‘It’s Only Water - Triple Bottom Line Analysis for Planners and Policy Makers about Direct Potable Reuse in Canada.’

A Master’s Report submitted to the School of Urban and Regional Planning
In conformity with the requirements for the degree of Master of Planning

By Aidan J. Kennedy
I would like to thank my supervisor Dr. John Meligrana for his constant feedback, support, interest in the topic of this report while allowing me the creative freedom to reach into unknown territory. I also will be forever thankful to Dr. Meligrana for picking me to intern in China; a trip that opened my eyes to a whole other side of the world. I would also like to thank Dr. David L.A Gordon for his leadership, inspiration and providing me with the ability to always ‘push a little further’. Moreover, for being the very core of the School of Urban and Regional Planning at Queen’s University. I would also like to thank Dr. Raul Pacheco-Vega (formally of the University of British Columbia) for his mentorship, friendship, and persistence on achieving excellence in all I do. Dr. Pacheco-Vega’s teaching is a testament to the value of quality post-secondary education. I also owe a great debt to Professor Patrick Condon from the University of British Columbia for enlightening my life with the concept of urban planning. Without his direction and support, I don’t believe I would be pursuing this degree.

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To the love, and light of my life Irene Orra Prat. You have been a rock in our lives through many good and challenging times; I am forever grateful for things you do every single day. We’ve come together from different parts of the world and have embarked on this crazy thing called marriage. We struggle, laugh, and cry, but we are now part of this larger experiment of bringing the world closer together. I look forward to years of travel, laughter, family moments and to watch you take your many talents and succeed in everything you choose to do.

To my family, Robert, Joanne, Chloe, Geoffrey, Luis, and Jing: Thank you for always believing in me and providing me with support. Without some of the amazing experiences our family shared together, I don’t think I would be the same person I am today.
EXECUTIVE SUMMARY

BACKGROUND AND OBJECTIVES

This report provides an analysis of the existing literature about direct potable reuse of water in developed countries: mainly the United States, Australia and Canada. Rudimentary indirect potable reuse of wastewater has been used for thousands of years, but only as direct potable reuse in the last half decade. A lack of public understanding integrated with expensive technology, led to a lack of implementation in North America during the 1970s and into the 1990s. An insufficiency of research or additional literature has furthered municipalities reluctance to invest in direct potable reuse. In order to better evaluate direct potable reuse projects, this report outlined the existing social, environmental and economic research that has been conducted about direct potable reuse. A mixed methods research approach was used to address the report’s three research objectives. The first method was a systematic review of the existing literature, particularly focusing on the areas of social, environmental and economic indicators for direct potable reuse projects. This lengthy review provided insight into what various fields in the world focus on when reviewing and studying direct potable reuse. After the information was gathered and analyzed using the second method, document analysis, the report then developed a TBL framework based on a similar framework used by the City of Calgary, and by asking specific questions, evaluated some of the general ideas and concepts gathered from the systematic review.

The report addresses the following research objectives:

1. What evidence exists about the use of decentralized direct potable reuse as a replacement for traditional Wastewater Treatment Plants, and how have these studies framed the transition and use of these systems in developed countries?

2. Propose a policy analysis for use in Canada that use a broad-based triple bottom line framework to measure the potential for direct potable reuse in communities (Slaper, 2011).

3. Discuss some of the policy and jurisdictional issues around implementing direct potable reuse in Canada.
KEY FINDINGS

The key findings of this report are:

- More collaborative research and careful public engagement should be carried out to ensure the public is supportive and understands the potential needs for DPR systems in Canada.

- Education and training should be adjusted to reflect more innovative technologies and models that may not be currently taught in planning, engineering, health or policy related curriculum.

- TBL frameworks and life cycle analysis will provide important models for municipalities to ensure decision making processes for wastewater are fair, rigorous and take into account the three pillars of sustainability.

- There needs to be much more research on life cycle analysis on water reuse and wastewater systems to understand the non-financial costs should be evaluated on projects.

- There needs to be more scientific research carried out of the existing DPR projects and more investment needed to bring more research projects on-line in municipalities.

- There needs to be more research to understand the policy implications of either allowing municipalities, the provinces and territories, or the federal government to take the lead on DPR policies and implementation.
GLOSSARY

Direct Potable Re-use – DPR: “The introduction of reclaimed water (with or without retention in an engineered storage buffer) directly into a drinking water treatment plant, either collocated or remote from the advanced wastewater treatment system” (US EPA, 2012).

Indirect Potable Re-use – IPR: “Augmentation of a drinking water source (surface or groundwater) with reclaimed water followed by an environmental buffer that

Water Treatment Plant – WWTP: “Is a facility involving a series of tanks, screens, filters, and other treatment processes by which pollutants are removed from water” (US EPA-832, 2004).

Triple Bottom Line – TBL: “The TBL is an accounting framework that incorporates three dimensions of performance: social, environmental and financial. This differs from traditional reporting frameworks as it includes...[environmental] and social measures that can be difficult to assign appropriate means of measurement. The TBL dimensions are also commonly called the three Ps: people, planet and profits” (Slaper, 2011).

Climate Change: “Climate change refers to any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among others, that occur over several decades or longer” (US EPA, 2016).

Wastewater: “Water that has constituents of human metabolic wastes as well as water that has residuals from cooking, cleaning and/or bathing” (Buchanan, 2015).

Water Reuse: “Domestic or industrial wastewater that has been treated to meet specific water quality criteria with the intent of being used for some beneficial purpose.” (Laurence, 2014; Crook 1996 and Surampalli; Exall 2004; US EPA 2012).
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“In the [world] today, attention is focused on shortages of water and the pollution in the air. There is plenty of water, but supplying it requires foresight.”

- Abel Wolman

the metabolism of cities
CHAPTER ONE
REPORT INTRODUCTION

1.1 Introduction

Direct potable water use of wastewater is still a relatively new phenomenon when compared with more traditional wastewater treatment plants. Although people have been drinking recycled wastewater for thousands of years, it is only very recently that technology has been able to offer solutions that allow wastewater to be treated in smaller, decentralized plants that rely on advanced treatment and in a very short period put that water directly back into the system. This can be done without a complicated maze of pipes, or with or without large amounts of discharge of cleaned water directly into aquifer, depending on the needs of the municipality.

Due to a combination of earlier research revealing that people were not very receptive to drinking wastewater that has been treated using more advanced methods (Milliken & Lohman, 1985; Bruvold, 1972; Bruvold, 1985; Carley, 1985; Dolnicar et al., 2011; Dishman et al., 1989; Dupont, 2013), and any lack of need in Canada, decentralized direct potable reuse has not been actively pursued. It should be stressed that from an environmental, social and economic perspective, it is also important to consider the sustainability contributions that can be achieved through Direct Potable Reuse, as 99% of wastewater is water (Vigneswaran and Sundaravadivel, p. 3, 2009).

This report is intended to serve as a broad overarching document and policy analysis for planners and policy makers that provides a comprehensive overview of the existing literature available on direct potable reuse (hereafter DPR) and decentralized wastewater servicing. This report should not be considered an independent report on engineering research and services. There are a multitude of actors involved at various stages of wastewater reuse: from the construction of the physical infrastructure, to the management and operations, and the end users. All of these actors should be considered throughout the research, planning, development and usage process.

Along with the idea of decentralization of wastewater, also comes the urban planners' need for suppression of sprawl’s burden on existing and future infrastructure demands. Until other sustainable energy systems are fully realized and implemented in municipalities, there is potential for decentralized DPR systems to have some negative consequences; this could result in isolated development that may require more infrastructure than higher density areas in cities. If these infrastructure developments can be envisioned with other sustainable technologies, they could altogether sever from an
energy grid. Even with these concerns, DPR of wastewater in Canada requires a serious consideration moving forward.

In order to evaluate policy decisions and technologies, many cities around the globe have turned to the Triple Bottom Line (hereafter TBL). The next section will discuss what the Triple Bottom Line is, and how each pillar: economic, social and environmental fit into the larger scheme of decentralized DPR projects.

1.2 Research Objectives

This report has three research objectives:

1. What evidence exists about the use of decentralized direct potable reuse as a replacement for traditional WWTPs, and how have these studies framed the transition and use of these systems in developed countries?

2. Propose development strategies for use in Canada that use a broad-based triple bottom line framework to measure the potential for direct potable reuse in communities (Stapler, 2011).

3. Discuss some of the policy and jurisdictional issues around implementing direct potable reuse in Canada.

The results from this masters’ report will help to provide insight to municipalities, provinces, educators as well as key regulatory agencies to develop future plans for direct potable reuse throughout Canada. This report should be able to support additional research around the multi-disciplinary role of the planner in the 21st century; ensuring that planners are readily involved in watershed planning in their respective communities. In addition, this report should add to the overall discourse as to whether or not Canada should consider a form of federal legislation that directs the provinces and territories, and therefore the municipalities, to work towards more decentralized direct potable reuse projects.

1.3 Scope of Work

This report focused on DPR research in developing countries. A scoping and document review was completed to understand where the current trajectory in research around decentralized DPR, and the various barriers and successes. The overall findings were then analyzed using the Triple Bottom Line framework (hereafter TBL) created by the City of Calgary and the Government of Australia. The City of Calgary was selected because it was one of the few Canadian cities that has implemented a TBL framework, and because of the unique challenges to water quality
the province of Alberta faces due to the oil sands development (Byrne et al., 2006). Therefore, Calgary’s framework could help to evaluate criteria of DPR projects initiated at the municipal level. Australian literature was often reviewed because administratively it shares many things in common with Canada (Pickford and Collins, 2016), and could serve as a transferable example.

