Identifying Barriers to Widespread Implementation of Rainwater Harvesting for Urban Household Use in Ontario

Chantelle Leidl, Khosrow Farahbakhsh, and John FitzGibbon

Abstract: The use of stormwater runoff for domestic purposes (rainwater harvesting; RWH) is increasing as part of the green building movement; however, significant barriers impede the widespread uptake of the technology. This paper reports on the results of stakeholder interviews conducted with representatives from municipal administrations, the building sector and commercial suppliers, identifying barriers faced by each party in implementing RWH. The most significant barriers were as follows: initial capital cost, liability for potential health risks, limitations on the end use of rainwater, the Building Code's poor differentiation between rainwater, greywater and non-potable water, and a lack of public environmental commitment. Health risks would be a paramount concern for public health officials, but were only a moderate concern for the majority of building practitioners interviewed. These barriers are elaborated upon and discussed in the context of technological lock-in of conventional water management systems and the resulting lack of capacity in alternate water management approaches. Flexible, iterative, reflective, and participatory processes are required to build capacity for sustainable urban water management.

Résumé : La récolte des eaux pluvieuse est une pratique ancienne de collecter les eaux de pluies de la surface d'un toit, garder dans une citerne pour une utilisation ultérieure. L'intérêt dans la récolte de l'eau de pluie augmente et va s'accélérer quand des facteurs comme les changements climatique, le renouvellement des infrastructures et l'augmentation de la population rendront évident le besoin pour des approches diversifiées et une adaption de la gestion des eaux urbaines. Cependant, des barrières importantes empêchent la généralisation de cette technologie. Cet article met en évidence les donnés recoltées lors d'entretiens avec les intéressés, avec les représentants des administrations municipales, du secteur de la construction et les fournisseurs commerciaux , et identifie les barrières de la récolte de l'eau de pluie. Les barrières les plus importantes qui sont apparues sont: les coûts, les responsabilités, les contraintes liées au Code de Construction, l'usage limité de l'eau de pluie et l'absence de différentiation entre les eaux de pluies et les eaux usées, et un manque générale de reconnaissance du public concernent les questions de l'eau. Les risques afférants à la santé seraient d'importance capitale pour les responsables en santé publique, mais ne représentaient qu'un souci modéré pour les praticiens en bâtiments. Ces

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barrières sont développées et discutées dans le contexte d'un blocage des technologies de gestions conventionnelles de l'eau; résultants dans un manque d'approches alternative pour la gestion de l'eau. Afin d'instaurer une gestion durable de l'eau en milieu urbain, des processus flexibles, itératifs, réfléchis et fort participatifs sont impératifs.

Introduction

Urban water management in Canada is characterized by centralized infrastructure for potable water, wastewater and stormwater, with public health and safety as a prime goal. The three systems are treated independently, each aiming to "keep up" with growing and uncontrolled demand, meanwhile potentially risking the deterioration of fresh water supplies. These systems have been highly subsidized by taxpayers, hiding the actual capital, construction, operation, and replacement costs (Swain *et al.*, 2005). However, the impacts of climate change, aging infrastructure, and population growth reveal the impracticality of maintaining a centralized and independent approach, and more diverse approaches are emerging across Canada (for example, Brandes and Ferguson, 2004; Exall, 2004; Farahbakhsh, 2007; Corps *et al.*, 2008). These approaches integrate the three water systems by matching water quality to end use and focussing on demand management. They promote decentralization, while maintaining the health and safety goals inherent in the centralized approach.

Collection and storage of storm runoff for domestic use (rainwater harvesting, or RWH) is part of the emerging approach to urban water management. The practice was prevalent in Canada prior to the establishment of municipal systems in the early 1900s, and is still practiced in rural areas where groundwater resources are poor. RWH is increasingly common in urban areas outside of Canada to supplement municipal drinking water supply and minimize stress on stormwater infrastructure (for example, Government of Victoria, 2005; Government of New South Wales, 2006; Koeing, 2005; State of Hessen, 2006), and is slowly being introduced in Canadian cities.

