RETROFIT OR REPLACE THAT TOILET ?

Paper presented to
The Energy Management Task Force of Manitoba
Winnipeg, Manitoba

June 14, 1996

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ABSTRACT
This paper arose out of a need to examine techniques to reduce water use demand in Canadian cities using practical, low cost, easily implemented strategies. In particular, it *focuses on cost effective measures to optimize water savings in residential and commercial buildings,* without changing quality of life characteristics. At the same time, the techniques considered do not preclude the introduction of maximum water saving measures over a longer time frame.

At least 40% of all of the water used indoors in Canada for domestic purposes, is used to flush potable water down sewers to transport human waste. At the same time, the area in which greatest progress can be made in increasing domestic and commercial water use efficiency without affecting quality of life, is through substantial reduction in the use of water for toilet flushing.

Replacing existing toilets with latest technologies and /or systems, can no doubt achieve maximum water savings, but at very significant cost. In buildings where most plumbing fixtures are operating well, except for quantitative inefficiencies, and could continue indefinitely with routine replacement of minor components, toilet replacement is not cost effective. Instead, low cost, permanently installed retrofit devices are now available for most existing domestic and commercial toilets which, by most criteria, are competitive with the option of replacement.

Some *key water efficiency issues* and strategies considered in this analysis:

- *Identify certain shortcomings of ULF toilets and retrofit devices*; including the fact that ULF's may use considerably more water per flush than their 6 litre design criteria, and non-permanent retrofit devices may have short life expectancy.

- *Introduce the concept of using permanently installed retrofit devices with a long life expectancy.*

- *Compare life cycle cost of ULF replacements with permanently installed retrofit devices to demonstrate a cost effective option for reducing toilet water use,* in large volume water saving programmes

- *Outline the potential scale of an extensive retrofit programme for Canada*, and *indicate some dimensions of potential impacts* in *reduced waste water and environmental pollution* and implications for *long term job creation.*

- *Demonstrate the rapid return on investment and depth of saturation that can be achieved,* thereby accelerating avoided costs for infrastructure expansion, such as municipal water processing and distribution, and waste water collection and treatment.

BACKGROUND
Although the flush toilet was first patented by Alexander Cummings, a London watchmaker, in 1775, and a similar version ,with a key valve improvement, was patented by a cabinet maker named Joseph Bramah three years later, Cumming's toilet with the addition of Bramah's valve continued in use in the same form for over a hundred years.

In North America, the extension of improved flush toilets to over 95% of homes, farms and businesses, has taken much of the 20th century. In fact, by the 1930's and 40's, the number of homes with indoor plumbing, including flush toilets, had become a key census indicator of housing condition in both Canada and the US. In the last quarter of the century, however, with all new buildings having included indoor plumbing facilities, the availability of bathrooms with flush toilets disappeared as a census indicator.

While a major focus of building improvement has continued to ensure that all dwellings as well as commercial and public buildings have adequate plumbing including flush toilets, until recently, little attention was given to the quantities of water required to flush human excreta into the environment. Since well built, vitreous china toilets are very durable, and will unlikely be replaced for a long time considering Canada's relatively new building stock, the challenge will be to find innovative, cost effective ways to retrofit existing plumbing fixtures to improve water efficiency and to reduce the quantities of potable water which are contaminated in the flushing process. Therefore, some emerging questions are: "Do existing toilets use too much water? If so, is it wiser to retrofit or replace them, to optimize water efficiency? Are simple inexpensive devices available to achieve this? What would a large scale retrofit or replacement programme cost?

Water Consumption in a Typical Household in Canada

Canada is the second highest water consuming country in the world. Within indoor space alone, each person uses approximately 350 litres (80 imp.gals.)of potable water every day. Of this amount, 40%, or approximately 140 litres, is used only for toilet flushing. On this basis, it has been estimated that 40,000 litres of fresh, usually potable water are used annually by each person to dispose of 650 litres of body waste* (Environment Canada).

