Climate Change Central

Water and Energy Efficiency
The Link

DISCUSSION PAPER C3 – 16

Prepared By:
Cheryl Arkison and Tanya Maynes
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Executive Summary

Reducing the amount of water used by Albertans saves energy. Reducing water consumption is thus good for air quality, the climate and the overall environment. Supplying water to home taps requires energy to capture, clean, store, and distribute water. From the water source to the tap, transporting water requires energy intensive infrastructure. Wastewater is treated in an energy intensive process before it is released back into the water cycle.

A clear understanding of both the water and wastewater treatment process in Canada is necessary to understand the amount of energy required to supply clean water to Albertans. The water treatment process is energy intensive. The key energy input is electricity production. In 2002, the efficiency score for one water treatment was roughly 633 kWh/Million liters. Translated into greenhouse gases (GHG) emissions, one million liters of treated water results in the production of over 625 kg of CO2. In Edmonton alone, its two water treatment plants are responsible for over 80,000 tonnes of CO_2 a year.

The current policy context for water conservation – from both a climate change and water perspective, is also discussed. The two key policy documents examined are *Water for Life*, Alberta's water management strategy, and *Taking Action*, Alberta's climate change plan. *Water for Life* addresses conservation, but does not make an energy link. *Taking Action*, though, encourages all sectors to reduce emissions. So while there is no explicit link between these strategies, these strategies are related because it takes energy to provide water and energy usage results in GHGs.

Changing water consumption patterns by implementing conservation programs is the also addressed. Successful conservation programs or measures will generally involve water metering, rate-based pricing, incentives for retrofits, or public information programs.

1. Introduction

Climate change is the shift in the average weather pattern of a region. It is believed to be the result of an enhanced greenhouse effect caused when gases, known as greenhouse gases (GHGs) are released into the atmosphere and trap heat from the sun. The resulting rise in temperature is a phenomenon called the greenhouse effect. Although GHGs and the greenhouse effect are naturally occurring, there is concern among the scientific community that the excessive quantities of greenhouse gasses being released, generally from the burning of fossil fuels, is leading to an intensified greenhouse effect. Addressing climate change is a challenge that will need to be addressed in the future and is most often done by addressing the source – the burning of fossil fuels and in this case reducing the amount of water used.

The burning of fossil fuels is required to meet our transportation needs, our heating needs, our electricity needs, and our water consumption requirements. The link between water consumption and the burning of fossil fuels is the focus of this paper.

When water is saved, energy is saved, because getting water to our taps is an energy intensive process. Transporting water from the source to our taps requires significant infrastructure and capital investment. Water must be captured, cleaned, stored, and distributed, all of which consume a significant amount of energy. After water is used, wastewater must be treated in another energy intensive process before it is released back into the water cycle. When energy is produced by burning fossil fuels, such as it is in Alberta, any reduction in the water consumption is not only a reduction in the energy use but also a reduction in greenhouse gas emissions.

