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**A Drop of Energy:
Water Demand Management in Canada**

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Abstract

This study explores the Canadian municipal water management system, outlines its challenges, and reviews possible solutions. To frame the discussion, the study mainly explores three questions: Why do Canadians need to be concerned with water policy issues? What is the role of municipal water management systems? How can water pricing structures be effective? In this regard, the study provides background and insight on the theory and practice of urban water management in Canada, identifies key challenges and offers recommendations to overcome these barriers.

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1.0 Introduction

1.1 Purpose and Overview

Canada is fortunate to have an abundance of freshwater resources. It is not surprising that water holds a prominent place in Canadian history, its economy and self-image. Canadian are dependent on these water resources not just for drinking purposes but also for recreation, manufacturing, industry, agriculture, and urban development. Despite the fact that water is basic for health, economy and recreation, it is often taken for granted, undervalued and overused. As a result, unlimited access to freshwater resources has become an expectation for Canadians and the demand has grown according to population and business growth. Engineers have always quenched the thirst by stretching the water supply. However, pressing reasons exist to manage the demand. High levels of urban water use, a growing number of municipalities facing supply and infrastructure limitations, and the increase in capital costs of infrastructure expansions are among the main reasons. Demand-side management increases the range of available managerial tools as well as the complexity of the management. Water pricing structures are one of the most powerful policy instruments that DSM provides. However, adoption of a conservation-oriented water pricing structure is a part of long-term comprehensive integrated DSM program that has to be phased into a water management system and requires overcoming many barriers and challenges. The water-energy nexus suggests taking one step backward and looking at the water and energy sectors as one whole. The new perspective further illustrates advantages of water conservation and provides new opportunities to overcome water pricing reform challenges.

1.2 Methodology

This study provides background and insight on Canadian water policy issues based primarily on recent academic research, as well as government websites and policy documents. Also, multivariate statistical analysis has been performed to illustrate the most and least effective factors on water consumption, where the dependent random variable of water consumption is compared against the independent random variable of water cost, urban population density, conservation measurement, type of water resources and water pricing structure.

2.0 Why do Canadians need to be concern about water policy issues?

2.1 Canada and water

There is no argument that water is a vital substance for life. Nevertheless, it is the most inexpensive material all over the world. Canada, the country of lakes and waterfalls, has always had unlimited access to freshwater resources. As a result water availability has never been a serious issue until recently after a significant drop in Great Lakes water surface levels.

Even Canada, with an abundant supply of freshwater, is not without water concerns. There are two main reasons that Canadians need to pay greater attention to water issues: water availability and water quality (McFarlane & Nilson, 2003). Higher pressures being placed on water resources over time in the form of increasing consumption and contamination is a cause of concern. At the same time, although from a comparative global perspective Canada has a good standing on safe water provision, the variation of water quality across country makes it a public health issue. Outbreaks of waterborne disease in Walkerton, Ontario and North Battleford, Saskatchewan demonstrated the $300 million per year water contamination health-care cost (McFarlane & Nilson, 2003) is considerable and demands more consideration.

2.2 Water availability

According to McFarlane and Nilson (2003) there are five key factors affecting water availability in Canada. The first factor is urbanization. Canada's urban population grew by 45.7% between 1971 and 2001 (Statistics Canada, 2003a) so that almost 80% of Canadians reside in urban areas of at least 10,000 people (Statistics Canada, 2003b). A quick look at the geographical distribution of Canada's population shows that 90% of its citizens are situated adjacent to the United States border where water resources have already been stressed by human activities.

Infrastructure capacity and finance is the second factor. Much of the water supply infrastructure in large Canadian centers is over 50 years old (Brandes & Ferguson, 2004). It is estimated that existing municipal infrastructure systems have used over 79% of their service life (Canadian Society for Civil Engineering, 2003) and more than 50% of water supply lines are currently in need of repair (Environment Canada, 2001a). Modern water and wastewater systems are the most capital intensive of all public works (Brandes & Ferguson, 2004). The water main replacement rate is 0.6% in Canada and it would take 150 years to fully replace at current rate (Canadian Society for Civil Engineering, 2003). Also unmet water and wastewater infrastructure needs has been estimated to be in the range of $23-$49 billion (Brandes & Ferguson, 2004). This deteriorating infrastructure is having a significant influence on water supplies throughout the country, it can be expected that significant water losses will continue if required infrastructure improvement are not addressed.

Fresh-water contamination also affects water availability. Industry, landfills, urban runoff, sewage disposal, agriculture and nature itself are the source of a variety of chemicals polluting water. Municipal effluents come from municipal sewer systems and water treatment plants, rainfall and snow melt carrying pollutants, sediment nutrients and pesticides used for agricultural purposes, and acid rain are examples.

