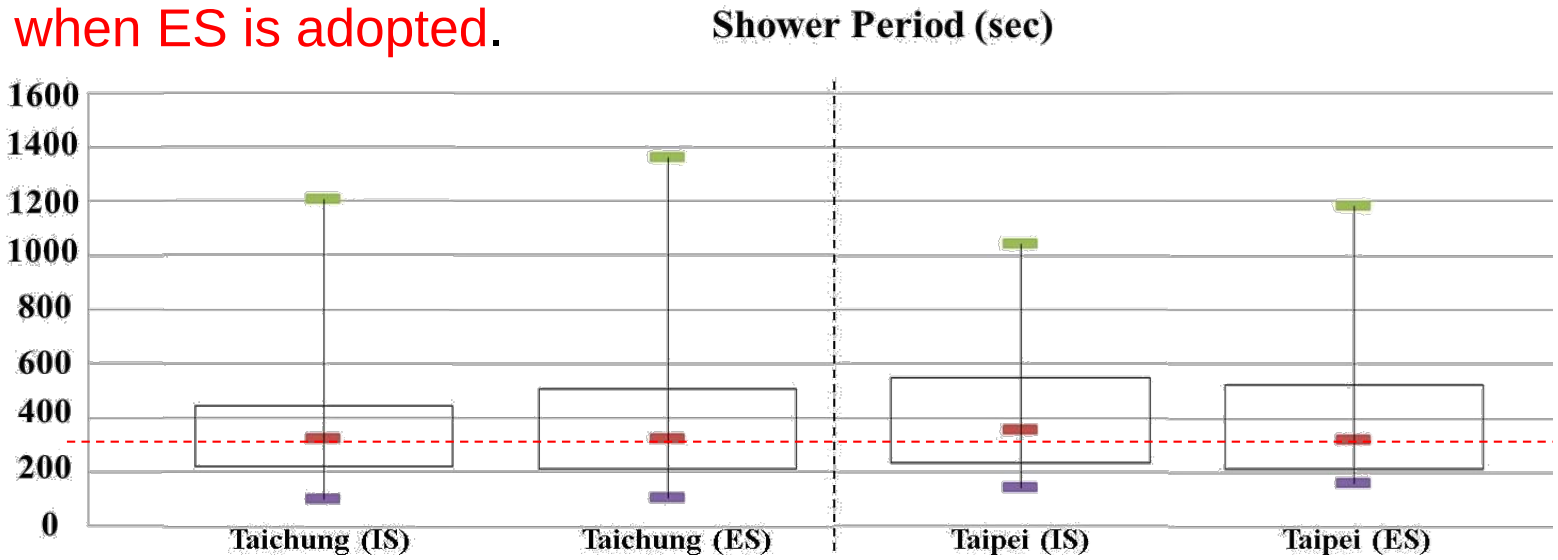
Shower comfort sensation votes



- Users in Taipei are long-term staying in high water pressure, users have already accustomed by strong feeling, other feelings between high pressure and low pressure are similar in dense sensation and soft (tender) sensation.

Shower period

- The average of shower period in ES is longer than it in IS in Taichung, but it is opposite in Taipei. The reason is related with the water supply pressure and comfort sensation with air-in shower head (ES).
- The figure presents the average shower period is around 300 sec. but the average water flow rate in ES is only 70% with IS. It means the showerhead water saving rate *REWS* is about 0.7 when ES is adopted.



$$Q_i = v_i \times t_i$$

$$E_{Ui} = Q_i \times \rho \times s \times (T_H - T_C)$$

$$T_C = 0.93 \times T_a + 1.78$$

Water saving flow rate and level

- The accumulated percentage in 9.9 l/min decrease the accumulated percentage in 9 l/min to save 9% water demand, in 8 l/min is saving 19%, and in 7 l/min is saving 29% in Taiwan.

