<u>Adopting Sustainability:</u>

Greywater Recycling and Ontario's Transitioning Water Management Regime

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i Foreward:

This Major Paper brings together the three major components of my Plan of Study: Environmental Planning, Resource Management, and Politics of Water in order to fulfill the requirements of a Master in Environmental Studies degree.

Environmental planning is the overarching theme of this paper and its core notions are embedded within its text. Using an environmental planning approach issues related to urban water management have been identified. A critical examination of these issue can be used to improve interactions between human and natural environments to improve sustainability. Through this element of my research, I have satisfied my learning objectives to strengthen my knowledge of environmental planning and the interplay between resource management practices and planning. I have also, advanced my knowledge of current theories and practices in contemporary environmental conservation in relation to water management.

I employed the concepts of resource management and the politics of water to explore sustainability technologies in relation to water management. I completed a thorough review of greywater recycling technologies and a policy assessment of Ontario's provincial/municipal planning structure. This allowed me to achieve my objectives of improving my understanding of natural resource management and conservation, resource management practices within the urban environment, and developing an understanding of resource management law. Additionally, this aided me in developing a strong understanding of the political and regulatory regime associated with water management in Ontario.

A theoretical analysis of these two elements was completed through the application of the multi-level perspective. The multi-level perspective provides a theoretical framework for understanding transitions within sociotechnical systems. The multi-level perspective allowed for me to illustrate an ongoing technological transition within Ontario's water management regime that is inclusive of greywater recycling technology. Greywater recycling technology's adoption was chosen as an area of focus due to this technology's widespread potential as a water demand management tool.

ii Abstract:

Greywater is a technology with the potential to reduce water demand. This paper looks to answer, is Ontario's water management regime is undergoing a sustainability transition that is conducive of greywater technology's adoption? The multi-level perspective has been applied as a theoretical framework to comprehend this as a technological transition within a sociotechnical system. The multi-level perspective perceives transitions to be the result of interactions between actors at multiple levels of a system. Policy was identified as the dominant factor in determining the answer posed by this research. Selections from Ontario's policy-led planning structure illustrate how the province's water management regime is currently transitioning toward sustainability objectives that are accepting of greywater technology. However, widespread adoption of the technology has not occurred. A review of key barriers suggests that amendments in policy could potentially facilitate adoption of the technology.

Contents

1.0 Introduction:

1.1 Objective:

This paper examines the existing regulatory, policy, and institutional regime around urban water resource management in Ontario. Particularly, this paper evaluates the treatment of greywater recycling within this framework. Greywater recycling is a technology that offers significant potential to contribute to the sustainable management of water resources at both local and global scales. Potable water supplies are under an increasing threat. Greywater recycling can potentially save substantial volumes of potable water (Revitt, Eriksson, and Donner, 2011). Utilizing a sociotechnological transitions framework, the paper examines policy to illustrate how the current urban water resource management regime in Ontario is undergoing a sustainability transition that is conducive to greywater recycling technology's adoption. Additionally, the paper identifies a number of key barriers to the adoption of greywater recycling technology in Ontario and provides recommendations to overcome barriers and facilitate adoption.

1.2 Background:

Across the world there are great disparities in the availability of safe water supply for human consumption and use. It is estimated that 1.2 billion people face the issues of a lack of a safe water supply and sanitation every year (Aoki and Memon, 2005). Approximately one third of the global population resides in countries affected by varying levels of water stress, where consumption exceeds more than 10% of renewable freshwater resources (Aoki and Memon, 2005). Additionally, water stressed nations have experienced degradations in water quality as a result of over-pumping and pollution (Aoki and Memon, 2005). Both water demand and water stress are going to continue to increase due to external factors that place constant pressure on our water resources.

A major factor contributing to this increased demand is population growth, a particular concern for developing countries. The global population is increasing at a tremendous rate. Between 2002 and 2011 the global population increased from an estimated 6.2 billion to 7 billion (WBGES, 2012). Future projections suggest that by 2050, Earth's population will reach 9.3 billion (WBGES, 2012). This presents a particularly serious situation for developing countries as well as countries within semi-arid regions of the world, which are already undergoing water shortage issues (Exall et al., 2004). Under the current pressures of water stress and population growth by 2025 two thirds, or approximately 5.5 billion people, will live in regions of moderate to severe water stress (WBGES, 2012). Estimates suggest that due to population growth and rapid urbanization, by 2030 more than 60% of the global population will reside in cities (Bolund and Hunhammar, 1999). The increased population is going to have massive implications for water supply. Urbanized areas are going to have to adapt to facilitate the increasing demand on urban water supplies.

Furthermore, climate change is going to have wide ranging impacts on global water resources. The depth of groundwater tables and recharge rates will be directly affected by climate change. Surface water resulting from precipitation events is considered to be the main factor that will affect groundwater (Bates et al., 2008). Increased frequency of high volume precipitation events will have regionally specific impacts. Infiltration capacity will potentially be exceeded in humid regions causing a decrease in groundwater recharge rates. Inversely, arid regions might benefit in terms of groundwater recharge due to high frequency rainfall events (Bates et al., 2008).

Issues also exist at areas of higher altitudes where thawing of permafrost will result in changes to groundwater table levels and water quality (Bates et al., 2008). However, increased frequency of high volume precipitation events entails higher risk of flash and urban flooding (Bates et al., 2008). The threat of flood events poses serious risks to human health and safety. At the same time, variability in extreme weather patterns will result in higher temperatures, which will increase the frequency of droughts. Drought events will have a direct impact on water resources, as widespread water stress will increase. However, droughts also have consequences for human health. Reduced food production and drinking water shortages will result in widespread malnutrition. Additionally, droughts increase the risks of waterborne and foodborne diseases (Bates et al., 2008). Increased water temperature, intensified precipitation, and prolonged periods of low flows will intensify water-based pollution (Bates et al., 2008). In turn this will promote bacterial, fungal, and algae growth. Ecosystems, human health, and reliability and the operating costs of water systems will be greatly affected as a result (Bates et al., 2008). Further degradation of water quality will be caused by other factors associated with high intensity rainfall events. One major factor in the reduction of water quality is soil erosion and the resulting sedimentation in receiving waters, thereby altering their turbidity (Bates et al., 2008). The other is transportation of pathogens and other pollutants within runoff to surface and groundwater (Bates et al., 2008). The implications of climate change in relation to water resources are wide ranging. It is only reasonable to infer that these problems are going to severely affect urban areas, as high population density is already placing pressure on finite water resources.

There are contemporary issues related to almost every facet of water and water management. Canada possesses about 6.5% of the planet's accessible freshwater supply. This supply is in decline as a result of increasing pressure from population growth and industry. Statistic Canada recorded that between 1971 and 2004 there has been a decline of 8.5% in water yield. Water yield is defined as the average amount of freshwater acquired from unregulated flow across a defined watershed over a particular period of time (Bemrose et al., 2009). This process is anticipated to accelerate under climate change (Barlow, 2016).

Drinking water endangerment is still common practice in wastewater management. Raw sewage is still released into our watercourses on both coasts of Canada as well as everywhere in between. Environment Canada has reported that raw sewage is the largest source of pollution related to water. It is estimates that over 150 billion litres of raw sewage are released into waterways every year (Barlow, 2016). The City of Toronto undergoes multiple sewage bypass events every year. Bypass events can occur two different ways. Sewer system overflows occur when sanitary sewers are inundated with storm water. A mix of storm water and sewage is directly released to local waterways to avoid damage to local infrastructure in the form of flooding (Overflows and Bypasses, 2016). Toronto was historically built with combined sanitary and storm water sewers. Overflow events involving combined sewers are referred to as combined sewer overflows .

The second way bypasses occur is through wastewater treatment plant bypasses. This occurs when flow exceeds treatment plant capacity. The outcome of bypasses are similar to overflows. Raw sewage and storm water are once again discharged into receiving watercourses to prevent risk of flood. Treatment plants treat as much wastewater as possible before initiating a bypass. Bypasses reduce the quality of treatment wastewater receives before being discharged (Overflows and Bypasses, 2016). In Toronto, all flow receives screening, grit removal, primary treatment, phosphorous removal, and disinfection during wastewater treatment bypass events (Toronto C.O., n.d.). One of the best documented cases was during the July 2013 storm. The stress placed on Toronto's aging sewage infrastructure resulted in a bypass event of over 1 billion litres of raw sewage in a single day (Barlow, 2016).

The Canadian government should have a strong stance on the management of water resources. Canada is a costal nation and Ontario borders four of the five Great Lakes. Canada's management of water resources is criticized by water experts as being an uneven patchwork of policies and inadequate regulations (Barlow, 2016). Federal, provincial, and municipal governments share responsibility for water resources but the province has primary jurisdiction over water management and protection. However, the federal and provincial governments are more concerned with regional issues such as agriculture, health, and issues of national concern.

This leaves the local level management of drinking water, distribution, and wastewater in the hands of the municipalities. Both drinking water and wastewater treatment is left to the level of government with the lowest level of funding (Barlow, 2016). This disjointed approach to water management has prevented the adoption of a national drinking water standard (Barlow, 2016), a regulation that should be intrinsic to an industrialized nation. Over the past decades policies related to water management have only weakened protection of these resources. The water management budget had fallen as low as 0.5% (of the federal budget) between 1971-2000.

Under the Harper government many changes were made to policies and regulations that weakened protection of water resources in Canada. One notable instance was a change to the Fisheries Act, which loosened regulations on industrial operations discharging waste into open water (Barlow, 2016). Section 35 (Fisheries Act) now only applies the concept of serious harm to fish that fished commercially, recreationally, or are part of an aboriginal fishery.

As previously mentioned, climate change and population growth are external factors that directly place pressure on our water resources. Both of these factors have vast implications. The threat of climate change is further intensified by the great uncertainty associated with it. Fortunately, it is the vast implications of these two factors that have made them hard to ignore by policy makers. Mitigation strategies have emerged within various planning policies to combat the pressures from these factors. This form of ideological shift within policy is a good indicator of the start of a sustainability transition. Additionally, some of these initiatives have developed enough internal momentum that they have been pushed even further into the regulatory policy framework (Ontario Building Code) in the form of technological adoption of niche developments.

Canada has been presented with a unique opportunity to be on the vanguard of wastewater management. The following paper will illustrate how Ontario is currently undergoing a policy-led sustainability transition, especially in terms of resource management. In particular this paper will use greywater recycling technology as a case study. The technology will be highlighted to indicate how inclusion within policy has created a window of opportunity for niche-level sustainable technologies to emerge within and reconfigure the sociotechnical system of wastewater management. This paper will also address the barriers that are preventing the widespread adoption of the technology. These barriers will be assessed to identify specific strategies that could be used to expedite greywater technology's widespread adoption.