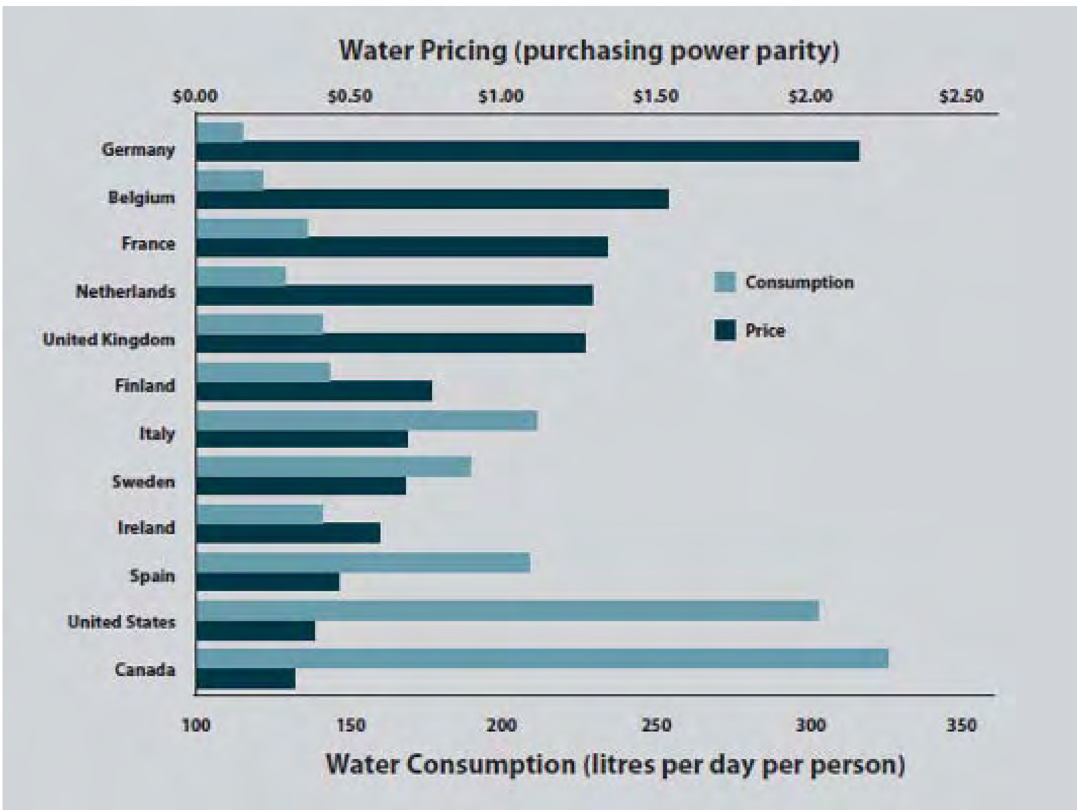

Figure 1: International comparison of municipal water prices and consumption (Council of Canadian Academies, 2009)

Without doubt consumption habits are one of the most effective factors in water availability. For example, total water withdrawal increased by 26% between 1980 and 1997 in Canada, while in the same period, despite economic and population growth, water withdrawal in United States dropped by 5% (Brandes & Ferguson, 2004). It is believed that development of a strong water conservation ethic in Canada has been hindered by two main reasons, current water pricing policy and a continuing myth of abundance. According to the recent International comparison of Municipal Water Pricing and Consumption, Canada has the highest per capita water consumption associated with the lowest price (Council of Canadian Academics, 2009).

According to Brandes and Ferguson (2004), the Canadian total municipal water consumption is 640 litres per capita per day (lcd), which is two and half times more than the European average. Recent assessments indicate that each individual requires approximately 50 litres of clean water per day to ensure the basic health and vitality needs are met (McFarlane & Nilson, 2003). However, a typical Canadian uses 343 lcd in their home. This rate has levelled out between 1986 and 1991, but due to increasing urbanization and population growth, total residential water consumption increased by 21% between 1991 and 1999. This increase in water demand has stressed both surface and ground water resources significantly so that one in four Canadian municipalities reported water availability problems between 1994 and 1999 (Environment Canada, 2001). Such problems suggest that the number of municipalities reaching the limits of their water supplies and infrastructure capacity is increasing.

The effects of environment and climate should not be underrated. Even though there is no certainty about the impacts of climate change, a consensus among scientific communities exist that global temperature is increasing. A long-term change in temperature affects evapotranspiration levels, wind patterns, humidity, and even surface flows. In other words it will affect the water cycle and in turn water resources; and Canadian water resources would not be an exception. The impact of climate change is already being felt. Some bold examples are low water levels in the St. Lawrence Seaway which have threatened navigation, a drop in Great Lakes water levels, and loss of glacial mass in Alberta (Brandes & Ferguson, 2004). However, regardless of supply limitations and source degradation impacts due to climate change, each Celsius degree warming can be translated to a 1.3% increase in municipal water consumption in the Great Lakes region (McFarlane & Nilson, 2003). The worst scenario will occur when an increase in demand, coupled with a decrease in supply will create a serious situation of water availability. Here is when David Schindler, Killam Memorial Professor of Ecology, said: "Water will become Canada's foremost ecological crisis early in this century".

As a result of these challenges, concerns about water management are increasing and the situation will worsen as municipal water use continues to rise. Given that it is impossible to stretch Canada's water supply significantly, the only available options in the way of sustainability are controlling the factors affecting water availability and demand. The complexity of the problem necessitates a "comprehensive, long-term, integrated approach to water provision by many different actors including all levels of government, professional associations, civil society, and end users," (Brandes & Ferguson, 2004) with fully integrated demand management.

3.0 Paradigms of urban water management

3.1 Supply side management

The water availability crisis suggests fundamental reform is required in urban water management. The traditional approach is a range of supply-side options. "The Primary concern of supply-side management has been securing and treating sufficient quantities of water to meet forecast demand” (Maas T. , 2003). Supply Side Management, in simple terms, means stretching the available water supply in order to quench the growing thirst by constructing or expanding diversion projects, dams, reservoirs, groundwater pumping stations and treatment plants (Brands and Ferguson, 2004). According to Tate (1999), “water management in Canada has focused on manipulating the country’s massive supplies of fresh water to meet the needs of Canadians.” Underlying this paradigm is a “sprawling” stock of infrastructure. Construction of 54 interbasin diversions and over 150 large dams put Canada among the world’s most advanced practitioners of the ‘Science of water development’ (Shrubsole & Tate, 1993). While Canadians are hitting the borders of accessible water supply, the increasing pressures being placed upon existing water supplies is a cause of concern. Given the situation, Canada has only two options: limit the impact of factors that reduce availability, and/or reduce demands (McFarlane & Nilson, 2003).

Water availability and water demand are two ends of the same pipe and management of each side will affect the other one. Enough water resources guarantees meeting water demand. In the same way, management of water demand by any means, conservation or increasing efficiency, would protect water resources and secure water availability. Referring to the aforementioned five key factors affecting water availability, water conservation improves water availability by influencing water consumption habits and also the environment. Since energy is the single largest water consumer in Canada (Environment Canada, 2005) water conservation means saving water and energy, and at the same time, reducing green-house gas emissions. In other words, water conservation is a mitigation strategy for climate change, a protection factor for water availability and a critical step in demand-side management, all at the same time.