In typical Canadian households, per capita water consumption for indoor uses breaks down as shown in Table I:

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* Note: This can be confirmed as follows: Assume each toilet is flushed approx. 7000 times / year, (i.e. an average of 4 persons flushing at least 4.8 times per person per day) at 22.7 litres / flush, or 7008 flushes / unit / yr x 22.7 litres / fl. / 4 persons / unit = 39, 770 l p c / yr, (rounded to 40,000 l p c / yr).

TABLE I: WATER CONSUMPTION - TYPICAL CANADIAN HOUSEHOLD.

Use	Vol. / Use	Total %	Consumption	Total
(1) Toilet Flushing	22.7 l / Flush	40	x 350 l p.c.	140.0 litres
(2) Showers Baths	@ 22-45 l / min. @ 90-110 l / bath	35	x 350 l p.c.	123.0
(3) Laundry/ Dishes	(5-30 l / load)	20	x 350 l p.c.	70.0
(4) Drinking & Cooking		5	x 350 l p.c.	17.5
TOTAL		100		350.5 litres

(Source: Environment Canada, 1990)

By comparison, other industrial countries achieve greater capital efficiency than Canada, in particular for investment in water efficiency. For example, the European Community uses 40% of the water per capita per day consumed in Canada (140 l/p/d Vs 350 l/p/d.), and significantly less energy, for pumping and water heat. By comparison, the total daily per capita water consumption for the EC is equal to Canada's per capita daily consumption for toilet flushing alone.

In Canada, the current figure of 22.7 litres / flush for most conventional toilets is high and can be substantially reduced. This can be done in *at least two ways: (1) replacement of conventional toilets with low flow (LF) or ultra low flush (ULF) units, or (2) retrofitting conventional or low flow toilets with durable, low cost, water saving devices* which will enable the modified units to approach the performance of LFs or ULFs (Table II).

REPLACEMENTS - The LF or ULF Option

The issue of life cycle analysis is important for both low flow replacements and retrofit devices because some *negative consequences of long term poor performance are premature rejection of the idea of increased efficiency through retrofit devices or low flow replacements; disillusionment with the notion of beneficial technologies; and cynicism with promises of positive results for device performance by building owners and managers.*

Maximum absolute reductions in water use for toilet flushing, under current building codes, can be achieved with ultra low flow toilets. ULFs reduce water consumption by as much as 74%, from 22.7 litres / flush for a base case conventional toilet to approximately 6 liters / flush in a ULF unit. Typical low flow (LF) units can reduce water for flushing by 50%, to 11 litres / flush. Retrofitting LFs can further increase water efficiency by 20 %. However, acceptable LF and ULF replacements cost in excess of $450 / unit*, while permanent retrofits of conventional or low flow units cost $50.00 or less.

Given that new building completion's represent only a small proportion of total building stock in any year (currently less than 1%), and that major renovations to buildings represent at best another 3-4 % of stock, gradually replacing toilets can have only limited effect in reducing water use in the short to medium term. Also, replacements are usually only economically feasible in either new construction or major renovation, and in high volume use areas such as schools, restaurants, pubs etc., or in communities where combined water and sewer rates are $1.65 per 1,000 litres or higher (City of Edmonton Toilet Retrofit Programme -1995)

Although ULFs substantially reduce water consumption, especially in high use situations, *problems can develop where toilets are inadequately installed or maintained over product life.* For example, *many ULFs have a built in design weakness* whereby they use an early closure flapper device to achieve water savings. A weakness *arises from the fact that replacement with the wrong component can raise water use in a ULF toilet from 6 to 18 litres flush.* Thus, if ULF toilets, which perform properly on initial installation, are subsequently repaired or put out of adjustment by the use of conventional flapper valves by uninformed do-it-yourselfers, or other unskilled persons, toilets will revert to operating at a water level close to a conventional flush unit, and most water savings will be lost, without users even being aware of a substantive change in performance.

