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Wave of the Future:

The Case for Smarter Water Policy

Steven Renzetti

In this issue...

The current state of municipal water pricing in Canada is significantly flawed, with costs that include underfunded water agencies, aging infrastructure and excessive consumption. Reforms are required, including the expanded use of water meters and seasonal surcharges that better reflect costs.

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The Study in Brief

In the past, most Canadian municipal water agencies have viewed water prices as a mechanism principally for revenue generation and not as a policy instrument to signal scarcity or to encourage efficient water use. As the recent report of the Ontario Water Strategy Expert Panel shows, however, there is growing interest in the potential role for water pricing to achieve these roles. This paper critically assesses the current state of municipal water pricing in Canada and finds it to be significantly flawed, with costs that include underfunded water agencies, an aging infrastructure, and excessive consumption.

Economic theory and empirical evidence argue strongly in favour of reforming water prices. Potential avenues for reform include:

- expanding the use of water meters;
- moving to a full-cost-accounting approach for water pricing; and
- using seasonal surcharges to better reflect the marginal costs of water use during peak summer months.

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Canadian municipal water agencies are marvels of engineering science. They supply billions of litres of clean drinking water reliably to millions of Canadian households and businesses every day. At the same time, Canadian municipal water agencies are in trouble.

On average, they lose or cannot account for 20 percent of the water leaving their treatment plants. They face a significant backlog of infrastructure repairs, and replacement costs have been estimated to be billions of dollars. They do not know how much water is consumed by the one-quarter of their residential customers whose water use is unmetered. And, in 2007, the revenues they earned represented only 70 percent of their recorded expenditures – which by most accounts understates the costs of their operations.[1]

How can one reconcile these two disparate images of Canadian water-supply agencies? A major part of the puzzle lies in the fact that water agencies spend a great deal of time and effort on ensuring water quality and reliability and less on determining the correct price of water. While the immediate costs of making a mistake regarding water quality are much more severe than those of getting the price of water wrong, the long-term consequences of mispricing water are significant, and include excessive consumption, overextended infrastructure, stifled innovation, and diminished water quality.[2] Furthermore, future demand for water is expected to rise due to increases in population and income, while water supplies might become less reliable due to climate change. In the future, then, the costs of undervaluing water will become more severe.

The purpose of this *Commentary* is to document the underpricing of water, identify its causes and consequences, and consider options for the promotion of rational water pricing. Analysts and researchers have brought the issue of water pricing to the public's attention regularly over the past 30 years with little result. Thus, this *Commentary's* discussion of the options for policymakers pays particular attention to the informational, institutional, and legislative challenges that confront water-pricing reforms in Canada. The most important of the suggested reforms would see municipalities implement universal residential water metering and move toward full-cost-accounting methods for water pricing. Further, water agencies should institute seasonal surcharges to better reflect the marginal cost of water use during peak summer months and amalgamate smaller, high-cost water agencies to exploit scale economies and promote innovation.

Current Practices

It is important to begin by presenting an accurate picture of the current state of water pricing in Canada. The good news is that Environment Canada regularly surveys municipalities and reports on their pricing of water-supply and sewage-treatment services. The bad news is that the most recent survey (Environment Canada 2008), by providing data for 2004, is rather out of date. In addition, the survey's coverage is uneven: Environment Canada acknowledges that the response rate for small towns is rather low, which skews the results since, as we shall see, small towns often have the most inefficient price structures.

Canadian Municipal Water Prices

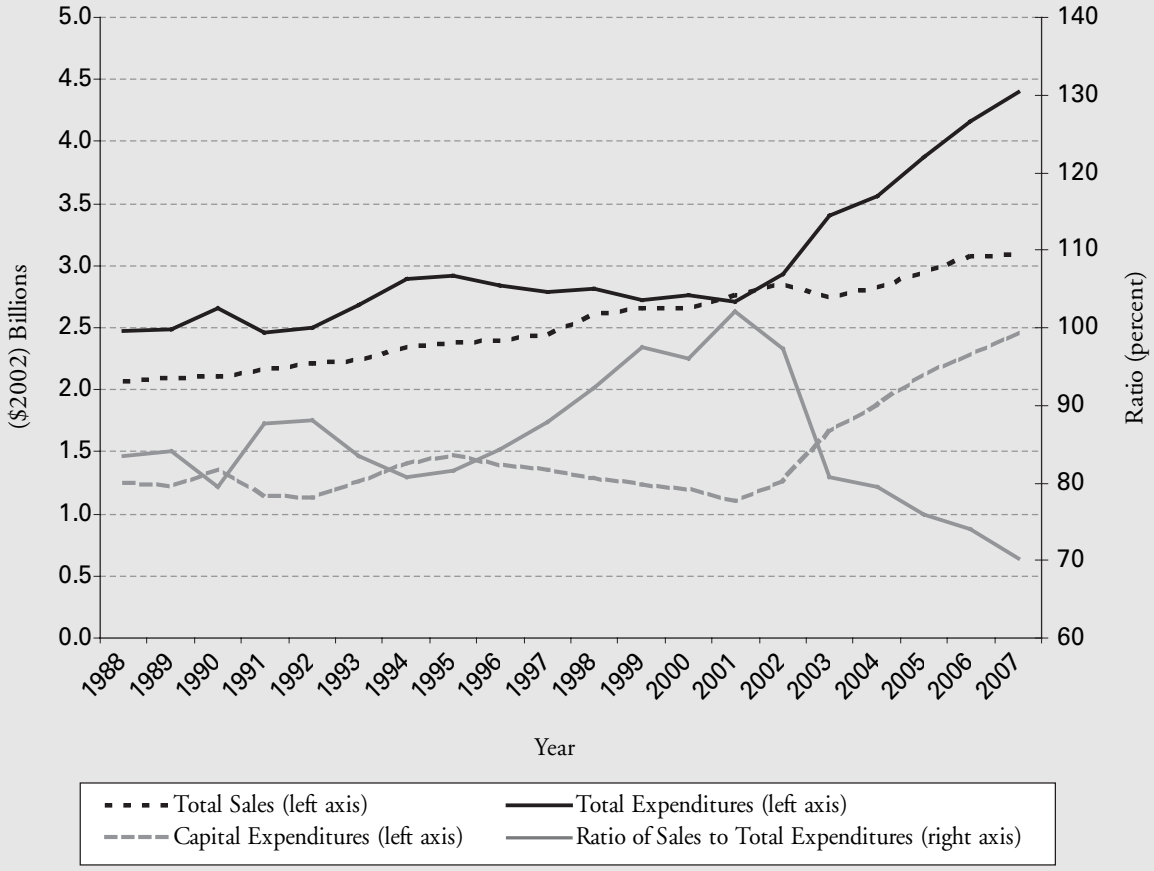
Canadian water-supply agencies employ a variety of means to collect revenues from their customers. Some revenues are simply transfers from the municipal government of which the agency is a part; other revenues, typically for capital projects, might come from provincial and federal sources. Most revenues, however, are collected through charges of various sorts levied on residential, commercial, industrial, and institutional customers. These charges include one-time fees for new accounts, ongoing charges for connection to the system – which tend to be differentiated across user groups and by the size of the pipe connecting the consumer to the network – and water prices.