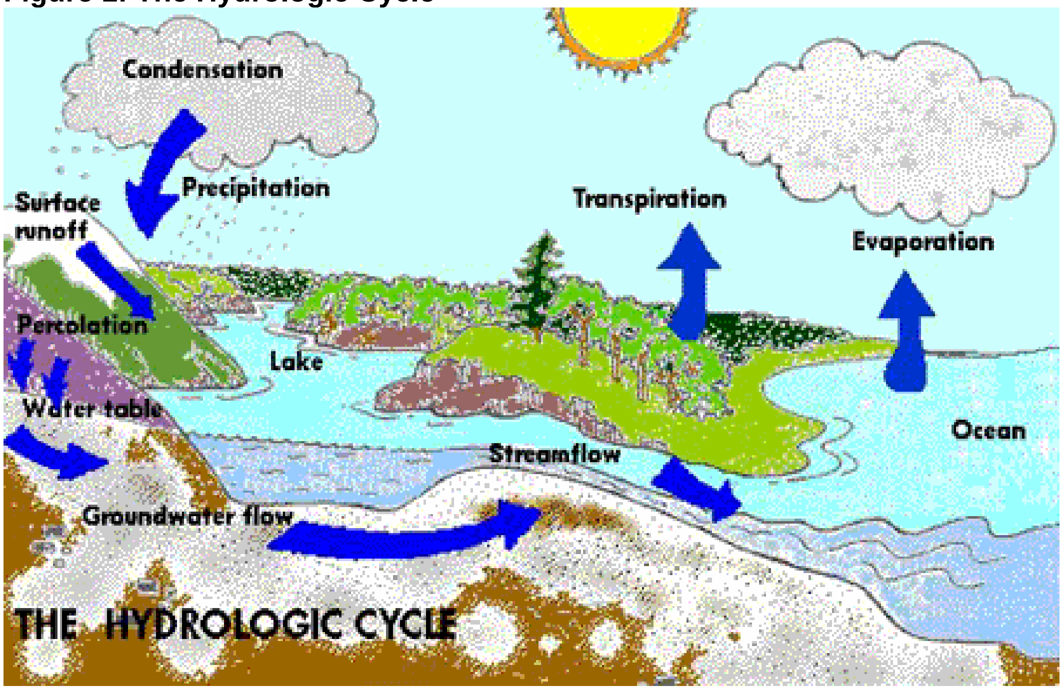
This paper examines the linkage between water conservation and energy conservation by examining the water and wastewater treatment processes in Canada, including a discussion of energy use and greenhouse gas emissions. To put this discussion in context of current policy, Albertans current effort to address water and climate change is also included. Both *Water for Life*, Alberta's water management strategy, and *Taking Action*, Alberta's climate change plan are reviewed. A discussion of successful conservation programs is included to identify best management practices used elsewhere for potential use in Alberta and Canada.

2. Water and Wastewater Treatment

Water treatment, both raw water and waste water treatment, is one of the world's greatest advancements in civilization. It provides clean drinking and washing water, creating healthier living environments for billions of people. Water treatment is a straightforward, multi-step process. It removes both the dirt and impurities we can sometimes see, and the bacteria and pathogens we can't see. Treatment also cleans our water once it goes down the drain, replenishing the water source with water than can be cleaner than what we took out for use. Energy is required throughout this process.

The basis of our water supply is the hydrologic cycle (See Figure 1). Human impact on any one part of this process affects the entire process. If we do not return water clean, we are harming the water taken out of the cycle again. What we do at one point, influences the rest of the cycle. For example, agricultural run-off can increase the levels of giardia or cryptosporidium in the water supply, increasing the need for treatment downstream. Alternatively, pollutants in water bodies can evaporate and form precipitation along with the water, impacting the entire cycle. Figure 2 highlights the many ways that humans can impact the water cycle. Our influence on the water cycle results in a direct impact on the energy requirements for treating water and wastewater.

Figure 1: The Hydrologic Cycle[1]



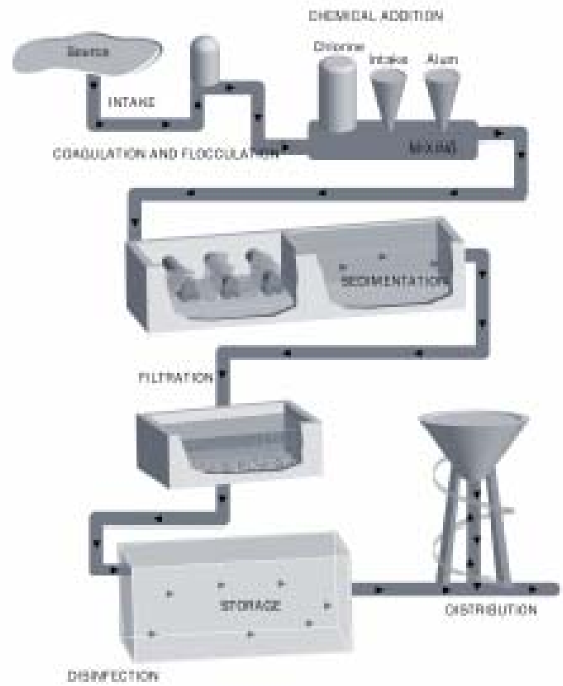
What is important, then, is addressing all inputs into the water cycle and also managing what we do with what we take out of it. It is important to manage the entire watershed when thinking about water conservation. So it is for energy consumption in the treatment process. By consuming less water, less water has to go through the treatment process, thus less energy is consumed.