Another serious problem arises *where certified plumbers deliberately set the adjustments on ULFs too high from the outset, so that there will be a surfeit of water flow, necessitating fewer callbacks* (i.e. for unsatisfactory performance other than water savings). Toilets then operate above their 6 litre/flush design criteria, without homeowners being the wiser, until they realize that water bills are higher than projected, and / or municipal water departments do not achieve expected reductions in water demand.

While a some ULFs demonstrate a high level of performance, there are also a number of ULF toilets, which perform poorly, create considerable inconvenience and additional expense to remedy problems, or may even require replacement. Consumer Reports (Feb. 1995) have also observed that not all ULF toilets reviewed actually operate at 6 litres / flush or less. For example, CR downrated at least three of the 32 models it tested because they were above the 1.6 (U.S.) gal./ flush (6.05 lpf) U.S.government mandated, performance criteria. (e.g. units as delivered operated at 7.6 instead of 6.05 lpf). It also found that at least 13 units had poor waste removal; 6 others had poor washdown; 15 had high soiling odour potential, while 5 of the best units tested had high noise levels.

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* Note: ULFs, the lowest water consumption flush toilets, currently on the market, and acceptable under most State or Provincial codes, cost at least $300.00 (Can) /unit. This figure also corresponds with an average price of $324.50 (Can.) for the 32 models of ULFs tested by Consumers Reports (Feb. 1995). However, to this capital cost must be added at least $150.00 (Can) / unit, for refinishing the toilet surround in most installations.

RETROFIT DEVICES

Effective toilet retrofits should permit a retrofitted unit to function as good or better than the original conventional or LF unit. Currently, there are on the market, several low cost devices, which are very durable, with great material integrity. Properly installed, such devices can enable a retrofitted toilet to function better than the original unit, for upwards of 20 years. This functional improvement includes receiving continuous benefits from permanent water savings once capital payback has been achieved. To ensure these savings, however, retrofit devices must be permanently installed in the toilet and must have a long life expectancy, in effect giving a retrofit at least as long a useful life as most LF or ULF manufacturers warranty for key components such as closure valves and tank/bowl fill valves.

Retrofit Device Characteristics

Retrofit devices for toilets can be classified into two categories: *(i) Non Permanent Installed Devices*; *(ii) Permanently Installed Devices*. For simplicity, the following table identifies the performance characteristics of typical retrofit devices:

Table ll: Comparison of Toilet Retrofit Device Performance

Description	Type	Water Savings	Life Expectancy (years)	Permanent Installation Capability	Comments
Displacement devices	• Tank dams • Water bags • Containers • Foam Tank Liners	Low Low Low Low	3-5 1-3 3-5 5	No No No No	1. Plastics will break down in toilet water environment
Early closure devices	• Free floating • Flapper & float • Flapper with adjust. Air release	High High High	5-7 3-5 3-5	No No No	1. May not fit all toilet tanks 2. Flappers must be replaced when they deteriorate 3. Flappers may be replaced with non conserving flappers 4. Can be easily removed
Bowl fill control devices	• Bowl fill diverters	Low	3-5	No	1. Usually effective for only 30% of toilets manufactured
User controlled devices	• Flapper weights	High	5-7	No	1. Poor user acceptance
Dual flush devices	• Fastened floating • Installation kits	High High	15-20 7-10	Yes Yes	1. Some difficult to install 2. Poor user acceptance 3. Replacement parts difficult to find 4. Kits considered expensive
Permanently installed early closure devices	• Permanent mounted floating	High	20-25	Yes	1. Can be dual flush for maximum savings 2. High benefit/cost

(i) Non Permanent Installed Devices. Many of these devices have been on the market and used in utility retrofit programs for at least 25 years. Their major shortcoming is an effective life expectancy of only 6 months to 5 years. Because the devices lack permanence, they must be replaced with new units as they wear out, thereby losing most of their anticipated economic savings.