Study Objectives

Despite potential advantages and international precedent, several barriers prevent the widespread uptake of urban RWH. As part of a larger project promoting RWH in Ontario (Despins, 2008; Leidl, 2008, Despins *et al.*, 2009), this study aimed to identify these barriers from the perspective of local RWH practitioners. Barriers are discussed in the context of technology lock-in and capacity development.

Several authors have identified barriers for sustainable urban water management in Canada. Canadian Water and Wastewater Association (CWWA) (1997) reports no absolute regulatory barriers to on-site water reuse, but rather points to a lack of regulations, specifications or guidelines as the most significant impediment. Marsalek *et al.* (2002) identify the need for water quality standards, end-use guidelines, and technology performance standards to fill this regulatory gap, in addition to other government and research initiatives. Brandes and Ferguson (2004) focus more broadly on demand-side management and discuss attitudinal barriers, financial barriers, data/information barriers, and administrative barriers. Issues such as the myth of abundance, low and subsidized water prices, lack of comprehensive cost-benefit models, an engineering bias that favours centralization, and fragmented administration, are particularly relevant to RWH.

Study Approach

At the time of the study, there were very few practitioners active in RWH in Ontario and it was therefore difficult to find a substantial number of informed respondents. Sixteen semi-structured interviews were conducted with active stakeholders representing: municipal water conservation officers (3); municipal building inspectors/backflow prevention officers (3); architects (2); engineers (2); builders (2); and RWH system/cistern suppliers (3). The experiences and perspectives of the respondents reflect the current state of practice and are further validated by the authors' experiences designing and installing several RWH systems.

It is important to note that no interviews were conducted with professionals directly involved with health and water quality. This perspective is represented by several studies reporting on the state of water reuse in Canada and decentralized water systems in Ontario.

Each interview began with a discussion of the respondent's activities with respect to RWH and their familiarity with pertinent regulatory devices. The remainder of the interview focussed on the following questions.

1. What are the regulatory and non-regulatory barriers impeding the widespread implementation for RWH?
2. What can be done to overcome these barriers and further encourage the widespread implementation for RWH?

Content analysis of the interview data involved the following steps.

- Transcribe interview verbatim and extract relevant points.
- Compile list of issues raised by all participants and cross-reference each transcript summary.
- Assign each issue a significance rating: [0] = not mentioned or insignificant; [1] = significant; or [2] = very significant, for each transcript. These ratings were determined based on the intensity of the response for each issue, i.e., how often the interviewee repeated the issue and how strongly they emphasized it, relative to other issues.
- Seek verification and/or amendment of ratings from each respondent (75% response rate).
- Sum the significance ratings for each issue to determine total score.

Regulatory Context for RWH

A regulatory framework is comprised of overarching policy that provides direction and sets expectations; regulatory devices that allow for enforcement of policy; and support mechanisms that interpret policy and regulation, and encourage implementation.

In Ontario, no overarching policies specific to urban stormwater use could be identified. Several statements refer to water conservation or sustainable stormwater management, and one statement, found in the 2006 Places to Grow legislation, encourages source substitution (Government of Ontario, 2006a). However, these statements are all embedded in broader documents and receive little attention on their own.

The Ontario Building Code (OBC) is the primary regulatory device governing RWH. It states that "*Storm sewage* (rainwater) or *greywater* that is free of solids may be used for the flushing of water closets, urinals or the priming of traps…" (Government of Ontario, 2006b, Section 7.1.5.3). As rainwater is permitted inside the building, the potential exists for cross connection and backflow of rainwater into the municipal supply. The Code therefore prohibits cross connection between potable and non-potable systems (Section 7.7.1.1), and requires a reduced-pressure (RP) backflow preventer to isolate the premise from municipal supply (Section 7.6.2.4 [8] and [9]). The OBC refers to CSA Standard B64.10, which classifies an auxiliary water supply and potable water as severe health hazards. Under OBC Section 7.6.2.4 [9], buildings with a potentially severe health hazard must be isolated with an RP device. The Code does not, however, mandate the testing or maintenance of backflow devices. In addition to backflow prevention, several clauses govern other aspects of RWH design, including the sizing of downspouts and conveyance pipes, pipe spacing and labelling, outlet locations, and overflow discharge.

