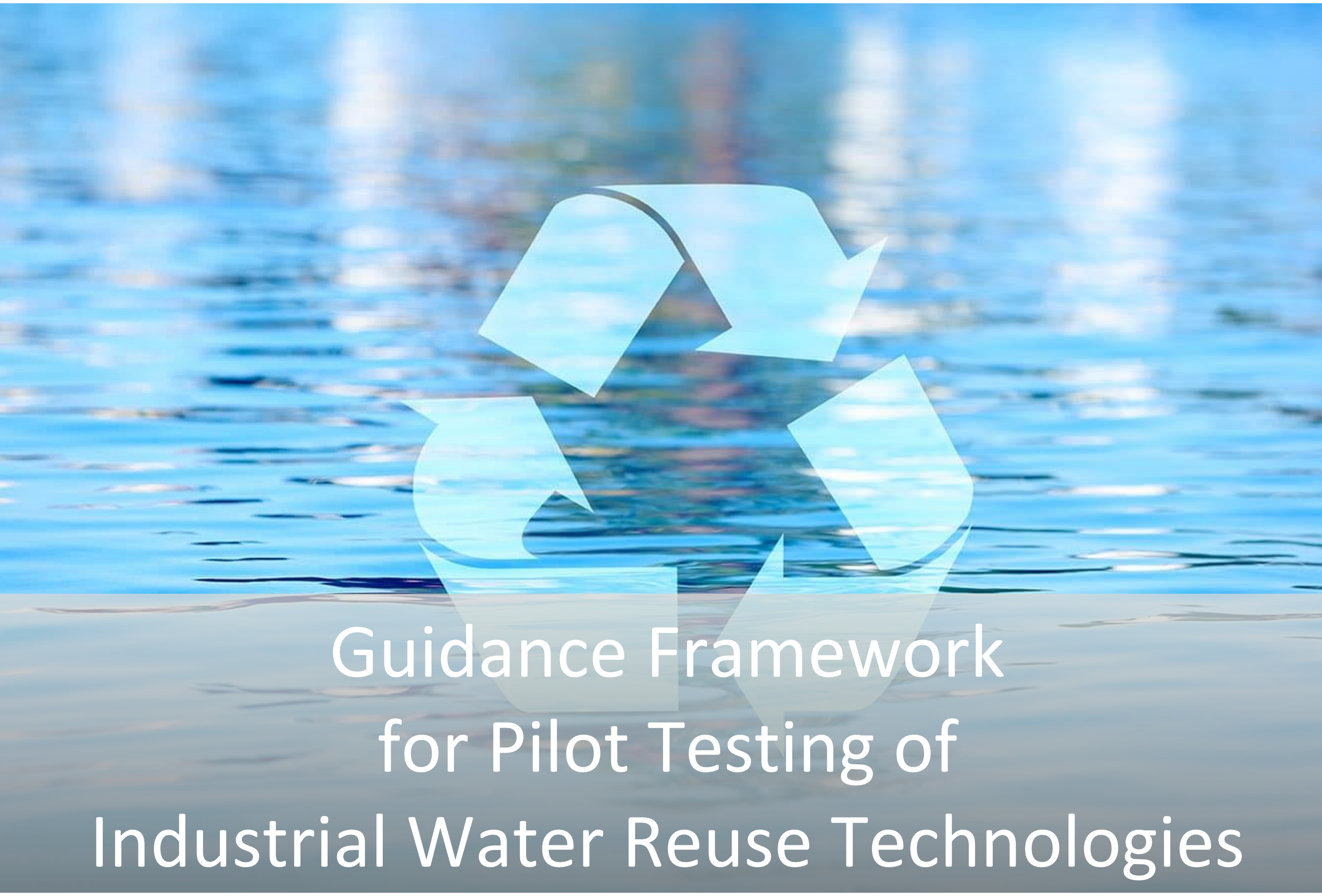

Guidance Framework for Pilot Testing of Industrial Water Reuse Technologies

ACWA
Advancing Canadian Water Assets
An Urban Alliance initiative

waterSMART
Water Management Solutions

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Context and Need

Commercialization of industrial water reuse technologies will benefit Canadian industry and help achieve positive environmental impacts. Pilot testing, while a critical part of the technology commercialization journey, often has unclear or misunderstood objectives. This can result in unnecessary costs and missed opportunities. With mounting pressure to adopt new innovations faster, many industrial sectors face significant challenges related to de-risking and validating new technologies.

Intended Use

This Guidance Framework is intended to provide guidance for those who are planning, championing or funding pilot tests for industrial water reuse technologies. Using the guidance and tools provided, a clearer pathway through the piloting process can be developed, to facilitate better funding applications, more focused business and technical assessments and faster commercialization pathways.

This Guidance Framework was primarily written for use by the oil and gas sector (not including mining and in situ oil sands, which have specific piloting considerations). However, the general concepts presented here are also applicable to other sectors (e.g., manufacturing, agriculture, food processing, etc.).

This is not a regulatory or policy document, nor is it a how-to manual for conducting the actual pilot tests. It is also not intended to guide the assessment of how to manage water at your facility or how to assess whether water reuse holds strategic potential for your situation. There are other processes and documents that address those topics, many of which are situationally specific and regularly updated.