The water treatment process begins when water is taken from the source. In Alberta, some major water sources are the North Saskatchewan River, the Bow and Elbow Rivers, and the Red Deer River. The major watersheds in Alberta are the Peace/Slave River Basin, the Athabasca River Basin, the Hay River Basin, the Beaver River Basin, the North Saskatchewan River Basin, the South Saskatchewan River Basin, and the Milk River Basin.

Figure 2 outlines the water treatment process in generalized terms. The rest of this section discusses that process in greater detail.

[1] Environment Canada February 2003

Figure 2: The Water Treatment Process[2]



Water that has not been treated is called raw water. The quality of raw water varies. It can carry a lot of dirt and silt and other contaminants. It is generally not potable (drinkable) at this point, and must be treated. Water treatment at the municipal scale is usually for surface water. Water is drawn from the surface water using pumps and is passed through coarse screens to remove large particles. This is where the treatment process essentially begins. The next stages of the process are cleaning and disinfecting the water to make it potable.

This first step is referred to as clarification, or coagulation and flocculation. The goal of clarification is to remove microscopic particles of silt, clay, and organic materials. This is also the first point of chemical additions into the water treatment process - alum (aluminium sulphate) and a polymer are added to the raw water. These materials attract the silt, clay and organic materials. The water is rapidly mixed with these materials to make them more likely to stick together. This happens because particles in water typically have a negative charge. Rapid mixing combined with the addition of a positive coagulant makes it easier for the particles to attract each other. As the water passes through the clarifiers the mixing slows. Particles that have bonded together, called floc, settle by gravity. Chlorine may also be added at this time. The rapid mixing required in this step contributes to the overall energy consumption for the process.

The next step in the process is sedimentation. Water flows slowly though large, deep, often concrete, basins. The floc settles out of the water as it moves through the sedimentation basins. Pumps are used to move water throughout the process.

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[2] Pollution Probe 2002

From the sedimentation basins, water flows through filters. The filtration process removes any particles that were not heavy enough to settle in the sedimentation step. Remaining impurities are captured as the water passes through the filters made of sand and/or coal. Periodically, filters must be cleaned. Backwashing is used to clean the filters. During backwashing, a pump pushes clean water backwards through the filter. Particles that were trapped within the filter material are loosened and carried away to a waste handling system.

A critical step in the treatment process is disinfection. There are two ways this can be done: through the addition of chlorine or with a UV light process. Chlorine may be added anywhere throughout the process, it largely depends on the water treatment plant. UV disinfection is a relatively new process, not widely used in Alberta. In the process water passes a series of light bulbs that put out intense blue ultraviolet light. The light sterilizes any remaining organisms, such as cryptosporidium and giardia.

Following disinfection water is stored in reservoirs, usually for never more than a few days, and distributed to municipal users. Reservoirs can be above or below ground. There are often reservoirs located at the water treatment plant site. Additional reservoirs may be located throughout a municipality, especially large municipalities, for ease of distribution.

To move the now potable water to the storage reservoirs and the distribution system, high lift/high pressure pumps are used. The pumps push water through the pipes. When someone turns on his or her tap, the pressure pulls the water into the home system from the distribution system.

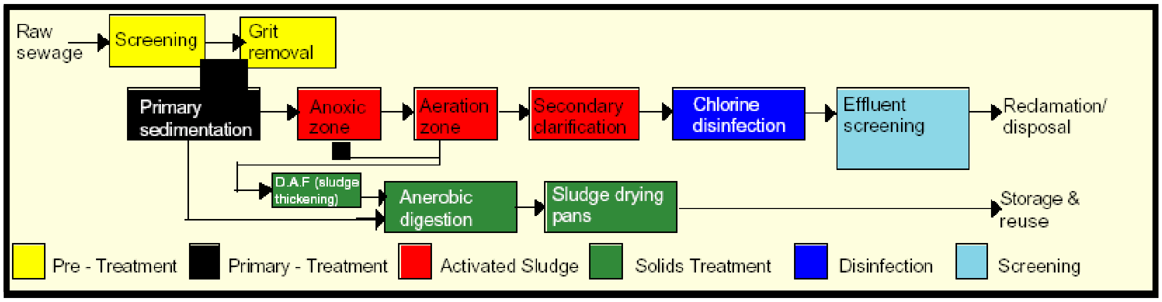
Consumption is the ultimate end of the water treatment process. For cooking, cleaning, drinking, and the rest of daily life we use water. On average, a residential household uses 343 litres of water a day[3]. What does not get ingested ultimately ends up going down the drain. This water does not flow directly back into the water source. It must first be treated.