CSA Standard B64.10 has less stringent backflow requirements than the Code. The 1994 edition allows cross connections if they are protected by an RP backflow preventer and the 2007 edition permits a dual check valve (DuC) in place of an RP device to isolate residential buildings with an auxiliary water supply, if the auxiliary supply is not directly connected to the municipal supply (Canadian Standards Association (CSA) 1994, 2007). While Standard B64.10 is referenced in the Building Code, these specific clauses are superseded by the sections of the Code described above. Further, both the OBC and CSA B64.10 can be superseded by municipal bylaw, if the bylaw is stricter than Code requirements. Approximately 24 municipalities in Ontario have a cross connection program specifying requirements for backflow prevention and managing the testing of these devices (Ontario Ministry of the Environment (OMOE), 2008). There is currently a Backflow Prevention Working Group led by the OMOE to recommend a framework for provincial regulation to assist municipalities in developing backflow prevention programs and to promote consistency among the Building Code, CSA standards and municipal requirements (OMOE, 2008). It is uncertain if changes to CSA B64.10 or the establishment of provincial regulation and municipal programs will result in backflow requirements that are more or less severe for RWH; however, backflow prevention was emphasized in the Walkerton Inquiry (O'Connell, 2002a) and subsequently included in the 2002 *Safe Drinking Water Act* (Government of Ontario, 2002 Section 20 [1]). It will likely remain a dominant issue for RWH.

On a national level, proposed amendments to the National Plumbing Code will allow for the use of rainwater for toilet flushing and underground irrigation systems (National Research Council Canada, 2008). The Canadian Standards Association published CSA B.128, which prescribes specifications for non-potable water plumbing and requirements for maintenance and field testing (CSA, 2006). This standard is being proposed for the National Plumbing Code, but at the moment has no legal bearing in Ontario.

Few resources could be found to support the implementation of urban stormwater use. Brief mention is given in documents such as the Toronto Wet Flow Guidelines and the Toronto Green Development Standards (City of Toronto, 2006, 2007), but there is no practical support for design or installation. RWH is not discussed in Ontario's Stormwater Management Planning and Design Manual (Government of Ontario, 2003). The Region of Waterloo has introduced a rainwater harvesting pilot project, subsidizing large cisterns for outdoor use (Region of Waterloo, 2009), and the City of Guelph has included substantial subsidies for 10 large-scale RWH systems per year as part of their Water Conservation Strategy Update (City of Guelph, 2009).

Overall, the regulatory framework for RWH in Ontario is extremely limited, but improving. While the Building Code permits limited forms of RWH, there are no broader policies to endorse the practice and technical support is minimal. Recent advances in the National Plumbing Code and new municipal initiatives indicate that the regulatory framework is slowly evolving to be more supportive of RWH, however, impending backflow prevention initiatives may result in increasingly strict requirements for RWH.

Results of Interviews

The strongest and arguably most important trend throughout the interviews was the opinion, expressed by all participants, that interest in RWH is growing and will continue to accelerate in the future.

Table 1 lists the barriers identified by the interview respondents, along with the sum of the significance rating.

The principal barriers that were identified were cost; liability; limitation on end-uses; poor differentiation between greywater; rainwater and non-potable water; and a lack of environmental commitment among the public. These issues are highlighted in Figure 1 and addressed respectively in the following sections.

Key Barriers Identified for RWH

Cost

High capital cost emerged as the most significant barrier, discussed by 81% of participants. Typical buried concrete RWH systems are $6,000 to $10,000 to install (Leidl, 2008). These high costs inhibit demand, which would lower the cost to more reasonable amounts. Most systems are one-off systems which rely on custom design and installation and so there is little cost saving by volume. Also, the local market for RWH is not well developed so components are often imported, adding to the cost. The relative cost of RWH is exacerbated by low municipal water tariffs which often do not account for the full cost of water services (Swain *et al.,* 2005), resulting in exceedingly long pay-back periods. Two participants suggested the limited end-use of rainwater further constrains economic performance as additional water savings, and thus cost savings, could be realized if more end-uses were permitted. A link between cost and liability was also mentioned, as designers and regulators may favour conservative, and therefore more expensive, designs in order to ensure health and safety concerns are mitigated to the maximum possible degree. The resulting cost of RWH is much higher than municipal water tariffs or other household environmental technologies.