2.0 Methodology:

Is Ontario's urban water resource management regime in a sustainability transition that is conducive to the adoption of greywater recycling technology? This paper looks toward Ontario's policy-led planning structure to answer this question. Planning policy is becoming increasingly inclusive of a sustainability agenda. Technologies like greywater systems present potential solutions to multiple regime problems. However, these technologies are not widely implemented as urban water demand management tools.

After assessing the sociotechnical system of wastewater, policy is determined to be the most important element in this review. In terms of planning, policy has two forms; guiding and regulatory. In the context of this paper, guiding policies act as catalysts for sustainability transitions. Regulatory policies are the vehicles through which technologies are implemented and regulated. The policies chosen for review were selected to construct a simplified framework for urban water resource management within the provincial/municipal planning structure. All information required to complete this analysis was openly accessible data. Relevant policies were obtained through the webpages of each policy's respective level of government. Additionally, other information, such as City of Toronto wastewater statistics, were obtained from the respective sections of the City of Toronto website.

In order to determine whether the current regime is conducive to greywater technology's adoption a comprehensive theoretical framework was applied.

Technological transitions are typically complex. Geels (2005) has proven that technological substitution approaches are too simple to develop an understanding of complex transitions. Therefore, the multi-level perspective was chosen as the theoretical framework to develop an understanding of greywater recycling technology's adoption. The multi-level perspective perceives transitions as a series of non-linear interactions between actors at three analytical levels; niches, sociotechnical regimes, and the sociotechnical landscape (Geels, 2011).

The largest anticipated problem was the lack of complementary research. Multi-level perspective is a well developed theoretical framework. However, the application of the theory may prove difficult. Most of the available research related to technological transitions and multi-level perspective has been conducted on vaguely associated societal functions. Some conclusions within this paper were based on the findings of case studies of unrelated sociotechnical systems.

A comprehensive review of the theoretical framework which guides this paper will be conducted. This will include an introduction to sustainability transitions, technological transitions, and an extensive explanation of the multi-level perspective. A discussion related to greywater recycling will follow. This section is not intended to be a review of greywater technologies from a scientific perspective. The intent is to introduce the concept of greywater recycling and explore the benefits of this technology and the barriers hindering its adoption. A comprehensive review will be conducted of a select set of policies associated with urban water resource management in Ontario. Examination of these policies will highlight policy objectives that illustrate a sustainability transition in the urban water management regime. These instances will further be used as examples to indicate how greywater recycling technologies can meet multiple policy objectives. These finding will be used to answer the question posed by this paper. Finally, strategic recommendations for adoption will be based on indentified barriers.

3.0 Sociotechnical Transitions Theory:

3.1 Transitions Towards Sustainability:

Transitions that involve the improvement in the sustainability of a given practice are referred to as sustainability transitions. Sustainability transitions can be identified through the recognition of a defined set of characteristics. Smith et al. (2005), identify the first characteristic of sustainability transitions as being goal oriented or purposive (as cited in Geels, 2011). The purposive nature of a sustainability transition is typically to address a long-standing environmental issue (Geels, 2011). However, as sustainability is a common good, private actors have little incentive to take part in sustainability transitions unless legally obligated to do so due to the problems associated with free-ridership (Geels, 2011). The free-rider problem occurs when members of a population benefit from a good, service, or resource but do not contribute to them financially (Baumol, 1965). For this reason public authorities and society in general are pivotal in advancing sustainability transitions. The power to propagate these transitions comes in the forms of public education, changes to the economic framework, and increased support of sustainability practices (Elzen et al., 2011 as cited in Geels, 2011).

Once again the collective nature of sustainability plays an important role in the second characteristic required to identify a sustainability transition. During sustainability transitions two attributes of a sustainable solution typically present themselves. The most obvious to the consumer is that the sustainable solution is typically less competitive in relation to price versus performance metrics (Geels, 2011). The second attribute is that many sustainable solutions do not provide the users with a direct user benefit (due to the collective nature of sustainability) (Geels, 2011). This characteristic is of great importance in relation to sustainability transitions as with most developments the bottom line is the most important factor. Due to this, the replacement of existing systems with environmentally sustainable innovations has a low chance of success. Changes to framework of economic conditions (eg. Subsidization, regulatory changes, and taxation) will be crucial (Geels, 2011). However, this type of disruption to "business as usual" would require policy changes likely to be contested by vested interests such as large incumbents backing the existing systems (Geels, 2011).

The third characteristic involves the empirical domain in which sustainability transitions are required, such as resource management. Large firms define these domains. These firms are in control of expansive resources, specialty assets, and large-scale operational capabilities (research and development, distribution, service networks) (Rothermel, 2001 as read in Geels, 2011). Incumbent firms have the ability to become innovators due to their vast resources. However, they may not spearhead sustainability transitions. Instead, large incumbents have the ability to accelerate the advancement of sustainable innovations through the provision of assets and resources (if they support the innovation). This presents a conflict, as incumbents would require strategic realignment while simultaneously backing the existing systems and regime (Geels, 2011).

3.2 Technological Transitions and Sociotechnical Regimes:

Technology is always in some form of transition. As technology evolves, newer technologies typically replace the functions of older existing technologies. In the context of this work, transitions refer to the structural changes in societal operations (Van der Brugge, Rotmans, & Loorbach, 2005). Rotmans et al. (2000), have defined transitions as being long term processes, between 25 to 50 years, that results from the co-evolution of cultural, institutional, economical, ecological and technological processes and progress made on various scales. Over the course of a transition, various events occur between actors and elements across multiple levels that positively reinforce the transition (Rotmans et al. 2000). This definition of transitions allows for expansion of the transition concept. Transitions can better be described as the reconfiguration of a relatively stable system to another through the co-evolution of markets, networks, institutions, technologies, policies, individual behaviour and autonomous trends (Van der Brugge, Rotmans, & Loorbach, 2005).

A technological transition (TT) is defined as a major technological transformation in the way societal functions such as transportation, communication, housing, feeding, are fulfilled (Geels, 2002). During a technological transition, individual technologies are only part of the elements in transition. Technological transitions also involve changes in user practices, industrial networks, regulations, infrastructure, and symbolic meaning (Geels, 2002). This is because for a technology to have a need it must be linked to human agency, social structures, and organizations (Geels, 2002). This has been illustrated through the exploration of the transition from horse-drawn carriages to automobiles (Geels, 2005). The need for a technology empowers a technology's function. Functionality gives a technology its purpose. Without functionality a technology is rendered useless (Geels, 2002). Functions are the products of interactions between regime level actors (Markard and Truffer, 2008). A model of technological functionality has been well developed by Hughes (1987). This model uses the concept of a "seamless web" which models technological functionalities as the result of a combined efforts between natural resources, artifacts, organizations, scientific elements, and legislation (Geels, 2002). These interrelated elements within the network are referred to as a regime.

Nelson and Winter's (1982) concept of the technological regime was structured on the idea that cooperation between different groups within the regime was the result of organization and cognitive routines. Replication of routines within practices such as engineering eventually leads to the creation of a technological regime. As the various groups within the regime are aligned in the same direction, reproduction of these activities forms technological trajectories, which guide innovation. The core concept of the technological regime is that the interactions between groups within the regime are aligned and coordinated (Geels, 2002). However, the concept of technological regimes has been broadened by Rip and Kemp (1998) and is defined as "...the grammar or rule set comprised in the complex of scientific knowledge, engineering practices, production process technologies, product characteristics, skills and procedures, and institutions and infrastructures that make up the totality of a technology" (Kemp et al., 2001 as read in Truffer, 2008). Rip and Kemp's (1998) definition is far more inclusive and reevaluates the composition of a technological regime. The Nelson and Winter (1982) definition is focused almost exclusively on the practices and processes of the engineering community. Rip and Kemp's(1998) definition activates additional social groups aside from the engineering community. This has helped to illustrate how technological trajectories are not merely influenced by engineers but by multiple social groups such as policy makers and users of technology (Geels, 2002). In reaction to the expansion of the technological regime definition, Geels (2002) believes that a more suitable descriptive term would be "sociotechnical regime" as both groups, technical and social, are subject to a set of semi-coherent rules (Geels, 2002).

3.3 Multi-level Perspective:

"The multi-level perspective (MLP) is a middle-range theory that conceptualizes overall dynamic patterns in socio-technical transitions" (Geels, 2011). The analytical framework of the multi-level perspective is a combination of various theories. The concepts of trajectories, regimes, niches, speciation, path dependence, and routines are derived from evolutionary economics. “Deep structures” formed by rules and institutions and how they shape knowledge and actions of actors is extracted from structural and neo-institutional theory. While concepts of science and technology studies manifest themselves in social networks, sense making, and innovation as a social process shaped by a broader social context (Geels, 2011). Geels (2004) and Geels and Schot (2007, 2010) have addressed the specifics of the multi-level perspective’s analytical framework. The multi-level perspective has been an effective framework in various studies of historical transitions but has also been effectively applied to contemporary studies of transition including sustainability transitions (Geels, 2011).

The logic behind the multi-level perspective originates from the sociology of technology which discusses the relationship between three dimensions: sociotechnical regimes, actors and social groups, and sociotechnical systems (Geels, 2005). The creation, reproduction, and refinement of sociotechnical systems are the result of social groups (Geels, 2005). These actors operate in accordance with the social structure in which they are embedded and follow a set of cognitive rules (Geels, 2005). Action is guided by these coordinating rules. It is important to understand that rules are both reinforced and amended through action and enactment (Geels, 2005). Additionally, rules are not individual. They are part of a much larger set of rules that are linked together referred to as a regime (Geels, 2005).

The sociotechnical regime operates at the meso-level of the multi-level perspective. A regime is comprised of artifacts, institutions, rules and social norms structured to maintain economic and social activities (Berkhout et al, 2004). Dominant practices, rules, assumptions, beliefs, and social norms control regime dynamics. These elements form the basis of strategies of various actors within the regime. However, many of these actors are interested in the preservation of the existing systems through optimization (vested interest) as opposed to investments in systems innovation (Van der Brugge, Rotmans, & Loorbach, 2005). The coordinated and coherent interaction within the sociotechnical regime is recognized as the "deep structure" (Geels 2004).