3.2 Demand-side Management

Urban water management is a complex process because of diversity of its factors, for example: growing water use, lack of supply, seasonal droughts, failing infrastructure, and associated financial cost. Combinations of such factors make economic, ecological and social concerns related to municipal water supplies that need to be addressed by communities. “Supply side management approaches take water needs as given and treat fresh water as a limitless resource to be harnessed and distributed to meet growing demands” (Maas T. , 2003). The basic paradigm of water management has brought tremendous benefit to countless number of people. However, it is needless to say that expansion of limited supply to meet an unrestrained demand is impossible.

Demand side management is the reoriented paradigm for water management. Demand-side management is generally defined as “the planning and implementation of programs to influence the amount, composition, or timing of demand for some commodity or services” (Shrubsole & Tate, 1993). In the context of urban water systems, demand-side management is referred to as “design and implementation of policy and practices to induce physical and practical changes that increase the efficiency of water use” (Maas T. , 2003) and promote water conservation. The terms demand-side and supply-side management are often used to differentiate between efforts to change the way water is used versus the way water is supplied to the consumer.

3.3 Framing the DSM approach

Demand-side management increases the range of managerial tools available for planners and managers. DSM is well appreciated due to the higher level of flexibility it brings to the system and enables the system to meet uncertainties (IPCC 1996). However, more available tools increase the complexity of management, as many tools are interconnected and complementary. Therefore, “the challenge of the DSM approach is not one of selecting the correct tool, but rather arriving at an appropriate mix of tools to suit local conditions and values, and to take advantage of the interconnections and synergies among them” (Maas T. , 2003).

The process of DSM can be divided into three main categories: the means for reducing demands, the policy instruments available to motivate these means, and the obstacles that further complicate DSM by impeding the shift from traditional paradigms to new ones and posing barriers to its widespread adoption.

Reduction in water demand can be achieved through structural and operational techniques separated into behaviour changes and physical changes. Changing lawn watering times to early morning when evaporation losses are minimized is a behaviour change. Change of older toilets with water efficient models is an example of technological efficiency improvement. Technological efficiency improvements and water reuse are the two main groups of physical changes (Maas T. , 2003).

Developing and providing these means do not ensure their adaptation and implementation. Socio-political and economic techniques provide policy instruments to encourage or mandate desired behaviour and physical changes. These policy instruments are grouped in three categories: Education, Economic Incentives, and Mandatory Mechanisms (Maas T. , 2003).

Improvement in the general level of awareness regarding water issues and, importance of water conservation and associated techniques, are two fundamental factors to encourage behavioural and physical changes. This is especially true in Canada where unlimited access to fresh water is an expectation. This is not something just for public education at primary levels but also for university students, engineers, politicians and decision makers who all need appropriate education. One of the barriers in the way of the DSM approach is the engineer's dominance over the management sector as they mostly tend toward supply-side options. Engineers usually focus on single, rather than multiple, benefits and design methods that optimize components in isolation (Brandes & Ferguson, 2004).

Mandatory mechanisms or 'command and control' are instruments to prescribe behavioural and physical changes to promote water efficiency. Plumbing and building codes and regulatory instruments are typical examples. However, the literature tends more toward economic incentives as a policy instrument. Lack of economic incentives is widely held as the most significant impediment to DSM in Canada (Maas T. , 2003). The analysis emphasizes the emerging theoretical and empirical evidence that using prices to manage water demand is more cost-effective than implementing non-price conservation programs (Olmstead & Stavin, Comparing Price and Non-Price Approaches to Urban Water Conservation, 2008). Water cost and pricing structure are two main factors in this regard.

Shifting from traditional paradigms to a new conservation-oriented one in the 21st-century is not so much about how to do it; it is more about how to make it happen. Bocking (2003) puts it well: “we have so much knowledge about water that we are not using: we know what we should be doing, it’s just a matter of getting on with it”. To address this issue we have to know the source of impediments. Brandes and Ferguson (2004) categorise all barriers in four groups: attitudinal, financial, data and informational, and administrative. The following Table explains barriers that impede the adoption of DSM in Canada.

Table 1: Barriers that impede the adoption of DSM in Canada (Brandes & Ferguson, 2004)

Attitudinal Barriers	***Financial Barriers***	***Data and Informational Barriers***	***Administrative Barriers***
• Myth of superabundance • Human economy and human-built infrastructure considered separate from the environment • Ideal of free market society without government intrusion • Belief that reduced water use imposes a reduced standard of living • Concern that DSM savings are unreliable and/or insubstantial • Political preference for high visibility projects	• Subsidies and low pricing • Need for predictable and stable revenues • Need to maintain sufficient revenues (in the face of overcapitalization) • Lack of funding for DSM • Gap in payback	• Wariness about DSM by decision makers • Lack of comprehensive cost/ benefit models • Ineffective DSM programs	• Fragmented administration • Centralized engineering bias • Formulaic thinking • Inflexible policies

3.4 A Great Example

If there is one issue that constitutes Canadian water crisis, which is misinformed public perception. A common misconception in Canada is that we have more than enough water and that there is no water crisis but one in four Canadian municipalities reported water availability problems between 1994 and 1999 (Environment Canada, 2001).

The Great Lakes with 20 percent of the world's surface fresh water have always been manipulated as an undeniable evidence of amply fresh water resources. The Great lakes are an inheritance of the last ice age and 99 percent of their water supply is non-renewable (Ontario Ministry of Environment, 2008). It means that once they used they are gone forever. On top of that, Great Lakes have been shrinking rapidly as illustrated by the following example (Mittlestaedt, 2007):

> "The falling water levels aren't news to Gary Vent, whose home overlooks Georgian Bay, an arm of Lake Huron, near Waubaushene, Ont. He can see the effects: The shoreline that used to be 50 metres from his house is now more than 150 metres. Newly emerging land from the drying lakebed means that, where he docked his boat just six years ago, he now plays golf."

In addition, Great Lakes water quality is also an issue. A joint report in late 1985 by the Royal Society of Canada and the U.S. National Research Council said that people living around the lakes are probably exposed to more toxic chemicals through their food and drinking water than any other population in North America (Keating, 1986).