The author wishes to thank the Canadian Water Network for research support. Diane Dupont, external referees and the Institute staff provided valuable comments. All errors and omissions are solely the responsibility of the author.

1 Sources for the reported statistics are Environment Canada (2004, 2008); Infrastructure Canada (2005); and Statistics Canada (2008).

2 Most of what is said here also applies to the municipal agencies that treat sewage. The inadequate cost accounting and pricing of sewage treatment services only reinforce the conclusions reached here. See Renzetti (1999) for empirical estimates.

Figure 1: Revenues and Expenditures of Canadian Municipal Water Agencies, 1988 to 2007



Source: Statistics Canada (2008).

Despite the number and types of revenue sources, it is clear that the revenues municipal water suppliers collect are inadequate: over the 1988 to 2007 period, except for 2001, revenues earned by all municipal water agencies in Canada consistently fell short of expenditures (Figure 1). What is surprising about these figures is that, since 2001, the aggregate ratio of revenues to expenditures has been falling, and in 2007 stood at only 70 percent. But if users are not paying the full cost of water supply, someone else is. In other words, this phenomenon represents a complex set of undocumented, poorly understood, and unplanned transfers to one set of Canadians – water users who are not paying the full cost of their water service – from another set of Canadians. What is even more remarkable about these statistics is that these recorded expenditures understate the full cost of providing potable water to Canadians. Capital costs have been undervalued, investment rates have failed to maintain and replace aging supply networks, raw water has been obtained for free, and the economic costs of the environmental damages arising from sewage operations have gone unmeasured. Thus, the gap between what Canadians pay for their water supply and the full cost of that supply is even greater than the Statistics Canada data indicate.

One can categorize water agencies according to whether or not the revenue they receive from an individual customer depends on the volume of water the customer uses. It is quite common for water agencies to charge a preset monthly fee – often termed a "flat rate" – that provides the customer a virtually unlimited volume of water. Some agencies, however, charge a specific price for each cubic metre of water the customer uses. In order to levy a price, the agency must measure the customer's water use with an onsite water meter.

Table 1: Distribution of Residential Price Structures, 2004

Price Structure	Number of Cities	% of Population
Flat rate	489	23.4
Volumetric	427	76.6
Constant	304	45.4
Decreasing block rate	84	7.9
Increasing block rate	39	23.3

Source: Environment Canada (2008).

These prices can be constant (price does not vary with the volume of water purchased), increasing (price rises with the volume of water purchased), or decreasing (price falls with the volume of water purchased). When price increases or decreases with the volume of water used, the marginal price (the price on the last unit consumed) usually changes discretely. For example, Edmonton's residential water rate schedule is composed of a monthly connection fee that varies depending on pipe size ($5.42 for a 16 mm connection and $23.22 for a 50 mm connection) plus an increasing block rate for consumption. The latter is $1.5362 per cubic metre for consumption of less than 60 cubic metres per month and $1.5879 per cubic metre for consumption in excess of 60 cubic metres per month (EPCOR 2008).

It does not end there. Water prices can be further complicated by additional features, including minimum charges, surcharges for sewage-treatment services, provisions for lowered prices for some initial low level of water use, and special charges meant to build up capital reserves. What is interesting about Canadian water prices, however, is that they typically do not exhibit some features that are commonly found in other regulated or public agency prices, such as prices that vary according to time of use, season, or distance. I return to this important point below.

The distribution of residential water rate structures across Canadian municipalities is shown in Table 1. Of the 916 municipalities that responded to Environment Canada's most recent survey of municipal water-pricing practices, slightly more than half (486) employ flat rates. Residents of these towns and cities effectively have access to unlimited water use for a preset fee, since the marginal price (the price they pay for each additional cubic metre of water) is zero. The remaining municipalities employ some type of volumetric charge, with constant prices being by far the most popular choice. A very small number of cities employ decreasing block rates, and even fewer use increasing block rates. These figures are somewhat misleading, however, as the cities that use flat rates tend to be the smaller ones. In fact, only about a quarter of Canadian households face flat-rate water charges, while three-quarters face some type of volumetric charge. Further, because the largest cities tend to use increasing block rates, one-quarter of Canadians experience such charges.

An unusual feature of the Canadian municipal water-supply sector – compared to other types of public utilities and to water-supply practice in other countries – is that the water use of many households is not metered, making it impossible for their water supplier to charge a volumetric fee. In 1991, only about half of households had water meters in their homes. Coverage has slowly increased, to about 63 percent by 2004, but about one-third of Canadian households are still without water meters. Most of these households are in eastern Canada – Newfoundland and Labrador, Prince Edward Island, and Quebec have the lowest rates of residential water metering.

Aside from acting as a barrier to reforming water prices, the absence of water meters has important

Box 1: Water Demand and Prices

The factors that influence residential water demand include climate, house and lot size, number of family members, income, and price. It is the last of these that is most relevant here. If water demand were truly insensitive to water price, the major issue surrounding the design of water prices would be whether they generate enough revenue to finance water agencies' operations. On the other hand, if demand is sensitive to price, the potential effect of prices in determining water consumption levels is relevant. What is the empirical evidence on the sensitivity of water demand to price?

Statistical analysis of the relationship of residential water demand to water price has been conducted in a variety of contexts and locations. Taken together, these studies conclude that residential water demand is inelastic at currently observed prices. In an analysis of 162 estimates generated between 1963 and 1993, Espey, Espey, and Shaw (1997) obtain an average price elasticity – that is, the expected percentage change in demand when price increases by 1 percent – of -0.51 percent. Similarly, Dalhuisen et al. (2003) obtain an average price elasticity of -0.41 in an analysis of almost 300 price-elasticity studies conducted over the past 20 years. These studies also confirm that short-run elasticities are typically smaller than long-run elasticities – in other words, demand for water responds more to higher prices over time, whereas demand is less flexible to higher prices in the short run – and that the price sensitivity of outdoor summer water usage exceeds that of indoor water usage.