Examples of such non permanent devices range from plastic bags, foam liners, or tank dams which simply displace a small amount of water compared to early closure devices. Many problems also develop with both early closure and water tank displacement devices where designs are incompatible with flush cycle hydraulics engineered by toilet manufacturers. Few of these devices approach a reasonable product life, which only well-designed permanent devices can ensure.

(ii) Permanently Installed Devices. The key to the success of a retrofit product achieving permanent or long term (upwards of 20 years) savings is that the device must be installed so that it cannot be removed, or its water savings potential cannot be significantly reduced throughout the product life expectancy.

In a 1992 study of 32 retrofit devices analyzed and tested by Stevens Institute, the top three performers which emerged, and might be considered permanently installed devices, were all above a 600 acre feet (739,800 m3) per year savings level. These products were as follows;

- FUTURE FLUSH, at 666 acre feet (821,178 m3);
- POP FLUSH, at 655 acre feet (807, 615 m3);
- FLUSH 1, FLUSH 2, at 643 acre feet (792, 819 m3).

Of these three devices, which offered the highest water savings among the products tested, the POP FLUSH, a Canadian made product, has been selected for base case comparison with replacement LF and ULF toilets in this analysis for four reasons:

(1) It saves more water than any other similar device currently available. Recent versions have demonstrated that this device alone can reduce water use in conventional toilets by 35%, and when combined with other devices by 45%. It can also reduce LF consumption by up to 20% and can be used in ULF's as a user controlled dual flush mechanism to reduce water use for liquid flushing by 50% to as little as 3 litres per flush. (A drawback to this practice however is that such an arrangement is user controlled, and as such depends on deliberate and appropriate flushing by each user).

(2) It is lowest in capital cost (e.g. $7.50 U.S./ unit installed) of units Stevens reviewed.

(3) It is as durable, high quality, and long lasting as any available retrofit product. Enviro-Energy, POP FLUSH's Canadian manufacturers guaranty the entire assembly for 20 years. It has also been successfully installed in over 100,000 homes throughout B.C. under BC21/Power Smart programme, and 80,000 homes in Vancouver, Washington in a Watt and Water Saving programme.

(4) It is the only device which, when permanently installed within the tank of an existing conventional or low flow toilet, will last as long as other basic toilet components. It achieves this permanency by application of a special adhesive to the device's mounting clamp, thereby enabling it to adhere to the toilet overflow tube indefinitely.

COMPARING BASE CASE ULF REPLACEMENT WITH CONVENTIONAL AND LF RETROFITS

Table Ill compares the relative savings per flush for selected retrofits of conventional and low flow toilets with water efficient low flow and / or ultra low flow toilets replacement. It demonstrates that a retrofitted conventional toilet closely approaches the performance of a low flow (LF) unit and that a retrofitted low flow unit can approach the performance of a new ultra low flow (ULF) replacement .

TABLE Ill: COMPARATIVE SAVINGS / FLUSH FOR SELECTED RETROFITS OF CONVENTIONAL AND LOW FLOW TOILETS WITH WATER EFFICIENT REPLACEMENTS (ULFs).

Case	Description	Approx. Flush Characteristics litres/flush	% of Base case Water Use
Base Case	Conventional toilet	22.7-27.5	100
Case 1	Conventional toilet. with POPFLUSH device only	14.75	65
Case 2	Conventional toilet with POP FLUSH, water conserving fill valve and flapper.	12.48	55
Case 3	Low flow (LF) flush Replacement toilet	11.00-11.35	50
Case 4	Retrofitted low flow (LF) flush toilet	8.88-9.08	40
Case 5	Ultra low flow (ULF) Replacement toilet	5.90-6.06	26-30

In Table IV, three cases of retrofit or replacement of conventional toilet units are selected and compared from among five cases listed in Table Ill. They include:

Case 1: represents *capital investment for a POP FLUSH retrofit device only*, without the addition of a water conserving fill valve and replacement flapper, at an installed cost of $10.00 / unit. .

