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Analysis of Water Conservation Potential in Campus Based on WATERGY

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ABSTRACT

In order to estimate water conservation potential and evaluate payback on investment of water conservation facilities, WATERGY, a spreadsheet model instead of traditional water quota method, is discussed and used in campus. WATERGY was coined by American Alliance to Save Energy to describe the strong link between water and energy in municipal water systems. The assumptions and parameters used in WATERGY model applicable to campus case were fully considered and modified according to relative Chinese standards and specifications. As a result of BUCEA campus water conservation case study, it is estimated that most water efficient measures repay themselves within 1~4 years and yield many rewards. Energy savings of water conservation measures are as important as water savings. The difficulties of applying WATERGY model, such as lacking adequate water meters and general survey data are also discussed.

Keywords: WATERGY model; water conservation; demand side management; energy savings; campus

1. INTRODUCTION

Faced with rising water demands and increasing supply uncertainty, there is a pressing need to engage governments, water utilities and the public on water conservation issues if future water shortages and environmental problems are to be avoided (Inman and Jeffery, 2006). Analysis of water use and water savings, as well as evaluation of benefits and costs is an essential step to develop a water conservation plan. (American Water Works Association, 2006; Vickers, 2001). Water conservation models provide a tool to compare effectiveness of water conservation practices. Since IWR-MAIN was first developed in 1968, various water conservation models, such as CUWCC BMP models, US EPA Guidelines, Confluence, DSS (Demand side management least-cost planning decision support system) model, AWWA/CUWCC Avoided Costs Model, WATERGY and AWE water conservation tracking tool have been developed and applied in constructing water efficient plans (Corum, 2009).

In the past over 20 years in China, even up to now, water quotas are mainly used in planned water supply and management systems. Water quota methods are usually based on census and experience, as a result its uncertainty and subjectivity make it difficult to compare and assess effectiveness of water conservation practices (Liu and Sang, 2007). In recent years, theory of End Use Analysis (EUA) and Demand Side Management (DSM) have been gradually introduced in water demand analysis for water conservation plan (Long et al., 2006), for analyzing urban public

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water conservation and wastewater reclaim potential (Chu and Chen, 2009), for constructing peak time water price or award prompting mechanism model (Chen et al., 2009), for evaluating the prompting requirement of water efficient facility replacement (Deng et al., 2010). However, there has been sparse coverage of advances in the application of DSM tools and water conservation models due to lack of data and knowledge in China until now.

In order to address Beijing's 13th conservation year of drought, a feasibility study of water conservation potential in Beijing University of Civil Engineering & Architecture (BUCEA) main campus based on WATERGY, a spreadsheet model instead of traditional water quota method, is conducted to identify water saving opportunities and evaluate payback periods of facilities' investment.

2 METHODS

2.1 WATERGY modeling approach

WATERGY was coined by American Alliance to Save Energy to describe the strong link between water and energy in municipal water systems (Barry, 2007). The WATERGY approach helps cities realize significant energy, water and monetary savings through technical and managerial improvements, creating efficiencies that provide consumers with quality service with a minimum of water and energy. Efficiencies in the water sector involve both the end use of water as well as efficiencies in the supply of water.

The WATERGY model was developed in Lotus 1-2-3(Release 5) and later converted to Microsoft Excel (deMonsabert and Liner, 1996, 1998). The spreadsheet is organized into six distinct worksheets entitled Instructions, Introduction, Utility Rates, Attachment A, Input & Assumptions, and Output. Water conservation survey along with audit information, including quantities, characteristics, energy and water rates, facility inventory and water use on site of existing system, should be prepared and entered on Utility Rates and Attachment A. Input & Assumptions worksheet is guided to identify target usage of screened water conservation measures. Default parameters on Assumptions worksheet should be reviewed to ensure applicable to the given situation. Results on Output worksheet are calculated by two kinds of equations: which provide the general methodology to relate water and energy conservation.