There is a limited amount of evidence that households respond to the structure of water prices as well as to their level. Reynaud, Renzetti, and Villeneuve (2005) find that the sensitivity of Canadian residential water demand to a 1 percent increase in price differs according to the pricing scheme used: demand changes by 0.02 for flat rates and by -0.16, -0.25, and -0.10 for constant, increasing, and decreasing block rates, respectively. Thus, the pricing structure per se plays a significant role in influencing price responsiveness of residential consumers.

Finally, although industrial and commercial water demand has received significantly less attention than has residential water demand, the available empirical evidence indicates that firms respond to water prices just as households do. A study of water use in the Canadian manufacturing sector finds that water intake decreases by 0.8 percent with each 1 percent increase in price (Dupont and Renzetti 2001).

Table 2: Trends in Municipal Water Prices and Household Expenditures, Canada

	Average Constant Charge	Average Marginal Price at 35 Cubic Metres	Average Monthly Household Expenditure at 10 Cubic Metres per Month	Average Monthly Household Expenditure at 25 Cubic Metres per Month	Average Monthly Household Expenditure at 35 Cubic Metres per Month
	($ per cubic metre)			*($)*	
1991	0.95	0.98	17.73	26.12	31.96
2004	1.13	1.27	26.08	40.47	50.44
Annual change, 1991–2004	1.35%	2.0%	3.3%	3.9%	4.1%

Note: All dollar amounts are in constant 2004 dollars.

Source: Environment Canada (2007, 2008).

Figure 2: International Water Price and Consumption Comparison, 1999

[a] Purchasing power parity.
[b] Litres per day per person.
Note: The comparison for 1999 is the most recent available. The National Round Table on the Environment and the Economy (1996) has a very similar figure showing that, in 1989, Canada had the second-lowest prices and the second-highest per capita consumption level.
Source: Expert Panel on Groundwater, forthcoming.

and more immediate consequences. The typical Canadian household charged a flat rate uses an average of 467 litres per day per person, while the typical household facing a volumetric price structure (whether constant, decreasing, or increasing block rate) uses 266 litres per day per person. Although these households might differ in other important respects – such as income or family size – that could influence their water use, these factors explain some, but certainly not all, of the observed difference in demand (see Box 1).

One can also consider recent trends in the levels of water prices and the expenditures that are associated with water use in Canada. Water prices have been rising slowly over the past 15 years. The typical household with metered water service faced an average price of $1.13 to $1.27 per cubic metre in 2004 (Table 2) compared to $0.95 to $0.98 in 1991. Because most households face volumetric charges, in 2004 the average monthly expenditure varied with the amount consumed, with households consuming an average volume of water (25 cubic metres per month) spending $40.47 per month.[3] Taking inflation into account, monthly expenditures have been rising steadily at a rate of 3.3 to 4.1 percent per year.

Despite the recent recorded increases in both water prices and water expenditures, it is important to recognize how low Canadian water prices are in comparison to prices in other countries (see Figure 2). There is no obvious reason why Canada should be the cheapest supplier of water – the technology of water supply is roughly the same across developed

3 This expenditure does not include spending on bottled water or sewage charges.

Table 3: International Comparison of Water Productivity

Country	Water Productivity
	(2000 US$ per cubic metre)
India, Peru, China	5-10
Mexico, Russia, South Africa	10-12
Canada	**13**
United States	18
France, Germany	35-40

Note: Productivity is defined as GDP per unit of recorded water withdrawal.

Sources: Postel and Vickers 2004; the figure for Canada is author's calculation.

economies. Furthermore, as a number of researchers have documented (see, for example, Bakker 2007), the apparent abundance of Canada's water resources is more firmly rooted in Canadian popular opinion than in hydrologic science, and the proximity of water sources to Canada's major urban centres is little different than in much of northern Europe. Indeed, Canada's climate variability and low population densities mean, if anything, that this country should have higher-than-average water prices. The message is startlingly clear: Canadian water prices are remarkably low by international standards.

The immediate consequence of these low prices is also clear: by having such low water prices, Canada has encouraged its households, farms, and businesses to be among the heaviest users of water in the world. Although many factories and farms are not connected to municipal water systems, provincial regulations governing water allocation to these "self-supplied" users have also been criticized for providing water at subsidized rates (Renzetti 2007). Further, the fact that this situation has persisted for decades ensures that these wasteful water-using practices have become firmly embedded in households' habits and appliances and in firms' productive technologies. One piece of evidence in this regard is the measure of Canada's "water productivity" (Postel and Vickers 2004), analogous to the more familiar labour productivity concept that measures the value of output produced by hours worked. Thus, the dollar value of output produced in Canada by each unit of water can be computed and compared with that in other countries. As Table 3 shows, Canada's water productivity is quite low – comparable to that of Mexico or Russia but significantly below that of the United States or Germany.

Pricing Rules

The variety of water-rate structures across Canada is quite remarkable. How a city comes to have a particular pricing structure is often difficult to determine, but is likely a complex result of historical practice, local politics, adherence to industry rate-setting principles, accident, and other factors. The most detailed source of guidance is the widely followed rate-setting manual of the American Waterworks Association (AWWA 2000).

The AWWA approach to water rate setting reflects an approach to public utility pricing that is quite different from that adopted by economic analysts. It begins with a determination of an agency's "revenue requirements" – essentially, the agency's operating and maintenance and capital costs of service and, hence, its requirement for revenue in order to break even. The definition of capital costs varies across jurisdictions and between privately owned and publicly controlled agencies. For example, privately owned agencies commonly include depreciation and a competitive return on their invested capital as a part of their capital costs, while public agencies tend to exclude these. The total estimated costs are then allocated across the services the agency provides and across customer classes. An important part of this procedure involves the allocation of joint capital costs across customer classes. While motivated by the

principle of finding an equitable apportionment of an agency's costs across customer classes, this allocation is fraught with difficulties, as there are many equally ad hoc ways of dividing joint costs;[4] however, it results in an estimate of the costs for which each customer class is responsible. Finally, each customer class's water-rate schedule is designed so that it collects the customer class's revenue requirements while reflecting any other goals important to the agency. The resulting rate schedule typically has two components: a connection fee that is meant to recover the customer class's share of the agency's fixed costs, and a volumetric charge that is meant to recover the variable costs.