This document provides an overview of the numerous considerations that need to be addressed when planning the journey from a technology proof-of-concept (i.e., typically something that has been shown to work at the bench-scale in a laboratory or workshop) through to a technology that has reached full-scale commercial maturity and is ready for marketplace adoption. Just like a map for other journeys, this is a planning tool that bridges big-picture aspiration with on-the-ground realities and seeks to reduce the missteps that could occur.

Acknowledgements

Funding for the development of this Guidance Framework was provided by CRIN (Clean Resource Innovation Network) and Alberta Innovates. This Guidance Framework was developed by ACWA (Advancing Canadian Water Assets) and WaterSMART Solutions Ltd., in consultation through a series of workshops conducted in 2022 and 2023 with over 45 representatives from technology end users, technology proponents, government funders and regulators. We could not have completed this without you!

Executive Summary

This Guidance Framework is structured to provide guidance for those who are planning, championing or funding pilot tests for industrial water reuse technologies. This includes technology developers, technology end users and the funders and regulators that they work with through the commercialization journey. It is divided into four key sections, each of which addresses a core aspect of preparing a pilot test plan, as laid out in the Document Structure section on the next page.

This Guidance Framework strikes a balance between being too specific, which would limit its applicability to very specific situations, while also avoiding being too high-level and conceptual, which would limit its practical value. It is meant as a general guide for a wide range of situations and applications. Developing water reuse technology is complex and each situation has its own unique considerations. Therefore, it is highly recommended that users go through this entire document to understand all the key aspects that must be considered when planning a pilot test program.

This framework recognizes several key considerations that need to be addressed when preparing a pilot test plan for an industrial water reuse technology. These include:

Initial considerations:

1. Has sufficient market demand been proven to warrant embarking on the necessary effort and expense involved in pilot testing?
2. What considerations related to sustainability, environmental impact, social impact (e.g., water availability and quality) and economics need to be included?

Regulatory considerations:

3. Are the types of source water(s) that will be used known? Is the end use of the reused water fully understood?
4. Given the source water and end use, which regulations and policies apply for the specific reuse application that will be piloted for? What obligations does this place on the proposed treatment system and its operators?

Technical performance:

5. What questions related to technical performance will the technical pilot test(s) need to answer to retire the key technical risks and unknowns?

Economic performance and operational integration:

6. What key questions related to economic performance and operational integration will the economic pilot test(s) need to answer to demonstrate that the proposed treatment system can provide better value and/or easier operations than existing approaches/technologies?

Provided within this document are planning tools (flow charts, assessment questions, etc.) that form a toolset which is high-level enough to be broadly applicable yet provide some reasonably detailed structure to be applicable to many of the pilot planning needs for industrial water reuse.

1.0 Introduction

Commercialization of industrial water reuse technologies will benefit Canadian industry and help achieve positive environmental impacts. More effective pilot testing is a critical component of achieving this. This framework is intended to provide guidance for those who are planning, championing and/or funding pilot tests for industrial water reuse technologies. As stated above, this Guidance Framework is meant as a general guide for a wide range of situations and applications. Therefore, it is highly recommended that users go through this entire document to understand all the key aspects that must be considered when planning a pilot test program.

1.1 Document Structure

The document is organized into a workflow that facilitates mapping of the validation journey. It starts with important *Initial Considerations* to review before a decision is made to pursue pilot testing. *Regulatory Considerations* are then presented, allowing for clearer planning of the pilot test. Finally, key aspects for validating T*echnical Performance*, as well as *Economic Performance and Operational Integration*, are also provided. Along the way, an illustrative example is provided to demonstrate how a model company, ABC Co., would utilize the framework to support their validation journey.

Figure 1 shows where this document fits within the overall commercialization pathway.

Definitions for key **bolded terms** are provided in Appendix A. Throughout the document, each section includes information and questions which should be used as tools to support technology development. In most cases, users can develop answers to these questions using non-confidential information, which means the responses can be shared with potential funders and partners to facilitate next steps for technology validation.

1.2 Purpose of Pilot Testing and Role of "Failure"

This document is intended to provide a framework to assist building a plan for **pilot tests**, defined as a **pilot test plan**, which has clear objectives and effectively addresses the key considerations, questions and performance verification needed to advance a technology through the **Technology Readiness Levels (TRLs)**. The goal of advancing a technology through the TRLs is to make commercial sales, often starting with a first customer for whom the technology has been sufficiently de-risked, and eventually leading into the broader marketplace. Note that development of a marketing plan or go-to-market strategy is beyond the scope of this document.

Validating that a new technology works under specified conditions is a typical requirement of almost all end users. Pilot tests are one of the primary methods for achieving this validation. A single pilot may address multiple technical, economic and operational considerations. However, more than one pilot is typically required to address all these considerations and advance the technology through its de-risking stages. Each stage of technology de-risking needs to provide information to inform or guide the next stage of technology de-risking. The technical planning team needs this information. It is also often needed by funders or investors, who use these results as milestones to guide subsequent investment decisions.

> "A failed pilot is one where no learnings are gathered."
>
> - *Workshop participant*

In addition to showing that a technology works, pilots often need to show what conditions cause it to *not* meet the performance criteria. A pilot which demonstrates these conditions is NOT a failed pilot. Rather, this provides critical information for prioritizing subsequent development steps (i.e., where best to apply the available resources). Eventually, this information will also help establish the acceptable operating conditions for that technology or model. The section below on Technical Pilots provides more detail on the different types of testing that can be done and shows how purposely pushing technology beyond its performance capabilities is a key feature of certain tests.