1.6 Report Outline

The following chapter will provide an overview of the methodology that explains the qualitative methods that were used in this report. Chapter three will outline the scoping and document review conducted for this report as well as the triple bottom line framework, as well as a brief history of traditional WWTPs and DPR. Chapter four will organize and discuss the results of the scoping and document review and attempt to answer a series of questions that have been adapted from the TBL framework from the City of Calgary. In chapter five, it will draw conclusions from the overall research findings and highlight gaps in existing literature about DPR. It will also offer recommendations about what can be done moving forward about decentralized DPR in Canada.
CHAPTER TWO
BACKGROUND

2.1 What is the Triple Bottom Line?

To better evaluate the value of DPR in Canada, this report used the comprehensive TBL framework developed by the City of Calgary in 2005, with the most recent update being completed in 2011. This has allowed for more specific questions and analysis at the municipal level. There have been further adjustments made to the questions by using the TBL framework established by the Government of Australia.

The TBL is a framework that focuses on the economic, environmental and social aspects of a company, or a state actor. It was originally conceived by John Elkington (1994) as a way for businesses to introduce the concept of ‘three Ps’ - ‘People, Planet, Profits’ throughout their business models. Since then, it is frequently used in many academic research and business applications (Glasset, 2004). The TBL framework goes beyond adding only economic value through dollar values for the criteria included, but also combines environmental and social aspects that can be added or removed (Goonetilleke and Yigitcanlar, 2010). It also may include social, environmental, or economic aspects that may not have a designated monetary value (Goonetilleke and Yigitcanlar, 2010). Some of the more recent TBL frameworks have attempted to put a dollar value on various ecological organisms such as a forest. These ideas differ from past ideologies that had placed no previous non-economic value on a tree within a capitalist market, outside of traditional economic measures of wood volume. This can further complicate environmental matters, because it may result in creating commodities of ecosystems that in the past may have been considered public goods. It can also give a monetary value to many things, such as cultural identity that can be near impossible to replace (Bunten, 2008).
The TBL has a lot of potential for municipal governments to adopt more sustainable initiatives and policies. Goonetilleke and Yigitcanler (2010) conclude that even in the narrowest form, the TBL can be utilized as a flexible framework to measure and report on economic, social and environmental goals. What makes the TBL framework so useful for business and municipalities alike is that it can be used for one off development projects or infrastructure, or as a long term policy document that guides municipal policies (Elkington, 1980; Suggett and Goodsir, 2002). Therefore, this type of framework provides municipalities with an understanding that planning and policy decisions can no longer be made solely on the basis of economic accounting principles, and conveys this acknowledgement of understanding to the public. It also allows municipalities to start thinking about how they can better account for infrastructure projects by putting ‘values’ on less tangible goods such as clean air, or clean ground water (City of Calgary, 2011).

Once embedded into the governance of a municipality, there can be stronger ethics and more sound judgement throughout the city or municipality when it comes to making complex policy decisions (Environment Australia, 2003). TBL frameworks can also better prepare municipalities for much more robust risk management by identifying more complicated economic, social and environmental characteristics that may not have been highlighted previously. That same process can lead the municipalities or policy makers to take into account concerns from other stakeholders that fall into categories that may not have been considered in the past, and open up new types of dialogue with these stakeholders.

Lastly, a TBL framework allows municipalities to establish a performance benchmark needed to develop progressive policies that can help to educate, grow the economy, and help to investment and direct other municipalities to consider setting up similar frameworks (Environment Australia, 2003). A TBL analysis should follow a step by step process in order to ensure that the indicators are somewhat measurable and comparable to other municipalities. For example, Australia’s recommended process can be broken down into a straightforward three step process. During the initial phase, key stakeholders should be identified by the impact of municipalities' project choice, or policy directive (Environment Australia, 2003). It is very important that all stakeholders should be given a voice and information correctly and properly dispersed amongst the stakeholders. The next phase involves identifying the specific environmental indicators that are going to be used. Once the environmental indicators have been highlighted, the city or municipality will have to make a selection based on the public, experts and elected officials. This decision should be based on relevance, impact on business, risks, and data collection (Environment Australia, 2003).
2.2 Direct Potable Reuse and Traditional Wastewater Treatment

Traditional wastewater treatment in Canada

When people think of traditional WWTPs in North America, it is often associated with an out of sight, out of mind perspective. The wastewater treatment plants will be located somewhere on the peripherals of a municipality and seek to move unpleasant wastewater and associated smells and other negative associations far away from the population. For the sake of brevity, the report will briefly describe the history and growth of ‘traditional’ WWTPs only in the province of Ontario.

Waste water treatment began with threats to human health and a search for technological solutions to move as much volume of waste as possible. It was during the 1800s in London, England, that modern wastewater plants and systems were needed to prevent citizens from dying from parasites that had penetrated the ground water. Similar to London, England, the largest city in Canada, Toronto also experienced cholera and typhus outbreak in the mid-1800s (City of Toronto, 2017). Interesting to note was that Canada did not build its first wastewater treatment plant until 1910, well after the United States and Great Britain. The Toronto WWTP, known as the ‘Main Treatment Plant,’ had daily capacity that was rated at 150,000 cubic metres of wastewater per day (City of Toronto, 2017).

After the Second World War, Ontario’s wastewater treatment system was in dire need of upgrading from the rapid pace of urbanization and pollution that had accumulated throughout the Great Lakes (Koci and Munchee, 1985). To counter some of the immanent and immediate effects, the Province of Ontario passed the ‘Ontario Water Resources Commissions Act’. This legislation would eventually go on to create the Ontario Water Resources Commission. The creation of the OWRC allowed for sweeping leverage, and financing options for municipalities to construct large-scale wastewater treatment facilities through the 1950s into the 1970s, and would lead to many of the traditional WWTPs that are still in operation in many municipalities across Canada (OSWCA, 2001).

Before the creation of the OWRC, municipalities had only two options to fund wastewater treatment (OSWCA, 2001). Funding had to be secured through municipal taxes or by borrowing large sums of money and offering some sort of collateral. Under the OWRC, municipalities were given new powers to negotiate loans with the OWRC for up to 40 year periods (OSWCA, 2001). The second option was to have the OWRC “design, construct, finance, operate and own the waterworks on behalf of
the municipality” (OSWCA, 2001). Throughout the 1960s these schemes were continued and extended to include all water and waste below and above ground (OSWCA, 2001). Around the same period, wastewater treatment plants were also viewed by planners to promote regionalism and to prevent fragmented urban growth (Jackson, 2001). Unfortunately, this did not quite happen as was originally intended. The demands created by traditional WWTPs were based on assumptions of water access may no longer be accurate. It is very likely that this will need to change.

hat flows from your toilet in your home, through a bar screen and into a grit tank. From there, the wastewater is sent to a settling tank that tries to separate liquids from solids. Solids are then forwarded to the digester, while the more liquid waste is sent on to the aeration tank. From there, the liquid waste is sent to the clarifier tank, which mixes the effluent to remove as much sludge as possible. Sludge remaining is then forwarded to the digester tank, while the liquid moves onto various treatments of chlorine and UV etc. before being sent back to receiving water to municipalities. Sludge left over from the digester tank is removed and can be used for various purposes like agriculture, or sent to a landfill or incinerator (Kumar, 2015). Figure 2 on the following page, provides a visual representation of how traditional wastewater systems work.

![Fig. 2. Flowchart of a traditional WWTP created by Aidan J. Kennedy from Kumar, Parul. “Processes of Waste Water Treatment: 4 Process (With Diagram 59.17).” Biology Discussion, 16 Oct. 2015.](image-url)
2.3 Direct Potable Reuse and Traditional Wastewater Treatment

Indirect potable reuse has been employed for at least 5000 years and can be traced back to ancient Greece, where human waste was used as irrigation (Angelakis and Snyder, 2015). There are also historical records of waste used for irrigation in Britain, Germany, India, and China (Angelakis and Snyder, 2015). It was during the 18th century where wastewater re-use became framed as a biohazard, and our engineered systems of today that focus on diversion and efficiency of moving wastewater away from the human population.

The earliest beginnings of a more technical form of direct potable reuse date back to 1969 in the Namibian City of Windhoek. This system was constructed due to the extreme weather conditions in, and around Windhoek and the dire need for potable water. Due to climatic challenges, the pre-existing Goreangab Dam could now longer meet water demand for the city and the Goreangab Water Reclamation was constructed to treat wastewater and reintroduce back into the water system (du Pisani, 2005). In 1968, the United States Environmental Protection agency gave the City of Denver permission to explore various types of water reuse. Eleven years later in 1979, the City of Denver developed a demonstration facility for DPR; this plant would not become fully operational until 1985 (Van Riper and Gesebract, 1999; National Research Council, 1998). Throughout the 1970s and 1980s, there was significant interest and research conducted in in Colorado and California that had promising results for future direct potable reuse (Asano and Levine, 1996). In Canada, DPR is not used extensively and the focus tends to be on IPR for agriculture. Where DPR does exist is in experimental building sites and housing (Schaefer et al., 2013). Currently many of the online DPR systems tend to be at the site, or building scale and not designed for neighbourhood scale.

Decentralized DPR systems work using sophisticated cleaning technology, such as MBRs that can take up far less space than typical aerators and digesters. If these decentralized systems can be modified into mostly closed looped systems in the future, water could be recycled over and over again, with little need for additional water flows. This could allow for significant time for ground water to recover and replenish over the long run. As water usage grows from rapid urbanization, producing very high quality water for all forms of water usage makes little sense (Angelakis and Synder, 2015). Decentralized DPR systems can allow for a more distributed system that can be interconnected, but disconnected and controlled as needed for certain areas of a municipality. Figure 3 on the following page depicts the flow schematic.
of one type of DPR system. Figure 4 below, contains a list of all the existing DPR projects, and includes a new plant scheduled to come on-line in 2020 in Texas.