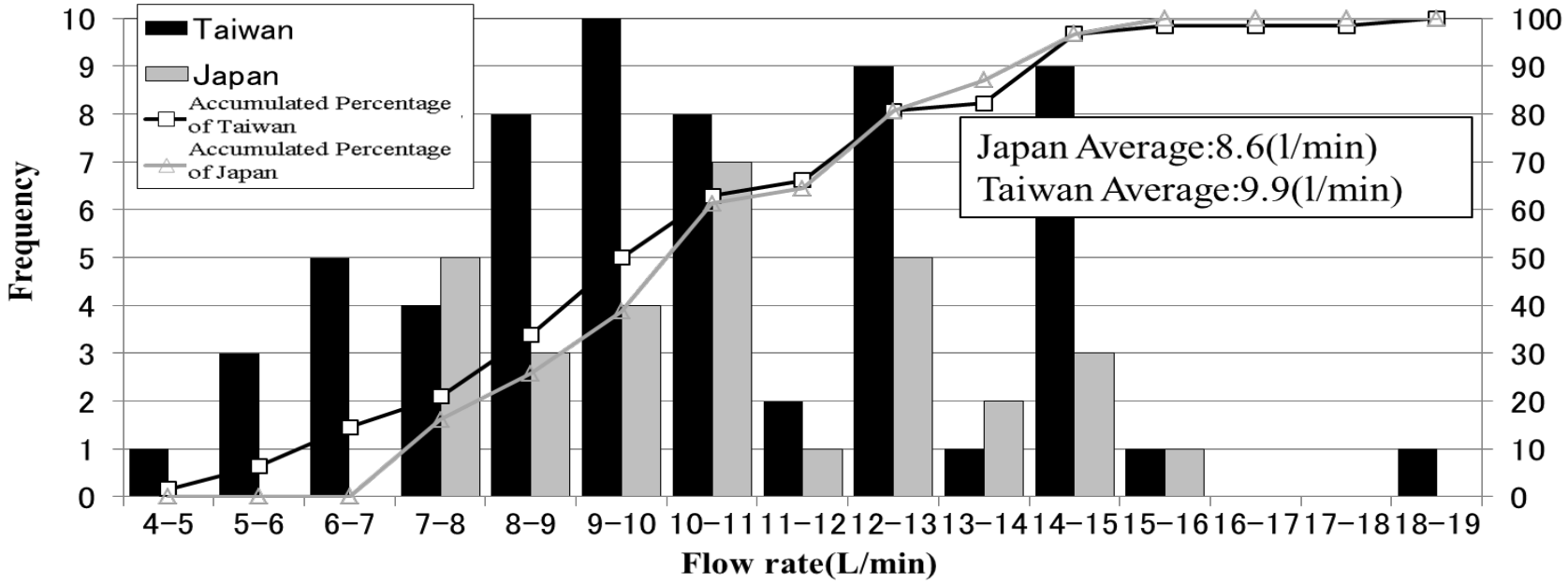


Table 6 Water saving level via water flow rate

Level	Water Flow Rate (*l/min*)
★★★	~7
★★	7~8.5
★	8.5~10.0



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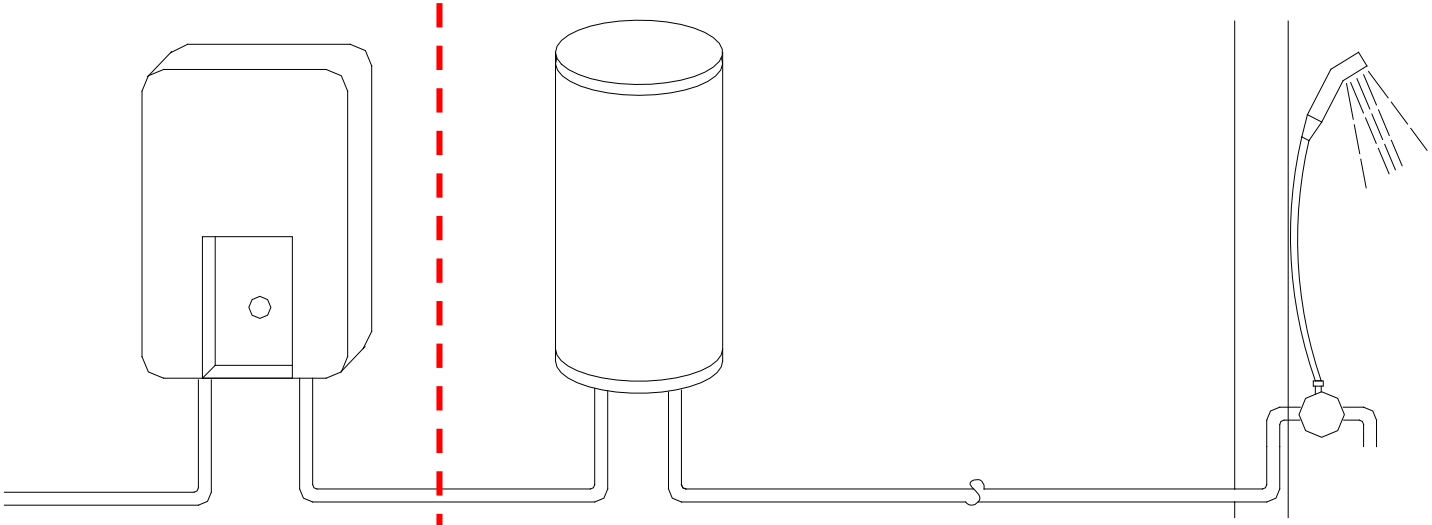

Heater	Storing & Transmission	Hot water using
Energy consumption of Hot water generating	Energy consumption of cooling by ambient temp.	Energy consumption via hot water demand

Heating Part

- The energy consumption of heating part almost equals the energy consumption of transmission part and using part.
- The *COP* of heaters is improving in these years for energy consideration, such as *COP* of heat pump between 2.0 to 6.0, gas heater over 0.95 (0.8 in the past), electric heater over 0.8 (0.6in the past).
- This study investigated with current installed heaters and evaluated with the energy consumption of each person while showing with 45L in 39 ℃ (the water temperature of heater outlet is set in 55℃ for deducing Legionella bacteria, cold water is set as 23℃).



Energy reducing evaluation

- One example from our investigation in original and improving condition of energy consumption in whole hot water system in Taiwan.

$$E_H = (E_P + E_U)/COP \quad \text{kWh}$$

$$E'_H = (E'_P + E'_U)/COP \quad \text{kWh}$$

$$E'_P = E_P - E_{PWS} \quad \text{kWh}$$

$$E'_U = E_{Ui} \times REWS \quad \text{kWh}$$

$$E_E = E'_H / E_H \quad -$$

EP : energy of transmission in piping system
EP': energy of transmission in circulated piping system