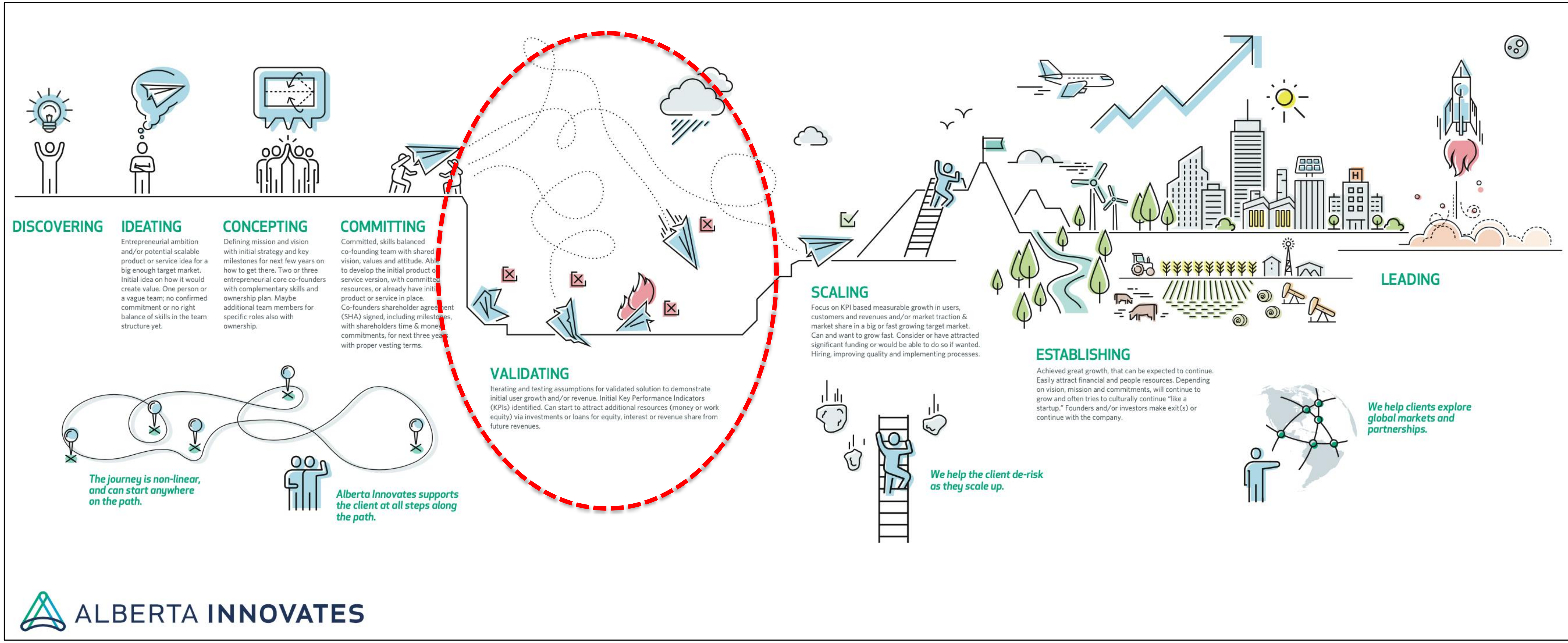

Figure 1. Pilot testing is within the Validating stage of the Commercialization Pathway.
Source: https://albertainnovates.ca/programs/technology-development-advisors/

1.3 The Current State of Water Reuse

The US Environmental Protection Agency (EPA) provides a useful definition for water reuse and explanation of its potential applications:

> *"Water reuse (sometimes referred to as recycling or reclamation) utilizes water from a variety of sources then treats and reuses it for beneficial purposes, such as agriculture and irrigation, potable water supplies, groundwater replenishment, industrial processes and environmental restoration. Water reuse can provide alternatives to existing water supplies and can be used to enhance water security, sustainability and resilience.*
>
> *Potential sources of water for reuse can include municipal wastewater, industry process and cooling water, stormwater, agriculture runoff and produced water from natural resource extraction activities, among others. These sources of water are adequately treated to meet **fit-for-purpose** specifications for a particular use. Fit-for-purpose specifications are the treatment requirements to bring water from a particular source to the quality needed, to ensure public health, environmental protection, or specific user needs"*[1]

Within this context, Section 1.3 provides a high-level overview of the current water reuse policy environment in Alberta, Canada and globally. See Regulatory Considerations, below, for further discussion on navigating the Alberta policy environment to progress water reuse technologies. In addition, a list of relevant regulatory documents is provided in Appendix C.

Water Reuse Policy and Legislation in Alberta

Currently, Alberta does not have a formal, cross-cutting policy for reuse of wastewater in the province. Multiple sectors have expressed interest in various water reuse and stormwater use opportunities, in response to which the Alberta Government has issued several interim guidance documents and regulatory instruments to support some specific water reuse activities. The most recent publications have focused on public health guidance.