In contrast to the detailed guidance provided by the AWWA, most Canadian provinces have demonstrated surprisingly little interest in municipal water pricing and, until recently, have provided little regulatory oversight of municipal agencies' rate-setting practices aside from requirements regarding debt levels (see Water Strategy Expert Panel 2005; Furlong and Bakker 2008).

Finally, part of the puzzle of how municipalities arrive at their water rates is a result of the limited empirical research aimed at identifying the factors that determine their choice of water-rate structures. A study of a sample of US municipalities finds that, under sunnier, warmer, and drier weather conditions, utilities in the United States are more likely to adopt increasing-block-rate structures (Hewitt 2000). In another study, which looks at the structure of Canadian residential water demand and the decision-making process municipalities follow in choosing water-rate structures, the authors conclude that "[the] choice appears to reflect a combination of efficiency considerations, equity concerns and, in some cases, a strategy of price discrimination across consumers" (Reynaud, Renzetti, and Villeneuve 2005, 1114).

Assessing Water Prices in Canada

Even a superficial analysis of the current state of water pricing in Canada, and the rate-setting guidelines underlying those prices, demonstrates features that give cause for concern. These include the inadequacy of revenues, prices that are remarkably low by international standards, the prevalence of municipalities with unmetered service, and the lack of seasonal or distance-related pricing. While these concerns are significant enough, it is possible to go further and assess the economic features and consequences of Canada's water prices.

A variety of criteria could be used to carry out such an assessment. For example, the AWWA suggests that sufficiency of revenues, promotion of fairness across users, simplicity of rates, and promotion of conservation should be the goals when setting water prices (AWWA 2000). In a recent paper, I propose four criteria: revenue generation, economic efficiency, environmental sustainability, and fairness (Renzetti 2007). Here, however, I take a simpler route and consider primarily one criterion: do Canadian water prices promote economically efficient decisionmaking with respect to Canada's scarce water resources? The reasons for focusing on this single criterion are that, in the past, efficiency has received the least attention of the various criteria and it is the one that economic analysis is best suited to consider.

The main conclusion arising from this assessment is that municipal water prices in Canada understate the full costs of water use, a situation that promotes inefficient decisionmaking by both suppliers and consumers of water. This inefficient decisionmaking, in turn, has significant costs for Canadian society that are manifested in wasteful levels of water consumption, misallocation of scarce infrastructure funds, degraded water resources, and stifled innovation. Fortunately, these costs are avoidable and, in the next section, I suggest potential policy reforms.

It is useful to divide the general concept of economic efficiency into allocative and productive efficiency. *Allocative efficiency* means that society is made as well off as possible through the allocation of its limited resources to producers and consumers. This general concept has been applied to a number of specific municipal contexts, including water supply (see Dewees 2002). With respect to the level of production (or consumption) of a good, allocative

4 Indeed, this particular criticism of the AWWA rate-setting method was first made in the seminal work on the economics of water pricing by Hirshleifer, DeHaven, and Milliman (1960).

efficiency occurs when the cost of the last (marginal) unit of production equals the benefit consumers enjoy from that unit. Thus, the role of price is to signal the marginal cost so that consumers can choose to consume whenever their marginal benefit exceeds the price.[5] Allocative efficiency occurs when consumption and production are aligned so that the marginal cost equals the marginal benefit and a price exists that leads this level of production and consumption to be chosen in the market.

A second, related, concept of efficiency is *productive efficiency*: whatever is the mix of goods and services that society chooses, production should occur at the lowest possible cost. This requires that agencies do two things: produce at the correct scale and avoid waste. There are several reasons this might not happen in the case of water agencies. For one, the small size of a municipality might not allow its water agency to take full advantage of scale economies. For another, the management and organization of the water agency might not lead it to produce at the lowest possible cost.

If allocative and productive efficiency were the primary goals for which water agencies should strive, agencies would need to:

- account properly for the full social costs of production;
- set the price of water equal to the marginal cost of supply;
- produce the resulting level of output at the lowest cost; and
- allocate water efficiently when demand equals the system's capacity.

Each of these behavioural requirements is discussed below.

Full-Cost Accounting

The first requirement for the efficient supply of water is to account fully for all the costs incurred in supplying it. Given the complexity of water-agency operations, the longevity of their capital assets, and their interaction with the natural environment, it is not surprising that disagreements arise about how to measure and record these costs for the purposes of rate setting. Part of this debate has been about how best to record capital costs and to compute the opportunity cost of capital for public agencies (see Kitchen 2006). More fundamentally, the debate has concerned the definition of the "full costs" of water supply. One perspective – adopted by the Walkerton Inquiry (O'Connor 2002) and Ontario's Water Strategy Expert Panel (2005) – argues that full costs are represented by a complete accounting of all the expenditures of an agency, including capital and regulatory costs. This is also the view implicit in Ontario's *Sustainable Water and Sewage Systems Act,* which requires the province's water and sewage-treatment agencies to revise their accounting procedures so that the full costs of their activities are recorded and reflected in prices.

Another perspective argues that full-cost accounting requires a broader measure of the costs of water supply, one that includes the opportunity costs of all productive resources used to supply water – such as the opportunity costs of raw water withdrawn by the water agency,[6] the costs of protecting water sources, and the costs of any reduction in environmental quality that occurs from the operations of water or sewage agencies. It is this broader view of full costs that is contained in the European Union's Water Framework Directive, which compels member states' water agencies to reform their pricing to reflect the full costs of their operations (Chave 2002).

There is very little real-world evidence to indicate how far existing accounting methods fall short of either the narrow or the broad definition of full costs. A recent case study, however, examines the implications of incomplete cost accounting by considering the operations of the agency responsible for water supply and sewage treatment in the Niagara region (population 410,000) of southern Ontario (Renzetti and Kushner 2004). The agency supplies more than 80 million cubic metres of potable water and treats more than 85 million cubic metres of sewage. The study finds that, when the full costs of

5 This rule can be generalized when there benefits external to individual consumption – for example, water use improves sanitation and thus reduces health risks – but the principle remains the same.