2.2 Current campus water use

BUCEA covers an area of 118,000 square meters and has the population of about 11,000. Water consumed in BUCEA main campus comes from three means: municipal water, reclaimed water and rainwater. 237,373 m^3 of municipal water was used in 2010, this cost the university 949,492 Yuan. Water price keeps increasing occasionally and the current price is 2.5 times more than that in 2000. Among 237,373 m^3 of municipal water, 9 % was used by staff residence; the others were used by teaching buildings, office buildings, library, labs, student dormitories, cafeteria, bathhouses and landscape. It can be seen as in Figure 1 that water consumption in campus doesn't vary much monthly except March when was Spring Festival holiday and winter vocation then. In addition, BUCEA has a reclaimed water treatment facility with the treatment capacity of 100 m^3/d, mainly been used for toilet flush in No.4 and No.5 student dormitories. Most storm water goes unused except that rainwater from one roof is collected in a barrel for lab usage. BUCEA is supplied by municipal heating system in winter.

It is necessary to take a survey of plumbing fixtures and other water consumption facilities in the campus. The result is aggregated and simplified in Table 1 and input in WATERGY Attachment A. There are five student dormitories in the campus. Most plumbing fixtures of No.4~6 dormitories were installed in 1994 and 1995 except that urinals were replaced in 2001. Most plumbing fixtures currently used in No.2~3 dormitories were installed in 2004 and 2000. Coin-operated washing machines were installed in student dormitories in 2005. Most time-lapse self-closing squatting pans and infrared sensor urinals were installed in 2005. Bathhouses and hot water room were updated, where hot water metering system was installed with IC card system in 2009. Three hot water boilers which provide hot water for drinking and bathing and consume natural gas only, were upgraded in 2009. In landscape irrigation system, most greenbelts have been installed with micro-irrigation system, so landscape irrigation system isn't considered during WATERGY modeling.

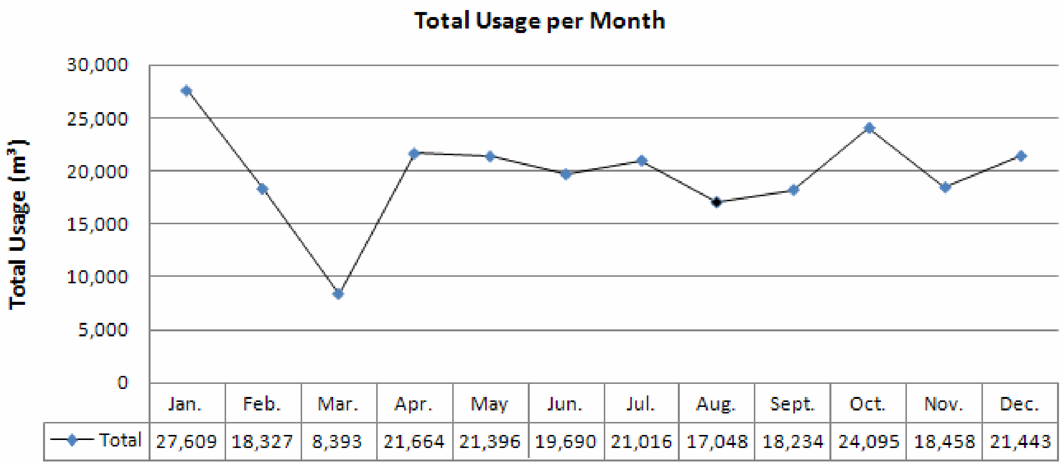

Figure 1 Total water usage per month in 2010 of BUCEA

Table 1 Total campus plumbing fixtures data statistics

Nameplate	Number	Description
Time-lapse self-closing flush valves	662	12 liters per flush
IR sensor urinals	40	4.5 liters per flush
IR sensor urinal troughs	70	3.3 liters per flush
Single handle faucets for lavabo in dormitories	372	7.6 liters per minute
Single handle faucets for lavabo in other buildings	93	7.6 liters per minute
Single handle faucets for mop sink	126	12.78 liters per minute
IR sensor faucets	25	6.6 liters per minute
Showerheads	162	12 liters per minute,180min avg. use per day
Boilers	3	CLHS0.47-4000-0, for hot water only using natural gas
Coin-operated washing machines	29	120 liters per use, 6 times per day
ZANUSSL dishwashers	2	380 liters per use, 3 times per day