Case 2: represents *capital investment for a POP FLUSH retrofit device permanently mounted on the reserve tank overflow tube of a conventional toilet, together with a water conserving fill valve and a new flapper valve;* all at a cost of $50.00 / toilet unit installed and based on a 20 year life cycle investment.

Case 5: represents *capital investment for a typical ultra low flow (ULF)toilet*, at an installed cost of $450.00 / unit.

TABLE IV: COMPARATIVE PERFORMANCE OF A ULF TOILET WITH RETROFIT OF A CONVENTIONAL UNIT BASED ON A 20 YEAR LIFE CYCLE

	Cap. Cost Installed in $	% Water Savings	Annual Savings L/yr	Total Life Cycle Savings Litres	Life Cycle savings in litres / $ Invested	Payback in Years best case
Case 1: Retrofit	10	.35	55, 615	1, 112, 300	111, 230	.22
Case 2: Retrofit	50	.45	71, 505	1, 430, 110	28, 602	.84
Case 5: Replacement	450	.74	111, 230	2, 224, 600	4, 944	4.04

From Table IV, it is apparent that a simple, durable, permanently installed retrofit device, such as the *POP FLUSH, can out perform a typical ULF replacement in water savings per $ invested, payback, and in benefit cost ratio.* For example, water savings of at least 64% of the performance of ULFs are possible, using a retrofit device permanently installed in a conventional toilet tank; and savings of at least 81% of ULFs are possible, in retrofitting a typical LF unit with a similar device.

Although in terms of absolute reduction in water use, a ULF replacement will save approximately 25 - 30 % more water than retrofitting a conventional toilet with best available devices, as *in Case 2 of Table IV, a retrofitted unit would be 5.78 times more efficient than a ULF in water savings per $ invested, based on a 20 year product life.*

In Case 1, installation of a POP FLUSH device alone, in a conventional toilet retrofit, would be 22.5 times as efficient in water saving / $ invested as a ULF replacement, while achieving almost half of the water savings of a ULF (e.g. saving 35% vs 70-74% of the consumption of a conventional toilet).

From TABLE IV, both Cases 1 and 2 indicate less than a one year payback in $ value of water savings. This compares with a capital payback of upwards of four years on an investment of $450 for a ULF. It assumes average municipal water and sewer rates of $1.00 / 1000 litres and that toilets operate at 7000 flushes per unit per year. Then the comparative ratio of savings would be

Case 2 : Case 5 = 21,452 / 3,707 = 5.78 : 1

Case 1 : Case 5 = 83,423 / 3,707 = 22.5 : 1

Case 1 : Case 2 = 83,423 / 21,452 = 3.89 : 1

TOWARDS A NATIONAL WATER CONSERVATION STRATEGY

Potential National Water Savings

In terms of water savings on a national basis, what might this mean ? If it is assumed that there are at least 15 M toilets in buildings in Canada; that most of these toilets operate at an average of 22.7 litres / flush; and that a simple ($10.00) retrofit device, such as a POP FLUSH, can be permanently installed in each of these toilets, then *potential water savings* would be :

% savings / unit x litres / flush x no. of flushes / yr. x no. of units

35% x 22.7 l / flush x 7000 flushes / year x 15 M toilets = *834B litres / year.*

If the cost of these retrofit devices was in the order of $10.00 installed, then the cost of a comprehensive programme, however financed would be $150 M.

Translating 834 B litres / year in terms of avoided costs for water and sewage treatment at approximately $1.00 / m3 or / 1000 litres (e.g. Metro Toronto's current retail charge for water supply and sewage treatment), then *potential avoided costs* would be:

834B litres x $ 1.00 / 1000 litres = *$834M*

Thus, through an expenditure in the order of $150M, environmental treatment costs in excess of $834M could be avoided resulting in a benefit / cost ratio well above 5.5.