6 The opportunity costs of raw water are the lost benefits another user would have enjoyed if the water agency had not withdrawn the water.

capital, raw water, and environmental degradation are considered, the agency's costs could rise by $10.4 million to $34.9 million, or 16 percent to 55 percent of those actually recorded. Clearly, this is an area where more data and research are required.

Marginal Cost Pricing

The second requirement for the efficient supply of water concerns water pricing. The fundamental test for allocative efficiency in a single market is whether consumption occurs at a level at which the marginal benefit from consumption equals the marginal cost of supply. In other words, efficiency is achieved when people consume to the point where the benefit they receive from an additional unit of water equals the cost it took to produce it. In a market such as that for potable water, where the supplier sets the price and consumers choose the level of consumption, meeting this goal requires the water agency to set the price equal to the marginal cost, and to supply the resulting demand for water.[7]

The "marginal" in marginal cost can be defined in a number of different ways. The most obvious is with respect to the quantity of water: the price should reflect the cost of supplying one more unit. Marginal cost can also be defined with respect to either time or distance: if the marginal cost of supplying one more unit of water also depends on *when* that unit is delivered (summer vs. winter; morning vs. evening) or *where* it is delivered, then the price should reflect these conditions. Thus, for water, as for other commodities, efficient pricing should differ according to the quantity consumed, the location of consumption, and the time of consumption. (Efficiency also dictates that prices vary across customer classes, but only if the marginal cost of serving them differs.) Remarkably, although a limited number of municipal water agencies do have prices that vary by consumption, almost none differentiates water prices by location or time of consumption.

There are two reasons to believe that Canadian water prices do not reflect the marginal costs of supply. The first is that water agencies do not intend prices to reflect marginal costs, as highlighted by the fact that no agency has adopted marginal cost pricing as a principle in water-rate design. The second reason is that the empirical evidence, though limited, shows that prices do not reflect marginal costs. An early case study of the effects of employing residential flat-rate price schedules estimated that the short-run marginal cost of supply in Vancouver, where residential water use was unmetered, varied from $4.35 (in constant 1986 dollars) per thousand cubic metres in the winter to $8.94 in the summer, while the long-run marginal cost, which included capital costs, varied from $53.89 in the winter to $85.83 in the summer. Marginal costs were higher in the summer due to higher energy costs and lower water levels in the system's reservoirs (Renzetti 1992). A more comprehensive study compared water prices and the estimated marginal cost of supply for 77 Ontario water agencies, most of which use some form of volumetric charge for residential consumers, and found that prices understated marginal costs for both residential and non-residential customers by a wide margin (Renzetti 1999).

Minimizing Costs

The third requirement for economic efficiency concerns the cost of providing potable water. Specifically, two things are required: the agency must avoid waste, and it must organize its operations and technology and choose its level of output so that it operates at the lowest-possible average cost.[8] These two conditions are distinct but closely related. The first requires that, whatever amount of water the agency supplies, it does not use more inputs than necessary. The second requires that the agency find the level of output and scale of operations that allow it to supply a cubic metre of water at the lowest-possible average cost.

There are a variety of ways in which either of these conditions might not be met. The first facet of

7 In the research on public sector pricing, this simple rule has been extended to meet a number of real-world complications, such as break-even regulations, uncertain and cyclical supply and demand, water-supply technologies characterized by discrete increments to capacity, heterogeneous customer classes, and imperfect information. See, for example, Brown and Sibley (1986); Wilson (1993); and Russell and Shin (1996).

8 These are technical conditions rooted in microeconomic theory, where the first condition requires that the agency operate on, rather than above, its average cost curve, and where the second condition stipulates that the agency operate at the minimum of its average cost curve.

productive efficiency considers whether water agencies are producing their output at least cost or can find ways to cut their input use while still providing the same level of service. A recent consideration of the productive efficiency of a sample of Ontario water agencies operating in 1996 finds that, after accounting for external factors such as population density and climate variability, a significant number of agencies do not operate in a cost-minimizing fashion (Renzetti and Dupont forthcoming). Specifically, the average water agency in the sample could reduce its inputs by approximately 18 percent and still achieve the same level of output. Furthermore, only 8 out of 64 agencies in the sample were found to have no economic waste. This finding suggests that a significant degree of waste exists among water agencies in Ontario and likely throughout Canada.

The second facet of productive efficiency considers whether water agencies are organized to take advantage of economies of scale and, thus, to achieve lower costs of production. For example, suppose there are four adjacent municipalities whose water agency each serves a customer base of 25,000 households, but the technology of water supply in this area dictates that average costs reach their minimum only if 100,000 households are served. Productive efficiency would require that these agencies amalgamate and lower their average costs and, thus, their prices. The possibility that small, high-cost agencies were operating at inefficient levels of service was a main driver behind a number of the recommendations of Ontario's Water Strategy Expert Panel. In its final report, the panel recommended that "[t]he scale and capacity of systems must increase. Systems must join together to better manage risks, increase the depth of their expertise, gain economies of scale and scope, and help the high-cost customers" (Water Strategy Expert Panel 2005, 11).

Rationing

The fourth requirement for economic efficiency concerns how water should be allocated when demand threatens to exceed the agency's rated capacity to supply water – for example, in times of drought. In the summer months, it is not uncommon for a water agency to seek to limit water use when raw water supplies decline and/or demand approaches its supply capacity. One extreme example is the drought that Victoria, British Columbia, experienced a few years ago. The BC capital region relies on reservoirs, primarily the Sooke Reservoir, for its water supply, but winter precipitation in 2000/01 was only half the average amount, and the lowest since 1900, which dropped reservoir levels by more than 30 percent below normal. As a result, Victoria instituted a series of measures to curb water use, including bans or restrictions on most forms of outdoor water consumption (Walker 2002). Administrative rationing – such as allowing even-numbered houses to use water for outdoor purposes only on even-numbered days or limiting outdoor water use to specific periods of the day – might seem straightforward to implement, but it does not guarantee that scarce water resources will be allocated to its highest-valued uses. As a result, it typically results in an inefficient allocation of water.

Two alternatives might yield a more efficient outcome. The first is to raise the price of water, which signals its increased scarcity and value and provides an incentive for households to reduce their low-valued uses of water. A recent study comparing residential outdoor watering restrictions with drought pricing in various US and Canadian cities finds that, for a given targeted reduction in water use, the cost to consumers is lower under drought pricing than under quantitative water use restrictions (Mansur and Olmstead 2007). The main reason for this is that quantitative restrictions fall on all households, regardless of how they value their outdoor water use, while price-based restrictions curtail consumption only for households that have a low valuation of their outdoor water use.