2.3 WATERGY model assumption

The target usage for water efficient plumbing fixtures is revised comprehensively according to relative newest Chinese national standard and specifications, for example, GB/T23447-2009 Shower outlets for bathing, CJ164-2002 Domestic water saving devices, GB25501-2010 Minimum allowable values of water efficiency and efficiency grades for faucets etc. as in Table 2. Since most plumbing fixtures used in campus were installed before these standards issued, it could easily to find the great gap between survey result and the target value.

Model assumptions are revised as in Table 3. Performance parameters of faucets, showers, dishwashers and boilers discharge are depended on the onsite survey in BUCEA. Performance parameters of dishwashers, washing machines and boilers efficiency come from their nameplates. Calorific efficiency of natural gas and electricity as well as energy consumption adopt common value. Leaks of hot water, unaccounted natural gas leaks and electricity line leaks are estimated according to experience. Cost rates of water, electricity and natural gas are quoted from Beijing Price Administration, while labor cost for replacing or modifying water conservation facilities is not considered. Total work days are assumed days, not total calendar days.

3. RESULTS AND DISCUSSION

3.1 Annual savings estimate

Based on the above statistics, annual direct water savings, annual direct and indirect energy savings of each water conservation facilities can be estimated. As in Figure 2, Effect of modification in time-lapse self-closing squatting pans is ranked the best, whose direct water saving is 139,200 Yuan per year by installing water efficient ones. The second is installing water efficient shower-heads with a savings of 104,980 Yuan per year. In the case of BUCEA campus, it is supposed that all single handle faucets for lavabo in dormitories are added aerators, all single handle faucets for lavabo in other buildings are replaced with IR sensor faucets, and all single handle faucets for mop sink are modified by installing pressure-reducing valves in pipelines. The total optimization for three types of faucets can achieve 48,830 Yuan direct water savings per year. Since urinals are already IR sensor types, the effectiveness of urinals are not so clearly, which is only 2,970 Yuan per year not considering waterless urinals.

Total direct energy savings is 354,540 Yuan per year, a little more than direct water savings. Among direct energy savings, the part of installing water efficient showerheads accounts for the most, about 223,700 Yuan yearly. The next are replacement with water efficient washing machines, boilers blow down optimization and replacement of water efficient dishwater one by one.

Compared with direct water saving and direct energy saving, indirect energy saving is small. It is only 37,640 Yuan per year, just 10.62 % of direct energy saving and 11.35 % of direct water savings. Among indirect energy savings, the part of water efficient showerheads accounts the most for 12,740 Yuan yearly. The next is water efficient squatting pans of 10,530 Yuan. Water efficient urinals account for the least part of indirect energy saving, with only 224.63 Yuan per year because of the high initial cost.

In conclusion, the total direct water savings is 331,600 Yuan per year, and total energy savings is 392,180 Yuan per year. Energy savings is as important as water savings.

3.2 Payback periods of water conservation facilities

Payback periods and net worth of each water conservation management can be calculated as in Figure 3. The total payback period of BUCEA's water conservation management options recommended in this paper is 1.24 years. In other words, BUCEA has great water conservation potential in these aspects.

The larger the slopes in Figure 3 are, the shorter payback periods are. Among the water conservation management options, the payback period of water efficient toilet installation is 1.62 years while installation of water efficient urinals is 3.5 years. Both IR sensor faucets and aerator faucets have great water conservation potential.