Liability

Liability was the second most important barrier, discussed by 50% of participants, the majority of

Table 1. Summary of Barriers Identified in Interviews.

Category	Barriers Identified by Respondents	Sum of Significance Ratings
Regulatory Barriers	Lack of awareness within building sector about existing regulatory devices for RWH	7
	Inconsistency in interpretation of existing regulatory devices for RWH	7
	Inertia and culture of risk aversion in provincial agency responsible for the Building Code	6
	Ambiguity surrounding municipal permitting process and requirements for RWH systems	6
OBC Barriers	Indoor use of rainwater limited to toilets	11
	Inadequate differentiation between greywater, rainwater and non-potable water	10
	Lack of details and/or clarity about requirements	8
	Ambiguity with respect to backflow prevention; inappropriate requirements	7
	Refers to rainwater as "storm sewage" - negative connotation	7
	Requires connection to municipal water supply, if existing	6
	Difficult to get permit for pilot or demonstration projects that do not comply with Code	6
	Prohibits the direct connection of a RWH system to the storm sewer	4
	Does not make reference to CSA Standard B.128	3
	Relevant clauses scattered and buried; onerous to interpret with respect to RWH	3
	Inadequate specifications for non-potable pipe identification	3
Non-Regulatory Barriers	Up-front capital cost, lack of business case	17
	Liability	12
	Lack of environmental commitment among public	10
	Lack of information, data and research about RWH for policy makers	8
	Lack of experience and familiarity with RWH among stakeholders	7
	RWH products and materials are not readily available	6
	Public health and safety	5
	Lack of practical, how-to information for end-users	3

whom were municipal representatives. The ultimate concern is the potential for someone to get sick due to the consumption of contaminated rainwater. A second concern was the possibility of property damage due to system failure. These concerns are particularly valid, given the lack of guidelines to assist the design, installation, and maintenance of RWH systems. Much is left to the discretion of the homeowner/designer and the judgment of the inspector.

Conservation officers expressed concern about municipal liability when endorsing something that is not clearly regulated. They cannot encourage practices that are prohibited in the Building Code and are hesitant to promote anything that is subject to ambiguity. They are responsible for ensuring the safety and efficacy of what they promote and in the absence of guidelines from higher authorities, the municipalities are liable for any information they provide. They look to provincial or federal bodies for endorsement of RWH, recommended implementation strategies, and design requirements.

Municipal building inspectors have the added concern of personal liability and stressed their legal responsibility for approvals they grant. If permit applications are in compliance with the Code, they are not liable for any consequences that may result. However, they are responsible for the consequences of any "legal non-conformances" that they permit and for the interpretation of more ambiguous parts of the Code. While all three inspectors support RWH and want to approve more progressive uses (i.e., laundry),