The second alternative employs differences in households' valuation of access to the supply network. To illustrate, suppose that, at the beginning of each year, households could signal to water agencies their valuation of continued access in times of rationing by purchasing differing levels of service reliability – higher levels of service reliability would cost more. As water supply must be maintained for indoor and fire-protection needs, this scheme would be applicable only to outdoor water use. Once households signalled their respective willingness to pay for reliability, a ranking of differing households could be established: the more a household paid for access, the lower the likelihood that its access would be interrupted or

Table 4: Results from Ontario Water-Pricing Study

	Residential Water Supply	Non-residential Water Supply
MC[a] *($ per cubic metre)*	0.87	1.49
PRICE[b] *($ per cubic metre)*	0.32	0.73
DEV[c] *(%)*	47.52	62.87

[a]MC measures the average of long-run marginal cost estimates across the sample of Ontario municipalities.
[b]PRICE is the average of residential prices across the sample.
[c]DEV measures the percentage difference between observed consumption and the consumption predicted to occur if marginal cost pricing were employed.
Source: Renzetti (1999).

curtailed. In times of rationing, such a scheme would ensure that only households that value water the highest would use the scarce resource, since households with the lowest valuation would be the first to be excluded from use. Such a mechanism could reduce the costs of meeting water-use-reduction targets (see Collinge 1994).

Implications

Of the four requirements for efficient production and consumption presented above, none is met in Canada, a finding that has a number of implications. First, no matter what pricing rule is employed, to the extent that water agencies' accounting procedures understate the full costs of supply, consumption will be artificially subsidized and, thus, excessive. The costs to society of this overconsumption are compounded by the costs associated with water agencies' operating wastefully and/or at levels of output that do not exploit economies of scale.

The second implication concerns the effects of prices that fall short of the marginal cost of supply. The most obvious is the inefficient overuse of water that subsidized water prices encourage.[9] The excess consumption is, of course, most pronounced in cities that rely on flat rates and whose consumers face a marginal price of zero. Overconsumption induced by underpricing water can also be significant, however, in cities that have volumetric charges. A study of 77 Ontario cities with volumetric charges finds that water use by residential and nonresidential customers deviated from levels that would be expected under marginal cost pricing by 47.5 percent and 62.9 percent, respectively (Renzetti 1999). The results are summarized in Table 4.

It is important to remember that overuse of water is possible only when water agencies overexpand the size of their supply networks. This process is facilitated by periodic infusions of infrastructure grants from provincial and federal governments that are accompanied by few, if any, requirements for accounting or pricing reforms. In water-scarce environments, underpricing typically leads to shortages and unreliable service. In a relatively water rich environment such as exists in parts of Canada, underpricing has combined with overexpansion of supply networks, with no reduction in the available supply or reliability of service. Thus, the strongest signal of inadequate pricing – shortages – has been nullified by water agencies' unwavering commitment to supply whatever demand arises at the going price.

The overconsumption of water can also refer to consuming too much water at a specific time and in a specific place. It is a well-established principle in public sector pricing that, when demand varies cyclically, as in the case of water, efficient prices should also vary with time. Specifically, water demand rises during the summer due to the presence of outdoor watering needs, but water supplies either remain the same or even decline. If

9 Water agencies' rate-setting policies also make it possible for inefficiencies to arise when prices exceed marginal costs. For example, industrial and commercial water prices in Vancouver exceed estimated marginal costs, effectively cross-subsidizing households that face flat rates for their water (Renzetti 1992).

demand rises so much that it is constrained by the supply network's capacity during peak periods, the marginal-cost-pricing rule leads to the use of a peak-load-pricing formula whereby the price is set at short-run marginal cost during off-peak periods and at long-run marginal cost during peak periods. In this way, consumers face the appropriate signal whenever they use water. During off-peak periods, consumption is less than capacity and a small increase in water use merely incurs additional variable costs, such as those for raw water, energy, and chemicals. In peak periods, when consumption is close to system capacity, an additional increase in water use requires additional variable and capital costs. Canadians are already familiar with this type of pricing with respect to the supply of telecommunications, energy, and even toll highways.

The difference between prices and short- and long-run marginal costs is likely to be dramatic. In the case study of the Vancouver Regional Water District noted earlier, long-run marginal costs were significantly higher than short-run marginal costs because the former included capital costs; moving to peak-load pricing was predicted to reduce peak demand by 10 to 15 percent (Renzetti 1992). While this does not sound like a major reduction, it is important to remember the significance of peak demand when it comes to designing water networks: like most services based on capital-intensive supply networks, water systems typically are built to serve projected peak demand for consumption and firefighting (see Ontario 2005). Thus, the failure to curb peak demand through appropriate prices directly feeds into pressures to overbuild water supply networks. Ironically, one is left with a situation where some of the lowest-valued water uses, such as car washing and lawn watering, are facilitated by the highest-cost supplies of water.

Similarly, failure to price according to distance means that consumers who live farther away from the supply source are subsidized by those who live closest to the supply source. Thus, the suburban sprawl witnessed outside many of Canada's cities has resulted partially from a failure to price correctly many forms of infrastructure and municipal services, including water. Unfortunately, no empirical studies exist that establish the extent to which the mispricing of water is responsible for this phenomenon.

The final implication of underpricing water is that it very likely stifles innovation. Consider the business or household that is asked to spend its scarce resources to innovate and reduce its water use, but is also told that it would save little by doing so because the price of water is so low. In such a case, there would be little incentive to innovate and save water. Even if a water user believed that the benefits of conservation exceeded the costs, could we expect engineers, inventors, and product designers to turn their attention to reducing the water requirements of appliances and equipment when no price signal exists to inform them of the profit opportunities of doing so?

Statistical evidence exists of the link between innovation and water prices for all major user groups. In the United States, for example, increases in water prices have led farmers to adopt more efficient irrigation technologies (Renzetti 2002). In Canada, manufacturing firms are more likely to invest in equipment that allows them to undertake internal water recirculation if water intake prices are higher (Bruneau, Renzetti, and Villeneuve 2007). In another example, the reaction of households in California to price and nonprice conservation measures adopted by water agencies confronted with repeated droughts has been to curb their water demand by retrofitting water-using appliances (Renwick and Green 2000).