The wastewater treatment process is multi-staged, like the water treatment process. But there are some significant differences due to the nature of the contaminants and materials to be removed from the water. The wastewater treatment process cleans grey, or dirty water, in order to remove sewage, materials, and contaminants picked up through use or surface water run-off. Wastewater treatment generally includes storm water treatment as well, in order to remove salts and residues such as fertilizers.

Following collection through a pipe system that utilizes both gravity and pumps, wastewater arrives at the treatment plant. The first step, like in the water treatment process, is to pass the water through a series of screens. This removes larger materials such as plastic bags, toilet paper, and toys, for example. This area in the treatment plant is called the headworks. The wastewater then travels to grit tanks where heavier materials settle to the bottom. Removed materials are generally landfilled.

[3] Environment Canada September 2003.

Figure 4: Activated Sludge Process[4]



The wastewater then flows, by gravity, to the primary clarifiers. For a period of a few hours the water is left to sit in large tanks. Sediment and materials settle at the bottom of the tank and skimmers lift floating material. The water moves on to the next stage in the wastewater treatment process while the materials removed move to a secondary treatment process. This is where the wastewater treatment process splits, as the sludge, or waste materials must also be treated.

Secondary treatment of wastewater begins with aeration. Air is injected into the tanks, also called aeration tanks or bioreactors. At the same time, the water is mixed with a high concentration of naturally occurring microbes. The process is designed to encourage the growth of the microbes so they can break down and feed on impurities left in the water. Through aeration, the microbes are brought into contact with the organic materials and are stimulated to activity. This part of the process is called the air-activated sludge process. The sludge that is formed from the microbial activity stays mixed with the water and it all moves to the secondary clarifiers.

During secondary clarification the activated sludge settles by gravity in the large tanks and the remaining water moves through the process for disinfection. As in the primary clarification stage, skimmers are used to remove scum and grease from the water. Most of the settled activated sludge is returned to the tanks and bioreactors used in the previous step in order to repopulate them with microbes. The skimmed material is considered sludge and is also treated.

Disinfection is the last stage of the process before water is released back to the water source. Disinfection, as in water treatment, can be done with chlorine or UV lights. This part of the process will kill the microbes or disrupt their ability to reproduce. The water is then safe to return to the water source. However, an additional step is performed in some water treatment plants, including many in Alberta. This step involves the removal of phosphorous and nitrogen through chemical or biological processes, called biological nutrient removal.

The secondary process in water treatment is the treatment of sludge. These solids are not released back to the water supply, but must be treated. This process allows the sludge to be recycled into fertilizer and soil conditioners, sometimes for use in local agriculture.

[4] South East Water 2001

The first step in the treatment of sludge is anaerobic digestion. The sludge is digested in large covered tanks. In the absence of oxygen, the naturally occurring bacteria break down organic materials into substances such as water, methane, and carbon dioxide. Odour diminishes over time and many disease-causing organisms die. The gas produced through digestion is re-circulated in the digester, with continuous mixing, to maintain a constant temperature and enhance digestion. After a period of time, up to a month, the sludge is removed, stored for further decomposition, and sometimes sold as fertilizer for agriculture. Alternatively, sludge can be composted. This is aerobic, as opposed to anaerobic digestion, but achieves very similar results. Water remaining at this point returns to the start of the wastewater treatment process.