Without definitive water reuse policy guidance, the existing policy and regulatory environment in Alberta is complex, and navigating this complexity can sometimes be challenging for technology proponents and project developers. However, water reuse has been ongoing in Alberta on an individual project approval basis in several forms (e.g., municipal wastewater for hydraulic fracturing and industrial cooling, industrial effluent for hydraulic fracturing, rainwater capture for individual and public buildings, etc.). There are many examples of successful water reuse projects in the province, and there is information available to support prospective projects. For example, WaterSMART Solutions Ltd. has published several documents that provide details on the water reuse regulatory environment in Alberta Water Reuse in Alberta - 2008 - 2015 - WaterSMART Solutions.

The Alberta Government produced a document with guidelines for the authorization of use of treated wastewater, the *Interim Guidance to Authorize Reuse of Municipal and Industrial Wastewater*[2]. This

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[1] Basic Information about Water Reuse (USEPA) – available online here.

[2] *Interim Guidance to Authorize Reuse of Municipal and Industrial Wastewater - https://open.alberta.ca/publications/interim-guidance-to-authorize-reuse-of-municipal-and-industrial-wastewater*

provides a clear direction for authorizing wastewater use within the mechanisms of existing policy. Such projects require authorization from the regulator and appropriate treatment of wastewater to make it acceptable for discharge to a receiving water body. The standards for treated wastewater quality approved for release to surface waters are defined in Part 3 of *Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems*[3].

In 2021, the Alberta government released the *Public Health Guidelines for Water Reuse and Stormwater Use*[4]. This guidance document was developed for non-potable use scenarios and provides details about the public health assessment and information that will be required as part of an application for a wastewater reuse or stormwater use project where human exposure to non-potable water is likely. It identifies that Alberta has taken a fit-for-purpose approach.

Canada

In Canada, there are currently no national guidelines or regulations for water reclamation and reuse, with the exception of the *Canadian Guidelines for Domestic Reclaimed Water for Use in Toilet and Urinal Flushing*[5]. The Provinces maintain jurisdiction over water allocation and reuse opportunities. British Columbia has the clearest regulatory framework for domestic and municipal wastewater reuse with their regulations under the *Waste Management Act*. Across Canada, especially in British Columbia and Ontario, there are many examples of wastewater reuse and stormwater use for various purposes, including agriculture, domestic and industrial use.

International

In the US, there are no specific requirements or restrictions placed on water reuse by the EPA. Instead, primary regulatory authority is held by the States. As in Canada, there is variability in the extent to which each State has established programs for managing reuse, possibly including integration into existing regulatory programs. However, foundational guidance which State and local governments leverage is provided by the EPA through the Safe Drinking Water Act and the Clean Water Act[6].

In California, for example, the *Water Quality Control Policy for Recycled Water* (Recycled Water Policy)[7] encourages the safe use of recycled water from wastewater sources that meets the definition in the California Water Code, in a manner that implements state and federal water quality laws and protects public health and the environment. The Recycled Water Policy provides direction to the regional water boards, proponents of recycled water projects and the public regarding the methodology and appropriate water quality control criteria for the State Water Board and the regional water boards to use when issuing

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3 Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems - https://open.alberta.ca/publications/5668185

4 Public Health Guideline for Water Reuse and Stormwater Use - https://open.alberta.ca/publications/public-health-guidelines-water-reuse-stormwater-use

5 Canadian Guidelines for Domestic Reclaimed Water for Use in Toilet and Urinal Flushing - https://www.canada.ca/en/health-canada/services/publications/healthy-living/canadian-guidelines-domestic-reclaimed-water-use-toilet-urinal-flushing.html

6 EPA Guidelines for Water Reuse - https://www.epa.gov/sites/default/files/2019-08/documents/2012-guidelines-water-reuse.pdf

7 *Water Quality Control Policy for Recycled Water - https://www.waterboards.ca.gov/water_issues/programs/recycled_water/policy.html*

permits for recycled water projects. There are many examples of water ruse in California for a wide range of purposes (e.g., agricultural irrigation, groundwater recharge, geothermal energy production, etc.).

Florida is another state that offers some examples related to water reuse. A variety of non-potable water reuse activities have been ongoing for many years, for example landscape irrigation, golf courses, industrial uses and groundwater recharge. Some advantages Florida has found arising from non-potable water reuse include reducing demand on surface and groundwater supplies, reduction or elimination of wastewater discharge and protection of drinking water sources, and an environmentally sound way of managing wastewater (e.g., limits nutrient loading)[8]. Due to various pressures on the groundwater supply, the primary source of drinking water in Florida, the state is now working toward potable water reuse. A recent publication in 2019, *the Framework for Implementation of Potable Reuse in Florida*, details a collaborative project of the Florida Potable Reuse Commission. This document identifies the regulatory changes that would support and promote potable water reuse in the state, while protecting public health and the environment.

In Israel, nearly 90% of the nation's wastewater volume is recycled, primarily for agricultural irrigation Israel's national policies support water recycling technologies, research and development, and smart water management including leak detection and high efficiency systems[9]. Israeli companies are supporting countries around the world in water efficiency and improving overall water security.

Australia is also widely recognized for wastewater reuse and rainwater capture, with regulations that support dual piping systems (also known as "purple pipe") in some cities. Direct potable use of reclaimed water is not legal in Australia, but it is an ongoing discussion for some communities, especially when facing recent severe droughts. One of the original drivers for wastewater recycling was wastewater treatment plant discharge regulations for environmental protection[10]. The Australian government supported greater use of recycled water by issuing new guidelines *Managing Health and Environmental Risks* and *Augmentation of Drinking Water Supplies; Stormwater Harvesting and Reuse; and Managed Aquifer Recharge*[11].