<table>
<thead>
<tr>
<th>DPR project</th>
<th>WRP inlet</th>
<th>Metres cubed/day</th>
<th>Blending - reclaimed water / 'natural water'</th>
<th>Additional treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windhoek, Namibia, NDWRP (2002)</td>
<td>Secondary domestic effluent</td>
<td>21,000</td>
<td>25/75 (treated domestic water + ground water)</td>
<td>None</td>
</tr>
<tr>
<td>Benoni West, South Africa (2011)</td>
<td>Secondary municipal effluent</td>
<td>2,000</td>
<td>20/80 (treated domestic + ground water), max. 30% of reclaimed water; blending in storage tank</td>
<td>None</td>
</tr>
<tr>
<td>Big Spring, TX, USA (2013)</td>
<td>Disinfected tertiary municipal effluent</td>
<td>7,600</td>
<td>15/85 (untreated lake and dam water); blending in raw water pipeline</td>
<td>Conventional WWTP</td>
</tr>
<tr>
<td>Wichita Falls, TX USA (2014-2015)</td>
<td>Secondary municipal effluent</td>
<td>19,000</td>
<td>50/50 (untreated lake and dam water); blending in a splitter box</td>
<td>Conventional WWTP</td>
</tr>
<tr>
<td>Cloudcroft, NM, USA (2016)</td>
<td>Secondary effluent from M&amp;R</td>
<td>379</td>
<td>49/51 (spring and well water); blending in an engineered storage buffer</td>
<td>Advanced WTP (UF, UV, GAC, NaOCl)</td>
</tr>
<tr>
<td>Brownwood, TX, USA</td>
<td>Tertiary municipal effluent</td>
<td>5,700</td>
<td>Blending in the distribution system with treated lake water</td>
<td>None</td>
</tr>
<tr>
<td>El Paso, TX, USA (2020)</td>
<td>Tertiary municipal effluent</td>
<td>27,300</td>
<td>Primary goal: blending in the distribution system</td>
<td>None</td>
</tr>
</tbody>
</table>

CHAPTER THREE
METHODOLOGY

This chapter outlines the methodologies that were used in this report to address the research objectives highlighted in chapter 1. The chapter then goes on to describe the two research methods that were used to collect and organize data, as well as limitations and reflections on the review process.

3.1 Data Collection

The research method that was used in this report focused on qualitative data collection through:

- A scoping review through three online databases: The University of British Columbia, Queen’s University, and Google Scholar; and specific document review of relevant papers, reports, and other documents that discussed research on DPR in developed countries.

3.2 Scoping and Document Review

This report borrowed from the methods developed by Arksey and O’Malley (2005), to clarify and highlight the importance and methods needed for a scoping study (Daudt et al., 2013). These types of methodologies are “often conducted to examine previous research activity ... identify gaps in research and ... determine the value of conducting a full systematic review.” (Wilson et al., p. 1, 2012; Arksey and O’Malley, 2005). The report has also utilize methods from Bowen (2009) when analyzing various studies, reports, white papers and theses that evaluated various environmental, social, and economic aspects of direct potable reuse. The information collected was applied through a series of questions within a TBL framework.

Figure 5 represents the flowchart of scoping and document review and explains the three main databases used. It also highlights the main sources that were used: peer reviewed literature, reports and government publications and grey literature. Figure 4 represents the quorum chart that was used to sift through the initial analysis of articles, and how they were systematically added or removed. Additional research questions were compiled; the quality of source was examined; documents were summarized, and findings interpreted (Khan et al., 2003). To ensure high validity and
consistency of data, the scoping and document review was completed of upwards of 200 documents and other sources. Three different databases were needed because access to some of the articles were unavailable on the different databases, or had paywalls.

Fig. 5. Flowchart of the scoping and document review by Aidan J. Kennedy. The chart highlights the main databases used in the report, the types of literature needed and some examples of more specific databases searched.

For additional accuracy in the report, citation scanning was used to find additional, documents in the bibliographies of already selected publications. The main keywords that were applied in the search engines were: ‘blackwater,’ ‘direct potable reuse,’ ‘wastewater reuse,’ ‘decentralized direct potable reuse’, ‘NeWater,’ ‘Canadian direct potable reuse’. In order to provide more accuracy and relevance of the scoping and document review, material about direct potable reuse dates back to as earlier as 1971; the older literature was mainly used to present social research rather than possibilities of DPR. The majority of the findings in this report come from material complied in 2005 or later, and tend to focus more on cost, environmental efficiency and more recent public opinion. Each document evaluated contained either one, or a combination of environmental, social and economic aspects related to decentralized DPR.

Due to the largely understudied nature of DPR, the scoping and document review ensured that as many studies and documents for each pillar of the TBL were complied during a specified time period. There were specific stopping rules identified during the proposal stages of this report. It was decided that each pillar of the TBL would each be denoted roughly a month, to a month and a half of research and analysis before moving on to the analysis. When extra time was identified, returns to areas that yielded less information during the initial analysis. Future research conducted on a longer time-frame should seek to reach a further saturation point of all relevant research on DPR.

During the document analysis and scoping review, excel spreadsheets were created to organize the documents or articles selected and the data analyzed from them. Figures 7, 8, and 9 on the following three pages (13-15) provide examples as to how the analysis was carried out, and how the all the information was selected that ended up being used in the report. Figure 7 will be discussed in further detail in section 4.1 People: Social Perspective, starting on page 19. Figure 8 will be discussed in further detail in section 4.2 Profit: Economic Perspective, starting on page 21. Finally, Figure 9 will be discussed in further detail in section 4.3 Planet: Environmental Perspective, starting on page 23.
<table>
<thead>
<tr>
<th>Author and Year</th>
<th>Title</th>
<th>General Findings About DPR</th>
<th>Social Data Analyzed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elter et al., 2007</td>
<td>‘Overcoming barriers to evaluation and use of decentralized wastewater technologies and management.’</td>
<td>Significant data on membrane bioreactors and the overall feasibility of DPR on a neighbourhood scale.</td>
<td>Three major barriers to initializing DPR. Lack of knowledge about DPR in curricula; lack of systems thinking for DPR; financial reward for using traditional WWTPs.</td>
</tr>
<tr>
<td>Menegaki et al., 2009</td>
<td>‘What’s in a name: Framing treated wastewater as recycled water increases willingness to use and willingness to pay.’</td>
<td>The importance of descriptive terms used when creating questionnaires for the public about DPR.</td>
<td>When farmers in Greece were asked if they would pay for recycled water or treated waste water, many selected the first option. This is important knowledge that can be used during public consultation stages.</td>
</tr>
<tr>
<td>Gingras, 2012</td>
<td>‘Access to information: An asset for democracy or ammunition for political conflict, or both.’</td>
<td>N.A</td>
<td>The importance of providing openness and transparency in a democracy and the fact that people’s participation depends on what is known about the dealings of a government and financial spending.</td>
</tr>
<tr>
<td>Dong and Saphores, 2015</td>
<td>‘Obstacles to wastewater reuse: an overview.’</td>
<td>Data about health risks and cost considerations about DPR. There is significant research about opinion polling that was carried out in the United States, and why it was successful or a failure.</td>
<td>Opinions from different cities in the United States and Australia.</td>
</tr>
<tr>
<td>Dishman et al., 1989</td>
<td>‘Gaining support for direct potable water reuse.’</td>
<td>Reviewed comprehensive phone interviews carried out in the United States from the 1970s to the early 1990s.</td>
<td>How language, questionnaires, and other information is vital to gaining the publics support on any sort of water or wastewater project.</td>
</tr>
</tbody>
</table>