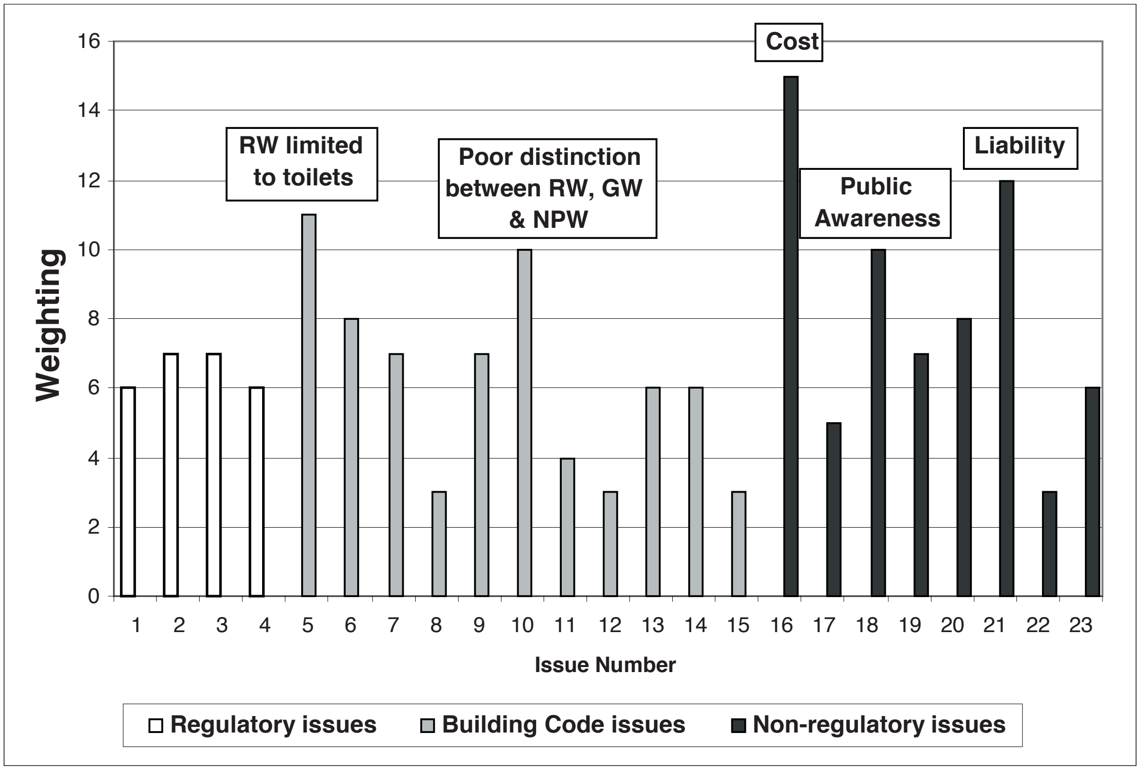

Figure 1. Summary of key barriers for RWH identified in interviews.

they all felt constrained to more conservative decisions due to the liability they face.

Developers and builders also strongly felt that any ambiguity in the Code increases their liability. They need a clear Code to understand what the minimum standards are, to assess whether those standards are sufficient, and to be confident that they are able to meet them. As developers may not have the technical expertise to design their own systems, they depend on the Code to ensure a minimum level of safety. Liability issues tend to delay the permitting of environmental features, further discouraging developers.

Contrary to these perspectives, the engineers and architects who design RWH systems and the suppliers who sell RWH products did not express significant concern over liability issues. They understand the systems they promote and are able to design the technology to mitigate risk to their own satisfaction and to that of the Code. While this may lead to over-design and subsequent cost escalation, it does alleviate liability concerns.

Limitation on Permissible End-Use

The limited use of rainwater for toilet flushing, as prescribed by the Building Code, was viewed by 63% of respondents as a major barrier to the widespread adoption of RWH and the expansion of permissible applications was the strongest recommendation. End-use was considered critical because current constraints prevent maximum water savings from being achieved.

Figure 2 indicates the additional water savings that can be achieved under different end-use scenarios. For example, using an 8-m^3 cistern, total household water savings increase from 24% to 35% just by including laundry as an end application.

Expanding permitted end-uses is critical because it corresponds directly with financial savings. For the rural context, the custom builder suggested that if rainwater was permitted for all household applications, a RWH system could potentially replace the need to drill a well and would be an economically viable alternative. Improved economics facilitates an increase in demand, which in turn creates incentive in the commercial sector