This example proves that Great Lakes are not a limitless source of fresh water resource and Canada is not as rich as it seems in terms of water resources. However, the notion of "water abundance" exacerbated by the cheap cost of water has placed Canada among the biggest water consumers in the world (Council of Canadian Academics, 2009).

The *Lack of comprehensive cost-benefit models* is another barrier which affects any DSM program. DSM programs are usually associated with indirect benefits that if taken into account will compromise some of their deficiencies. The first example which comes to mind is water conservation. Saving water is typically associated with energy savings and reduction of wastewater production. Incorporation of these benefits in models can increase the cost-benefit ratio even more than 1:15 (Brandes & Ferguson, 2004). This may attract the decision-maker's attention and help to compromise *lack of funding* by replacing some *subsidies* (Maas T. , 2003). As a result of *fragmented administration*, municipal and provincial levels of government are often unable to coordinate their efforts effectively (Maas T. , 2003). Many of these barriers work together to entrench the current situation. This type of situation, that individual drivers are closely interconnected and interdependent, can not be rectified with traditional isolated strategies. Getting out of this gridlock needs tackling a number of barriers simultaneously and strategically.

4.0 Water Conservation and Water Pricing

4.1 Water Pricing

Low pricing was another barrier to the adaptation of DSM in Canada. There is no argument that water is a vital substance for life. Nevertheless, it is the most inexpensive material all over the world. For instance, a cubic meter of water is cheaper than a cup of coffee. "Water prices in Canada do not reflect the 'true' values of the resource and seldom even recover the complete cost of treatment and distribution" (Maas T. , 2003). Underpricing of water will have inadequate incentives to improve efficiency or reduce use, both of which will lead to overuse. Overuse will lead to over-construction of infrastructure and unnecessary investments in one way, and reduction of the quality of water in another way (Brooks & Peters, Water: The Potential for Demand Management in Canada, 1988).

TYPE OF WATER CHARGE	HOW TYPICAL WATER CHARGES ARE APPLIED
Constant Unit Charge	A constant fee is charged per unit of water used.
Declining Block Rate	Water use in billing periods is divided into successive volumes or blocks, with each block charged at a lower price unit than the previous block.
Increasing Block Rates	The unit price of water increases progressively through the blocks of a rate schedule.
Complex Pricing	Price is based on a combination of Constant Unit Charge, Declining Block Rate, and/or Increasing Block Rate structures.

SOURCE: Derived by Canada West Foundation.

Figure 2: Volume Based Rate Types (McFarlane & Nilson, 2003)

However, "rate structures are as important to the DSM approach as the actual prices charged" (Brooks, Against the Flow, 2003). Many academics and water policy experts argue that Canada's water resources are being unnecessarily depleted as a result of existing pricing structures (Renzetti & Kushner, 2004). Canadian municipal water pricing structures, which are typically set by municipal agencies, vary significantly in Canada (Figure 2). Pricing policies can be divided into two major groups: flat-rate and volume rate. In flat-rate systems, users obtain unlimited access to water services upon a fixed payment or sometimes a portion of their taxes. In volume-rate systems the cost is based on the amount of water used. According to a 2008 municipal water pricing report, only

63 percent of the municipal population was metered in 2004. Volume-based structures are more effective than flat rate systems from the standpoint of water conservation. As evidence, customers paying flat rates use 50% more than those paying volume-based rates (Environmental Canada, 2001).

Figure 3 shows the percentage of Canadian population served by each rate structure. This figure explicitly shows that 77% of the population are served by pricing systems which do not provide efficiency incentives and it totally makes sense given Canada's standing in global water consumption rankings.

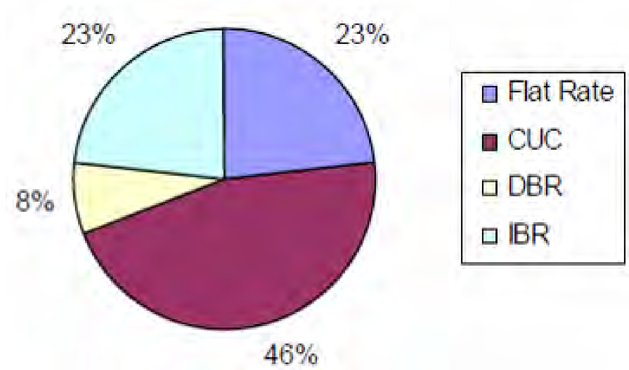

Figure 3: Percentage of Rate Structure (Environment Canada, 2008)

4.2 Statistical Analysis

There is a growing literature supporting economic incentives as the most cost-effective factors for DSM adaptation, and water pricing as the one of the most powerful instruments. In support of this notion a statistical analysis study has been conducted. Ontario and Quebec were selected as the sample regarding the fact that Ontario is on its way to becoming a global leader in water technology and services for water conservation and treatment by launching the Water Opportunities Act. Also, the Great Lakes-St. Lawrence River Sustainable Water Resource Agreement mandates implementation of water conservation and efficiency for any new or increased diversion in the Great Lakes

Basin for all eight Great Lakes States, Ontario and Quebec.The population of interest was all 924 municipalities in Ontario and Quebec; however applicable data were only available for 274 municipalities.

A model was designed to compare the effect of various variables influencing water consumption in municipalities. The purpose of this study was to test the well accepted hypothesis of positive effective of higher cost on reducing water consumption, and also to assess the impact of implementation of different water pricing structures. The methodology used to analyze the data was linear regression applied to a 2004 municipal water and wastewater survey database, published by the Ministry of Environment in 2008. A brief description of the different variables is found below.