Fig. 7. A sampling of the social documents and data analysed by Aidan J. Kennedy., from Bowen, Glenn/ Document Analysis as a Qualitative Research Method Qualitative Research Journal, vol.9, no.2, 2009, pg.27-40. Academic OneFile.
<table>
<thead>
<tr>
<th>Author and Year</th>
<th>Title</th>
<th>General Findings About DPR</th>
<th>Economic Data Analyzed</th>
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<tbody>
<tr>
<td>Lahnsteiner et al., 2017</td>
<td>‘Direct potable reuse – a feasible water management option.’</td>
<td>DPR can offer a more cost effective option that IPR and in the next 5-10 years can have the potential to become a very feasible alternative to other traditional WWTP processes.</td>
<td>By removing the buffer systems that are often used in many IPR designs, there can be considerable cost savings from less damage to the environment, smaller distribution networks and storage of water.</td>
</tr>
<tr>
<td>Guo, 2014</td>
<td>‘Principles for Optimizing the Scale of Direct Potable Water Reuse: Economic Network Modeling Studies.’</td>
<td>DPR can be a cost effective option compared with more traditional WWTPs in some cases, depending on a number of factors.</td>
<td>The financial model presented by Guo supports DPR as a potential alternative water source for use by 100-10,000 homes in an urban or suburban area.</td>
</tr>
<tr>
<td>National Research Council, 2012</td>
<td>‘Water reuse: potential for expanding the nation’s water supply through reuse of municipal wastewater.’</td>
<td>Very robust report that looks at the many facets of DPR and how they are all interrelated.</td>
<td>In particular data was used about the costs ($/kgal/yr) of water in Denver and other case studies. Further important information that was used from the study focused on distribution network costs and energy costs were.</td>
</tr>
<tr>
<td>Lundie et al., 2004</td>
<td>‘Life Cycle Assessment for Sustainable Metropolitan Water Systems Planning.’</td>
<td>Research modelling found that in some cases DPR along the coasts lines in Australia can cost much more than traditional WWTPs.</td>
<td>Life cycle analysis has a strong role to play when conducting future triple bottom line analysis. There should be more research done to better incorporate the two.</td>
</tr>
<tr>
<td>Curtovo, 2015</td>
<td>‘Potable water reuse history and a new framework for decision making.’</td>
<td>DPR can be a safe, robust and less intensive process to improve water efficiency and support growth.</td>
<td>DPR systems can help to offset costs within the pre-existing structures of water use in many North American cities.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Author and Year</th>
<th>Title</th>
<th>General Findings about DPR</th>
<th>Environmental Data Analyzed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raucher, 2015</td>
<td>‘The Opportunities and Economics of Direct Potable Reuse,’</td>
<td>General background and overview of DPR and some case studies from California.</td>
<td>Comparisons of the potential advantages of DPR for energy requirements, and carbon footprint.</td>
</tr>
<tr>
<td>Guest et al., 2009</td>
<td>‘A New Planning and Design Paradigm to Achieve Sustainable Resource Recovery from Wastewater.’</td>
<td>The importance of rebranding and transforming a paradigm shift from wastewater to resource water. The importance of enhancing ecosystem quality while providing additional water demands.</td>
<td>The potential for DPR to offer types of water recovery, energy recovery and material recovery in the future.</td>
</tr>
<tr>
<td>Equinox Centre, 2010</td>
<td>‘San Diego’s Water Sources: Assessing the Options.’</td>
<td>General report on various water options in San Diego.</td>
<td>The costs of using DPR in the San Diego area are within the cost parameters of more traditional systems and meet water needs without having to use more expensive options such as desalination.</td>
</tr>
<tr>
<td>Levin et al., 2012</td>
<td>‘Overcoming the tragedy of super wicked problems: constraining our future selves to ameliorate global climate change.’</td>
<td>N.A</td>
<td>The difficulty of creating a conceptual framework to analyze global climate change with many actors.</td>
</tr>
<tr>
<td>National Research Council, 2012</td>
<td>‘Water reuse: potential for expanding the nation’s water supply through reuse of municipal wastewater.’</td>
<td>Very robust report that looks at the many facets of DPR and how they are all interrelated.</td>
<td>The costs benefits that can be associated with remediation of the environment by using DPR. When less effluent is put into the environment, including listening the need for environmental buffers.</td>
</tr>
</tbody>
</table>

3.3 Triple Bottom Line Analysis

The TBL analysis borrowed from scoping and document review to inform a series of charts and questions that were adapted from the City of Calgary (2011). The document review allowed for efficient method of data selection; exactness of the information and stability for repeated reviews of the information gathered (Bowen, 2009). The existing questions from the City of Calgary provided reasonable probing questions both planners and policy makers could use to inform the public about the value of specific projects that had been proposed for a municipality, and whether they could meet a series of economic, social and environmental sustainability goals.

In the following chapter, charts were then created to visually express on a ranked scale how the various social, environmental and economic indicators related to DPR would meet municipal needs in the form of questions. Visual representative charts, similar to these in the report, are commonly used in the social sciences to evaluate qualitative research (Allen and Seaman, 2007; Bartram, 2007; Misiak, 2014). The charts included questions and responses based on a ‘1-4’ forced choice Likert Scale. The weights were: 1: very unlikely; 2: somewhat unlikely; 3: somewhat likely; and 4: very likely to meet each goal established by each question. Each circle that is included in the charts provides a visual representation of the ability to achieve the goal based on the research findings. The first style of circle represents 1, or ‘very unlikely’. The second style of circle represents 2, or ‘somewhat unlikely’. The third style of circle represents 3, or ‘somewhat likely’. The last style of circle represents 4, or ‘very likely’.

Although there is much uncertainty around the use of even or odd Likert Scales, and how many points should be used, an even scale with a low value was selected. This was done because research highlighted “no differences found in the utilization of scale points beyond [sp] the 3-point scale” (Matell and Jacoby, p. 508, 1972). Lozano et al. (2008) also highlight that “The optimum number of alternatives is between four and seven. With fewer than four alternatives the reliability and validity decreases, and from seven alternatives onward psychometric properties of the scale scarcely increase further” (Lozano et al., 2008). Therefore, for the purpose of this report and display of information, it forces the observer and graphic to provide either a positive or negative approach, rather than neutral. By no means is this an exhaustive or complete list of all options available to a municipality, but it can allow for some initial questions and ideas to be probed further.
3.4 Limitations

There were a number of limitations that should be addressed at the early stage of this report. When conducting the scoping and document review, it was found that there was an overall lack of research on DPR in the municipal context and for developed countries. There was a fair amount of research that came from China, as well as other developing countries, but often language was a barrier. If there was additional time available for this report, it would have added an additional layer of reliability to have questioned and surveyed some of the experts in the field of decentralized direct potable reuse. It should also be noted that this report is not intended to represent standalone chemical analysis or technological analysis of specific DPR systems or their performance. The final limitation was overall scope of the report. It is extended as a report is focused on evaluating policy in relation to planning, rather than engineering.
Chapter four presents the results from the analysis from the scoping and document review. The below figure represents an overall flowchart of decentralized water use and how the analysis will address each pillar of sustainability therefore informing policy on direct potable reuse. The flowchart also depicts the overall complexity of DPR and interconnected topics within each pillar. During the analysis stage, over 200 articles were read and reviewed, with information from 120 articles used for this report.

4.1 People: Social Perspective

The social pillar of direct potable reuse may be one of the most difficult for planners and other professionals to gain support to move towards DPR and will require significant public engagement and participation. The technology can better perform outcomes than other WWTPs, and provide additional benefits to the community but can still meet considerable resistance. Unfortunately, similar data reviewed earlier in this report about opinions about DPR in the United States have been difficult to come across about Canadian’s attitudes toward DPR. Based on similar wastewater management practices and general attitudes on governance in places such as the United States and Australia, it could be suggested Canadian responses would likely be similar (Dupont, 2013).

Some of the earliest research conducted in 1971 reported that in five different cities, researchers received similar negative feedback at 44% of respondents who would not drink wastewater that had been recycled (Kasperson et al., 1974; Dishman et al., 1989). A Gallup poll two years later conducted in California highlighted similar concerns. Gallop called 2,927 landlines across the United States and found that 55% were not in favour of any form of DPR (Dishman et al., 1989). Similar results in 1985 were reported in California (60% opposed). Additional research conducted throughout the 1980s consistently reported negative attitudes in the 50s-60s percentiles towards direct potable reuse of wastewater (Milliken & Lohman, 1985; Bruvold, 1972; Bruvold, 1985; Carley, 1985; Dolnicar et al., 2011; Dishman et al., 1989). Although previous studies used a variety of research methods, most studies arrived at similar conclusions across the United States (Dishman et al., 1989). What is concerning is that a communities’ experience of drastic climate-related incidences, such as droughts or floods tends to be the main driver for DPR. As more and more individuals are exposed to dealing with water shortages, and the interruptions of everyday life, they are more likely to support DPR (Dishman et al., 1989). Therefore, it is likely that ‘water-rich’ communities in Canada may experience increased negative feedback out of a lack of immediate need to look for more efficiencies in the wastewater system. In order to further public support, it is very important that the phasing of DPR into water systems be done, slowly and gradually, beginning with just viewing reclaimed wastewater and moving to more contact (Dishman et al., 1989).

The public also demands access to an ever increasing amount of information and data about specific projects or initiatives (Gigras, 2012). Even more so when the money that is being used comes from the public purse (Gingras, 2012). Being able to find the information can also become a complicated and messy process. This is especially true if all the actors involved are poorly integrated and have a lack of
overall coordination (Eitner et al., 2007). Moreover, simply providing the public with a dollar figure of an infrastructure project and with no alternative options is no longer sufficient. Nancarrow et al., (2008) found that despite the public’s interest in a ‘triple bottom line approach’ to wastewater projects, planners and authorities tend to underestimate the public’s knowledge and provide them with more technical information than necessary (Marks, 2006; Russell et al., 2008). Therefore, planners, policy makers and engineers may fulfill their administrative duties to disseminate information, but it could very well be the wrong information needed for the public to become supportive of a project.

The other unfortunate consequence that tends to arise from this process is that the planners, water authorities, and public officials may have already pre-determined the outcome and will use the public engagement process to convince the public to be supportive of one project, rather than having public support during earlier planning stages. The process should allow a multitude of options represented and evaluated on their own merit by experts, politicians and the public (Pinkham, 1999; Lovett et al., 2007). Due to the very nature of a decentralized wastewater system, it may also require public utilities and planners to experience a dissolution of power to community groups or the private sector as these systems begin to be built (Lovett et al., 2007). There also tends to be an unfavourable climate for DPR; this can come in the form of lack of knowledge by the regulators or policy, as well as weak regulatory policies that may make policy makers reluctant to move towards decentralized systems (Eitner et al., 2007).

Many of the concerns about DPR also come from the health field due to the connection between human’s exposure to waste and disease. Much of the anxiety comes from the potential of microbiological pathogens and PPCPs that could remain in the water (Duong and Saphores, 2015). When establishing an easy to understand assessment of these pathogens, it can be done in five simple steps: “1) identifying pathogens of concern; 2) assessing exposure; 3) modeling dose-response relationships; 4) characterizing risk; and 5) managing risk” (Duong and Saphores, pg, 201, 2015). Technologies such as membrane bioreactors can leave a smaller footprint and in most cases out preform activated sludge treatment when removing containments; even when looking at pharmaceuticals (Radenović, 2009; Sipma et al., 2010). One study concluded that: “It was found that under stable operation the MBR demonstrated higher removal efficiency over the CAS for all the tested antibiotics” (Sahar et al., p. 4835, 2011). Therefore, if small scale MBR systems are able to remove particulates at a much smaller scale, there should be no issues with removal of other large particulates of waste. An additional benefit of using DPR technologies in the future is their ability to remove pharmaceuticals from out source water. As more
and more people take many different types of medications today, this MBR DPR technology could prevent the unintended consequence of the mixing of various types of medications from entering the water table (Vergili, 2013).