Table 2 Target usage for conserving plumbing fixtures

Plumbing Fixtures	Data	Requirement	Standards and Specification Sources
Water efficient toilets	7.0 liters per flush	0.3MPa	CJ164-2002 Domestic water saving devices
Water efficient urinals	3.0 liters per flush	0.3MPa	CJ164-2002 Domestic water saving devices
IR urinal throughs	3.3 liters per flush	0.3MPa	Chinese new product
Waterless urinals	0.004 liters per use	7-12litres hot water every 8,500 uses	Adoption from American standard
Faucets	7.5 liters per minute	(0.10±0.01) MPa	GB25501-2010 Minimum allowable values of water efficiency and efficiency grades for faucets
IR faucets	6.0 liters per minute	(0.10±0.01) MPa	GB25501-2010 Minimum allowable values of water efficiency and efficiency grades for faucets and American standard
Faucet aerators	4.20 liters per minute	(0.10±0.01) MPa	GB25501-2010 Minimum allowable values of water efficiency and efficiency grades for faucets, American standard
Water efficient showerheads	9 liters per minute	0.1MPa	GB/T23447-2009 Shower outlets for bathing
Water efficient roller washing machine	16.00 liters per kg load (with heat) 14.00 liters per kg load (no heat)	Maximum washing load capacity, high water level and a standard washing process, over the 0.8 wash rate	CJ164-2002 Domestic water saving devices
Water efficient dishwasher	12.0 liters per kg load	Maximum washing load capacity	Chinese new products

Table 3 Assumption of WATERGY Model

Nameplate	Data	Description
Energy consumption	0.099	kWh/liter water for natural gas heaters, when heating water from 15ºCto 100ºC
	9.9	Liter natural gas/liter water for natural gas heaters, when heating water from 15ºC to 100ºC
Heat of natural gas	36000	kJ/1000litres
Heat of electricity	3600	kJ/kWh
Faucet	0%	of usage is hot water
IR sensor faucet	0.17	Minutes per use
Shower	60%	of usage is hot water
Dishwasher	70%	of usage is hot water
Washing machine	25%	of usage is hot water
Leaks	10%	of usage is hot water
Electricity for water sup-ply	0.30	kWh/1000liters, indirect energy saving
Electricity for wastewater treatment	0.27	kWh/1000liters, indirect energy saving
Unaccounted natural gas	2.1%	Indirect energy saving
Electricity line leaks	8%	Indirect energy saving
Boiler efficiency	92.8%	Natural gas boiler
Boiler discharge	20%	Reduced by process optimization
Cost rate	2.96	Yuan/cubic meter, water supply
	1.04	Yuan/cubic meter, wastewater treatment
	2.05	Yuan/cubic meter, natural gas price
	0.488	Yuan/ kWh, electricity price
One year	300	Total work days assumed

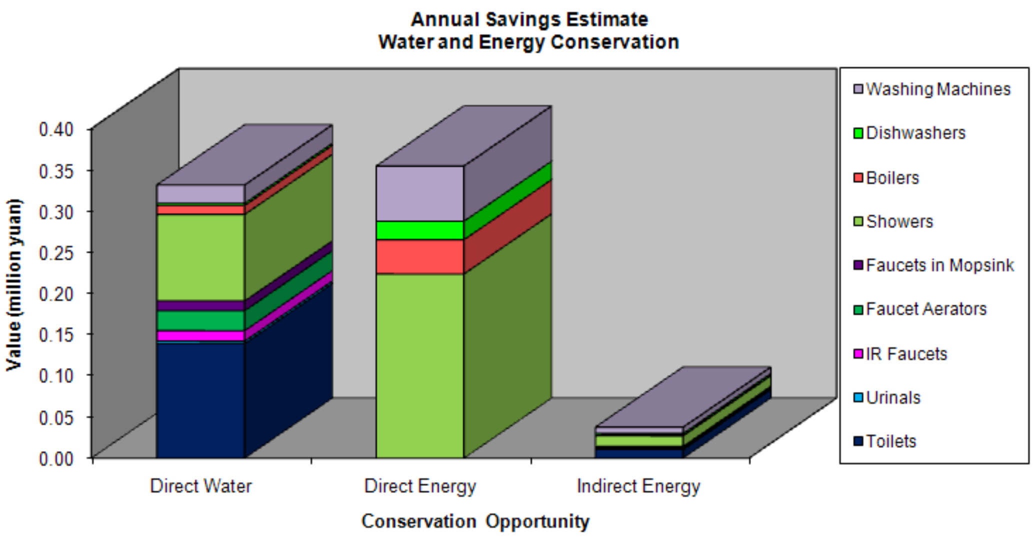

Figure 2 Annual Savings Estimate (Water and Energy Conservation)