Table 2: Variable Definition and Hypothesis Effect

Dependent		**Description**	
Consumption		Average Daily Flow of Water in municipality from all sources (Cubic meter/Capita)	
Independent Description		**Description**	**Impact**
Population		Population of each municipality (Capita)	+
Conservation Index		Number of water conservation measures multiplied by the percent each is currently implemented.	-
Ground Water		The Average Daily Flow from the "Groundwater Only" (Cubic meter)	+/-
Water price		The derived residential monthly price for 25 cubic meters of water (US Dollar)	-
Metering		Degree of water metering, as a fraction of served population (Percent)	-
Water pricing		Residential or Domestic Rate type:	
	Flat	Flat rate structure (binary)	+
	CUC	Constant Unit Charge (binary)	+/-
	DBR	Decreasing Block Rate (binary)	+
	IBR	Increasing Block Rate (binary)	-

Table 3 shows the result of four models and the outcomes are further discussed as follows. The first model includes all the independent variables. The Conservation Index (Conservation) is controlling the size of sample (N=67), this variable is not statistically significant, and it indicates the wrong direction regarding the hypothesis. Thus, the conservation index was excluded in the second model. The model size increased to 276, R-Square decreased, while significance of the other variables did not change. This suggests that either the sample of the first model (N=67) is biased or the conservation index is an effective factor and should not have been eliminated from the model. The third model tests this hypothesis. Model #3 consists of model #2 variables but run on the model #1 sample. The third model results were expected to be close to the 2nd model results. However, the results were closer to the 1st model. This indicates the sample was biased and the 2nd model was more accurate. Hence, we have to exclude the conservation index because it limits the size of the model and forms an endogenous sample.

Table 3: Results of Four Models

Variables	Model 1		Model 2		Model 3		Model 4	
	Beta (PCSE)	Standardize Beta	Beta (PCSE)	Standardize Beta	Beta (PCSE)	Standardize Beta	Beta (PCSE)	Standardize Beta
(Constant)	.808		.741		.840		.681	
	.150		.039		.151		.000	
Population	.000	-.147	.000	.023	.000	.006	.000	.030
	.000		.000		.000		.611	
Metering	-.002	-.398	-.001	-.165	-.002	-.406	-.001	-.186
	.001		.001		.001		.214	
Ground Water	.000	-.084	.000	-.034	.000	-.057	.000	-.034
	.000		.000		.000		.564	
Water Price	-.086	-.343	-.109	-.240	-.091	-.362	-.088	-.242
	.029		.029		.029		.000	
Conservation	.033	.234						
	.020							
Flat	-.010	-.018	.011	.018	-.015	-.027	.011	.018
	.135		.094		.137		.906	
DBR	.005	.004	.147	.077	.050	.044	.155	.103
	.129		.150		.127		.090	
IBR	.074	.089	.040	.026	.071	.085	.052	.042
	.094		.147		.095		.499	
Observation	67		276		67		274	
R2	.375		.116		0.346		0.129	
R2 adjusted	.289		.093		0.269		0.106	

The fourth model is the same as the third one except two outliers are eliminated. The final model (#4) shows water metering (Metering) controls the model to the highest degree. The cost of water (Water Price) is close to being statistically significant at the 95 percent confidence interval. The municipal population (Population) and type of water source (Ground Water) are neither statistically nor substantially significant. At the same time, the results indicate that all water pricing structures increase water consumption which is not consistent with the hypothesis and not even substantially acceptable.

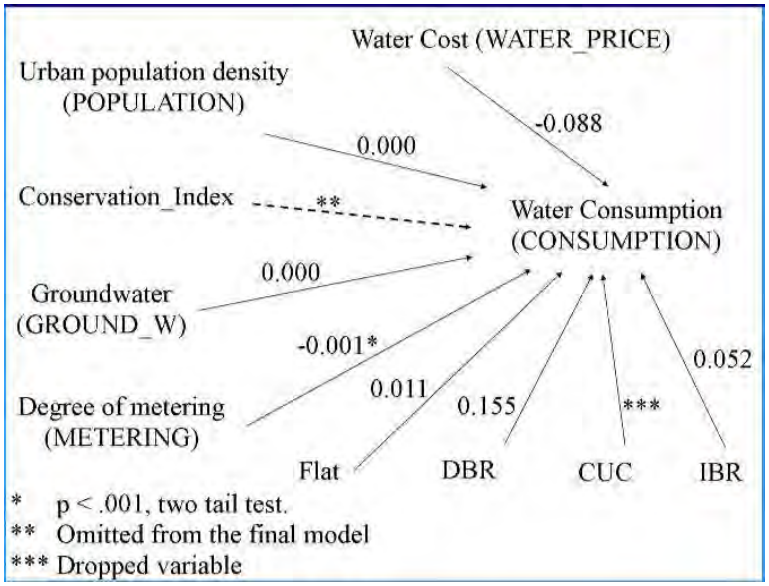

Figure 4: Relationship among Variables

The predicted effects of water pricing structures are plotted (Figure 5). Not only they show the opposite direction regarding the hypothesis, they are in the wrong order. The literature proposes that any sort of water pricing would decrease water consumption and Increasing Block Rate (IBR) has the highest effect (McFarlane & Nilson, 2003; Environment Canada, 2008) but the predicted effects are completely the opposite way.

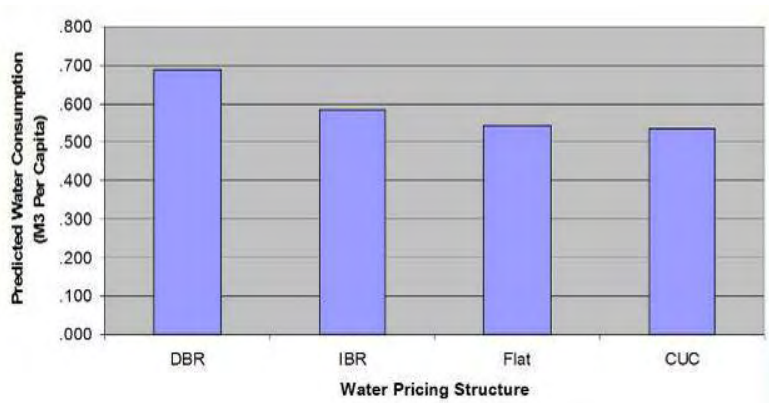

Figure 5: Predicted Effect of Pricing Structure Implementation

The frequency analysis of pricing structures (Table 4) shows 60 percent of required data are missing in population scope (924 municipalities) which is a firm proof for data deficiency. Also, just 6.2 percent of municipalities in the final sample (274 municipalities) implement the IBR structure which explains the final model result that IBR had the least effect in water conservation.