Another area within the social realm that creates many barriers is the education model of professionals that will be working on water projects. There tends to be a lack of knowledge of some of these systems because universities have no curricula that is aimed at cutting edge technological systems, and an overall lack of systems thinking brought into the classrooms (Eitner et al., 2007). This is in part due to lack of data, and available research funds for these sorts of projects (Eitner et al., 2007).

4.2 Profit: Economic Perspective

The economic pillar of the triple bottom line plays an important role as it typically dictates the business as usual model that is often used by businesses, municipal and provincial governments as a key driver in the decision making process. Due to the very nature of TBL cost accounting, it makes it difficult to evaluate the financial costs of each pillar of sustainability (Norman and MacDonald, 2004).

One very large incentive to use decentralized DPR systems is that they can allow overall capacity to match actual growth and demand, therefore matching needed expenditures on a project (Pinkham et al, 2004). Unfortunately, even in water rich municipalities, the cheapest and easiest access points to fresh water are often already tapped and used at growing rates (Duong and Saphores, 2015). Because of the nature of the direct potable reuse systems, there is also potential, where feasible, to treat the waste to high enough standards that adhere above US EPA or WHO standards.

DPR systems offer three types of renewable resources: opportunities for water recovery; energy recovery; other material recovery just from the nature of their system construction and operation. Water recovery allows water to be used more intensely, but also sensitively. Energy recovery allows for the recovery of methane, and potential use for heating the DPR facilities or surrounding properties. Other materials recovery are also possible. Materials such as bio solids can be recovered and used for fertilization processes. When performed correctly, each of these three recovery systems provides additional energy outputs that can lead to overall cost savings (Guest et al., 2009).
Additional large cost savings that can be achieved when transitioning from IPR to DPR by removing the need of the environmental buffers or additional discharge into surface waters, as well as storage and distribution networks for potable water (Lahnsteiner et al., 2017; Asano, pg. 768, 2007).

What this allows for is DPR systems to be installed in areas, such as urban centres, where there may not be enough space, or incompatible surrounding land uses types for a larger scale environmental buffer needed to treat an entire community.

DPR is often not considered because of the outdated and narrow focus of planners, engineers and decision makers about the life cycle analysis that is conducted for WWTP proposals. Burgess (2015) asserts that much more work must be done to understand the costing process under a TBL framework; a full lifecycle analysis must now include all inputs from cradle to grave. As many of the most recent DPR systems rely heavily on new technology, there is also a need to demonstrate consistent operational reliability and operation costs versus more traditional WWTPs (Curtovo, 2015). With few plants up and running, this is often difficult to model.

The longest running experiment in Windhoek has provided 48 years of clean and safe drinking water, and has reaffirmed that DPR can be a viable option. The cost of efficient and safe drinking water from Windhoek was delivered to the city for as little as 1.02 CAD / m3* (Lahnsteiner et al., 2017). Something that should consistently be reinforced is the actual costs associated with larger centralized WWTPs. The massive costs of needed infrastructure, including pipes, sensors, metres and pumps can be reduced or removed altogether with certain DPR options (Duong and Saphores, 2015); this is especially relevant when plants began to age and decisions must be made about expansion and retrofitting. *[Dollar figure is calculated from the original findings in (Lachsteiner et al., 2017) and may not reflect current currency fluctuation].

Wastewater expert, Tianjian Guo from the University of Miami, concludes in this PhD thesis that his modeled results suggest that DPR is cost competitive with current water and sewer technology. Guo (2014) also addresses the issues of land acquisition. It may be cost effective to acquire small parcels around a municipality, instead of looking for a large parcel of land on the peripherals of every expanding cities. Moreover, that smaller scale closed loop DPR systems can be distributed throughout a city or municipalities expansion of waste and water systems to address immediate demand needs in the future (Guo, 2014). Guo stresses that much more research needs to be conducted to confirm that DPR can provide 100% of closed loop municipal water use. Unfortunately, there are some major institutional-economic barriers that come along with DPR, and with trying to achieve a goal of 100% recycled water.
With many of the major projects in municipalities being constructed through public-private-partnerships, there is an inherent agreement that the private sector will be able to make continued profits through utilities construction and management. If there is a major shift to DPR systems, there is potential for large, lucrative contracts for WWTPs to become minimalized. This may come in the form of labour needed, as well as engineering firms being retained for repeat, larger infrastructure projects. There may be reluctance from all stakeholders, including financial stakeholders, to fund decentralized DPR systems due to scale, and potential unknown outcomes from the technological choices (Eitner et al., 2007). When public-private-partnerships are initiated for wastewater projects, there should be a level playing field of incentives for engineers to consider both centralized, and decentralized systems (Eitner et al., 2007).

4.3 Planet: Environmental Perspective

The environmental pillar of the triple bottom line can be complicated as a result of a nexus of many confounding environmental issues.

DPR has the ability to use existing water within one closed system, rather than removing water from potentially sensitive ecosystems close to our urban environments (US EPA Region 9, 2017). Additionally, when DPR reuse is increased in a certain area that can allow for all year water uses, it has the potential to decrease the demand for ground and surface water and lead to some level of remediation of local watersheds (Honeycutt, 2015).

Milly et al., 2008 argue that water availability can no longer be evaluated as a stationary operation. This is where the importance of smaller decentralized systems can be emphasized. Due to their size, and contextual placement, they are able to respond to more immediate water needs and stresses in the microclimate of a municipality. This must be taken into account when applying the TBL analysis to different municipalities across Canada; taking into account their specific ecological, physical and design needs (Short et al., 2012). In order to allow for proper contextual placement, land use and other policies must be adapted to ensure this is possible (Horne, 2015).

In Canada, the current raw extraction rate is at 343 l/capita/day with roughly 312 l/capita/day being discharged as wastewater, as of 2012 (Laurence, 2014; Exall et al., 2004; Statistics Canada, 2012). Laurence highlights the 65% of the total volume of waste that enters the WWTPs comes from residential sources (Statistics Canada, 2012). With such a high volume of wastewater being processed due to residential
needs, these small scale DPR systems would provide a lot of utility when connected at the residential scale (Chen et al., 2012).

One of the largest benefits of DPR systems is the ability to use them in areas that have extreme water stresses and that the water delivery does not require additional infrastructure to be constructed (Arnold et al., 2012). Although Arnold et al (2012) argue that DPR should be pushed more heavily in areas were water must be reclaimed, it should not be dissuaded from areas with more water security. Especially when evaluating overall water needs into the future. DPR can also have the ability to spur growth in other sustainable energies through innovation, and reduction in energy use in the long term (Hancock et al., 2013; Raucher, 2015; Dolnicar et al., 2009). If decentralized MBR systems can be established at the neighbourhood level, the energy needed to move the water around and purify it will be much less than a larger scale, traditional WWTP. Therefore, sustainable technologies such as wind and solar could be introduced to meet the immediate needs of these new facilities without having to tap into a grid that might already be stressed on capacity.

4.4 Social Analysis

The social aspects of the TBL have the potential to be very large and complicated because of the very nature of who you are measuring – people. As previously mentioned, people can be an important factor as to whether or not DPR projects can move beyond innovative ideas. As this report focuses mainly on issues within developed countries, a lot of the data comes from Australia. The Government of Australia recommends that one social indicator is a very key factor in DPR: education and training as well as consideration of the potential health impacts of the public (Government of Australia, 2012). If the planners, engineers and policy makers are unable to maneuver through the initial consultation process, there is potential for the diffusion of responsibility to protect water can grow. This concept of diffusion of responsibility, coined by Latané & Darley in 1969, underlines one of the major potential problems in the social aspect of DPR. At the very core of all the research, policy analysis, and technology is the individual. If people are unable to feel the direct affects of water stress issues, or feel the need to protect and preserve water well into the future, it is hard to move many of these projects forward (Frantz & Mayer, 2009).
In the United States and Canada, there are already pre-existing regulations and standards that address water quality and safety. Therefore, these acts or regulations could be extended to included DPR (Cotruvo, 2015). Contrary to the United States or Australia, Canada has no national policies around water reuse or supporting a future of water reuse. Only at the provincial level do British Columbia and Alberta have some mention of water recycling within their provincial regulations (Schaefer et al., 2013).

**Table: Triple Bottom Line Social Framework**

<table>
<thead>
<tr>
<th>Q1</th>
<th>&quot;Can direct potable reuse help to respond to the needs of a diverse population (regardless of age, income, culture, or physical ability) by supporting their access to services and amenities?&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q2</td>
<td>&quot;Can direct potable reuse ensure inclusion of persons from various social, cultural and economic background during the consultation process?&quot;</td>
</tr>
<tr>
<td>Q3</td>
<td>&quot;Can direct potable reuse help to create more transparency and a better consultation process?&quot;</td>
</tr>
<tr>
<td>Q4</td>
<td>&quot;Can direct potable reuse protect resident’s overall health?&quot;</td>
</tr>
<tr>
<td>Q5</td>
<td>&quot;Can direct potable reuse lead to a change in the municipalities or individual’s health?&quot;</td>
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</table>

Question 1: ‘Can DPR help to respond to the needs of a diverse population (regardless of age, income, culture, or physical ability) by supporting their access to services and amenities?’