The water treatment process is energy intensive. The key energy input is electricity production. EPCOR, a major water utility in Alberta, reports on both their water and energy efficiency in annual reports. In 2002, the efficiency score for water treatment was roughly 633 kWh/Million liters[5]. Translated into GHG emissions, one million liters of treated water forces the production of over 625 kg of CO2. For EPCOR's two Edmonton water treatment plants this results in GHG emissions of over 80,000 tonnes a year. These two plants are not the only water treatment plants in Alberta. Many municipalities have their own treatment plants. For example, the City of Calgary operates two water treatment plants.

Wastewater treatment facilities also rely utilize electricity usage as a key indicator for greenhouse gas emissions. Most operations re-circulate the gas from digesters in their processes. Using information from the Gold Bar Wastewater Treatment Plant in Edmonton[6], the efficiency of the wastewater treatment process is 14 tonnes per million liters of water treated. In terms of GHG emissions from the process itself, a useful intensity measure for a conventional activated sludge process is 36.2 grams of CO2 per cubic meter[7]. This number goes down as the treatment of sludge for nitrogen is introduced, as is the case with biological nutrient removal. This number is dependent on the emissions intensity of the electricity used. These numbers are inclusive of both indirect and direct GHG emissions. Indirect emissions can be traced to electricity consumption, while direct emissions originate from the cleaning process itself.

The largest energy inputs in the water and wastewater treatment processes are the use of pumps, mixing, and heating. These inputs can be split into process and facility use. Process use includes the pumps and equipment energy needs required to treat the water and wastewater. The facility needs include heating, lighting, and ventilation.

Facility improvements such as lighting or HVAC retrofits will reduce overall energy consumption. These efforts can have a significant impact[8] on overall energy consumption. However, they would not be impacted with water conservation activities.

Efficiencies in the process can be attained with equipment upgrades and maintenance, as well as treating water line losses. Water quality, however, must never be compromised. The easiest way for the water treatment process to reduce energy consumption is to reduce water consumption. The less water, and thus the less

[5] EPCOR Utilities Inc. 2003
[6] Corlett 2004
[7] Constantine, 2004
[8] Henderson and Reardon 2001

wastewater, that needs to be treated, the less energy inputs will be required in the process. The less energy inputs, the less greenhouse gases are generated.

4. Water Policy in Alberta

Water for Life is the Government of Alberta's strategy for sustainable water use and management. The demand for water is growing as the population grows, droughts continue to plague the province, and both agricultural and industrial demands increase. A safe, consistent water supply for all Albertans in the present and the future is the goal of *Water for Life*.

The plan identifies a number of smaller goals that will help Alberta achieve its three main goals: a safe, secure drinking water supply; healthy aquatic ecosystems; reliable quality water supplies for a sustainable economy. There are three areas of focus in the *Water for Life* strategy: knowledge and research, partnerships, and water conservation. The areas of focus define the activities that will achieve the goals of the strategy. The time frame for activities is divided into the short (2004/05-2006/07), medium (2007/08-2009/10), and long (2011/12-2013/14) term.

Knowledge and research is about making sure that Albertans have the necessary information to realize a safe water supply, efficient water use, and healthy watersheds. This critical focus area refers to scientific knowledge, an understanding of water issues and opportunities, and ensuring all Albertans are aware of water issues and can make effective management decisions. The activities identified under this focus area range from the establishment of a provincial, multidisciplinary water research center to establishing a provincial water information centre for the public and private sector, from undertaking regular research on the health of our water system to reporting the results of that research.

The partnership focus emphasizes that all Albertans will have the opportunity to actively participate in watershed management on a regional and community basis. All Albertans use water, and so all Albertans must share the responsibility for the use and sustainability of the water supply. Three types of partnerships are identified to help Alberta achieve success: Provincial Water Advisory Councils, Watershed Planning and Advisory Councils, and Watershed Stewardship Groups.

The water conservation mandate is that Albertans will be leaders in conservation by using water efficiently and effectively. Water conservation is important because a growing population is increasing demands on the finite water supply. In combination with the partnership approach, the approach to water conservation assumes that all Albertans take responsibility for the wise use and sustainability of the water supply.