Examples of successful reuse and piloting initiatives exist all over the world. Many of these are identified in *Water Reuse Within a Circular Economy Context, Series II*, a 2020 publication from the UNESCO International Centre for Water Security and Sustainable Management[12]. The potential benefits of water reuse are summarized," Rather than being a burden, with the necessary planning on a water basin or aquifer basis, marginal water resources can provide socio-economic opportunities that close the resource use loop while providing essential resources on local and regional scales. Successful pilot projects may be scaled up if the social and economic conditions exist within a governance framework amenable to a circular economy"[13].

[8] Framework for Implementation of Potable Reuse in Florida - https://watereuse.org/wp-content/uploads/2020/01/Framework-for-Potable-Reuse-in-Florida.pdf

[9] https://www.fluencecorp.com/israel-leads-world-in-water-recycling/

[10] Water reuse and recycling in Australia — history, current situation and future perspectives - https://www.sciencedirect.com/science/article/pii/S2666445320300064

[11] Australian guidelines for water recycling - https://www.waterquality.gov.au/guidelines/recycled-water

[12] Water Reuse Within a Circular Economy (Series II) - https://unesdoc.unesco.org/ark:/48223/pf0000374715.locale=en

[13] Ibid.

2.0 Planning a Pilot - Initial Considerations

This section contains information which technology proponents should review in detail after reading this entire document, and before starting piloting. The guidance in this section will help proponents evaluate the benefits of their technology and discuss these benefits in a meaningful way with potential end users and funders. Indeed, after completing this section, proponents should make a go/no-go decision on whether to proceed with designing, funding and executing a pilot plan, considering the trade-offs between the cost, effort and time required to develop and implement a pilot test plan versus a realistic estimate of the potential of the technology under consideration.

2.1 The importance of focus

As this document will explore, many factors must be considered when developing a pilot test plan. Implementing all necessary piloting to a satisfactory level to sufficiently de-risk a technology for commercialization can be an expensive and long process. Lead times for pilots can be highly variable and subject to the planning and budget cycles of end users and funders; broader economic cycles and trends; winter and summer seasons; capacity within a facility to host a pilot; process upsets and turnarounds; end user urgency; and regulatory review and approval timelines. In addition, piloting in an operational process or facility can be disruptive to end users, who must adjust established protocols and procedures to accommodate the pilot without assuming unacceptable risk to their processes and outputs.

Given these considerations, it is critical that novel water technologies address a market need that has been directly verified with potential customers. Technology proponents must consider the water quality requirements of their target market and focus their efforts on producing fit-for-purpose treated water. For example, a water reuse stream in an oil and gas process may not need to be treated to ultrapure quality standards, or even to drinking water quality standards. By stripping away unnecessary treatment levels, proponents can significantly reduce the cost and complexity of their technologies, while simultaneously improving their value proposition to their target market. Importantly, different end users may have different requirements, even within the same industry, due to differences in site characteristics and operating approaches. Proponents must spend time exploring these differences and their implications for the technology at an early stage of development.

Furthermore, proponents must be highly focused when planning their pilots. Working with partners and end users (discussed below), proponents should identify the required type(s), durations, sizes and complexity of pilots, with emphasis on how piloting will retire risks associated with the technology to a satisfactory level for end users, with minimal or manageable operational disruptions. Importantly, end users may not require (or even be interested in) piloting the entire treatment train or skid being developed by proponents, when these consist of unit operations which are already commercially available. Instead, the focus for piloting should be on de-risking the novel component(s) (i.e., the core of the new technology) and integration into the industrial process. The nature of piloting, as well as the potential future application of the technology, will also impact regulatory approval requirements (see the Regulatory Considerations below for further discussion).

Although piloting should be highly focused on de-risking a technology's ability to address a real problem, technology proponents must also be flexible and ready to shift their technology to new markets and/or purposes based on feedback received from the market. End user needs, funding availability and partnerships can be dynamic, and responding to these changes quickly and appropriately (i.e., "**pivoting**") is an important aspect of technology development. While working through this document and preparing a pilot plan, proponents should consider contingencies and "what if" scenarios to help manage and capitalize on future changes.

2.2 The importance of partners, customer champions and information sharing

2.2.1 Necessary skills for technology development

To successfully develop technologies, proponents need the right combination of skills and experience. In today's technology development ecosystem, collaborative teams of highly skilled individuals, who work together and are willing to share ideas and information with partners, are much more likely to be to achieve success than those who try to do it all alone or are overly concerned about keeping new developments a secret. The following types of skills and experience should be part of the technology proponent team:

- Inter-personal: Ultimately, water technology development relies on people and relationships, from the initial concept pitch all the way to ongoing sales. Proponents must develop effective, collaborative relationships with a wide range of individuals and organizations, which requires effective communication and the ability to connect on a personal level. Proponents should approach these initial interactions respectfully and with a mindset of curiosity.
- Technical: Proponents need subject matter experts to effectively design pilots and support pilots throughout execution so that useful results can be gathered. Having one or more qualified technical individuals will also lend credibility to the proponent team when communicating with potential end users, funders and partners. Proponents must be able to "speak the language" and provide confidence that they can achieve stated targets.
    - In addition, relevant operational experience is a major asset. Operating environments are complex, dynamic and have many nuanced constraints, including safety, operating permits and existing operations and maintenance patterns. Pilots must be designed to fit within existing constraints. In the absence of relevant field experience, proponents must demonstrate a willingness to learn from end users at an early stage of technology development.
- Business: Proponents must have a view to achieving commercial success. A technology cannot be piloted forever; the proponent team should include someone who will direct technology development efforts towards commercial sales and make the tough calls about when to stop testing and decide that the proposed technology isn't commercially viable. An "investor" mindset around a threshold for minimum financial returns can be an asset for technology development, including pilot planning.
    - Partners and funders of pilot testing will often contribute significant time, funds and/or in-kind contributions to the effort. Technology proponents need to acknowledge these contributions and ensure their contributions are aligned in direction and magnitude.

There are many avenues for proponents to add the necessary skills and experiences to their team, including through partnerships with external parties. Proponents should explore the resources and support available from organizations such as business accelerators and pilot testing networks, which can include skills training, advisory services and networking. In addition, these organizations may provide opportunities to leverage funding, making it easier to fund piloting efforts.

2.2.2 Customer partnerships

As seen in the illustrative example below, it is critical to establish trusted partnerships with potential customers and work with them in a collaborative manner throughout the technology commercialization process. The importance of the aforementioned inter-personal and communication skills for relationship building cannot be overstated. Without early buy-in from potential customers, there is no feedback on whether the technology under development is targeting the "right problem to solve" or if there is enough market demand and economic opportunity to justify the significant effort and costs it will take to complete the commercialization journey. As will be discussed below, the presence or absence of regulatory drivers for a technology should also be evaluated early, often in collaboration with potential customers.

The potential impacts of the technology to stakeholders and rightsholders should also be considered at an early stage. The individuals and groups potentially impacted by deployment of the water reuse technology may play a future role as supporters or detractors, and it is important to understand their perspective(s) and the associated opportunities and risks. A technology's social license to operate can be a key determinant of commercial success.

2.2.3 Customer champions

In addition to having early discussions with potential customers, it is also necessary to identify a specific individual, or small group, within each customer organization who can champion the new technology within their organization. Technology champions must not only understand the technical merits and potential of the technology, but they must also be sufficiently engaged in the technology development process within their organization to provide informed feedback on how this technology, once de-risked and validated, could be integrated into their organization's overall operations and growth plans. This could take the form of senior decision-makers as well as individuals elsewhere in the organization who have a direct line to the decision-maker(s) and can provide guidance on what will be important to inform that decision. Customer champions also need to have sufficient decision-making authority or influence to secure resources, financial or in-kind, to support the technology's development. Note that each end user will have their own internal processes for technology development, and there may be significant differences in:

- How they gather new technology ideas (e.g., through online portals).
- Which levels of decision makers are involved.
- The level of information required to make a decision.
- How and when decisions are made.

Technology end users can streamline their contributions to innovation development and commercialization by designating technology champions with clearly defined roles and authority. This is often done by establishing an innovation team that works with the organization's various operational groups to find and evaluate a range of beneficial technologies. Alternately, senior leaders in the various operational groups could also be designated and incentivized to perform this role.

2.2.4 Intellectual property

Once a technology proponent connects with a technology champion, open and trusting communication is key. Technology proponents can sometimes be concerned about retaining confidential information about how their technology functions, to the point that they are unwilling to share enough information with potential partners and funders to allow these parties to evaluate if this is an opportunity that they want to pursue or support. Since potential customers, partners and funders are regularly presented with many technology ideas, they are much more likely to engage with those technology proponents that are easier to work with, including those that willingly share the necessary information.

Confidentiality agreements are often used to address potential concerns about sharing proprietary information. However, potential customers also must be careful about receiving confidential information from competing vendors, which sometimes places them in the difficult position of inadvertently not being able to meet the terms of all the confidentiality agreements they have signed (because they end up “knowing too much”). Therefore, potential customers may not wish to receive confidential information if they are evaluating other competing vendors. Providing partners with as much non-confidential information as possible enhances a technology developer’s chances of success.

This does not mean that technology proponents should ignore protecting their **Intellectual Property** (IP). In the early stages, the IP portfolio is often one of the key determinants of a startup’s valuation. Getting informed advice (e.g., from an IP lawyer or a business accelerator coach) will assist a technology proponent in determining what aspects of their IP need to be protected, through patents or trade secrets, and what can be shared with potential customers, partners and funders.

When developing an IP strategy, it is beneficial to clearly articulate what is **Background IP** (i.e., existed prior to the pilot project and forms a foundation for the new developments or advances). For example, if a technology developer is contributing both IP that they have developed and own (e.g., a chemical additive’s formulation) and IP that they are using from either a partner or vendor (e.g., a treatment membrane), then both are Background IP. In contrast, **Project IP** is developed through the course of the project -- in this case, the pilot test(s) (e.g., development of a process to optimize dosing of the chemical additives into the membrane treatment system).