Table 4: Frequency Analysis of Pricing Structures

Population						
	Flat	DBR	CUC	IBR	Missing	Total
Frequency	238	13	100	19	554	924
Percent	25.8	1.4	10.8	2.1	60.0	100.0
Sample						
Frequency	167	11	79	17	0	274
Percent	60.9	4.1	28.8	6.2	0.0	100.0

In conclusion, acknowledging the simplicity and deficiencies of the model, there are a few interesting points in the results. The results confirm that metering is a foundational element of any comprehensive pricing program. Secondly, the frequency analysis outcomes suggest that the data used for this analysis were not strong enough. In other words, the sample is not a good representation for the real population and it is biased. According to Kirk Stainchcombe, the data which have been used are the best existing data-base. A few simple changes in the model may lead to different results and underlines a category of barriers for DSM adaptation: *Data and Information Barriers*. We need reliable data in order to draw constant and solid conclusions to convince decision makers.

Reynaud et al. (2005) have discussed that water pricing structure chosen by municipalities might be endogenous and this may lead to biased results in residential water demand analysis. Basically, some observable and unobservable characteristics of local communities determine pricing choice and residential water consumption level that have to be considered in the analysis. This is the reason behind unexpected outcomes of model #1, when we included the water conservation index. Cities implementing water conservation programs are mostly large cities with water availability problems. However, even though the consumer's price elasticity at current cost is very small (Olmstead, Hanemann, & Stavins, 2003), the pricing structure per se plays a significant role in influencing price responsiveness of Canadian residential consumers (Reynaud, Renzetti, & Villeneuve, 2005).

4.3 Conservation-Oriented Water Pricing Regime

An ideal water pricing structure would guarantee revenue sufficient to cover the costs, allocate costs between consumers, and provide conservation and efficiency improvement incentives (Reynaud, Renzetti, & Villeneuve, 2005). Designing the water rate is an important and complicated issue for water utilities because they follow four main interconnected objectives which conflict at times. Municipalities choose a particular pricing structure based on these factors. First, the price structure must be efficient or welfare maximizing. Second, water is a basic necessity and the water rate should guarantee affordability of minimum water needs for everyone in society. Price discrimination and risk aversion are two other considerations. Risk aversion explains why some municipalities prefer to use a flat rate rather than a volumetric rate. A flat rate reduces financial risk which may derive from the "volatility" of water consumption but send an environmentally damaging and economically misleading signal to the user at the same time (Reynaud, Renzetti, & Villeneuve, 2005).

Determination of the best rate is not easy because of criteria interconnections and conflicts. For example, there is a trade-off between maximising revenue and water conservation. On the other hand, a high portion of water service costs are due to capital investments and fixed. Therefore they do not vary with the quantity of water consumed. This makes cost allocation more difficult to achieve, and conservation promotion more challenging (Reynaud, Renzetti, & Villeneuve, 2005). However, a conservation-oriented water pricing system complies with all mentioned factors.

4.4 A Plan for Reforming the Pricing Regime

Setting up a conservation-oriented pricing system has many details and consideration. For example, how much revenue has to be collected? How to set the rate? And what are the components of the rate? Brandes et al. (2010) has answered all these questions in "Worth Every Penny: a primer on conservation-oriented water pricing", and they proposed a 10 step plan to reform pricing regime.

1. Have a plan, H2Ontario[1] is a good example.
2. Get buy-in and authority from senior management and elected officials
3. Get metered and start charging by volume
4. Get the water bill right
5. Improve accounting of water use in the community
6. Account for expenditure and understand costs
7. Consider starting with a seasonal surcharge
8. Make it a part of a complete program, like an IWRM plan for the whole watershed.
9. Recruit the aid of senior government
10. Take the long term view

[1] H2Ontarion, A blueprint for a comprehensive water conservation strategy, October 2, 2009, Carol Maas.

4.5 The Challenges to Conservation-Oriented Pricing

However, there are challenges for a conservation-oriented pricing adoption to be addressed. According to Environment Canada the median expenditure per household for water services in 2004 was $37.93 per month for 25 cubic meters. In another study, OECD (2010) assessed the portion of net disposable income of Canadian households spend on water and wastewater services is only 0.3%, among the lowest of 20 responding countries. Nevertheless, the first concern to move to conservation-oriented pricing is the threat of hardship for low-income families. A lifeline block in rate structure is the best option. This is a volume of water that is roughly equal to the amount of water required to meet the basic needs of a family. Another possibility is to provide giveaways or generous rebates to low-income families for high efficiency toilets or other water saving technologies (Brandes, Oliver M.; Steven, Renzetti; Stinchcomobe, Kirk, 2010).

Visibility of projects has always been a preference for politicians. Simply, cutting the ribbon of a dam project creates positive media exposure, but a rise in water price or low-flow toilets bring no votes to politicians and decision makers. Not only that, changing the water pricing structure may end up in angry and frustrated residents who criticize politicians and senior managers. However, it is well established that “no reform, no matter how beneficial, will be well received unless they are clearly understood” (Brandes, Oliver M.; Steven, Renzetti; Stinchcomobe, Kirk, 2010). A consultation and education public campaign to remind residents about the environmental benefits of reducing water use so that they do not feel they are being asked to conserve for the sake of conservation itself is the best and only solution (Reynaud, Renzetti, & Villeneuve, 2005).

Some fear that adoption of conservation-oriented pricing structure would increase revenue fluctuation and financial risk. First because volumetric rates increase revenue reliance on the volume of used water, while 75-80 percent (Brandes, Oliver M.; Steven, Renzetti; Stinchcomobe, Kirk, 2010) of spending of water service providers is fixed. Second, increasing the current water unit cost to the full-cost of water might result in "pricing death spiral". This spiral goes like this: the price increases, demand drops, revenue drops, the agency is faced with a budget shortfall and must raise prices again, and the cycle repeats (Reynaud, Renzetti, & Villeneuve, 2005).