The structure of the regime exhibits itself within existing sociotechnical systems in the form of stability (Geels, 2011). Stability is created through the reproduction of the regime's rule set in the form of cognitive routines and shared beliefs, user practice, regulation, legally binding contracts, and competences (Geels, 2011). The sociotechnical regime enforces stability for existing large-scale sociotechnical systems and guides innovation through the productions of trajectories (Geels, 2002, 2005, Schot and Geels, 2008). However, system stability also has a social aspect. Stability is created through mutual expectations between actors and organizations within the existing system (Geels, 2005). However, stability is not synonymous with stagnation. This system stability is dynamic. Innovation still occurs along the technological trajectory of the system incrementally (Geels, 2002, 2005). Technological trajectories are the result of highly coordinated activities. They are further stabilized by a series of lock-in mechanisms

(Geels, 2011). These mechanisms can take the form of social elements such as political discourse or shared beliefs or they can be tangible such as physical infrastructure (Unruh, 2000 as cited in Geels, 2011). Lock-in mechanisms are very problematic because they result in path dependence (Geels, 2011). Many existing systems, including those that are unsustainable, are stabilized through lock-in mechanisms, which produce major barriers for undertaking structural change (Geels, 2011).

The micro-level is referred to as the niche-level. This level is where individual actors, alternative technologies, and local practices are found (Van der Brugge, Rotmans, & Loorbach, 2005). At the niche-level, actors challenge the status quo based on new ideas and innovations through new techniques, alternative technologies, and social practices (Kemp et al. 1998 as cited in Van der Brugge, Rotmans, & Loorbach, 2005). "A niche can be defined as a discrete application domain (habitat) where actors are prepared to work with specific functionalities, accept such teething problems as higher costs, and are willing to invest in improvements of new technology and the development of new markets" (Hoogma et al., 2002).

The importance of niches has been recognized in multiple disciplines as being an epicenter for radical innovation (Geels, 2005). Furthermore, niches are considered crucial for transitions as they facilitate systemic change (Geels, 2011). During development niche innovations cannot directly compete with the established technologies of the regime. Therefore, the niche-level acts as a safe space for the early-stage development of radical innovations (Geels, 2005). These spaces are important as they also provide a platform for learning the several aspects of technological development: user preference, regulations, symbolic meaning, etc. (Geels, 2005). The hope for niche-actors is that their niche-development eventually is refined enough that it can be applied within the regime (with the ultimate goal being the replacement of the existing regime system) (Geels, 2011).

However, new technologies are often incompatible with the established sociotechnical system (Freeman and Perez, 1988). As explained previously, existing regimes are stabilized through various lock-in mechanisms making the breakthrough of niches into the regime very difficult (Geels, 2011). This can retain a niche-developed technology within the niche-level upwards of decades (Geels, 2005). Regime stability is a major barrier for the diffusion of niche technologies (Geels, 2005). Niche-innovation literature developed by Kemp et al., (1998) and Schot and Geels (2008) identify three processes in niche development: expectations or visions, network building, and learning processes. In short a niche can gain momentum when the expectations are focused and become broadly accepted, if various learning processed result in stable configurations (dominant designs), and support networks become large enough (especially if legitimacy is being provided through the participation of powerful actors) (Geels, 2011).

The sociotechnical landscape forms the macro-level. The sociotechnical landscape is influenced by a variety of factors that occur at the macro scale outside of the realms of the niche and regime. These factors include economics, politics, cultural patterns, population, natural environment, and common societal outlook (Geels, 2011, Schot and Geels, 2008, Van der Brugge, Rotmans, & Loorbach, 2005). The landscape is the level in which the niches and regimes are embedded (Markard and Truffer, 2008). As the sociotechnical landscape is the broader context in which the regime and niches operate within, the landscape has the ability to influence these other levels. Change does occur at the landscape-level, however these changes happen slowly (Geels, 2002, 2011, Schot and Geels, 2008). Conceptual similarities have been drawn between the landscape and the concept of the longue durée (Geels, 2011).

When viewed through the multi-level perspective, a transition is the result of interactions between processes occurring at separate but interconnected levels. Innovations at the niche-level gain momentum; landscape-level changes apply pressure on the regime for change, and the resultant regime destabilization produces windows of opportunity for the adoption of niche developments (Schot and Geels, 2008).

4.0 From Niche to Regime? Greywater Recycling in Ontario:

4.1 Water Reuse And Greywater Recycling:

The concept of water reuse has been gaining popularity in many areas of the world to combat the increasing issue of water scarcity. Arid regions of the world such as the Middle East, Australia, and the Southwestern United States make up the largest users of recycled water (Exall et al., 2004). Canadian interest in water reuse has existed for approximately 30 years. The Canada Mortgage and Housing Corporation (CMHC) funded one of the first large-scale studies into the concept during the mid-1980s (Exall et al., 2004). Today, the practice of water reuse in Canada has not diffused into the urban framework. Instead this practice is almost exclusively conducted at the niche-level. This is undoubtedly due to Canada's abundant source of fresh water and relatively high average annual precipitation of 600mm (Exall et al., 2004).

The availability of freshwater has fostered a cultural notion that the supply of water is unlimited. This has manifested itself in high consumption user practices. It can also be inferred that high consumption is related to low cost. The low cost of water favors the consumer but in turn is considered to be a major environmental issue (Memon et al., 2005). Environment and Climate Change Canada has been tracking residential water use in Canada using household water meters. Between 1991 and 2011, average daily water use per person has dropped 27% to 251 litres (ECCC, 2017). While this drop is significant the daily volume is still very high. In relation to other developed countries Canada is the second highest user of water daily per capita.

It is estimated that almost 90% of this consumption is returned to sanitary sewer system as wastewater (Exall et al., 2004). At the municipal level this presents a multitude of challenges, which include supply in relation to growing populations and managing wastewater flows and treatment before discharging wastewater into receiving water bodies (Exall et al., 2004). Uncertainties related to these issues are further intensified by climate change and associated extreme weather patterns (Exall et al., 2004).

This section is not intended to be a scientific review of various greywater recycling practices and treatment approaches. Instead, the intent of this section is to introduce the reader to the concept of greywater recycling technologies and explore the benefits of the application of greywater recycling within the urban framework. Furthermore, this section will highlight the barriers imposed directly or indirectly by the existing sociotechnical regime and landscape related to wastewater that is preventing the adoption and widespread diffusion of greywater recycling in Ontario. Barriers to implementation will be taken under consideration to produce a set of strategies to advance the adoption of greywater reuse within the urban framework as a water demand management tool.

There is no universal definition of greywater. The Wastewater Systems Effluent Regulation (2012) states greywater “means used water, other than blackwater, from sanitary appliances or from other appliances in a kitchen or laundry”. More definitively greywater refers to lightly contaminated wastewater (free of significant organic material or chemicals) usually produced from a sanitary basin (sink, tub, laundry). As this water is relatively free of contaminants in comparison with traditional wastewater it can be locally treated and repurposed for non-potable uses before requiring primary treatment (Memon et al., 2005).

There are a few important characteristics that define greywater from blackwater (traditional wastewater). Greywater contains about a tenth of the total nitrogen content of blackwater. Secondly, fecal pathogenic organisms are significantly reduced, as fecal material is restricted by greywater guidelines. Finally, the organic content of greywater decomposes more rapidly than blackwater (Oron et al., 2014). Of the wastewater produced within a household, greywater is estimated to account for 50-80% of the total volume (Kariuki et al., 2011). Reuse applications include urban irrigation, agricultural irrigation, ornamental purposes, and flushing of toilets (Oron et al., 2014).

Greywater recycling is permintted in the regulatory frameworks of many countries around the world. In the United States, the government of Arizona has been promoting greywater reuse to help alleviate stress on water resources. There are currently no permits required to operate a greywater recycling system between 400 and 3000 gallons per day (approximately 1500 and 11,355 L respectively) (Oron et al., 2014). However, applications, safety, and parameters of use are handled by regulation. Greywater reuse in Arizona is restricted to subsurface irrigation. The State of California has permitted greywater reuse since 1994 (Oron et al., 2014). However, regulations vary from those found under Arizona's legislation. Subsurface irrigation and the watering of non-consumable trees and bushes are the only permitted uses. Greywater reuse applications in Australia vary based on the level of treatment the greywater undergoes. Ornamental use, subsurface irrigation, surface irrigation, toilet flushing, and laundry uses are all permitted within Australia. Toilet flushing and laundry use are applications that require the highest level of treatment before reuse (Oron et al., 2014). Despite its rarity, regulations for greywater reuse and applications even exist within Canada. These will be discussed later on in this paper.

Treated greywater repurposed for toilet flushing has been applied at various scales, from single to multi-unit dwellings. An excellent example of a multi-unit application is the Nordhavnsgarden treatment plant. This greywater treatment plant is located under an apartment block in Copenhagen, Denmark (Revitt, Eriksson, and Donner, 2011). This facility treats bathroom greywater for reuse during toilet flushing for 84 single bedroom apartment units (a total of 117 inhabitants). This specific application uses a relatively comprehensive system consisting of a primary settling tank, a three-stage rotating biological contactor, a secondary settling tank, a sand filter, a ultraviolet disinfection unit, and a service-water storage tank (Revitt, Eriksson, and Donner, 2011). However, as greywater recycling systems are relatively new niche-developments they take many different forms and approaches to water treatment. However, as long as they meet the regulations associated with greywater in their region, a number of configurations are legal. Further research into the subject of greywater systems applications will reveal the various applications that exist worldwide.

There are many obvious benefits to the use of greywater within an urban context. The most obvious is that the applications of greywater use, substitute the use of potable water. The substitution of potable water within applications that don't require comprehensively treated water might reduce the cost of the potable water supply (CDR, 2004). While the current uses of greywater in Ontario (which will be summarized later) are few, their application has very significant impact. The most established use of greywater is for toilet flushing. It is widely agreed upon that the current format of using rigidly treated drinking water for flushing toilets is highly unsustainable at the environmental level (Memon et al., 2005). This application has the ability to reduce household water demand by 40-60 L/d per capita (Friedler and Hadari, 2006). Widespread adoption in this capacity has the implication of a reduction of 10-25% of the total urban water demand (Friedler and Hadari, 2006). A 2011 report, prepared by Alberta WaterSMART, found similar results. It is approximated that 258,000 cubic metres of residential greywater are produced daily in the province of Alberta. Additionally, it is estimated that 161,000 cubic metres of toilet water is flushed every day in the province. If the daily greywater produced was redirected and used specifically for toilet flushing in place of potable water, an estimated 59 million cubic metres of water could be conserved. This would account for 25% of Alberta's annual residential water consumption (Alberta WaterSMART, 2011).

Economic benefits exist outside the simple costs associated with potable water savings. Reuse has the potential to reduce the requirement to expand on existing supply and wastewater infrastructure (Exall et al., 2004). Furthermore, it can be concluded that greywater reuse has the potential to reduce the total volume of wastewater requiring treatment while removing the stress on aging sewage infrastructure and treatment facilities (Yu et a., 2013).

While the benefits make a strong case for the application of greywater reuse, the technology has not been widely adopted. Water is still not considered a basic human right in Canada. This is perhaps the largest barrier in relation to clean water technologies and solutions (Parker and Appelbaum, 2012). However, there are additional barriers impeding the adoption of greywater reuse.