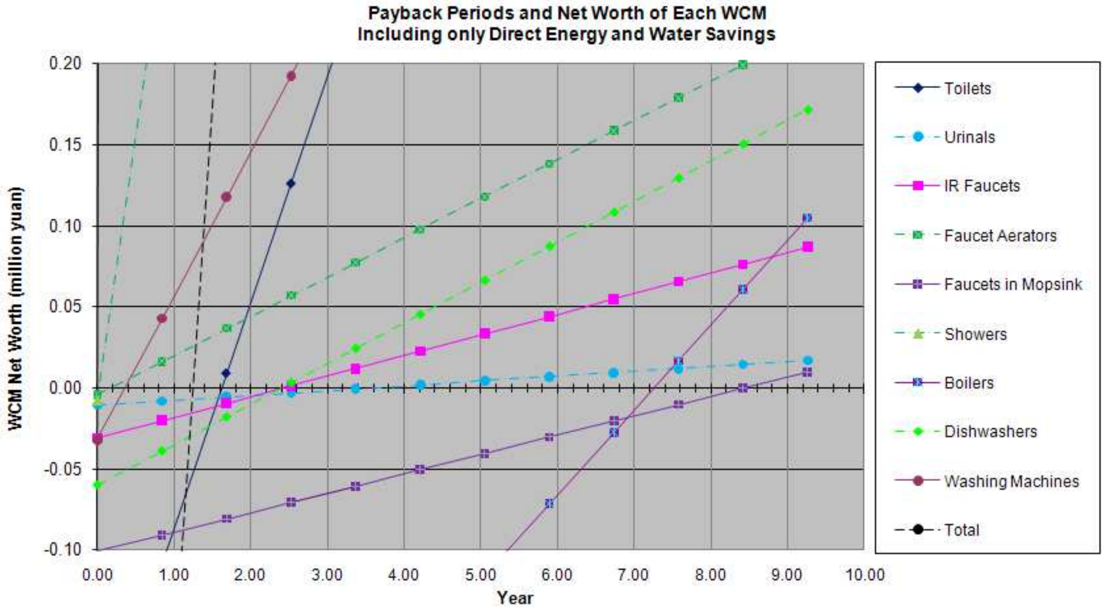

Figure 3 Payback Period（year）

As initial cost of IR sensor faucet is high while unit price of faucet aerator is only 10 Yuan, payback period of the former is 2.41 years while the latter is only 0.15 year. Because unit cost of pressure reducing valve is relatively higher than the other two types of faucets optimization, the payback of installing pressure reducing valves in pipelines of single handle faucets for mop sink is 8.42 years. It achieves great amount of water savings and energy savings by installation of water efficient showerheads, so their payback periods are very short, just 0.024 year. Besides, payback periods of replacing water efficient dishwashers and washing machines are 2.39 years and 0.36 year relatively. As total initial cost of three boilers is as high as 380,000 Yuan, so payback period lines of boiler blow down optimization is very gentle and its payback period is 7.25 years.

Above all, it can be concluded that every water conservation management mentioned in Figure 3 have good economical feasibility except installing pressure reducing valves in pipelines of single handle faucets for mop sink, and boiler blow down optimization.

3.3 Discussion

WATERGY model requires thorough water use statistics for all water using instruments. However, due to lack of sufficient meters and sub-meters, there are not sufficient water usage records for water using equipments in most places of China. So it is difficult to promote the wide use of WATERGY model. For example, during water use survey in BUCEA campus, it is found that routing records are only about total water meter and water usage monthly. In fact the total water consumption can’t reflect water leakage and reveal real water conservation condition. So the author installed water meter, pressure reducing valve and pressure gauge at the end of water using equipment to measure flow rates at the current pressure.