In the contracts for pilot testing, ownership of Background IP will usually remain unchanged (i.e., be retained by the contributing owner), but Project IP could end up with either shared ownership (e.g., the technology developer and the pilot test host/sponsor) or owned completely by either the technology developer, the industrial (co-)funder or the technical service provider (e.g., a researcher or commercial laboratory) that develops the project IP. Usage licenses can be granted to the other parties if needed. Therefore, it is critical to get qualified advice (e.g., from an IP lawyer) when establishing the IP terms in these project contracts.

Often, once an initial IP strategy is developed, it becomes clear that more information on the Background IP can be safely shared than what was originally assumed. This will allow the potential collaborators to better assess whether they are interested in the technology and enable discussions to progress faster and more fruitfully. It also becomes critical in pilot test planning, as information needs to be shared openly about the technology’s current unknowns and still-to-be-solved challenges. Sharing existing gaps and challenges with trusted partners and funders enhances the technology developer’s credibility; all parties have sufficient experience to realize that no technologies, especially emerging technologies, are perfect. They all have their shortcomings and challenges.

Being aware of other technologies that have been developed, and understanding why they either failed or succeeded, can provide a very helpful baseline for understanding the shortcomings and challenges of current technology. Theoretically, this could be done by reviewing results of previous pilot tests for similar technologies. In practice, this can be quite challenging for technology developers, for two key reasons: (1) results of previous pilot tests may not have been widely shared, and there is little to no awareness of the previous work amongst any of the involved parties (e.g., developers, end users, funders); or (2) the industry partner has access to results from previous work, but due to pre-existing confidentiality agreements, they are not allowed to share this information with other technology developers, even in a summary format. Therefore, industry partners and funders should explore ways to give new technology developers a mechanism for accessing previous results of what has already been tried and whether it worked.

Pilot testing is one of the key ways to achieve initial market adoption. Achieving market adoption earlier can often be more important than being overly cautious about protection IP, as it allows the proponent to capitalize on opportunities, many of which are time sensitive.

2.2.5 Funding Sources

Securing funding to cover pilot testing costs can be very challenging and take longer than expected. Starting the fundraising process early enough is a critical success factor. Timelines to secure funds for testing can range from several months to several years, and strategic planning is required to map out appropriate funding sources along the technology validation journey. Therefore, fundraising *cannot* be started once the pilot test planning is complete, but rather needs to happen in parallel, or in many cases even prior to the start of the planning process. It is also important to have a realistic estimation of timelines for the various pilot tests and other stages within the overall technology validation journey. Technology validation often takes longer, and costs more than originally anticipated, so securing funding in sufficient quantities and durations is important.

There are many funding sources available, including provincial and federal grant programs, business accelerators, partnerships with likely end users and equity partners. Each funding source participates at different TRLs with different objectives; will have different payment terms which impact project cashflow (e.g., up-front payments vs. reimbursements, grants vs. loans vs. equity); and will have different application requirements and timelines. To help navigate the funding landscape, technology proponents should consider engaging with technology accelerators and funding advisors (e.g., Alberta Innovates). Because the funding landscape is highly varied and always evolving, this document will not attempt to list all potential funding sources. Rather, it is up to the technology proponent to identify appropriate funding sources, leveraging existing tools and resources where available. The CRIN ecosystem map and Alberta Innovates' Connectica website are excellent starting points when developing a pilot funding strategy.

A key requirement for securing funds from any source is to clearly demonstrate the value proposition. Different funders will have somewhat different drivers and hence will need somewhat different value proposition articulations. However, all of them will need to be shown that (a) the technology under development solves a problem that customers acknowledge they have; (b) there is sufficient market demand to justify the investment of money and effort (i.e., a clear business case); and (c) there is a clear plan for how to retire the existing gaps and risks (technical and otherwise) for this developing technology and there is a reasonable chance of eventual commercial success. The Assessment Questions below can be used to gather the necessary information for developing an informed value proposition.

2.3 Market Assessment

A full pilot test plan can take years and cost from hundreds of thousands to millions of dollars to fully complete all its stages. Therefore, most organizations will require a thorough business case to justify this investment. A critical component of that business case is a realistic projection of the market demand for the technology being tested. This projection needs to determine the size of the **Total Addressable Market (TAM)** and a realistic estimate of attainable market share, plus who the probable first customers are (preferably backed up with partnership agreements or provisional purchase orders).

Attainable market share is often over-estimated. Even very dominant brands like Apple's iPhone typically capture <15% of the market. For example, Tesla's auto market share is <3%. New technology entrants can realistically expect much less than 1% initially, especially if successful incumbents already exist and/or switching costs are high. Market share growth rate is also key to consider.

Over-estimating either the attainable market share or growth potential can come across as “hype” and can be a significant barrier to securing quality partners and/or engaging with potential customers and funders. In its simplest form, the economic value of the opportunity is determined as follows:

Economic Opportunity = (size of Total Addressable Market) X (% realistic market share)

The costs of a pilot test plan can then be weighed against the realistic projections of economic opportunity, to determine payback periods and other assessments, and establish if pursuing this technology has sufficient upside for the proponent. Note that this assessment is separate from, but related to, the determination of a value proposition for end users.