In the United States regulatory policies seem to be the largest barrier associated with widespread development of greywater reuse technologies. The lack of consistency in legislation state to state creates barriers to adoption. A total of 41 states have defined greywater within legislation. However, only 5 of these states have included its definition within their respective plumbing codes and only 14 states provide a definition for greywater within other forms of state regulation (Yu et al., 2013). Inconsistency in the definition of greywater among states is regarded as problematic as it affects the acceptance of greywater reuse, system utility, and requirements of treatment (Yu et al., 2013). Additionally, inconsistent definitions of greywater are considered to be a regime barrier slowing the development of greywater treatment technology and its general standardization (Yu et al., 2013).

Within the Canadian framework similarities exist in terms of inconsistencies related to greywater at the level of policy and legislation. However, at the national level there are no regulations that bar on-site greywater reuse. It was suggested at the National Plumbing Code of Canada (1995) might affect implementation (CWWA, 1997). In terms of regulations, the report suggested that it could actually be the lack of regulations and consistent policy guidelines, which poses a significant barrier to greywater reuse's adoption.

Public health concerns at the provincial, territorial, and municipal level make up one of the largest barriers related to implementation within Canada. Issues of public health in terms of reuse relate to lack of standardization of equipment and water quality, effluent storage and distribution, odor management, and maintenance, etc. (CWWA, 1997). While many of the concerns associated with greywater reuse are not specifically addressed within Canadian legislation, Public Health Officials have the capacity to deny applications for on-site water reuse systems until they are deemed safe. Current building code regulations are also a barrier that is limiting the usefulness of this technology. An example of this is the prescribed use of greywater for subsurface irrigation within the Ontario Building Code. In dense urban areas there are particularly few opportunities for irrigation due to relative land constraints. Additionally, the requirement for the application to be subsurface increases costs (Yu et a., 2013).

Some factors at the landscape level, such as population growth and climate change, put pressure on a regime for change. These pressures materialize themselves in the form of a window of opportunity for a niche technology to be adopted within the existing regime. Inversely, there are factors that develop at the landscape level that create barriers that retard the adoption of a technology. In regards to greywater reuse cost is one of the major landscape barriers that exist. Greywater systems have high initial costs associated with implementation. High costs result in long return on investment periods. This deters many potential users as the economic benefit of these systems is small (Alberta WaterSMART, 2011). This cost is further exacerbated during retrofit situations where significant modifications are required to install these systems alongside established plumbing systems (Alberta WaterSMART, 2011). The final barrier relating to costs is that the low cost of water in many regions provides little incentive to conserve (Alberta WaterSMART, 2011). Lastly, public education on the subject of greywater recycling and water reuse is almost nonexistent (Alberta WaterSMART, 2011). Public education platforms are key to enhancing public knowledge and fostering a culture of sustainability.

While knowledge of these landscape factors is important to understanding the regime in which greywater recycling is situated, cost and public knowledge do not define the implementation of greywater technologies. The totality of the regime in which greywater recycling operates policy is by far the most important factor. Within the urban framework policy guides and regulates development, especially in relation to infrastructure. The provincial-municipal planning structure requires a review to understand how a technology like greywater recycling can be embraced and integrated or rejected completely.

4.2 A Regime in Transition:

As previously discussed, the sociotechnical regime has been defined by Geels (2002) as an interconnected network of actors and social groups which are aligned by a coherent set of rules. To better understand the adoption and ongoing development of a specific technology it is important to understand the regime dynamics in which the technology is embedded. In terms of the sociotechnical regime of wastewater management, policy is the most dominant element as it can help to establish a technology or effectively limit it. Policy is also a key element in dictating user practices and applications of technologies through regulation. Furthermore policy regulates infrastructure, which is one of the largest contributors to the perpetuation of a dominant technology through path dependency or lock-in mechanics. As this discussion of urban water resource management is being approached through a planning perspective, it is of great importance to assess the hierarchy of planning policies that govern both the use of our water resources as well as wastewater management practices.

The Ontario Water Resources Act states in section 0.1 that: "The purpose of this Act is to provide for the conservation, protection and management of Ontario's waters and for their efficient and sustainable use, in order to promote Ontario's long-term environmental, social and economic well-being" (Ontario Water Resources Act, 1990). As the Act's intent is to support the "efficient and sustainable use" of water resources, it is concerning that the Act lacks a definition of water recycling or reuse, let alone a definition for greywater. However, greywater recycling systems are technologies that would be applied within the urban landscape. Thus their implementation is more closely governed by municipal policy and legislation.

The following section is intended to describe and review the current urban water resource management regime. Climate change and population growth are the most prominent landscape pressures related to the current regime. As discussed earlier, their implications for urban water supply are far reaching. Over the past couple of decades these landscape pressures have greatly influenced the development of planning policies and regulations. Concerns associated with these landscape pressures have manifested themselves in the form of policy objectives and regulations. Effectively, the current policy-led sociotechnical regime is actually in a state of transition towards sustainability.

The provincial/municipal planning structure guides both development and resource management. These various planning policies set resource management objectives that are unlikely to be met without changes in user practices or technology. It is reasonable to infer that this implies the implementation of sustainable technologies. However, these policies promote the sustainable and efficient use of resources open-endedly. Without directly identifying any specific solutions to meet policy objective, the door for competitive innovation is left wide open.

Policies within this section can be separated into two categories. The first are guiding policies. These policies are used as a vehicle to enact theoretical aspects of planning as well as addressing common interests or concerns. The second category is regulatory policies, which control the implementation and regulation of physical infrastructure. These policies will be used as examples to illustrate how the advancement of the sustainability agenda has presented opportunities for adoption of sustainable technologies. Specifically, greywater recycling systems will be assessed in terms of urban water resource management. Concentrated areas of discussion will focus on The Planning Act, Provincial Policy Statement, City of Toronto's Official Plan, City of Toronto's Water Efficiency Plan, and the Ontario Building Code.

4.3 Planning Act (1990):

As greywater recycling technology is applied within the framework of urban infrastructure, the adoption and implementation of this technology is a matter of urban planning. To have a better understand of how greywater systems are in line with the current objectives of our planning policies, while still being restricted in legislation, would first require a review of the provincial/municipal planning structure. At the top of the planning hierarchy is The Planning Act of Ontario. This provincial statue establishes a framework that is led by provincial policy. The objectives of this Act are primarily laid out in the first three sections:

> "1.1 The purpose of this Act are,
>
> a) to promote sustainable economic development in a healthy natural environment within the policy and by the means provided under this Act;
>
> b) to provide for a land use planning system led by provincial policy;
>
> c) to integrate matters of provincial interest in provincial and municipal planning decisions."

While section 1.1 of the Act seems to provide a direct purpose of the goals of planning within the Act, articles (b) and (c) are elaborated on within the following two sections of the Act. Section 2 of the Act describes how regard to provincial interests is to be applied; the articles that are most important to greywater and greywater recycling technologies within the planning framework have been included:

> "2. The Minister, the council of a municipality, a local board, a planning board and the Municipal Board, in carrying out their responsibilities under this Act, shall have regard to, among other matters, matters of provincial interest such as,
>
> c) the conservation and management of natural resources and the mineral resource base;
>
> e) the supply, efficient use and conservation of energy and water;
>
> f) the adequate provision and efficient use of communication, transportation, sewage and water services and waste management systems;
>
> g) the minimization of waste;
>
> q) the promotion of development that is designed to be sustainable, to support public transit and to be oriented to pedestrians."

Section 2 directly states that conservation and management of natural resources is a matter of provincial interest; this statement is made without bias in terms of what type of resource shall be included or how management of the resource is to be conducted. Furthermore, efficient use of water is included in terms of provincial interest. Greywater recycling systems as a water demand management technology also aim to meet the goals included within articles (f) and (g) while also promoting "development that is designed to be sustainable" (The Planning Act, 1990) as prescribed in article (q).

Finally, section 3 empowers policy statements. Section 3(1) declares: “The Minister, or the Minister together with and other minister of the Crown, may from time to time issue policy statements that have been approved by the Lieutenant Governor in Council on matters relating to municipal planning that in the opinion of the Minister are of provincial interest.” The policy statements are produced in the form of the Provincial Policy Statement, which are reviewed every five years as stated in section 3(10)(Planning Act, 1990). The purposes of these statements are to provide a policy framework for addressing the provincial interests within planning. All planning decisions, comments, submissions, and advice "shall be consistent with" the Provincial Policy Statements in accordance with sections 3(5) and 3(6) (Planning Act, 1990). This policy framework includes promotion of a strong economy and communities as well as a healthy environment (Municipal Affairs and Housing, 2015). These statements also include policies on management and protection of resources and the environment (Municipal Affairs and Housing, 2015).

4.4 Provincial Policy Statement (2014):

The Provincial Policy Statement is not a set of separated and segmented policies. It is a cohesive plan that is meant to illustrate planning objectives based on provincial interests recognized by the Minister. "The Provincial Policy Statement is more than a set of individual policies. It is to be read in its entirety and the relevant policies are to be applied to each situation" (Provincial Policy Statement, 2014).

The Provincial Policy Statement is broken into five parts. The final section is the bulk of the document, which categorizes three essential components of planning and the policy goals, which reflect the public interest. The components are community, resource management, and public health and safety. The Provincial Policy Statement primarily directs land use planning. “Optimization of patterns of land use fosters long-term economic viability and reduces impacts on our resources” (Provincial Policy Statement, 2014). However, there is large element of the promotion of efficiency and sustainable development practices in terms of resource management. Provincial resources, including water, contribute environmental, social, and economic benefits. Long-term management of these resources is a pivotal provincial interest, which the province must secure sustainable methods of management in order to meet these long-term goals (Provincial Policy Statement, 2014).

Community improvement is the first topic addressed within the policy section of the Provincial Policy Statement. Section 1.2 outlines the need for coordination between levels of government (both within and across municipalities), agencies, and boards in the planning process. The lack of coordination between various levels of government is one of the commonly criticized factors that contribute to our countries fractured management of our water resources, which has resulted in the lack of a national water policy (Barlow, 2016). However, within section 1.2.1 it is stated that planning matters should be conducted not only in a way that is coordinated but also integrated and comprehensive. This includes planning matters for example, resource management practices such as water resources (Provincial Policy Statement, 2014). When referring to resource management the wording of "integrated and comprehensive" appears to be advocating for improvements in current practices. It is reasonable to infer that this would include technological advancements in established sociotechnical systems when making future planning decisions. This section is very important in terms of implementation of sustainable technologies as the policy can be interpreted as being inclusionary in advancing current resource management practices.