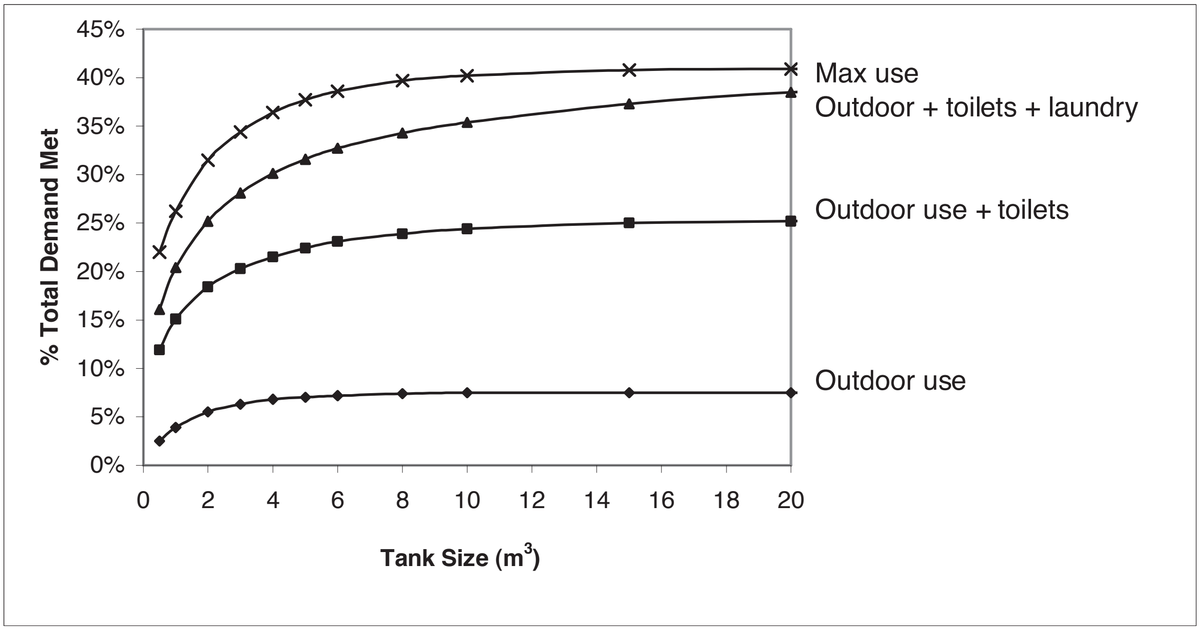

Figure 2. Water savings achieved with different end-use scenarios for RWH. Assumes 160-m^2 roof area, three residents, Guelph rainfall data (Leidl, 2008).

for innovation and investment, resulting ultimately in market development. The suppliers expressed desire to invest in product development, but need assurance of a viable market without excess regulatory constraints. This is a positive feedback loop as increased market capacity further lowers the cost of RWH, perpetuating a growth in demand, implementation, and overall water savings. This process is shown in Figure 3.

Poor Differentiation of Rainwater, Greywater and Non-Potable Water

The current structure of the Code was considered by 50% of the respondents to be unclear in its differentiation of rainwater, greywater, and non-potable water. Rainwater and greywater are lumped together in Section 7.1.5.3, which defines permissible end uses, while non-potable water has a separate section at the end of the plumbing chapter outlining installation specifications. This ambiguity was seen to exacerbate existing confusion among users of the Code about non-potable water, and specifically, cause water quality concerns associated with greywater to be imposed on rainwater. Separating greywater and rainwater was seen as a necessary prerequisite for expanding the end uses of rainwater as additional applications such as laundry are more feasible for rainwater than for greywater.

Lack of Environmental Commitment

Seventy-five percent of participants discussed the public's lack of commitment to water conservation as a major impediment to the widespread uptake of RWH, expressed as a very significant concern by 31% of respondents. Several participants had also experienced a lack of environmental commitment among municipal and provincial employees and throughout the building sector in general, serving to stifle any interest or demand from the public. This manifests itself as delayed approval processes, inflated installation costs, or the refusal of services altogether.

Most participants felt that public education is necessary to increase demand, which will, in turn, encourage progressive policy development, representing a bottom-up approach. Two respondents, however, argued that a lack of awareness and education is not the problem; that significant interest exists but is stifled by restrictive policies. Leadership is needed to create policies that allow existing interest to be acted upon and spur further demand. Specifically,