When analyzing whether or not DPR can help to respond to the needs of a diverse population by supporting access to services and amenities on a scale of 1-4, it scores a 3 or ‘somewhat likely’ to meet this goal. The score of 3 was given based on the previous findings in the social pillar of research, and scoring system mentioned in chapter 2.

Shifting to decentralized DPR systems at the neighbourhood level can, in many places, save energy and user costs in the long run as mentioned previously. Therefore, decentralized DPR projects can be used to create a more equitable access to water sources for all members of a community, especially if the project takes the form of a community based energy project. If the project is initiated by the public sector, it can ensure that the actual cost for water won’t be artificially suppressed, and loose potential funding dollars that could be used within that community for other infrastructure. This may prove challenging as it will require a lot of negotiations between the public and private utilities sectors, and the general public.

Another area where these decentralized systems play an important role in access to services is the intergenerational costs of infrastructure. If planners and policy makers can make decisions to install these decentralized DPR systems today, even if they have a higher capital costs, costs per litre of water along with conservation of water resources, as well as a need for less maintenance are passed on to the upcoming generations. If this type of intergenerational thinking can be levered by planners and policy makers with water, it has the potential to be duplicated in all other infrastructure projects. If the concept of projects being considered on intergenerational terms is vital to making sound decisions when building infrastructure that will last well into multiple generations of individuals. One could say that it would be negligent to not consider this time scale in a TBL analysis.

Previously mentioned in the report, is the ability for these DPR systems to be scalable. This could potentially lead to the eliminate some of the rural and urban divide of wastewater servicing. If capital costs fall under upgrading existing or new traditional WWTPs, there can be a transition toward paying the true cost of water for your neighbourhood, rather than an averaged citywide cost. This may allow one way for growth to pay for growth, at least with waste and water infrastructure (City of
Toronto, n.d). There may also be room for more discussion about higher development cost charges being levied against projects that do not meet a higher environmental, social, and economic standard.

**Question 2: ‘Can DPR ensure inclusion of persons from various social, cultural and economic background during the consultation process?’**

When analyzing whether or not DPR ensure inclusions of persons from various social, cultural and economic background during the consultation process on a scale of 1-4, it scores a 4 or ‘very likely’ to meet this goal. The score of 4 was given based on the previous findings in the social pillar of research.

By creating decentralized DPR systems that service a community there can be shared costs; capital investment may be initially higher, but as residents and tax payers live there over a longer period of term, the municipality and residents can realize the cost savings from adopting to such a process. If municipalities provide education and introduction to more people about innovative infrastructure such as waste and water, it can help to promote an overall message to sustainable energy systems and reuse throughout a community, and to younger children. Unfortunately, water rights laws are very complex and intricate and will therefore affect the possibility of individual municipalities to use DPR.

Since DPR systems tend to be complex, and require input from engineers, planners, health experts and council members, this can allow for an entrance for people of various backgrounds to join in re-imagination of our water systems. Much more research needs to be conducted to support risk-based legislation that will allow for some form of uniform standards to support health standards and implementation (NRC, 2012).

If the systems are constructed on a neighbourhood scale, there could be possibilities that even neighbourhoods with lower socio-demographic outcomes could be included in the management of DPR systems as they would be constructed to service their own neighbourhood. In order for ‘water rights’ to be guaranteed for all communities, there should be further application of legislated tools granted to municipalities and groups that work to further the improvement of wastewater reuse (NRC, 2012). In addition to rights of access, community education and training programs could allow for the training and hiring of individuals to work within a micro-utility setting. It could also be viewed that these sorts of capital investments will allow for individuals living in the neighbourhoods to feel as if the city or municipality wants to invest in them, and thus may lead to future economic growth in that area of the municipality.
Question 3: ‘Can DPR help to create more transparency and a better consultation process?’

When analyzing on whether or not DPR has the potential to help to create more transparency and a better consultation process on a scale of 1-4, it scores a 2 or ‘somewhat unlikely’ to meet this goal. The score of 2 was given based on the previous findings in the social pillar of research.

It may not be the technology of DPR that creates more transparency and a better consultation processes, but using the TBL framework as a vehicle and bringing in a range of experts from various fields can ultimately yield more transparency and a better experience for the public. This is not guaranteed. In addition to transparency, even as something as simple as public communication is key. In a study from Menegaki et al. (2009), farmers on the Island of Crete were willing to pay different prices for reclaimed water based on whether it was called “recycled water” or “treated wastewater”. Macpherson (2011) found that decision makers in the water industry did not have a standard list of definitions, which could ultimately hurt the project at hand. Typical concerns that should be taken into account by the planning professionals are: risk perception, sensory perception, delivery context, trust in utility and control over water quality (Doria, 2010).

In addition to addressing these concerns to better the consultation process, the social pillar can be designed to include particular engagement processes that were transparent and have succeeded. This is where the TBL guides created by the Government of Australia, City of Calgary as well as public input from California, and Colorado can play a positive role in laying the groundwork for a meaningful consultative process. One area that is very difficult to control is the people working on the project. It will depend on who is involved throughout the process and their intentions about DPR. Due to the very nature of innovative and creative technologies, it may also have the ability to attract the type of individuals whom fall outside of the traditional educational and consultative processes. Therefore, they may seek alternative models of consultation that strive to involve more people in the process and be more open to projects and ideas that do not fit the status quo. A large benefit of opening up the process to further ideas, review and scrutiny, is that you can avoid situations where wastewater options have been pre-selected by a council member or expert ahead of time. And where the sole purpose of the public consultation process is to sell the singular infrastructure intervention at all costs. Since DPR is still within its infancy, it also helps that there will be some disagreement amongst experts; this can allow for an even more rigorous process to get decentralized DPR projects initial support and through an approvals process.
Question 4: ‘Can DPR protect resident’s overall health?’

When analyzing on whether or not DPR has the potential to improve the city or municipalities overall health on a scale of 1-4, it scores a 4 or ‘very likely’ to meet this goal. The score of 3 was given based on the previous findings in the social pillar of research.

In many of the studies that evaluate DPR systems, it was often concluded that they can clean and filter water to a higher standard to traditional WWTPs in cities. When reflecting back on the research conducted by Radjenović, 2009; Sipma et al., 2010; Sahar et al., 2011, they highlight that MBR DPR systems have become so advanced that they can clean out much smaller particulate matter, such as pharmaceuticals, that traditional WWTPs with activated sludge processes cannot. Therefore, these decentralized DPR systems could be helping to diffuse a problem that we do not know much about at this time. Much of what planners and policy makers have to overcome is perceived risk; where the public has a difficult time overcoming their own personal biases with drinking recycled water (Hinton, 2014). The earlier mentioned forward is the same types of innovation that has come from the health field in-regsards to more multi-disciplinary care, and participation from the public involved (Chasen and Kennedy, 2013).

Question 5: ‘Can DPR lead to a change in municipalities or individual’s health?’

When analyzing on whether or not DPR has the potential to lead to a change in the city or municipalities or individuals on a scale of 1-4, it scores a 4 or ‘very likely’ to meet this goal.

Human health and safety is usually an important concern of society. When implementing DPR, there is still some uncertainty and potential risks that come along with any type of new, or well tested technology. Most of the risks and issues related to any sort of wastewater treatment system come down to having a proper risk assessment program and follow the procedures. A sad example of a tested and safe wastewater treatment facility failing from improper procedure was the Walkerton E. coli outbreak in Walkerton, Ontario Canada in 2000. There was nothing wrong with the technology, but a failure in proper management procedure and policy decisions lead to the deaths of seven individuals.

The National Research Council in the United States recommends that risk management for wastewater should include: hazard identification, exposure
assessment, dose-response assessment, and risk characteristics (NRC, 2012). In the early 1980s, the NRC and the US Army Corps of Engineers suggested that potable reuse should be tested directly against traditional forms of conventional wastewater treatment (NRC, 2012). In 2011, an extensive study was undertaken using three different scenarios in order to determine relative risk of contamination in potable reuse versus conventional treatment. The results are important. The NRC concluded that “it is appropriate to compared the risk from water produced by potable reuse projects with the risk associated with the water supplies that are presently in use” (NRC, p. 130, 2012). What this means is that although the risks of potable reuse and traditional treatment have similar risks, the use of DPR will be held up to a higher scrutiny because if its age, and social uncertainty from the public. As mentioned in the previous question, if technology such as MBR is selected, and risk assessment and management on future DPR is more rigorous, there may be the ability to remove more salinity, sodium, boron, additional pathogens, BPA, and APEOs from our water sources (NRC, 2012).

4.5 Economic Analysis

The economic analysis looked at guiding questions utilized by the City of Calgary when conducting a triple bottom line analysis and apply them directly to the previous knowledge and highlighted research about decentralized DPR. When municipalities are considering adopting decentralized DPR, there are some policy documents, if existing, should be amended to support DPR. With economic polices, these could include Municipal Development Plans; Growth Plans; or Water Efficiency Plans (City of Calgary, 2011). The National Research Council stress that if a municipality chooses not to “augment its water supply, it avoids those associated costs but also misses or postpones the benefits of doing so” (NRC, p. 145, 2012). The economic aspects of the TBL will provide important costing information to policy makers, engineers, planners and the public. One of the major areas that needs to be made more of a focal point when understanding the economic analysis is to conduct better life cycle analyses and the non monetary costs associated with DPR projects. This must be done to determine whether or not DPR projects make financial sense to a municipality in the long run. Too often, these types of calculations leave out climate change related criteria, or do not operate on a long enough life cycle to properly evaluate the financial and economic costs of DPR.