Furthermore, the Provincial Policy Statement directly addresses urban water issues within its community improvement policies. Section 1.6 discusses infrastructure and public services and section 1.6.6 sets out policy goals for water, sewage, and stormwater. The following is a set of policy goals within the Provincial Policy Statement, which promote the sustainable management of our current sewage and water services. These policy goals effectively encourage the application of new technologies to help mitigate degradation of current systems. Such policy objectives also highlight the importance of conservation and increased efficient use of our water supply. Only the subsections relevant to the application of greywater recycling technologies have been included:

"1.6.6.1 Planning for sewage and water services shall:

a) direct and accommodate expected growth or development in a manner that promotes the efficient use and optimization of existing:

1. municipal sewage services and municipal water services; and

2. private communal sewage services and private communal water services, where municipal sewage services and municipal water services are not available;

b) ensure that these systems are provided in a manner that:

1. can be sustained by the water resources upon which such services rely;

2. is feasible, financially viable and complies with all regulatory requirements; and

3. protects human health and the natural environment;

c) promote water conservation and water use efficiency;"

Section 1.6.6.1(a) directly supports the implementation of greywater systems. These systems reduce the amount of input of wastewater to municipal sewage services as water is being repurposed before requiring treatment. In turn this alleviates stress on municipal water services as the repurposed water replaces what would normally be potable water in applications such as toilet flushing or irrigation. As planning for growth is a matter of provincial interest (a response to population growth pressures) in terms of resource management, greywater systems are in line with policy goals. Furthermore, greywater recycling systems are promoted by section 1.6.6.1(b). The largest endorsement is that these systems are not only capable of being sustained on the water resources that they rely, but potentially reduce strain on the supply through reuse of the water supply before requiring primary treatment (Allen et al., 2010). Feasibility is no longer a question for this technology; there are many forms and many (though not nearly enough) have been implemented throughout the world. Greywater recycling systems become more financially viable in larger applications and very few regulations are currently in place to control their implementation (however, this is problematic and these topics will be addressed later in this paper). The issue of human health is addressed by the permitted uses of these systems. Additionally these systems reduce stress on our water supply, which in turn promotes the health of our natural water supply and the environment. Lastly, the purpose of a greywater recycling technologies is in alignment of section 1.6.6.1(c).

While the policy goals of the Provincial Policy Statement indirectly encourage the use of sustainable technologies to help achieve these targets, the absence of the identification of specific technologies such as greywater recycling technologies within the policy itself weakens their utility. However, what it does show is a shift in the regime towards embracing sustainability. Landscape pressures in the form of population growth are a major contributing factor that is increasingly recognized within planning policy.

The concept of managing growth in regards to resource management has been identified as being an issue of provincial interest. This issue directly affects urban water and wastewater management. Section 1.6.6.2 states: "Municipal sewage services and municipal water services are the preferred form of servicing for settlement areas. Intensification and redevelopment within settlement areas on existing municipal sewage services and municipal water services should be promoted, wherever feasible" (Provincial Policy Statement, 2014). While optimizing the use of existing infrastructure and reducing sprawl meets the objectives of best practice in terms of planning, if not approached comprehensively the result could be troublesome. In a city such as Toronto where infrastructure is aging, population growth causes massive stress on existing infrastructure such as our sewage systems. There is no current plan to upgrade or separate the existing combined sewage system. The costs are currently too great and developments in many areas are not feasible. Intense weather events such as the July 8, 2013 storm (while being an extreme example) highlighted the very problem of increased input into our aging sewage system. Additionally, landscape pressures in the form of climate change are predicted to increase the frequency and severity of these storm events (Schaefer, Exall, and Marsalek, 2004).

Combined sewer overflows are the result of over-encumbered sewage infrastructure. These events occur when the input volume of wastewater exceeds the treatment plant's capacity. When these events occur untreated wastewater is discharged directly into the receiving watercourse. In Toronto this means directly into Lake Ontario; part of the Great Lakes Basin, which is considered to be among the planet's most important freshwater ecosystems. Many sewage bypass events occur annually in Toronto. However, there is currently no public reporting system for sewage bypass events. This is problematic at the regime-level, as it dramatically reduces the level of public awareness to this problem. Each of Toronto's four treatment facilities release annual reports that do provide this information. During 2016, the Humber Wastewater Treatment Plant experienced 8 sewage bypass events. During these events only portions of the received flow underwent preliminary and primary treatment before discharge. The estimated volume of bypass flow for these events is 140 ML (Megalitres) (2016 Annual Report). Bypass events in 2015 totaled 388ML over the course of 11 events (2015 Annual Report). 16 bypass events occurred at the Humber plant in 2014 with an estimated volume of 348 ML (2014 Annual Report). In 2013, the year of Toronto's historic rainfall that was previously mentioned, the Humber plant experienced 28 bypass events. This resulted in 2081 ML of partially treated sewage to be discharged into Lake Ontario (2013 Annual Report). To make the severity of this issue more clear, based on 2016 statistics, the Humber Treatment Plant received an average influent flow of 257.3 ML/day (2016 Annual Report). That means in 2013 the Humber Plant alone discharged a total of just over 8 days worth of partially treated sewage into Lake Ontario. Growth management planning needs to strongly consider the implications of additional stress on this aging infrastructure. Current issues are only going to be exacerbated by population growth and climate change resulting in increased pollution from sewage bypass events. Statistics such as these reveal internal regime pressures as well as landscape pressures on the regime to facilitate change. Combined sewer overflows have environmental, social, and economic impacts. Pollution from sewage impacts water quality as well as biodiversity, public recreation is hindered, and the cost for treatment of drinking water can be affected.

The promotion of sustainable and efficient resource management practices, combined with greywater recycling technology's alignment to policy objectives and capability to reduce stress on existing sewage infrastructure, create a favorable window for adoption within a regime that is undergoing a transition toward sustainability. Greywater recycling technologies coordinate with intensification due to their capability to reduce stress on the existing sewage infrastructure without requiring heavy modifications due to the “bolt on” nature of the systems themselves. Unfortunately, the Provincial Policy Statement only mandates policy objectives instead of proposing technical solutions to matters of provincial interest. Greywater recycling technologies are aligned with multiple urban water resources policy objectives such as the optimization of infrastructure and efficient use. What is problematic is that since these technologies are only alluded to instead of openly discussed, they are disregarded by the planning departments of subordinate levels of government as solutions to policy objectives. This results in the stagnation of greywater technology’s adoption.

Section 2.0 of the Provincial Policy Statement discusses resource management specifically. Here the provincial objective is for planning authorities to protect, improve and restore both the quantity and quality of water resources (Provincial Policy Statement, 2014) through a variety of means. Once again the statement urges both the protection, and the efficient and sustainable use, of water resources through planning. The specific objectives of section 2.0 in relation to water are laid out in section 2.2. Only the articles of the subsection related to greywater recycling have been included, the policy reads as follows:

> “2.2.1 Planning authorities shall protect, improve or restore
> the quality and quantity of water by:
>
> e) implementing necessary restrictions on development and site
> alteration to:
>
> 1. Protect all municipal drinking water supplies and designated
> vulnerable areas; and

> f) planning for efficient and sustainable use of water resources, through practices for water conservation and sustaining water quality;”

Article (e) of section 2.2.1 is a clear indicator of a transition towards sustainability within the urban water resource management regime. The empowerment of planning authorities in terms of being able to restrict development to protect drinking water supplies facilitates a favorable climate for the adoption of niche technologies. Development restrictions typically materialize in the form of complications that require technical solutions. These instances work as catalysts for the niche developments to emerge and demonstrate their potential. Meanwhile, article (f) pushes the water resource management agenda of the policy by promoting efficient and sustainable use through conservation. Without further clarification this can once again be interpreted as example of the statement’s allusion to sustainable technologies to meet policy objectives.

Another criticism of the Provincial Policy Statement is the failure to include any sort of definition for sustainable technologies within its text. However, the statement does define and promote green infrastructure. The Provincial Policy Statement (2014) defines that green infrastructure "means natural and human-made elements that provide ecological and hydrological functions and processes. Green infrastructure can include components such as natural heritage features and systems, parklands, stormwater management systems, street trees, urban forests, natural channels, permeable surfaces, and green roofs”. The criticism is that green infrastructure is directly promoted within the policy objectives while the promotion of sustainable technologies is not. Under section 1.6 Infrastructure and Public Service Facilities the policy states:

> "1.6.2 Planning authorities should promote green infrastructure to complement infrastructure."

This is clearly an advancement in sustainability planning, not a negative. However, the promotion of green infrastructure has materialized within official plans. This has resulted in stormwater management and green roofs receiving almost all of the attention in terms of urban water resource management.

Green roofs have received so much attention that Toronto City Council officially adopted a green roof bylaw in 2009. The European Commission (2013) published an extensive green infrastructure and biodiversity strategy that promotes the use of various green infrastructures (including green roofs) to meet sustainability objectives.

The benefits of green roofs are promoted in a variety of different ways. Their benefits include regulatory ecosystem services such as stormwater management capabilities, climate regulation, and improve public health (Mell, 2017). Additionally, green roofs are promoted as being able to enhance local biodiversity through habitat creation and improved connectivity for wild life (Francis and Lorimer, 2011). However, there is much debate within the scientific community related to how effectively green roofs can provide these benefits. The biodiversity claims have received the greatest amount of scrutiny. Green roofs are commonly criticized for not producing viable habitats (Garmendia, Apostolopoulou, and Adams et al., 2016) that provide access to only highly mobile species hindering their usefulness in terms of connectivity objectives (Williams, Lundholm, and Maclvor, 2014). Researchers have expressed concerns that these habitats create ecological traps that are unable to sustain the changing needs of various species throughout their lifespan (Garmendia, Apostolopoulou, and Adams et al., 2016). The inconsistency is problematic because there have been recorded instances of policymakers leveraging green roofs as viable replacement habitats that are destroyed at ground-level during development (Williams, Lundholm, and Maclvor, 2014).

As stated, this criticism is not related to the inclusion of green infrastructure within the guiding planning framework. The criticism comes in the form of not fully understanding how one form of sustainability technology (one that is still frequently contested on the basis of its merits) can be promoted while another can be completely excluded. This criticism is especially relevant in relation to greywater technologies. The objectives of greywater technologies are perfectly aligned with multiple policy objectives. Additionally, greywater is already integrated within Ontario's regulatory framework. The absence of sustainable technologies from this guiding policy is a major barrier to in regards to technological adoption as it renders beneficial technologies such greywater recycling technologies as invisible and outside the realm of development.