While these numbers could, no doubt, be further refined, they at least demonstrate a magnitude of savings and benefit / cost ratio for a national water efficiency strategy that could result in retrofits of most of the water inefficient toilet units in Canada. Such a programme might be financed through rebates (e.g. "feebates") on water tax savings, environmental impact savings transfers from regional authorities having jurisdiction for ensuring regional water quality, or other measures.

JOB CREATION: SOME IMPLICATIONS FOR A NATIONAL PROGRAMME

Construction / Installation Related Jobs

Assume 1/2 hr / toilet for installation and at least 1.5 toilets per home or office .Then each home or office requires 3/4 hr of installation time. Then assuming each installer can retrofit 10 homes or offices / day, for at least 240 days per year, then each technician, could install toilet retrofits in at least 2400 homes or offices per year or an estimated 3600 retrofits per year. Therefore, to retrofit a universe of 15M units, 4167 person years of employment would be generated over a one year period for installation alone.

If all work were all done in a single year, then approximately 4200 jobs would be generated . If the work were assumed to be spread out over a longer time period, say 10 years then only 420 direct installation jobs per year would result. Assuming an employment multiplier of 3.0 to take into account both indirect and induced jobs, then *total employment per year over a ten year period would be in the order of 1260 jobs.*

Manufacturing Jobs
Assume 10 direct manufacturing jobs for every 10,000 units installed (Enviro-Energy).
Then 15 M units = 15, 000 manufacturing jobs x multiplier of at least 3.0 (for Canada as a whole) for indirect and /or induced jobs = 45, 000 person years of employment for one year, or in the order of *4500 jobs / year for 10 years*.

Total Employment
Combining installation and manufacturing jobs, including both direct, indirect, and induced employment, total jobs / year, over a ten year period would be at least 4500 + 1260 = 5760. Adding 10% for administration, then *total jobs would be in the order of 6340 jobs for 10 years.*

If such a programme were accelerated so that it could be completed in half the time, then the total jobs / year, over a five year implementation period, would be in the order of 13000.

SUMMARY AND RECOMMENDATIONS:

From this preliminary comparative market screening of retrofits vs selected replacements, the following briefly summarizes key points and recommendations:

(1) Retrofitting conventional and / or low flow toilets, using simple, durable, permanently installed devices, *is the single, most cost effective way to reduce water consumption and optimize water efficiency* in residential and commercial buildings without intensive use.

(2) Toilet retrofits with low cost, high performance devices can reduce indoor domestic water consumption up to 16 % and total water consumption for all land uses up to 7 %.

(3) Retrofitting a large part of the national building stock can result in major benefit / cost and environmental advantages relative to the capital investment required. In terms of water savings per $ invested, significant avoided costs can be realized by municipalities. At the same time, 15M units retrofitted as a national programme can generate at least 9000 person years of employment over 10 years.

(*4) Retrofitting toilets with appropriate devices offers the most practical means to optimize water efficiency in existing facilities*, until such time as buildings are obsolete, and both buildings and plumbing fixtures require replacement.

(5) Approved ULF's should have a safeguard to prohibit their being installed to operate at more than 6 litres/flush (e.g. It is suggested that CSA Standards and Plumbing Codes be amended to make this a mandatory condition).

(6) Government mandated water reduction programmes should carefully consider long term economies of permanent retrofit options (i.e. life cycle analysis).

(7) The Canadian Council of the Ministers of the Environment together with the Federal Minister of the Environment should give serious consideration to a need for long term studies of retrofit device and plumbing fixture performance.

(8) In domestic renovations in which toilet retrofit or replacements are *publicly funded programmes aimed at optimum water conservation should encourage owners to install ULF's selectively* (i.e. with the primary use fixture being a ULF toilet and the secondary use units being either retrofitted LFs or conventional units.

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