The outflow rates per flush of water using equipments sometimes can’t reflect true water usage. For example, in the water survey of BUCEA campus, it is found that although some time-lapse self-closing squatting pans have low flush water, the quantity of flush is relatively 2~3 times more than once per time. It may be caused by large amount of water leak in water supply line, or the pressure at the end of water using equipment is lower than required. So the record of water use per flush isn't realistic, it's better to record the total water use volume per using time.

Reclaimed water and rainwater utilization aren't included in WATERGY model. Reclaimed water and rainwater are important unconventional water resources in substituting urban fresh water, especially in the city of severe water shortage. Not only does unconventional water resources utilization reduce water costs, but also reduce water treatment costs. In other word, it could bring in much water savings and energy savings. Therefore it is suggested that reclaimed water and rainwater utilization should add to the model.

Indirect water savings isn't considered in the calculation of payback periods in WATERGY model. Though its saving amount is relatively small, as one part of four conservation types, indirect water saving is necessary, especially in the place where hot water or steam is largely demanded. Therefore it is suggested that all parts of savings should be included in the model. There is a lack of benchmarking research focused on other Chinese universities' water usage profiles. Therefore, it is not possible to accurate analyze BUCEA's water use against these benchmarks to verify the practical water conservation potential.

CONCLUSIONS

WATERGY model have been successfully applied in BUCEA campus demonstrated that water efficiency measures repay themselves quickly and yield many rewards: immediate improvements in water service, managing leaks, reduced water and energy consumption, more revenue for system upgrades and rigorous metering of end use. These improvements often pay for themselves within 1 ~ 4 years, depending on their own conditions.

With the help of adequate model tool, EUA or DSM water efficiency measures can be evaluated and provide definite water conservation benefit and cost, which are more scientific and reasonable than water use quota management now widely used in China. The method can also be used in other sites of water conservation projects including newly built or rebuilt facilities where there are sufficient data.

As every drop of water consumes energy, water conservation means energy conservation to some extent. WATERGY model combines water savings and energy savings together. By calculating payback periods, it shows great economic and environmental benefit to customers and water utilities, which may stimulate them to implement water conservation works.

ACKNOWLEDGEMENTS

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Fresh water includes water in ice sheets, ice caps, glaciers, icebergs, bogs, ponds, lakes, rivers, streams, and even underground water called groundwater. Availability of freshwater has determined the growth of civilization in the past.Â GIS-based watershed modeling process begins with a digital representation of the ground surface topography, or a Digital Elevation Model (DEM). Using GIS to analyze DEMs, an engineer can produce draft watershed delineation and drainage patterns with limited manipulation.Â Assessing Ground Water Potential. GIS and multi-criteria decision analysis techniques are used for identifying the groundwater potential zones and favourable artificial recharge sites. GIS-based multi-criteria analysis is also useful in mapping groundwater recharge zones. The Agricultural Conservation Planning Framework (ACPF) is an approach to precision conservation for agricultural watershed planning, which is supported by high-resolution watershed data providing spatial detail on land use, soil survey, and topography, which, in turn, are analyzed using an ArcGIS toolbox to identify conservation practice placement options for water quality improvement.Â This overview article describes the history and development of the ACPF, its role in a watershed approach to agricultural conservation, training and support for the ACPF, and future challenges anticipated as the ACPF is trialed outside the upper Midwest. Several watershed case studies are presented that were part of a symposium during the Soil and Water Conservation Society Annual Conference in 2017. It identies the achievements in water conservation and responds to the Regents Policy on Sustainable Practice. The WAP identies the active outreach programs and student-based activities that demonstrate the continued engagement in campus-wide water use reduction strategies. It identies new technologies to consider for the delivery of water for potable and non-potable use. It recognizes the commitment landscape operation sta have incorporated into daily operations and acknowledges the focus on maintaining ecient irrigation systems while promoting native and low water use landscapes. The WAP rev...