4.5 Official Plans:

Official plans are much like the Provincial Policy Statement. However, these plans are documents created at the municipal level. They are visionary plans that direct the municipality's development and growth. These plans address the built, social, economic, and natural environments. Another feature of these plans is to identify opportunities for development and also constraints. Included in these plans are long-term goals for protection of resources. Official plans "look up" to the Provincial Policy Statement, as the plans are subordinate. As previously stated under section 3(5) of the Planning Act, these plans must "be consistent with" the Provincial Policy Statement. As an example, Toronto's Official Plan will be used to demonstrate how an official plan is used as a vehicle to implement policy objectives. However, this type of policy will also be used to illustrate how policy objectives are set without properly providing an explicit direction on how these objectives will be met. In terms of resource sustainability goals this is a missed opportunity for a transitioning regime.

The Toronto Official Plan clearly states that its vision is to create a city with a good quality of life, which includes clean air, land, and water (Toronto Official Plan, 2015). Official plans, like the policy statement, are tailored to pertain to land use planning. However, much of the policy's focus is on the management of water resources. Section 2.1 of Toronto's Official Plan is titled "Building A More Livable Urban Region". This section discusses how Toronto must cooperate with neighboring municipalities and other forms of government (adhering to section 1.2

of the Provincial Policy Statement) in order to manage growth (Toronto Official Plan, 2015). The following is the policy section immediately concerned with water management:

> "1. Toronto will work with neighboring municipalities, the Province of Ontario and Metrolinx to address mutual challenges and to develop a framework for dealing with growth across the GTA which:
>
> c) results in better water quality through water conservation and wastewater and stormwater management based on watershed principles;"

This article clearly indicates that one of the major factors in improving water quality is through water conservation. The conservation of water through repurposing wastewater before requiring primary treatment is the principal goal of greywater recycling technologies. In terms of watershed principles, the argument could be made that the addition of greywater recycling systems would further evolve the technical aspects of the current approach to wastewater management. Additionally, this technical evolution aligns with management approaches that are continuous and multi-disciplinary. This is a core principle of watershed management (EPA, 2017). As stated previously, the reduced stress on combined sewage infrastructure can mitigate instances of combined sewer overflow, which can only be assumed to positively impact any local watershed where these events occur.

Section 2.2 of the Toronto Official Plan addresses what is referred to as "Service Foundations For Growth". Here the importance of infrastructure is addressed in relation to providing clean water to residents. This includes management and treatment of sewage and stormwater prior to its release into Lake Ontario. The plan indicates that water and water services are important foundations in terms of growth and quality of life. It is noted that to accommodate growth, improvements in municipal infrastructure may be required. Conscious acknowledgement is given to the need for water conservation efforts at the residential and commercial levels (Toronto Official Plan, 2015). This is another instance of landscape pressures manifesting themselves within regime-level policies. Policy in this instance is being used in an attempt to reconfigure the existing sociotechnical system related to urban water resource management. The direct inclusion of conservation efforts at the residential and commercial levels indicates an attempt to destabilize the existing system. This is being carried out by suggesting changes within the coherent set of rules that establishes stability in the system such as changes to lifestyle, user practice, and cognitive routines (Geels, 2005).The relevant policy under this section in terms of greywater recycling's inclusion are as follows:

> "5. The City's water, wastewater and stormwater management infrastructure will be maintained and developed to support the city-building objectives of this Plan by:
>
> b) supporting, encouraging and implementing measures and activities which reduce water consumption, wastewater and stormwater flows and improve water quality, in accordance with best management practices developed by the City for this purpose;"

This section of policy further reveals the shifting regime in terms of policy objectives and the transition towards sustainability. This article directly focuses on improvements related to water resource management infrastructure. However, once again this is an instance where no solution or specific plan to meet this policy objective is stated. Instead the possible infrastructure improvements are left open-ended. This should be interpreted as a window of opportunity within the regime. This type of open-endedness can invoke competition between niche technologies. Radically new technologies can face regime-level barriers in the form of incompatibility with the existing regime (Freeman and Perez, 1998, Geels, 2005, 2011). However, greywater recycling technologies typically work in-line with existing sewage infrastructure making them highly compatible with the existing physical regime. Niche developments that are compatible with the existing regime and posses the capability to address regime concerns are potentially more successful in terms of adoption than others (Markard and Truffer, 2008).

The Toronto Official Plan also addresses the restructuring and redesign of areas within the city. Avenues, for example, are corridors, which run along the major streets of the city. These areas are where growth is anticipated and are subject to various planning policies within the plan (Toronto Official Plan, 2015).

Environmental sustainability is a major policy objective in this redesign. This policy encourages environmentally sustainable building design practices that promote the reduction of stormwater flows, use of water, waste, and the promotion of recycling (Toronto Official Plan, 2015). Policy goals that urge water conservation can be found throughout Toronto's Official Plan during discussions of reurbanizing the various aspects of the city. This is another missed opportunity to further advance sustainability planning. The policy continues to push the sustainability agenda. However, there is no concrete plan of action. The plan only alludes to sustainability practices. Creating sustainability policy objectives in terms of development for reurbanization of older areas and areas where growth is anticipated is a major regime transition. This again provides opportunity for niche technologies to emerge within the regime for their ability to meet multiple policy objectives (Markard and Truffer, 2008). Greywater recycling technologies can aid in practically all of these sustainability objectives; efficient use of water, reduction of waste, and promotion of recycling.

The Toronto Official Plan in section 3.4 addresses protection of the natural environment. This is another example where the concepts of conservation and efficient use of Toronto's water resources are discussed and promoted within policy but the inclusion of a viable strategy to meet these policy goals is ignored. Though a specific solution was not presented within the policy, the regime's shift toward sustainable resource management is evident. Once again only the subsections and articles relevant to greywater will be included:

> "1. To support strong communities, a competitive economy and a high quality of life, public and private city-building activities and changes to the built environment, including public works, will be environmentally friendly, based on:
>
> c) addressing environmental stresses caused by the consumption of natural resources, by reducing:
>
> ii) consumption of water and generation of wastewater;
>
> 18. Innovative energy producing options, green industry and green building designs and construction practices will be supported and encouraged in building renovation and redevelopment through:

b) advanced water conservation and efficiency measures;”

The inclusion of sustainable design practices within the built environment creates opportunities for the emergence of niche developments as these policies encourages innovation. Greywater recycling technologies integration within the wastewater management regime would aid in the protection of the natural environment, as it would help in meeting the policy objectives stated above.

It is easy to criticize guiding planning policies such as the Provincial Policy Statement or Toronto’s Official Plan due to their context. If a policy goal is proposed, there must be at least a suggestion of a remedy. Policies lack weight when they do not propose solutions to the problems they attempt to address. However, this isn’t the case for all of the issues addressed within the policy. It is problematic when analyzing Toronto's Official Plan.

There are other instances where green infrastructures are listed specifically when discussing policy concerns. For example whenever the topic of the urban heat island effect is discussed the development of green roofs are indicated as a policy goal (Toronto Official Plan, 2015). In fact green roofs have been adopted in the form of city bylaw as of May 2009 and apply to any new building permit applications for residential, commercial, and institutional developments made after January 31, 2010 (Green Roofs, 2015). An example of a green roof can be found atop of York University's Computer Sciences Building. The green roof is 20,175ft^2. However, it was installed pre-bylaw in 2001 (Green Roofs, 2015). To clarify, it is not the inclusion of green roofs that is problematic. It is the disparity between policy objectives that is problematic. In some cases a policy objective is stated and a proposed solution is provided. This would be considered a strong policy objective. In other cases, an objective is proposed and no direction to meet the goal is provided. Policy objectives can provide unique and beneficial opportunities for niche developments to emerge as potential solutions to regime-level issues. This disparity is concerning in relation to the strength of policy objectives.

4.6 Toronto Water Efficiency Plan (2002):

Further defining local policy are supporting policies specific to individual sections of Official Plans. When dealing with the conservation of water it is typical that a municipality will develop its own individual plan. These policies are commonly referred to as conservation or efficiency plans. The City of Toronto's Water Efficiency Plan will be used as an example to illustrate how water efficiency is managed at the municipal level. More specifically, this specific section will highlight how the urban demand for water is increasing with population growth (Aoki and Memon, 2005) and how this type of landscape pressure has fostered the current sustainability transition within the sociotechnical regime.

As Toronto continues to grow the need for expansion and improvement of the city's water and wastewater treatment infrastructure is inevitable. However, effective use of the existing infrastructure is an efficient and less costly alternative (Toronto Water Efficiency Plan, 2002). The objective of the Water Efficiency Plan is to implement water conservation measures that will offset the need to expand infrastructure (Toronto Official Plan, 2015). Though the plan itself is not a form of regulatory legislation, it does provide a strategy to reach specific efficiency objectives.

At the time of this plan's completion in 2002, it was estimated that the City of Toronto provides approximately 1,230 ML of potable drinking water to its 2.59 million person population every day (Toronto Water Efficiency Plan, 2002). As mentioned previously this demand was anticipated to increase with population growth. Today the City of Toronto has a population of 2.79 million (Diversity, 2017). However, other factors influence demand such as hot and dry periods in the summer. The recognition of the need to create a plan to reduce the amount of water being used within the city can be traced back to 1993 when the former Metro Council proposed and adopted a target for a 15% reduction in water demand by 2011 (Toronto Water Efficiency Plan, 2002). This objective was to reduce both the supply and distribution of water as well as wastewater processes. The intention of the Toronto Water Efficiency Plan (also set for 2011) is the reduction of peak day demand by 275 ML/d and wastewater flows by 85ML/d (Toronto Water Efficiency Plan, 2002).

In order to achieve these goals many options were considered and assessed. A total of 70 potential options were reviewed. Some of these options were dismissed as impractical or unable to be implemented within the scope of the plan. Others were combined into the same category. The remaining 21 options were further scrutinized for their application in Toronto, technical feasibility, and social acceptability. This resulted in a total of 7 water efficiency measures (Toronto Water Efficiency Plan, 2002). The final 7 were: system leak detection, computer controlled irrigation, watering restrictions, toilet replacement, clothes washer replacement, outdoor water audits, and indoor water audits.

Water conservation was not the sole objective of the plan. The major objective of this plan was to reduce the costs associated with municipal water management in relation to population growth. This plan was proposed as an alternative to straight up investment and expansion of the City's wastewater infrastructure. This proposed alternative was very economically viable. The plan recognized that maximum savings would be based on 100% participation rate assuming that 100% of the measures would be implemented. However, calculations were based on expected participation rates. Total implementation of the plan (over the full period) was estimated at $74.3 million. This was a significant decrease when compared to the estimated $220 million in infrastructure upgrades or about a third of the cost (Toronto Water Efficiency Plan, 2002).