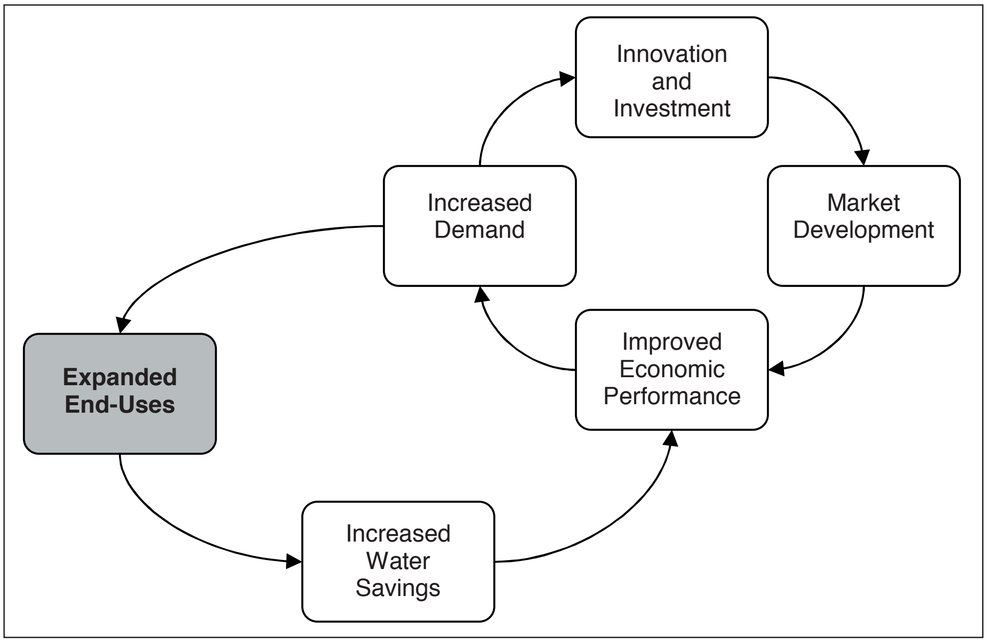

Figure 3. Spin-off effects of expanding end uses for rainwater in OBC.

end uses should be expanded to the full range of domestic applications such that RWH becomes more economically competitive. Education, one participant argued, is only necessary where there is no business case and appropriate policy would allow for an effective business case to drive demand.

Public Health

While public health was identified by the participants as a concern, most felt that potential health risks could be mitigated through proper design and management. Health concerns, however, would be paramount from the perspective of public health officials and provincial building regulators, who were not represented in the interviews. Water quality and public health are critical issues for water reuse and recycling (Schaefer *et al.,* 2004; Waller *et al.,* 1998; CWWA, 1997; Marsalek *et al.,* 2002; Health Canada, 2007). Even though the quality of rainwater is much higher than untreated greywater (see Health Canada, 2007; and Despins *et al.,* 2009 for comparison), similar concerns exist for RWH because it is a non-potable water supply managed by homeowners.

It is generally accepted that a well-designed and operated RWH system poses minimal risk to public health, either to users of the system or to users of the associated municipal supply. However, because RWH systems are the responsibility of the homeowner, it is likely that some systems will not be operated or maintained properly and users could be unintentionally exposed to contaminated water. Other decentralized technologies, such as private wells, septic tanks, and household water treatment devices, have been identified as posing risks to water quality due to improper operation and maintenance, as well as a lack of certification and system monitoring (Novakowski *et al.,* 2006; O'Connell, 2002a). The state of these systems justifies similar concern for RWH.

While it is possible at the time of installation to ensure there is no cross-connection between the rainwater and municipal system, it is easy to make a cross-connection anytime thereafter. Four hundred and seventy cisterns were found in Walkerton, Ontario, following the *E. coli* outbreak in 2000, "many of which were cross connected to the municipal distribution system" (O'Connell, 2002b). It is important to note, however, that it was considered unlikely that contamination from a small system could be distributed throughout the municipal water system. Nonetheless, cisterns were considered a significant risk and included in recommendations for municipal backflow prevention programs.

Discussion

Technology Lock-In

None of the barriers discussed above relate to the technical feasibility of RWH systems; rather, they relate to the social, institutional, and regulatory context into which RWH is being introduced and reflect the dominance of conventional systems, both technological and institutional. These systems are characterized by large, centralized technology that is publicly managed, aiming to deliver a bulk supply of potable water to meet increasing demand.

A single technology or approach may become "locked-in" as the dominant solution, not because of its inherent superiority; but rather, due to a series of positive feedback processes (Arthur, 1994). These processes are seen in terms of economic payback, social acceptance, knowledge accumulation, and coordination, each improving with greater levels of implementation. Both the technological system and the formal and informal institutions that govern it are subject to processes of lock-in (Foxon, 2002). While often used to describe energy, transportation, or IT infrastructure, the concept of technology lock-in is also applicable to urban water systems.