It is also instructive to compare and contrast recent trends in Canadians' use of water and energy. Per capita residential water use remained effectively constant between 1991 (at 341 litres per day) and 1999 (343 litres per day), but fell by 2004 to 329 litres per day (Environment Canada 2004). In contrast, over the same period, residential energy use fell by 9 percent from 0.122 petajoules per household in 1990 to 0.112 petajoules in 2004 (Natural Resources Canada 2006b). Part of this difference is explained by the difference in trends in water and energy prices: real residential water prices rose annually over the period 1991–1999 period by approximately 2 percent per year, but rose at an annual rate of 5.5 percent over the 1999–2004 period (Environment Canada 2008), while real residential energy prices rose by 4 percent per year over the 1991–2004 period (Natural Resources Canada 2006a).[10] Thus, there was little decline in water use

10 The latter number is a weighted average of residential energy price increases. Natural gas, heating oil, and electricity prices rose 7.5, 2.6, and 0.6 percent, respectively, per year over the 1991-2004 period, and their shares of residential energy use were 41.1, 14.5, and 36.3 percent, respectively (Natural Resources Canada 2006a).

over the first period (1991 to 99), in part because of income growth combined with a low rate of price increase, while during the second period (1999 to 2004), water use mimicked energy use as both declined in response to significant real price increases.

To summarize, the available evidence demonstrates strongly that Canadian water agency cost-accounting and pricing-rules are inefficient. Costs are understated, and prices fail to reflect marginal costs, leading to excess consumption, overextended and undermaintained infrastructure, and stifled innovation. Although economic efficiency is clearly not the only criterion by which water prices should be judged, it is equally clear that the costs of neglecting this feature of water prices are significant. Furthermore, future increases in water demand, coupled with the potential for a reduction in water supply reliability due to climate change, can only lead to higher costs from inadequate water pricing.

Proposals for Reform

A number of studies have demonstrated the benefits of moving to efficient water prices. In cities as diverse as Vancouver, Los Angeles, Sydney, Manila, and Hyderabad, researchers have demonstrated that reforming water prices increases social well-being while encouraging water conservation (Munasinghe 1992; Renzetti 1992; Hall and Hanemann 1996; Saleth and Dinar 1997; Grafton and Kompas 2007). For example, Renzetti (1992) estimates that the overall gains from reforming water prices in the Greater Vancouver Water District could amount to approximately 4 percent of the community's total well-being.[11] Moreover, because most policy reforms create winners and losers, these gains would be net of the costs of introducing universal residential water metering in the city. The Vancouver case study, however, is also instructive in that it yielded some unexpected results, including the fact that moving to seasonal peak load prices made households unambiguously worse off (since their water prices rose), but improved both the well-being of local businesses (since their prices fell) and the welfare of the local water agency (since its costs fell). Moreover, the Vancouver case study provides empirical confirmation of the theoretical prediction of the superiority of marginal cost pricing. Households were using water they valued much less than the cost of supplying it. By raising prices, consumption was curbed and the savings to the water agency and to the taxpayers who fund it far exceeded the reduction in benefits to water users. However, the case study also highlights the complexities and challenges facing any agency considering such a move, and shows that not enough is known about the likely effects of moving to marginal cost pricing for water. As a result, I propose a three-stage approach to policy reform, with the first stage concentrating on building the institutional capacity needed to reform water prices.

Build Institutional Capacity

A substantial amount of work needs to be done before water agencies are even capable of charging prices that are based on the marginal costs of supply. The first requirement is straightforward: universal metering. Nothing can be done to rationalize pricing until a water agency has the capacity to monitor water usage by all its customers.[12] The second effort should be directed at accounting more fully for costs. A valuable starting point is Ontario's *Sustainable Water and Sewage Systems Act,* which will require full cost accounting by water and sewage agencies. Related to this, however, is the need to organize cost accounting in a way that supports the calculation of marginal costs, since there is a lack of congruence between agencies' accounting methods and their estimation of marginal costs.[13] A second capacity-building effort should be directed at understanding the factors that influence water demand. Although the economic characteristics of water demand have been studied extensively, a number of

11 As measured by aggregate consumer surplus, which is the dollar amount by which a consumer's valuation of a good or service exceeds the price paid. It is a commonly accepted measure of the net benefit (or increase in welfare) from consumption.

12 Infrastructure Canada (2005) documents the benefits of metering and the growing interest of Canadian municipalities in its use.

13 Russell and Shin (1996); Dewees (2002); PriceWaterhouseCoopers (2003); and Kitchen (2006) are among the researchers that provide valuable guidance on this topic.

features are poorly understood – in particular, how residential and commercial water demand varies with respect to changes in energy prices, and the effects of age, family size, and appliances on water use.

Provide Near-Term Initiatives

Once water agencies have developed the capacity to reform water prices, a number of potentially valuable steps could then be undertaken. The single most important near-term strategy would be to adopt seasonal water pricing, perhaps as part of a package of price and nonprice measures to encourage conservation. In the cases where volumetric charges are already in place, this could be achieved by setting the price in off-peak seasons equal to short-run marginal costs, setting the price in the peak summer season equal to long-run marginal costs (which would be constant across all user groups), and raising or lowering the connection fee by an amount necessary for the agency to avoid a deficit. Such a strategy would provide the correct signal regarding costs, but it would not require a significant change in administration or billing. To counter any negative effect on low-income households, only consumption above a certain quantity might be charged the higher summer price. Also, it is likely that any effort to curb summer peak water use through pricing would be more effective if combined with educational programs and other nonprice measures (see Brandes, Maas, and Reynolds 2006).

There is clearly a role for senior levels of government and industry associations here. It would be inefficient for individual water agencies to undertake efforts such as demand studies, marginal cost calculations, or pricing simulations independently of each other. Agencies such as the Council of Canadian Ministers of the Environment and the National Roundtable on the Environment and the Economy are ideally suited to work with industry by developing costing templates, data collection, research, and the sharing of best-management practices. A number of the recent calls for a renewed federal water policy have emphasized this coordination and information provision role (see, for example, Morris et al. 2007). At the provincial level, reforms in cost accounting and pricing almost certainly would require some degree of enhanced regulations, such as those seen already in Ontario. Indeed, the Ontario Expert Panel's proposed regulatory framework is worthy of consideration. The Canadian Water and Wastewater Association has also made important contributions. Its rate manual (CWWA 1992) provides a useful starting point in the design of efficient seasonal water rates.