In answer, it is vital to remember that water pricing reform is a careful planning process. Given the existing academic studies on the price elasticity of water, lessons learned from others' experience combined with local information can be used to model, measure, and predict the impact of unit price change (Maas T. , 2003). In order to mitigate the revenue variability, water providers can use rolling average price techniques to make a balance between excess revenue and shortfall budget years. Also, including a fixed component to rate structure can ensure a significant degree of revenue certainty. Also support of senior governments to create revenue stabilization funding mechanisms for unexpected or severe revenue impacts as is some times done in the energy sector should not be underrated (Renzetti & Diane, 1999; Brandes, Steven, & Stinchcomobe, 2010).

4.6 Water-Energy Nexus

An integrated management program which can counter predominant formulaic thinking of engineers over management and focus on multi-benefit methods that consider indirect savings of water conservation can tackle many challenges and help in DSM adoption in the water sector. The biggest example which comes to mind is the Water-Energy Nexus.

The water-energy nexus is the story of mutual interconnection of water and energy (Figure 6). Large amounts of water are required to generate energy. Water is used to power the turbines in hydro-electric facilities and for cooling in thermal or nuclear energy plants. At the same time, large amount of energy are required to pump, treat, distribute, and heat water prior to be used for urban, agricultural, and industrial purposes. In the same way, dealing with waste water requires energy (Maas C., 2010).

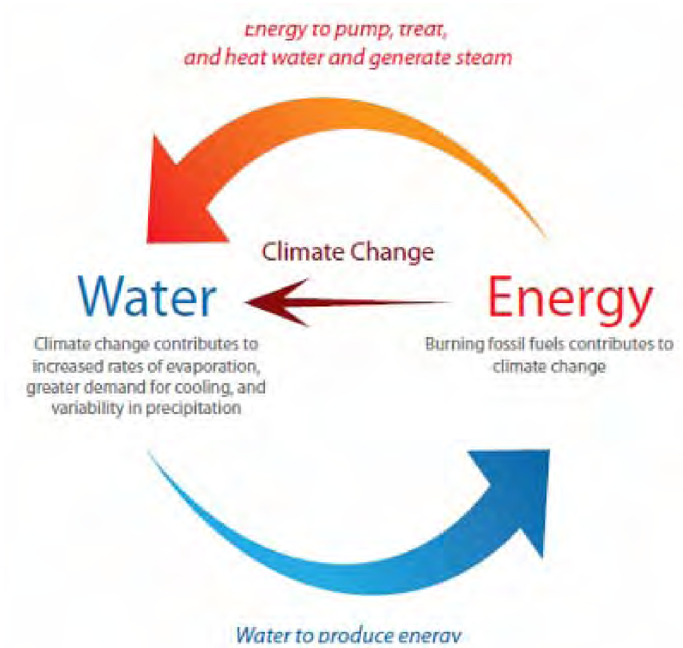

Figure 6: The water-energy nexus in the context of climate change (Maas C. , 2010).

The energy sector is the single largest user of water in Canada (Environment Canada, 2005). According to a recent study, water and wastewater services together represent a third to a half of a municipality's total electricity consumption – double that of street lighting (Maas C., 2009). This is while energy use for water services in Ontario is expected to rise significantly in the coming years. It is mainly due to expected population growth and higher demand on one hand and more energy intensity required for water treatment and pumping from greater distance and depths as a result of decline in water quality and availability on the other hand.

Rising energy costs, the imperative to reduce greenhouse emissions, water availability challenges, and necessity of water infrastructure expansion and/or rehabilitation implies that water and energy conservation are fundamental for sustainability. The water-energy nexus is leading to new opportunities to save water, energy and costs.

4.7 A municipal example: City of Toronto

Toronto is one of the cities that has identified water and wastewater facilities as significant energy consumers and has initiated progressive programs to improve the energy efficiency of these sectors (Maas C., 2009). Toronto, with 2.59 million residents, uses 1.23 billion litres of water per day and is among the biggest water consumers in Ontario, if it is not the biggest (City of Toronto, 2002). The Toronto residents' average water use, 253 litres per day per person (City of Toronto, 2002), is less than the Canadian average but still much more than the OECD average. Taking into account the water consumption rate and the prospective of population and employment, expansion of water production capacity is inevitable. Thus, the City of Toronto developed a Water Efficiency Plan (WEP) in order to mitigate financial expenses by reducing water use over a 10 year plan between 2002 and 2011. The prospective was to accommodate the population and employment growth at one-third the cost of infrastructure expansion. In terms of comparison, the total cost of implementing the WEP ($74.3 million) was 34 percent of capital requirement to provide the same capacity by expanding infrastructures ($220 million) (City of Toronto, 2002).

According to a staff report (City of Toronto, 2009), Toronto retail water consumption dropped from 401 million cubic meters at 2002 to 358 million cubic meters at the 2009 which works out to 117.8 ML/d reduction (City of Toronto, 2009a). Although it is still far away from the 275 ML/d predicted reduction in WEP for the entire 10 years plan, it has saved much energy and green-house gas emissions.

Maas C. (2009) provides the relative intensity of each component in the water use cycle (Table 5) and GHG saving related to each program (Table 6)

Table 5: Summary of Water Conservation Intensities (Maas C., 2009)

Energy Inputs into Water Use	Energy Intensity (equiv.kWh/m^3water)
Indirect Energy[1] (Municipal Pumping)	0.68-1.1
Direct Energy[2] (Hot Water – Electric)[3]	73
Direct Energy (Hot Water – Natural Gas)	103
Embedded[4] Chemical Energy	0.01

Indirect energy saved can be calculated using the indirect water conservation energy intensity for a large surface system (Table 5), with a factor of 0.68 kWh/m^3 .