Initiatives in the short term focus on creating a solid informational base of water use and related data for the province. These include establishing a system to monitor and report actual water use by all sectors on an on-going basis; determining and reporting on the true value of water in relation to the provincial economy and completing an evaluation and making recommendations on the merit of economic instruments to meet water conservation and productivity objectives. Also included in the short term is the establishment of a public awareness and education program on water conservation in Alberta.

Mid-term activities focus on the utilization of the data captured in the first phase of initiatives. The preparation of water conservation and productivity plans for all water using sectors builds on the monitoring and reporting system developed. And, if deemed necessary, economic instruments to meet water conservation and productivity objectives will be implemented at this time. There is currently no detail on the design of those economic instruments.

In the long term, the *Water for Life* strategy identifies an ongoing monitoring program to ensure all sectors are achieving water conservation and productivity objectives.

Climate change policy in Alberta is relatively silent on water issues. However, *Taking Action*, the Alberta Climate Change Action Plan, does state, "all sectors of the economy must play a role in reducing greenhouse gas emissions."[9] As this paper demonstrates, there are intrinsic ties between water and energy use, linking our water consumption to greenhouse gas emissions. The emphasis on conservation in *Water for Life* is the right step towards addressing greenhouse gas emissions in all sectors of the economy.

3. Consumption Patterns and Conservation Programs

Canadians use significant quantities of energy and water each day. Over consumption of energy over the past decades has lead to increasing concentrations of gases, including greenhouse gases, in the atmosphere. According to Environment Canada, energy use produces 90% of Canada's carbon dioxide emissions, 55% of sulphur dioxide emissions, 90% of nitrogen oxide emissions and 55% of volatile organic compound emissions[10]. Consumption of water requires a certain amount of energy for the treatment and distribution. This energy comes from the same sources that heat and power our homes, resulting in the same emissions.

Heavy subsidies and below cost pricing for water and wastewater services likely led to excessive water use in Canada relative to the rest of the world. However, by 1984 all direct federal assistance had stopped and municipalities were faced with aging infrastructure and rising demand for residential water. In 1999 the average Canadian used 343 liters of water each day, compared to the 50 liters of water a day necessary to meet basic needs such as drinking, sanitation, bathing and cooking.[11] The majority of this water is simply washed down the drain. Only 10% of indoor home water use is used in the kitchen or as drinking water while 65% of indoor water use occurs in the bathrooms by showers and baths and toilet flushing[12]. There are many opportunities to reduce consumption, thus conserving both water and energy.

A portion of Canada's present over-consumption of water can be attributed to current water policy in place in many parts of Canada, as water policy has a large impact on water use. Declining block rate structures, where the volumetric rate charged per unit decreases as the volume consumed increases, have been used as a means of encouraging industrial expansion. In 21% of surveyed Canadian municipalities, declining block rate structure was still the water pricing method used.[13] However, these policies lead to inefficient use of water because over-consumption is encouraged in

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[9] Alberta Environment 2002
[10] Boyd 2001
[11] Environment Canada July 2003
[12] Environment Canada July 2003
[13] Waller and Scott 2001

order to pay a lower rate. Other types of water pricing, as well as metering, can also lead to over-consumption[14].

Linking water use to energy use and utility bills is a necessary step to reducing both water and energy usage. Once consumers are aware of the costs associated with over consumption, it is easy to address the problem at the consumer level and it is easy to save both energy and water by making simple changes that won't affect lifestyle. By simply changing an older showerhead to a water efficient showerhead, for example, it is possible to save 9052 litres of water or 22% of annual consumption.[15] By changing an older model clothes washer to a water efficient clothes washer it is possible to save 20,732 litres of water per year or 34% of annual consumption.[16] These changes save the consumer money in three ways. These changes directly reduce the water used and therefore reduce water bills. Since they save water, they reduce the amount of hot water being used, therefore lowering gas bills. Finally, these simple changes also reduce the amount of water going down the drain therefore reducing the amount of water needing to be treated thus lowering the sanitary sewer bill.

Water conservation programs have become common across the country and although the majority of programs are undertaken to avoid the capital and operating costs of water treatment there are many benefits to water conservation and using water efficiently. There are environmental and social benefits, in addition to the monetary benefits from saving capital and operational costs associated with water supply and wastewater disposal.