Unruh (2000) delineates several levels of lock-in that also apply to water management. Firm-level lock-in occurs when private companies focus exclusively on existing technological systems and develop them into core competencies. Greater financial reward is often associated with the perfection and promotion of these core products, while new approaches require additional resources and offer less certainty of success. This firm-level lock-in precipitates sector-level lock-in as competition among firms requires each to offer the quickest and cheapest solutions. As firms promote similar solutions, the technological accessories, labour skills, and administrative processes required for implementation become uniform and lock-in occurs at the network level. This is reinforced by support institutions such as education and training facilities, professional or industrial associations, technical standards or media outlets, all of which focus on conventional solutions. This network is self-reinforcing as each addition strengthens the other components and further entrenches the status quo. Finally, lock-in can occur at the level of public policy, for example, through subsidies or regulations that favour a single approach.

Lock-in at all of these levels has created social norms that are based on conventional water supply systems, including the expectation of cheap, infinite and high quality water and the resulting patterns of inefficiency, waste and complacency. These norms in turn reinforce the perceived need for conventional water supply systems and resist new solutions that do not meet these expectations.

Centralized systems have been developed to address the human and environmental health concerns associated with private, decentralized water and wastewater systems (Benidickson, 2002). Centralization allows for a high level of operational control and quality assurance, managed by well-trained professionals. In contrast, it is evident from the current state of private wells and septic systems that decentralized technology has not been carefully managed in the past (Novakowski *et al.,* 2006; O'Connell, 2002b). However, there will always be a need for decentralized systems in rural and remote areas and there is growing interest in on-site reuse systems in urban areas. It is essential that the current water management paradigm be expanded to include both centralized and decentralized systems, and that effective management systems are established and enforced.

Capacity Development

The process of lock-in means that the most significant barrier for RWH, or any innovation, is the inertia of the status quo. This inertia prevents the development of capacity for alternative approaches to urban water management.

Farahbakhsh and Lewis (2007) define capacity development as the acquisition and application of knowledge. The respondents of this study had acquired knowledge regarding water management issues and the potential for RWH; however, many were struggling to apply that knowledge in the implementation of RWH, despite their interest and efforts. For example, the building inspectors interviewed want to approve greater end uses and believe it can be done safely, but are bound by liability issues associated with enforcing the Building Code. The developers believe there is a market for RWH, but due to high cost, a lack of technical support, and permitting delays, they are hesitant to invest. Each party requires resources, buy-in and support beyond their own means or realm of influence in order to apply their knowledge in practice. All parties must work together to address the issues that currently restrict RWH.

Farahbakhsh and Lewis (2007) identify three areas of capacity needed for the advancement of sustainable urban water management: environmental capacity (referring to the social and political context); organizational capacity; and individual capacity. All of the barriers identified by the interview respondents relate to one or more of these three areas of capacity development, and to achieve the goal of sustainable urban water management, all three levels must be advanced simultaneously. Further, in addressing these barriers, the goal of capacity building must not be to simply transfer knowledge; rather, all initiatives must enhance the ability of individuals and organizations to apply that knowledge to their own situations (Farahbakhsh and Lewis, 2007). This focus on application implies the need for dedicated resources, a commitment to innovation and experimentation, and an enhanced tolerance for risk.

Conclusion

Interest in, and demand for, technologies such as RWH is growing and will accelerate as broader issues such as climate change, infrastructure renewal, population growth and water pricing converge. Many players are currently active in promoting and implementing RWH; however, their efforts are stifled by issues such as cost, liability, limitations on permissible end use, and a lack of environmental commitment among the public. Health risks are a major concern for public health officials and regulators, but are seen by many building practitioners to be manageable.

These barriers are indicative of the dominance of conventional technological systems and their institutional support structures, both of which have become locked in as an exclusive norm. The implementation of alternative approaches for urban water management will require recognition of this inertia and strategic investment of resources to allow technologies such as RWH to compete with conventional alternatives. Concerted efforts will be required to develop capacity at the individual, organizational and environmental level; however, such capacity development needs to take place incrementally. As alternative water management practices represent a significant shift of paradigm, their implementation requires an inclusive feedback loop that involves stakeholders, whose engagement and capacity is critical to the success of such practices. Most importantly, the process of building capacity must be flexible and must allow for reflection on, and reinvention of, strategies and approaches. A true evolutionary and participatory process is needed to build water management systems that are sustainable and adaptive.

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