EU : usage consumption without considering heating conservation efficiency
EU' : usage consumption with considering heating conservation efficiency

- The transmission pipe belongs 13A stainless pipe in 8m long with non-circulation and circulation system, 45L mix hot water temperature around is set at 39℃ and the cold water temperature is set at 23℃, the water saving showerhead is around 70% than original showerhead.
- The energy reducing efficiency (*EE*) is estimated in 0.475, it means the energy saving 52.5% after submitting the solution in rising the *COP* of heater, individual circulation piping system, and change the water saving showerhead.

Conclusion

- Based on the energy consumption in each partitions to submit the evaluation equations for checking the efficiency of energy reducing. As the investigation and summited solution, the energy reducing efficiency (*EE*) was estimated in 0.475, the energy saving 52.5% after rising the COP of heater, individual circulation piping system, and change the water saving showerhead. If the heater changes into renewable energy, the energy reducing efficiency would be higher.

Original energy consumption in hot water supply system (E_H)		Improving condition of energy consumption in hot water supply system (E_H')	
$COP = 0.8$ Old LPG heater		$COP = 0.95$ New LPG heater	
E_P	E_U	E_P'	E_U'
0.30 kWh	0.77 kWh	0.07 kWh	0.54 kWh

$$E_E = 0.475$$



Acknowledgement

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Water saving between you and me

Thank you for your attention!