Indirect Energy Saved

$$= 43Mm^3/yr \times 0.68kWh/m^3 = 29.24GWh/yr$$

5 percent of water saved was assumed to be water that would have been heated by $55^\circ C$, and 70% of hot water heaters used natural gas (Maas C., 2009). Given this assumption, direct energy saved could be assumed as follows:

[1] Indirect energy (municipal energy to pump and treat water and wastewater)
[2] Direct energy (energy used at the end-use for heating water, household purification, and water softeners)
[3] Assumes a temperature increase of 55 degree Celsius
[4] Embedded energy required to manufacture chemicals (used in the treatment of water and wastewater)

Electric Hot Water Energy

$$= 43Mm^3 / yr \times 5\% \times 30\% \times 73kWh / m^3 = 47.085GWh / yr$$

Embedded Chemical Energy

$$= 43Mm^3 / yr \times 0.01kWh / m^3 = 0.43GWh / yr$$

Total Energy

$$= 76.755GWh / yr = 76{,}755MWh / yr$$

This is 1.4 percent of residential annual electricity[1] consumption in the City of Toronto and more than three times the energy reduction target for the next five years, 25,000MWh (City of Toronto, 2009b)

Table 6: CO_2e saving Water Use Reduction, by Province and Water Use Cycle Component (Maas C., 2009)

Province	Emission Factor	Transmission Factor	Water	Wastewater	Hot Water (gas)	Hot Water (electric)
	gCO_2e/kWh		gCO_2e/m^3			
Alberta	930	1.04	522	91	21514	70428
British Colombia	20	1.03	11.8	1.9	21514	1499
Canada	205	1.06	124	21	21514	15869
Manitoba	10	1.14	6.5	1.1	21514	826
New Brunswick	366	1.06	222	37	21514	28305
Newfoundland and Labrador	15	1.10	9.4	1.6	21514	1198
Northwest Territories	80	1.08	49	8.1	21514	6254
Nova Scotia	549	1.04	326	54	21514	41574
Nunavut	80	Not Available	46	7.6	21514	5816
Ontario	270	1.06	166	28	21514	20881
Prince Edward Island	192	1.06	116	19	21514	14849
Quebec	6	1.04	3.6	0.6	21514	454
Saskatchewan	810	1.06	491	81	21514	62643
Yukon	80	Not Available	46	7.6	21514	5816

Given the aforementioned assumptions, the associated end-use GHG emission saving in Toronto could be estimated as follows:

[1] The residential sector in City of Toronto consumes 5.27 million MWh/yr of electricity (Cuddihy, J. et al., 2005).

Indirect Co_2e

$$= 29.24 GWh/yr \times 0.270 kgCO_2e/kWh \times 1.06 \times 10^6 kWh/GWh \times 1 tonnes/1000 kg$$
$$= 8368.488 tonnesCO_2e/yr$$

Electric Hot Water CO_2e

$$= 43 Mm^3/yr \times 5\% \times 30\% \times 20{,}881 gCO_2e/m^3 \times 1 tonnes/10^6 g$$
$$= 134{,}68.245 tonnesCO_2e/yr$$

Natural Gas Hot Water CO_2e

$$= 43 Mm^3/yr \times 5\% \times 70\% \times 21{,}514 gCO_2e/m^3 \times 1 tonnes/10^6 g$$
$$= 32{,}378.57 tonnesCO_2e/yr$$

Total CO_2e Emission Saved

$$\cong 54{,}200 tonnesCO_2e/yr$$

Since one 1.5 MW Windmill offsets 1,064 tonnes CO_2e/yr, a saving of approximate 54,200 tonnes CO_2e/yr in City of Toronto would therefore save the construction and continuous operation of:

$$= 54{,}200 tonnesCO_2e/yr / 1.064 tonnesCO_2e/windmill/yr$$
$$= 50.95 \cong 51 Windmills$$

These calculations are “back of envelope” estimates to get an idea of the effect of water conservation. However, these simple calculations show how effective water conservation can be in order to tackle water availability problems, and to achieve green house emission and energy saving targets.

However, expenditures are predominantly funded through the sale of water to Toronto consumers and the Toronto water program is planned to become self-financing in ten years (City of Toronto, 2009a). Despite the significant increase in water rates and stretched budget in recent decades, infrastructure rehabilitation projects have always had financing issues. Although water conservation has many advantages, it has to be financially possible. Since a big portion of expenditures are fixed and do not vary by water consumption, a considerable drop in water consumption can have financial consequences for City of Toronto. The Water-Energy Nexus can play a bridging role and connect two sectors. This connection can solve some of these problems by replacing some energy subsidies to water sector.

5.0 Discussion and Recommendations

Canadian water resources are not abundant, even though we have four of the largest lakes on the planet around us. Compared to other jurisdictions with similar living standards, Canadians and specifically Ontarians waste large amounts of water. Ontario water resources are already stressed out and an increase in water demand puts further pressure on them. Simply put, not only there is not as much as water we think, increase in population and demand associated with climate change, which diminishes water availability, forms a worst case scenario for Canada.

A growing literature supports the idea of controlling demand rather than stretching supply. Demand management in the context of water can be translated into "water conservation". There are four main groups of barriers that hinder the adoption of water conservation in the society: social awareness, data and information, financial, and administrative barriers. The misguided perception of water abundance is the first factor that needs especial consideration.

First Recommendation: Improve Social Awareness

Adoption of a conservation ethic and improvement in social awareness cannot be achieved except through education. This requires design of suitable programs for all levels of society including kindergarten kids, senior managers, and all groups in the middle.

Second Recommendation: Establish a Database of Water Use

In order to figure out where we are now in term of water issues, to decide where we should go, and to select the best plan and instrument which can bring us there, a strong foundation of science and data is required. Baseline information on Canadian water use and revenues is critical to assess the impact of water conservation measures on water withdrawal. Strong studies and undeniable conclusions are vital to influence decision makers.

Third Recommendation: Establish a holistic strategy

Administration and financial management are tightly related. Water conservation and efficiency are "no-regret" strategies. Beside environmental benefits, they have economic attractions as well. A holistic approach toward water and energy can further illustrate advantages of water conservation and also solve many other problems. From a bottom line, if it is possible to find the funds for massive infrastructure projects, we can certainly uncover sources of fund to conserve water.

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