In many cases, DPR tends to be undervalued when the entire economic costs are factored in, such as protection of a watershed and public health (Miller, 2005). When constructing decentralized DPR systems size, location, and distribution can often be the most important considerations with the project (NRC, 2012). With some
of these more flexible systems, municipalities may be able to avoid expansion or upgrading costs of older distribution systems of aging WWTPs that could remain in operation for another 50 years with increasing maintenance and upgrading required. Dependent on the size of the network, costs such as the electricity needed to run the pumps, and other parameters should be included in the lifecycle analysis and will most likely increase in the foreseeable future. In the case of the Government of Australia, they recommend that costs be broken down into the initial capital costs, then the lifecycle operations costs, and finally transition costs (Government of Australia, 2012). Next, they believe that benefits should be calculated and quantified. These benefits can include: increases of revenue; increase of productivity; additional costs that can be avoided; and value of assets that will no longer be needed (Government of Australia, 2012).

**Fig. 10. Economic guiding questions for adoption of DPR by Aidan J. Kennedy, from Calgary, City of Corporate Economics Community & Neighbourhood Services, Environmental & Safety Management, Land Use Planning & Policy Office of Sustainability. The City of Calgary., 2011. Web. 2017.**
Question 1: ‘Does DPR have the potential to improve the municipalities business environment?’

When analyzing on whether or not DPR has the potential to improve the city or municipalities business environment on a scale of 1-4, it scores a 2 or ‘somewhat unlikely’ to meet this goal, and scoring system mentioned in chapter 2.

A major problem related to urbanization and growth is energy consumption (Gaspar et al., 2017; Eggoh et al., 2011; Hu et al., 2015; Lise and Van Montfort, 2007). As mentioned in Essenigher and Haouaoui Khouni (2014). This is where the importance of conducting a full life cycle analysis becomes critical. Two of the attractive features that arise from conducting life cycle analysis on DPR are a reduction in water supply from external water sources, and if there is some discharge allowed, the amount of water discharged is greatly reduced (NRC, 2012). Lundie et al. (2004) and Stokes and Horvath, (2006, 2009) used two different types of life cycle analysis to address water supply options in Australia and the United States. In Australia, Lundie et al. (2004) concluded that “increasing the level of treatment at wastewater treatment plants along the coast from primary to advanced ... [would] increase total energy use and greenhouse gas emissions without significant environmental benefits (NRC, p. 152, 2012), and that it would not be justified unless “additional environmental benefits can be generated by offsetting the demand for potable water through recycling” (NRC, p. 152, 2012). Similarly, Stokes and Horvath (2006) concluded that “non-potable reuse was substantially less than desalination, but larger than water importation, due to the distribution system pumping requirements” (NRC, p. 152, 2012). Additional research conducted by the National Research Council in the United States surveyed utility providers in California, Texas, and Colorado and found that one of the key factors to implementing water reuse and investment in water reuse was the diversification of water supply. It is important to point out that both of these analysis do not look directly at DPR.
Question 2: ‘Can DPR provide an investment in infrastructure that can advance the city or municipalities economic development goals?’

When analyzing on whether or not DPR can provide an investment in infrastructure that can advance the city or municipalities economic development goals on a scale of 1-4, it scores a 4 or ‘very likely’ to meet this goal.

DPR costs may appear to be large upfront capital costs, but if certain municipalities do not look to the future and augmentation of their existing water supplies, the simply postpone the inevitable. An example of water supply and conservation options in Denver, Colorado presented water supply alternative at $30.00-150.00 ($/kgal/yr) for DPR, and at $90.00-150.00 ($/kgal/yr) (NRC, p. 161, 2012). Taking into account two other major studies, the National Research Council determined that “current reclaimed water rates do not typically return the full cost of treating and delivering reclaimed water to customers” (NRC, p. 164, 2012). Niemer et al., (2014) acknowledge that engineers should think long term, while solving short term problems. This is paramount when designing infrastructure systems in municipalities.

Question 3: ‘Does DPR support innovative and entrepreneurial activity?’

When analyzing on whether or not DPR has the potential to support innovative and entrepreneurial activity on a scale of 1-4, it scores a 4 or ‘very likely’ to meet this goal.

Due to green technologies such as decentralized DPR requiring forward thinking individuals and municipalities that can see that such energy systems have the ability to benefit more people over the long run, this can attract certain innovative individuals and businesses to an area (El-Hagger, 2016). Dr. Gary P. Pisano from the Harvard Business School notes that without initial innovative strategies and ideas, any sort of future improvements may come in the form of a mixed bag of best practices, rather than leading to breakthrough R&D in your own sector, but also moving into additional sectors (Pisano, 2015). Therefore, as municipalities invest more money, be it public, or through public-private-partnerships, this infrastructure growth can spur demand for more alternatives and additional innovation in the green energy sector.
Question 4: ‘Does DPR improve a municipalities overall quality of life, additional housing choices and additional access to services?’

When analyzing on whether or not DPR has the potential to improve a municipalities overall quality of life, additional housing choices and additional access to services on a scale of 1-4, it scores a 3 or ‘somewhat likely’ to meet this goal.

If biodiversity can be improved through the use of DPR, not only is the environment have potential for remediation, but it can also provide health benefits to members of the community, such as cleaner water and air. Therefore, any type of technology or system that helps to better protect biodiversity adds to the lifeline system that is extended to all living beings (Hostetler, pg. 11, 2012). Therefore, by implementing decentralized DPR systems, it can also allow for building of residential homes in areas that may have been impossible in the past. There is also the potential for decentralized DPR to be used in very remote areas of Canada where this would be the only sustainable solution to implementing neighbourhood scale wastewater systems. This could be considered a tool that may increase sprawl, but if used in conjunction with other sustainable energy systems, it can allow people greater housing, lifestyle choices and higher quality of life (Hall, 1993).

Question 5: ‘Can DPR systems be designed and managed to optimize use in municipalities?’

When analyzing on whether or not DPR systems can be designed and managed to optimize use in municipalities on a scale of 1-4, it scores a 4 or ‘very likely’ to meet this goal.

Whether or not DPR is considered a viable option must take into account depends on many factors such as region, population, water and waste water management strategies or continuing to do the status quo (NRC, 2012). This is where the many factors affect the costs and ability to optimize DPR for municipalities. Size of plants, transmission and pumping needs, water quality, and timing, storage needs, and energy must be included in the management of DPR (NRC, 2012). Ensuring each of the previous needs are considered, designs can full optimized. To coincide with the previous inputs, smart technology in wastewater management systems can further the optimization. Eckman et al. (2010) mention that the keystone to smart infrastructure projects is integrative modeling frameworks. This allows for both experts and no experts alike to participate in ‘data gathering, planning, monitoring, and reporting.
with cross disciplinary modeling’ to better management and improve infrastructure servicing (Harrison et al., 2010). As decentralized DPR systems can be fully scalable, and even more so in the future, it allows for even more precision when conserving water, and ensuring that as little waste as possible is produced.

**Question 6: ‘Can DPR support affordable housing or employment nodes?’**

When analyzing on whether or not DPR can support affordable housing or employment nodes on a scale of 1-4, it scores a 2 or ‘somewhat unlikely’ to meet this goal.

If decentralized DPR is realized, the long term costs can end up being far less costly than traditional WWTPs and all their additional infrastructure. This money that is saved through maintenance and operations could then be used for affordable housing or investment in employment nodes. The decentralized DPR units themselves could create little employment modules for the running, servicing and monitoring at the neighbourhood levels. Again, this will depend on the ownership of the wastewater system, and the sort of community groups who may be involved in the management. DPR system also have the potential to generate good quality jobs at the neighbourhood scale. Further research should be conducted to look into how decentralized DPR systems could be constructed into affordable housing projects.

**4.6 Environmental Analysis**

The environmental analysis looked at guiding questions utilized by the City of Calgary when conducting a triple bottom line analysis and apply them directly to the previous knowledge and highlighted research about decentralized DPR.

The environmental analysis is an incredibly difficult and complicated process as there are so many controllable and non-controllable factors progressing at the same time. Due to so many components, both environmental and non-environmental that overlap, pinpointing specific indicators and goals can take some time. As pointed out by Rittel and Webber (1973) who conceptualized ‘wicked policy problems’, the environment is a key example. Wicked problems describe the overall complexity of planning for something like global climate change on various stages with various actors (Levin et al., 2012). In addition to the initial complexity, There may also be a general lack of understanding amongst various actors that achieving one goal, may take away from another goal. As the environmental analysis for DPR involves discussion on energy...
requirements, greenhouse gas emissions, solids disposal and regulation and permitting, there needs to be much more discussion and research. When municipalities are considering adopting decentralized DPR, there are some policy documents, if existing, should be amended to support DPR. Municipalities should be looking at plans such as: Climate Change Plan; A Municipal Development Plan; Sustainable Building Policies; and other Environmental Policies (City of Calgary, 2011). Depending on the regulatory framework is pursued in Canada, and at what level of Government, there is a lot of valuable information that can be gained from the Clean Water Act, and Safe Water Drinking Act from the United States and provide for a set of controls that already assures that water quality and public health are protected (Cutruvo, 2015).

<table>
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<th>Triple Bottom Line Environmental Framework</th>
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### Reducing energy needs and combatting climate change

<table>
<thead>
<tr>
<th>Q1</th>
<th>“Can direct potable reuse decrease energy consumption and greenhouse gas emissions from buildings, transportation and use?”</th>
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<tr>
<td>Q2</td>
<td>“Can direct potable reuse incorporate energy efficient or renewable energy?”</td>
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<tr>
<td>Q3</td>
<td>“Can direct potable reuse help to reduce waste, recycle or reuse material?”</td>
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![Likelihood Chart](image)

Question 1: ‘Can DPR incorporate decrease energy consumption and greenhouse gas emissions from buildings, transportation and use?’