Unfortunately, greywater recycling systems did not make the list of water efficiency measures. However, there are good reasons for this decision. The plan listed various measures that were not considered at the time of the plan's adoption. These measures may have not been recommended due to their minimal water savings, need for further study, or restrictions within regulations. Regardless, for a municipality to conduct such a comprehensive study into urban water conservation methods are a good indicator of a sustainability transition. Greywater was listed within this section. The plan stated: "Re-using greywater for domestic purposes is currently not allowed by the Ontario Building Code, due to possible cross-contamination between potable and greywater piping systems. In a community that is accustomed to using high quality potable water for all water uses, there may also be public resistance in using grey water" (Toronto Water Efficiency Plan, 2002). While public resistance could be resolved through public education platforms, it is clear that during the time of this plan's adoption provincial regulations were the most significant barrier for the application of greywater technology.

While excluded from the plan itself the potential of greywater recycling has been recognized by the City of Toronto as being a potential water demand management technology since 2002. The City of Toronto vocalized the importance of technologies in transitioning towards sustainability within the plan itself. "New technologies have already resulted in greatly improved efficiencies in toilets, showerheads, and clothes washers, and there may still be further improvements made in these and other technologies. Other advances, such as waterless toilets or grey water recycling, may eventually be developed to such an extent as to further reduce water demand" (Toronto Water Efficiency Plan, 2002). Greywater recycling systems were identified as being a potential measure within residential, industrial, commercial, and institutional sectors within the plan. Furthermore, the plan advises that the revision of provincial regulations to include greywater recycling would significantly increase the potential for water demand reductions in the City of Toronto (Toronto Water Efficiency Plan, 2002).

The 2002 Toronto Water Efficiency Plan unfortunately is not regulation. The purpose of this plan was to guide development in terms of water resource conservation. The plan was subject to review by the City of Toronto Budgeting Committee in January of 2011 where recommendations were made for its revision but its objectives remain the same.

4.7 The Ontario Building Code:

The overarching guiding policies such as the Provincial Planning Statement and the subordinate Official Plans are the vehicles for the praxis of planning. However, sustainable technologies and their implementation are governed solely by regulation in the form of building codes. The Ontario Building Code is a very powerful set of regulations in terms of water management. Simple changes within this code can result in massive offsets of daily usage of our water resources. In 1996 the Ontario Building Code was amended which mandated the use of water efficient toilets and showerheads in all new developments. These toilets only consumed 6 litres of water per flush, while the efficient showerheads reduced flow to 9.85 litres per minute. It was estimated that this individual change would result in the reduction of daily water usage in Toronto (by 2011) by 62 ML/d. Due to this change, this reduction would occur regardless of the success of the Water Efficiency Plan's implementation (Toronto Water Efficiency Plan, 2002).

Since the time of the plan's inception greywater has been added to the Ontario Building Code. In fact, the Ontario Building Code is one of the only regulations in Ontario that includes greywater within its text. The inclusion of greywater within the Ontario Building Code is of major importance. The addition of the greywater to the building code effectively knocks down the largest barrier in terms of this technology's application within the urban framework. Furthermore, it is a major indicator of a sustainability transition as it highlights the regime's acceptance of sustainable or niche technologies as a solution to problems within the regime. Change to a powerful policy like the building code is potentially the result of top-down pressure from the macro-level (landscape pressures) or bottom-up pressure from the micro-level (internal momentum) materializing itself with planning policy (Van der Brugge, Rotmans, & Loorbach, 2005). In this case, the result of interaction at multiple scales has created a window of opportunity for greywater recycling.

One of the most important things the Ontario Building Code does is provide a definition for greywater in terms of sewage systems. These definitions can be found within section 1.4.1.2. The definitions and their relevant subsections are as follows:

> "Greywater means sanitary sewage of domestic origin that is derived from fixtures other than sanitary units.
>
> Sanitary sewage means,
>
> (a) liquid or water borne waste,
>
> (i) of industrial or commercial origin, or
>
> (ii) of domestic origin, including human body waste, toilet or other bathroom waste, and shower, tub, culinary, sink and laundry waste
>
> Sewage system means,

(b) a greywater system”

As mentioned previously, greywater is not defined in any other forms of policy or regulations. Due to this, the application of greywater recycling as a tool for efficient and sustainable water management goes practically unnoticed. The Ontario Building Code regulates the use of greywater within the province. Section 7.1.5.3.(2) which sets out regulations for water distribution systems states the permitted uses of a supply of greywater:

> “(2) Storm sewage or greywater that is free of solids and treated to conform to Article 7.7.4.1. is permitted to be used as a water supply for,
>
> (a) water closets,
>
> (b) urinals,
>
> (c) sub-surface irrigation, or
>
> (d) the priming of traps.”

As greywater systems are "non-potable water systems for re-use purposes" (Ontario Building Code, 1992) they must strictly adhere to standards of conformance. While these standards of construction are not restrictive they are worth referencing to highlight the strict protocol in regards to greywater within the legislation. Conformance standards are listed under section 7.7.4.1.(1):

> “(1) Non-potable water systems for re-use purposes shall be designed, constructed and installed to conform to good engineering practice appropriate to the circumstances such as described in,
>
> (a) the ASHRAE Handbooks,
>
> (b) ASPE Data Books, or

(c) CAN/CSA-B128.1, "Design and Installation of Non-Potable Water Systems".

While the permitted uses of greywater in the Ontario Building Code are not restrictive themselves, the actual systems that can be implemented are. Greywater recycling systems are limited by their classification prescribed within the regulations. Under section 8.1.2.1. greywater systems are referred to as a "Class 2" sewage system (Ontario Building Code, 1992). Section 8.4 provides the regulations for "Class 2" sewage systems. Under this section regulations for aspects such as scope and construction requirements can be found. However, there are two sections of regulation that stand out as being particularly restrictive in terms of greywater system application. Sections 8.4.1.2. and 8.4.2.2:

"8.4.1.2. Application

(1) A Class 2 sewage system shall be designed only for the treatment and disposal of greywater.

(2) The total daily design flow for a Class 2 sewage system shall be calculated based on the fixtures discharging to the system as follows:

(a) 200 L per fixture unit where there is a supply of pressurized water, and

(b) 125 L per fixture unit where there is no supply of pressurized water.

8.4.2.2. Maximum Sewage Flow

(1) A Class 2 sewage system shall not be constructed where the daily design greywater flow to the system exceeds 1 000 L/day."

These two specific regulations do not seem that restrictive. However, they limit the application of greywater systems to a great extent. These regulations reduce the scope of greywater system applications to the residential level only.

There are very few circumstances where these regulations would be beneficial at the commercial, institutional, or industrial scales. While greywater systems would contribute greatly to the reduction of water demand at the residential level, these systems are much more viable at larger scales.

5.0 Conclusions

This paper attempts to answer the questions: Is Ontario's urban water resource management regime in a sustainability transition that is conducive of greywater recycling technology's adoption ? An assessment of the sociotechnical system of wastewater, determined policy to be the most important element in answering this question. Two significant landscape pressures have been identified as a result of this review that will have ranging impacts on local and global water supplies. Climate change and population growth are part of a much larger context which influences gradients for regime-level development trajectories (Geels, 2002). The impacts of these two landscape pressures on urban water resources are far ranging.

At the current global population, an estimated 1.2 billion people annually face issues related to a safe water supply for drinking and sanitation (Aoki and Memon, 2005). Varying levels of water stress affect countries that contain approximately one third of the global population (Aoki and Memon, 2005). However, the global population is rapidly increasing. Estimates suggest that by 2050, Earth's population will exceed 9 billion (WBGES, 2012). Population growth will have serious implications on developing countries as well as regions currently affected by water scarcity (Exall et al., 2004). It has been speculated that due to rapid urbanization and population growth, 60% of the global population will reside in cities (Bolund and Hunhammar, 1999). The increased population influx into cities worldwide will have significant implications on local water supplies.

The impacts on water resources are going to be further compounded by complications associated with climate change. Increased frequency of extreme weather will impact the hydrologic cycle differently at the regional scale in a variety of ways. Changes to groundwater quantity and quality, thawing of permafrost, and increased frequency of flooding and droughts have been identified as major impacts (Bates et al., 2008). These impacts have consequences that directly affect human health and safety. Flooding can result in damage to infrastructure and endanger human lives. Droughts can increase stress on water supplies, reduce food production, and exacerbate the risk of waterborne and foodborne diseases (Bates et al., 2008).

As a result policymakers are directly targeting these concerns and have embedded them in planning policy and regulation. A shift toward sustainability practices can be observed in guiding planning policy. Many instances have been highlighted within this paper. As discussed earlier, sustainability transitions have three distinct characteristics. This shift towards sustainability is goal-oriented and addresses a long-standing environmental issue (Geels, 2011). Improvements made in sustainability will not provide direct user benefits and will like be less cost effective then current practices (Geels, 2011). Finally, this transition involves resource management , an empirical domain that is categorized by large firms (Geels, 2011). However, urban water resource management is typically defined by only one existing firm (the municipality).Based on these characteristics, the changes to planning policy in relation to urban water management elucidate a sustainability transition. In terms of the multi-level perspective, the described sustainability transition is the result of a series of multi-level interactions. Sociotechnical landscape factors like climate change and population growth have broad impacts on demographical trends, ideologies, economic patterns, and societal values (Geels, 2011).In turn, landscape level changes materialize in the form of pressure on the existing regime for change (Geels, 2011).

In this particular case, Ontario's urban water resource management regime has responded with a sustainability shift. However, this transition toward sustainability could be interpreted as the sociotechnical regime manipulating the deep structure of the system. By changing the semi-coherent rule set that comprises the regime through policy, the regime can configure actors, maintain stability, and proceed with innovation incrementally (Geels, 2011).

Greywater recycling technologies were reviewed within this paper to illustrate their effectiveness as an urban water management tool. The application of comprehensively treated potable water for non-potable uses is unsustainable (Memon et al., 2005). Greywater can be reused for non-potable applications like irrigation and toilet flushing (Oron, et al., 2014). Estimate suggest that 50-80% of total residential wastewater volume is greywater (Kariuki et al., 2011). This should be concerning as the average Canadian consumes 251 litres of water daily (ECCC, 2017). Greywater was specifically reviewed in the context of this paper to determine if the current regime sustainability transition is conducive of this technology's adoption. The sustainability transition of the urban water management regime indentified by this paper is conducive of greywater recycling technology's adoption. The review of the provincial municipal planning structure revealed several occurrences where multiple stated policy objectives could be aided by the implementation of greywater systems. Section 1.6.6.1 of the Provincial Policy Statement was an example used to illustrate how these niche-level developments are aligned with multiple policy objectives.