Undertake Long-Run Initiatives

Once experience with relatively straightforward applications of marginal cost pricing develops, more sophisticated efficient-rate structures could be considered. These include nonlinear price schedules that reflect changes in marginal costs over the relevant range of output, satisfy break-even constraints, and allow water agencies to gain further information on customers' characteristics (see Brown and Sibley 1986; Wilson 1993). Consideration could also be given to efficient rationing methods such as those discussed earlier.

In addition, in the long run, accounting and pricing reforms could be part of a broader set of governance reforms concerned with issues such as the optimal scale of operations, improved transparency in decision-making and enhanced integration among local, watershed, and provincial agencies and ministries. Particularly important among these reforms is the need to reorganize local water agencies to enable them to exploit economies of scale fully and, thus, to lower costs.[14] An important requirement of these longer-term changes is that they be guided by a change in water agencies' operating philosophy. Most agencies currently view their primary task as supplying water; if future water use is to be efficient and sustainable, they need to see their primary task as balancing the costs of supplying water and the benefits of its consumption.

14 Valuable potential directions for reform have already been identified by researchers in the Canadian Water Network, the Water Governance program at the University of British Columbia, the POLIS group at the University of Victoria, and the Water Policy and Governance Group at the University of Waterloo. See, for example, Brandes et al. (2006); Bakker (2007) and Furlong (2008).

Challenges

Despite the conceptual and empirical arguments in favour of marginal cost pricing and the full-cost accounting needed to support it, few Canadian water agencies have adopted marginal cost pricing, and much opposition remains. Perhaps water agencies are more concerned about ensuring revenue stability, maintaining seemingly fair rates, and avoiding the ire of their customers or political masters. Whatever the reasons for their reluctance to adopt marginal cost pricing, it is important to examine the challenges water agencies face in doing so, two of which are the potential effect on low-income households and the practical difficulties that confront water agencies considering such a move.

Perhaps the most serious concern facing the reform of water prices in Canada is the potential negative effect on low-income households. This concern stems from the possibility that any effort to reform prices would harm the poor disproportionately more than others since they likely spend a larger proportion of their income on water supplies. But does this necessarily mean that the poor would be harmed by a move to marginal cost prices?

Fortunately, the answer need not be yes, for two reasons. First, for many low-income households, a move to marginal cost pricing might lead to a reduction in water bills. Burke, Leigh, and Sexton (2004) point out that more than three million Canadian households are in towns and cities with volumetric water-rate structures that include a minimum monthly charge that reflects a volume of water use greater than the normal residential level. Reducing or eliminating that monthly charge could lower water bills for many households (such as seniors) that use relatively low volumes of water. The second reason is that water-rate reform could deliberately avoid harming low-income households.[15] It is worthwhile to consider one real-world example where this was achieved. Hall and Hanemann (1996) report that Los Angeles appointed a panel of experts to investigate the reform of water prices as part of a broader strategy to address the city's recurring water-supply problems. The panel made several important recommendations, one of which was to switch away from conventional public utility cost accounting and toward the economically more meaningful marginal cost accounting. Another was to adopt sophisticated price structures that would better reflect the cost of supply to different parts of the city, different climate conditions, and even different lot sizes. At the same time, the panel, aware of the potential effects of rate reform on low-income households, recommended that some of the excess revenue generated by the proposed increasing-block-rate structure be used to subsidize water consumption by low-income consumers.

The second significant challenge facing the reform of water prices in Canada concerns the practical difficulties confronting water agencies. Many features of their operations, such as data collection, demand forecasting, cost accounting, project assessment, and asset management are not geared to promoting an efficient level of output through marginal cost pricing. Ontario's recent legislation requiring the adoption of full-cost accounting and pricing and the establishment of asset-management plans requires significant operational and administrative changes. It should be possible to go further, however, and design a regulatory environment in which agencies are rewarded for their efforts toward encouraging innovation, cost saving, and improved customer service. Here, guidance and assistance from agencies such as the Canadian Council of Ministers of the Environment and the National Roundtable on the Economy and Environment would facilitate innovation and avoid duplication of effort.

A related potential challenge arising from the shift to efficient prices is the possibility of greater revenue variability. Although this is unlikely to be a significant problem for agencies that already rely on volumetric prices, it would pose a more significant challenge for agencies that use flat rates to earn their revenues. It is important to remember, however, that an efficient pricing structure is likely to have a fixed component (to recoup fixed costs), in addition to a volumetric component (that reflects marginal costs). This fixed component would provide a significant degree of revenue certainty for water agencies. In

15 This section is drawn on the discussion of the distributional effects of water pricing reforms in Renzetti (2007).

addition, enhanced modeling of water demand would improve agencies' ability to predict demand and, thus, revenues.

Summary

It is disheartening to realize that many of the arguments regarding the costs of mispricing water and the need to rationalize those prices were made as long ago as 1985, in the report of the Inquiry on Federal Water Policy (Pearse, MacLaren and Bertrand 1985), and subsequently articulated in a statement of federal water policy in 1987. Thus, it was already clear more than 20 years ago that the underpricing of water, combined with senior governments' periodic infusion of infrastructure financing, was fuelling overconsumption by households and firms and overbuilding of supply networks by water agencies, and had pushed Canada to the bottom of international rankings of water efficiency.

There is a plethora of evidence – conceptual, statistical, and case-study based – that reforming water agency cost accounting and pricing provides real benefits. Efficient prices provide an invaluable signal to consumers and producers alike of the scarcity and value of all the inputs used to supply Canadians with potable water. Properly calculated, they also signal when expansions to supply capacity are truly warranted.

Such a transition would not be without challenges and difficulties, including defining and measuring marginal cost; making agencies' accounting procedures compatible with economic principles of costing; developing the institutional capacity to develop efficient prices; anticipating consumers' responses to price changes and convincing them of the benefits of realistic pricing; and, finally, avoiding the negative distributional effects that might follow from reform.

The alternative, however, is continued waste, overconsumption, and lack of innovation. This *Commentary* has provided a multistage set of policy reforms that could help to make the transition to an efficient and sustainable water industry. The most important of these reforms are as follows:

- continue the trend toward universal residential water metering;
- move to full-cost accounting;
- institute seasonal surcharges to better reflect the marginal costs of water use during peak summer months; and
- amalgamate smaller, high-cost water agencies to exploit scale economies and promote innovation.

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