When analyzing on whether or not DPR decreases energy consumption and emissions on a scale of 1-4, it scores a 4 or ‘very likely’ to meet this goal, and scoring system mentioned in chapter 2.

Each of the above indicators can be difficult to compare across disciplines and technologies when no complete, comprehensive, life cycle analysis framework exists at this time. This takes us back to the “wicked problem” issue, where even beginning to identify problems can be challenging. Highlighted in the National Research Council Report is that energy usage of water reuse is highly variable and site specific. The Equinox Centre (2010) in San Diego estimated that potable and non potable reuse require significantly less water than desalination and have similar rates to that of traditional waste water reclamation. Unfortunately, when it comes to greenhouse gas emissions there can be no simple answer at this time. Due to a lack of carbon taxing and strategies to put a value on carbon emissions around much of the globe, placing a value on energy requirements for wastewater reuse becomes very difficult. In order to counteract this, better methods must be created to analysis to estimate values (Kidson et al., 2009), and much more considerate life cycle analysis (NRC, 2012). Much of the research that has been carried out and mentioned previously in this report, highlights an overall decrease in energy use for many facets of decentralized DPR over the last few decades. Due to the design of a decentralized system, there is a lot of a lot of room to remove long pipes needed to connect vast areas of a municipality or city to one WWTP. Without these long connections, less energy is required to move wastewater and use can be more easily regulated on the neighbourhood scale. Some further analysis of recent decentralized DPR reuse systems highlights that they can have decreased life cycle costs, lower overall power consumption, and high quality of effluent that can be used for farming (Epeco, n.d).

There are many possibilities in the future that with lower technology costs, lower energy costs, and more concentrated urban populations that decentralized DPR projects will become feasible and easily implementable at the neighbourhood scale.
Question 2: ‘Can DPR incorporate energy efficient or renewable energy?’

When analyzing whether or not DPR can incorporate energy efficiency and renewables on a scale of 1-4, it scores a 4 or ‘very likely’ to meet this goal.

DPR systems can offer different types of renewable energy recovery: water recovery, energy recovery; and material recovery (Guest et al., 2009). When compared with more traditional WWTPs, DPR is able to meet five major environmental sustainable goals: “increase[ing] the use of available local resource, diversifying existing portfolio, reliable climate-independent yields, avoids the socials costs of water shortages and associated curtailments, and decreases the discharges of less treated effluent to ocean or inland surface waters” (Raucher, 2015). Due to the small footprint of these decentralized DPR plants, there is also potential to incorporate other sustainable technologies, such as solar power, to enable operations onsite. As these plants are intended to operate on the neighbourhood scale, there could be a lot more customization that would address site specific requirements without needed large capital investments like larger traditional WWTPs.

Question 3: ‘Can DPR help municipalities reduce their overall consumption of resources?’

When analyzing whether or not DPR can help municipalities reduce their overall consumption of resources on a scale of 1-4, it scores a 4 or ‘very likely’ to meet this goal.

Unfortunately, there is little research about DPR being used to augment existing water supplies for ecological augmentation. This is something that should be further research, and perhaps tested in some municipalities in Canada. The National Research Council stresses that the issues around DPR being used to augmentation would most likely not exceed any risks than using normal surface water as discharge (NRC, 2012). When you compare IPR and DPR, there are even more environmental gains to be achieved. When using DPR, there is likely no need for an environmental buffer and avoid potential contamination within the buffer, may be able to avoid some water rights issues, and avoids the development and research costs of the buffer (Raucher, 2015). It should be noted that when municipalities are looking over a longer time period, such as 50 years, the transition to DPR can create a reduction in overall carbon footprint, energy savings, increased air quality, increased groundwater and surface water quality, and less carbon footprint from the removal of
piping (Raucher, 2015). There are some cases, where decentralized may be technically possible, but municipalities may not have the time nor budget to carry out such research needed to weight the costs and benefits of DPR. There is where additional funding models, or help from upper tier levels of government may be needed to carry out checks and balances such as a full life cycle analysis.
CHAPTER FIVE
DISCUSSION

5.1 Summary of Analysis

The systematic review of the existing literature of decentralized DPR suggests that in many cases DPR can be a viable alternative to traditional WWTPs; in some situations, it can exceed the performance of the traditional WWTPs. Unfortunately, at this time, there is still not enough research or active plants to determine if DPR can be established on a much larger scale.

Within the social pillar, the results are very clear. When municipalities are considering a shift to DPR, there needs to be meaningful consultation from the initial first stages of a project. While conducting the public engagement, planners, engineering and policy makers should ensure information does not overburden citizens with technical information, but at the same time, should not withhold information because experts feel the public may lack the knowledge or understanding to provide accurate feedback. There should also be careful consideration when organizing information sessions and presenting DPR research and projects to the public. Throughout the last 40 years, public outreach, polling, terminology and language and information sharing was handled quite poorly. Time and time again in the United States, Australia and Canada, citizens would report negative feedback when asked about drinking recycled wastewater. This was reported all the while they drank a form of recycled water from the traditional waste water processes. The ‘Toilet to Tap’ program in California is a good example of poor communication between experts and the public which resulted in a 10-15 year delay in moving forward DPR projects.

Another finding in the social pillar is the curriculum taught to water managers in post secondary education. There maybe a combination of lack of research as well as educators that specialize in cutting edge technology, and therefore it is not taught. Post secondary education should do more to focus on curricula that includes alternative energy models and policy solutions. More work should be done by the institutions to bring in academics and practitioners that may work more in grey literature and research.

The environmental pillar is by far the more complicated to research and most unknown factor. Due to so much variability based on the size and placement of DPR plants, this complicates issues further. Canada is such a large country featuring a
variety of landscape, temperature, and environmental challenges to water infrastructure that makes providing a standardized template incredibly challenging. There needs to be much more research conducted on unmeasurable environmental factors, such as greenhouses gases, in order to create a more complete, and rigorous life cycle analysis.

In the economic realm, there is a lot of promising research that points to decentralized DPR either being already competitive, or shortly becoming competitive against traditional WWTPs. Capital costs can still be higher, but as soon as you take into account longer lifecycle analysis than what is typically done, smaller scale DPR can become very cost effective. If barriers are removed that focus on traditional financing models, and more incentives are created for the business community and the public to seek alternative energy sources, this will enable a situation where growth creates growth.

This report highlights that some of the major barriers to implementing DPR, and the findings suggest that these are some of the major reasons that DPR has not been implemented in Canada. These barriers are: a lack of understanding on public opinion around drinking and using recycled wastewater for potable reuse; policies and regulations are varied across provinces, territories, and municipalities; Canada has not had to experience as many extreme weather events as a result of global warming; a lack of research and interest by industry, academia, and the federal government. On the other hand, using the Triple Bottom Line as a research method was useful, but also very challenging. As previously mentioned, the TBL can offer municipalities a lot of flexibility when designing policies and goals that suite the goals and outcomes desired by decision makers. This same flexibility, also creates a large challenge. Due to the variance in chosen indicators, and policies attached to various TBL frameworks, it can be hard to determine which are the most rigorous or successful. Moreover, due to the diversity of climate, urbanization, and landscape across Canada, it can be difficult to standardize a TBL that could serve as the backbone for many municipalities. Further investigation and research should be conducted in the Canadian context.
5.2 Recommendations Moving Forward

Given the smaller scope of this report, there are many exciting opportunities that can be researched and discussed moving forward. The increasing need for clean potable water, exasperated by climate change, will never decline but DPR can ease the stressors on our systems and provide extremely clean water without having to drastically change our waste and water systems.

- More collaborative research and careful public engagement should be carried out to ensure the public is supportive and understands the potential needs for DPR systems in Canada.
- Education and training should be adjusted to reflect more innovative technologies and models that may not be currently taught in planning, engineering, health or policy related curriculum.
- TBL frameworks and life cycle analysis will provide important models for municipalities to ensure decision making processes for wastewater are fair, rigorous and take into account the three pillars of sustainability.
- There needs to be much more research on life cycle analysis on water reuse and wastewater systems to understand the non-financial costs should be evaluated on projects.
- There needs to be more scientific research carried out of the existing DPR projects and more investment needed to bring more research projects online in municipalities.
- There needs to be more research to understand the policy implications of either allowing municipalities, the provinces and territories, or the federal government to take the lead on DPR policies and implementation.

If policy makers, planners, engineers, health experts and the public come together, there will be opportunity for decentralized DPR technology that can have the potential to elevate energy concerns, create water than can be more clean than WWTPs and policies and regulation that offer incentives for these types of systems to be built. Just as the took time for the places in the world to transition from the outhouse to indoor plumbing, transitioning to another type of wastewater system will take time, investment, government and public support.
REFERENCES


Doria, Miguel De França. “Factors influencing public perception of drinking water quality.” Water Policy, vol. 12, no. 1, 2010,
wp.iwaponline.com/content/12/1/1. Accessed 2017.


IMAGES AND FIGURES

American Water Works Association. “Potable Reuse 101”.

Empside LTD. “Triple Bottom Line.” CSR Ambassadors, OADAD,
www.csrambassadors.com/corporate-social-responsibility

DART Controls. Wastewater Treatment. Digital image. Water / Wastewater

Moher, David, et al. “Improving the quality of reports of meta-Analyses of
randomised controlled trials: the QUOROM statement.” The Lancet, vol. 354,
no. 9193, 1999, pp. 1896–1900.,

Petticrew, Mark, and Helen Roberts. Systematic reviews in the social sciences: a
practical guide. Malden, Blackwell, 2006,