In 1998 a survey of 102 Canadian municipalities was undertaken to determine the status of municipal residential water conservation initiatives[17]. The survey had a response rate of 64% and represented about one half of the Canadian population in communities over 1000 people. The survey identified water conservation initiatives that municipalities undertook, including water metering, infrastructure projects, retrofit programs, exterior water use limitations, water rates structures, laws and regulations, public awareness programs, and school programs. The study concluded that water conservation programs are widely used and highly successful, however there is no universal program that is appropriate for every Canadian municipality.

The study was able to identify elements of programs that were successful. One of the findings of this study is that water metering is considered a primary element in an effective water conservation program. With respect to water conservation, studies show that people use less water when there are demand management measures in place such as meters and water pricing. Worldwide studies confirm that the introduction of water metering has a major deterring effect on the consumption of residential water demand[18]. Water metering is widely accepted as the necessary first step for effective water management as it provides the basis for any attempt at demand based pricing and demand management[19].

[14] Roach et. al. 2004
[15] City of Calgary July 2002
[16] EPCOR Utilities Inc. January 2004
[17] Waller and Scott 1998
[18] Holtz and Sebastian 1978
[19] Tate 1990

Water pricing is one of the most prominent and widely used methods of influencing water demand[20]. Of the Canadian municipalities that were part of a 2001 study by Environment Canada, only 45% of the population was found to be under a rate structure that provided a definite incentive to conserve water. Changing water-pricing structure from a declining block structure to a rate based structure not only decreases water use, but also results in decreased energy use and encourages innovation.

Other successful components of conservation programs include residential retrofit programs and public information campaigns. Retrofit programs range from universal retrofit programs, where public information programs are designed to encourage residents to retrofit, to programs that provide incentives in the form of subsidized fixtures, fixture modification and installation.

6. Conclusions

Water supply and management is a growing issue in Alberta. Industrial and agricultural use, a growing population, droughts, and climate change are all increasing the demands on our water supply. Consumption on a per capita basis is also increasing. Water is a valuable resource, but with current pricing and seeming availability, that true value is not fully understood by consumers.

There are many ways to reduce water consumption. Chief among them are through appliance replacement or retrofit. Appliances such as the toilet and washing machine use the most amount of water in a household. Reducing water consumption in the household also saves the consumer energy, directly, through the heating of water, and indirectly, through the energy use for treatment. Water use is inherently linked with energy use.

There are three key sources of information and programs on conservation, for both water and energy conservation. Governments, at all levels, offer information and programs. This includes municipally run campaigns or programs. Second, non-governmental environmental advocacy organizations will provide information and sometimes run or partner in programs. And third, organizations devoted solely to water or energy conservation.

Central to these organizations or departments is that they act as a center for information dissemination. More than that, they often offer programs to encourage active consumer or public participation through incentives or otherwise. This takes conservation beyond public education. Conservation programs are more successful if they provide either feedback to consumers, offer an incentive, or establish new social norms[21]

There are many energy conservation organizations in Canada. Adding water conservation to the mandate of an energy conservation organization does not require a major change to that organization. A refocus of the mandate is required, but the organizational infrastructure is the same, as are the resources of the organization itself. For example, the Manitoba Efficiency Office, announced in late 2003, has the potential to demonstrate the success of linking water and energy conservation.

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[20] Waller and Scott 1998
[21] Ciona 2000

To date, the connection between the water issues we are facing in Alberta and climate change has not been explicit. This paper identified those connections in general terms. The potential impacts of climate change on precipitation, growing seasons, snowpack, and the hydrologic cycle in general may cause drought, increase in the number and severity of weather events, increased flooding and other general impacts on water quality and quantity.

The relationship between water and climate change is circuitous. Climate change will likely have impacts on water quality and quantity. And water and wastewater treatment necessitates the production of GHG emissions, generally believed to be contributing to climate change. Thus, as water supplies become threatened by climate change consumers will be forced to seriously address conservation activities. But by addressing conservation in the near term, a reduction in GHG emissions can be achieved.

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