In relation to the multi-level perspective this sustainability transition can be identified as a timeframe where landscape-level changes are influencing niche dynamics (Geels, 2005). Geels (2005), explains that gasoline cars were able to gain more market niches due to landscape pressures associated with suburbanization and the consumers general desire for transportation options. Climate change and population growth have presented greywater technology with a similar opportunity. The creation of a market niches, afford niche developments the opportunity to establish dominant designs, not necessarily exposure to selection (Schot and Geels, 2008). However, it was previously established that greywater has been incorporated within the Ontario Building Code. From the multi-level perspective this should be the ultimate indicator of a sustainability transition conducive of greywater technology's adoption. This means that greywater technology has become more widely accepted, has more precise expectations, learning processes have resulted in stable configurations, and large enough networks have been established (Geels, 2011) to be embedded in regulatory policy.

This is the fundamental understanding of the multi-level perspective at work. Transitions are the result of interactions at multiple levels. In this case a niche innovation (greywater) has built up a significant amount of internal momentum. Changes at the landscape level (climate change/population growth) place pressure on the regime (urban water resource management). The regime undergoes a period of destabilization which results in windows of opportunity for the niche to further establish itself (Schot and Geels, 2008).

5.1 Recommendations:

Despite the window of opportunity, greywater technology has not experienced widespread diffusion within the water management regime in Canada. This is the result of the various barriers that were discussed earlier. Surprisingly, past reports have determined that there are no regulatory barriers to on-site greywater reuse in Canada (Exall et al., 2004). Barriers however, exists within other parts of the regime, are part of the sociotechnical landscape, or a found at the niche-level.

Niche-level barriers are related to high initial costs and long return periods on investments associated with implementation of greywater systems (Alberta WaterSMART, 2011). Landscape dynamics have also been identified as creating barriers at the niche-level. While favorable to the consumer, the low cost of water in many regions provides little reason to conserve (Alberta WaterSMART, 2011). Barriers at the landscape-level are dominated by concerns regarding public health. Issues of public health relate to lack of standardization of equipment and water quality, storage of effluent, distributions, and odor management (CWWA, 1997).

Public perception of exposure to treated wastewater is considered to be one of the largest barriers by experts in Canada (Schaefer, Exall, and Marsalek, 2004). The events that transpired in Walkerton Ontario, have reinforced landscape values that demand high levels of public health protection related to government regulation (Schaefer, Exall, and Marsalek, 2004). Lack of public education on the subject of water reuse has also been highlighted as a landscape-level barrier (Alberta WaterSMART, 2011). Finally, are the barriers that develop at the regime-level. These barriers are not quite as obvious as those at the niche and landscape levels. Yu et al. (2013) identified a particularly strong barrier that exists within greywater's regulatory framework. Though, the prescribed uses of greywater are not restrictive, the ability to implement these uses in an urban setting can prove otherwise. Land constraints in densely populated urban areas present few opportunities for irrigation (Yu et al., 2013). Additionally, the current regulations for greywater systems within the Ontario Building Code, on the basis of daily permitted use restricts these systems application to the residential level.

The demand for rapid technological innovation is a required to establish a sustainable and equitable future (Parker and Appelbaum, 2012). Innovation is required in a range of sectors which includes water management. The long term demands of the current and future human populations for water cannot be sustainably provided by the traditional or industrial systems of today (Parker and Appelbaum, 2012). As stated in the Toronto Water Efficiency Plan (2002), greywater recycling systems have the potential to greatly reduce water usage and are an asset to water demand management. The following is a series of recommendations based on the barriers identified within this paper. The purpose of these recommendations are to help propel greywater technologies from niche development to adoption within the regime.

As resource management is a matter of planning, the provincially led policy system needs to be addressed in order to facilitate a change. A change to the Provincial Policy Statement would be the most important factor in making greywater reuse a mainstream water demand management practice. Section 1.6.2 of the Provincial Policy Statement states: "Planning authorities should promote green infrastructure to complement infrastructure" (Provincial Policy Statement, 2014). While the definitions of sustainable technologies and green infrastructure are not congruent, the underlying element of sustainability is. However, because green infrastructure is defined within the context of the Provincial Policy Statement, it can be promoted within development.

A definition of sustainable technologies needs to be included within the Provincial Policy Statement. Sustainable technologies could be defined similarly to the way environmentally sound technologies (ESTs) have been defined by the

United Nations Environment Programme. “Environmentally Sound Technologies (ESTs) encompass technologies that have the potential for significantly improved environmental performance relative to other technologies. Broadly speaking, these technologies protect the environment, are less polluting, use resources in a sustainable manner, recycle more of their wastes and products, and handle all residual wastes in a more environmentally acceptable way than the technologies for which they are substitutes” (Aoki and Memon, 2005). This way sustainable technologies like greywater recycling are provided a platform on which they can be operationalized from. In terms of the multi-level perspective changes to the sociotechnical regime have significant impacts. Policy comprises part of the semi-coherent rule set that forms the deep structure of existing sociotechnical systems (Geels, 2011). These rules coordinate actors at all levels and reproduce the elements of these rules within the sociotechnical system (Geels, 2011). Amendments in policy would bring change to the existing set of rules. This could lead to potential changes in cognitive routines, share beliefs, lifestyles and user practices, and regulations (Geels, 2011). As the interactions of the different actors are aligned and coordinated (Geels, 2002) this change could lead to the creation of new technological trajectories. New trajectories will be based on sustainability practices aim at destabilizing currently implemented unsustainable systems stabilized by lock-in mechanisms (Unruh, 2000 as cited in Geels, 2011).

A similar section in 1.6.2 of the Provincial Policy Statement could empower planners to explore sustainable technology solutions to urban problems. The addition of sustainable technologies into the policy statement would provincially mandate their use. After all, the policies found within the Provincial Policy Statement represent minimum standards, which decision makers and planning authorities must adhere to (and potentially exceed). The implementation of sustainable technologies would become part of a trickledown effect, as Official Plans must be consistent with the Provincial Policy Statement. Traditional water and wastewater treatment system built on large-scale infrastructure create natural monopolies and lack market competition (Corcoran et al., 2010). This could give sustainable technologies like greywater the potential to break through and compete with the established regime (Geels, 2005). This ability to compete has the potential to stabilize rules, further establish dominant designs, and foster the development of low-cost systems.

With the addition of greywater recycling to the Ontario Building Code, future water efficiency plans should always consider greywater systems as a potential measure for water demand management. However, the potential impacts of the landscape pressures addressed in this paper demand reconfiguration of the current regulatory framework. Restrictions on volume of storage and limiting outdoor use to strictly irrigation are limiting the benefits of greywater technologies (Yu et al., 2013). The current applications prescribed by the Ontario Building Code need to be restructured in order to expand the application of greywater systems. The current iteration of Class 2 Sewage Systems requirements are far from acceptable and one of the largest barriers that needs to be addressed. As explained earlier in this paper the average Canadian uses approximately 251 litres of water daily (ECCC, 2017). Under the Ontario Building Code, class 2 sewage systems can't exceed 1000 litres of daily greywater flow (Ontario Building Code, 1992). Based on average use, a Canadian family of four is exceeding 1000 litres of potable water daily. Well not all, up to 80% of this wastewater will be greywater (Kariuki et al., 2011). Lifestyles and user practices in Ontario related to water usage are not currently congruent with regulations. This low volume of storage for greywater indirectly restricts these systems to the residential level. Very few applications can be suggested at the commercial and industrial level based on the limitations of section 8.4.1.2 of the Ontario Building Code. Furthermore, high implementation costs and low returns on investment have already been discussed as landscape barriers related to greywater's adoption. It can be inferred from this analysis that the residential level is not the preferred level for implementation at the current stage of this niche's development.

Amendments should be made to the Ontario Building Code that allow for greywater systems to exceed current system parameters. These systems should target multi-resident buildings, commercial buildings, and institutional facilities that generate significant amounts of greywater. Greywater systems become more economically viable the larger they are in size. Additionally, unit cost of treatment decreases in relation to the increased size of the system (Memon et al., 2005). The inclusion of large-scale systems should be enforced by the Ontario Building Code during future large-scale commercial and institutional developments. The Ontario Building Code has enacted policy-led incremental innovation in the past with great success. The 1996 amendment, discussed earlier in this paper, that introduced low-flow bathroom fixtures to Ontario significantly impacted sustainable and efficient use of water resources in Ontario. Greywater recycling has the potential to do the same.

Greywater technologies are fortunate in the sense that they exhibit a high level of compatibility within the existing regime. New technologies that are faced with incompatibilities with the existing regime can remain stagnant as niches (Geels, 2005). However, greywater technology possess a hybridization mechanism (Geels, 2002). Greywater recycling technology is a technological add-on to the existing system that can easily link up with the established physical infrastructure (Geels, 2002). Furthermore, greywater technology has the potential to provide solutions to multiple regime-level bottlenecks in terms of water management (Geels, 2002).

Therefore, a regime-level approach to integration should be developed. Public acceptance of a technology like greywater could be increased if this technology was entrenched within the physical infrastructure associated with a trusted institution. This operational trajectory loosely follows that of the widespread adoption of steamship technology described by Geels (2002). Between the years 1780 and 1900, mail was the dominant form of communication and oceanic shipping was one of the major forms of mail transport (Geels, 2002). Steamships were a niche development that addressed many of the issues related to shipping at the time of their inception; speed, predictability, regularity, lack of control, and coordination (Geels, 2002). Steamships proved to be very successful within the mail transportation niche. As the postal service was an established and trusted institution, steamship technology diffused widely into other markets (Geels, 2002). It is reasonable to conclude that any technology that meets and improves the needs of a regime will become successfully adopted when backed by an established and trusted institution. In the urban context associated with greywater technology, hospitals provide a good example of a trusted institution.

Within large institutions like hospitals significant volumes of greywater a produced daily. Additionally, they are controlled environments where disposal of contaminants is typically going to be conducted by staff members. As public health concerns are arguably the largest barriers in Canada related to greywater (Schaefer, Exall, and Marsalek, 2004), hospitals provide one of the largest platforms to combat current public perception. The level of public attention this type of integration would get would widely diffuse public education on the topic of greywater. Additionally, this would bring public awareness to the strict standards of conformance set out in section 7.7.4.1 of the Ontario Building Code related to greywater. This type of regime-level approach has the ability to reconfigure the semi-coherent rules of the regime while potentially altering landscape factors such as cultural and normative values, and addressing environmental problems.

At the current time, regime level adoption of greywater in Ontario does not seem likely. This can be attributed to major barriers such as the low cost of potable water. However, in terms of landscape pressures, the impacts associated with climate change and population growth are only going to intensify. The implications of these pressures will only compound the issues associated with urban water resource management. The urban water resource management regime is clearly in a sustainability transition that is conducive of greywater technology's adoption. The climate for the adoption of a niche-level development that meets multiple policy objectives and are compatible in terms of the existing system's framework is favorable. The findings of this paper conclude that a proper approach to integration is the final barrier. The realization of an effective integration strategy will result in the successful adoption of greywater recycling into the urban water resource management regime.

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