In some cases, market demand is driven by things other than economics, such as a need to meet regulatory obligations, allowing expansion of existing facilities (e.g., where new water allocations are not economically available) or commitments to improving sustainability. In these cases, it is critical to have detailed discussions with potential customers to understand the nuances of their drivers and potential price sensitivity. These conversations will allow the proponent to complete an informed assessment of market demand. The unique drivers and market sizes across different jurisdictions should also be considered. In many cases, a sufficiently attractive economic opportunity can only be generated by targeting markets in multiple jurisdictions.

As can be seen in the Example below, water treatment technologies can often apply to more than one market sector. Therefore, pilot test plans need to anticipate that the commercial offering may be applicable to markets that are significantly different, but which share similar water treatment needs. Pilot tests may need to verify performance for multiple sectors, or multiple pilots may be required. However, while a broad perspective is useful for strategic business planning, when it comes to pilot planning and implementation it is critical to focus on the initial application for the technology, to avoid trying to do too much at once.

Illustrative Example

Throughout this document, a fictional example is provided, to illustrate how the concepts and tools provided here could be used by those evaluating a pilot test plan.
(Note: any potential resemblance to existing companies or technologies is unintentional and coincidental.)

ABC Corporation has developed a membrane-based solids removal technology. The initial impetus came from one of the founders, who became aware of an opportunity to help commercial car washes and industrial vehicle washing stations improve their sustainability by achieving full reuse of their water and thereby achieve Zero Liquid Discharge. ABC Co.'s founders felt this was a compelling offer, especially in large cities and regions where water shortages were growing.

So far, they have invested $2MM of their own money and government funding into developing the technology and it works reliably in the lab. They feel they are close to having a market offering.

They evaluated the market demand, using the tools provided in this document. The car wash market in the US plus Canada is over $30B and growing at a **Compound Annual Growth Rate (CAGR)** of 3.1%, which is a healthy market size and growth rate[2]. However, when they dug a bit more, they found that a typical car wash that reuses its water will only spend about $35,000 to $100,000 per location for water treatment (typically a simple settling basin or cyclone separator)[2]. When multiplied by the 17,000 existing car wash facilities[2], they realized that their TAM for *car wash water treatment systems* only was in the range of $595MM to $1,700MM. With an optimistic target of attaining 1% market share within
5 years, their total Economic Opportunity was only $6MM to $17MM and they would be competing with much simpler and less expensive technologies already were established in the market. Given the funds already invested, the likely ongoing business costs once they started sales efforts, plus the competitor landscape, they realized that they needed to find more favourable market segment(s).

They then evaluated water reuse opportunities in breweries, agricultural feedlots and oil and gas hydraulic fracturing opportunities. They selected the hydraulic fracturing opportunity as the most suitable **beachhead market** and started conversations with hydraulic fracturing service providers, to better understand the nuances of this marketplace.

See Footnote [14] for sources.

2.4 Technology Maturity

To effectively plan the technology validation journey, it is necessary to objectively evaluate the **technology maturity** of what is being developed. This is often ignored, or technologies are arbitrarily assigned a TRL score that is not justified when examined more objectively. Technology proponents and their collaborators are encouraged to objectively assess a technology's TRL using third-party criteria and be objective about the current shortcomings or gaps of the technology. This enhances credibility and also enables clear planning for how to close those gaps.

[14] Sources from the illustrative example:
https://www.grandviewresearch.com/industry-analysis/car-wash-service-market
https://www.census.gov/library/stories/2021/06/americas-love-affair-with-clean-cars.html
https://www.detailxpertsfranchise.com/blog/2014/05/16/wastewater-recycling-system-much-cost-car-wash/

Pilot testing is typically performed on technologies that have already been shown to work in a **bench test** in the lab or workshop. According to the US Department of Energy's TRL assessment guide (Appendix B), a technology needs to be TRL 6 before it is ready for pilot testing. This means that most of the core science and engineering considerations have already been solved. What remains is largely:

1. Determination of how the inevitable scale-up and engineering challenges will be overcome (using technical pilots).
2. A detailed estimate of what the full-scale operations and maintenance costs will be (using economic pilots).
3. An assessment of how to overcome the challenges associated with integrating this new technology into an existing facility or operational workflow (through an operational integration assessment).

Using the information gathered from discussions with prospective customers, especially related to technical and economic performance needs, it becomes clearer what performance indictors need to be designed into the pilot tests.

Illustrative Example

ABC Co. was proud of their innovation, specifically the proprietary chemical additives they had developed to modify the electrokinetic surface potential of the suspended solids and dramatically improve the removal efficiency of the membrane they use.

When their technical team used the TRL Assessment Guide (Appendix B), they realized that their technology was considered to only be at a TRL 4. Up to now, due to their original target market, they had only tested their technology on inert solids (sand and other grit), not frac water. They realized they were not ready for a pilot test.

After reaching out to several of the potential customers (hydraulic fracturing service companies) that they had already been talking to, they found one that was willing to provide some samples of frac flowback water. They raised additional funds and accessed specialized laboratories to safely perform more bench tests and technology development with these new samples. The bench tests were only a fraction of what pilot testing would have cost them.

Over the next 6 months of dedicated and often frustrating testing, they realized that their technology could not achieve the necessary treatment performance for frac flowback water. An undetermined combination of hydrocarbons and frac water additives interfered with their chemistry.

Undeterred, they explored other avenues with their frac service company partner and discovered that sometimes municipal effluent is used as a source water for hydraulic fracturing, and depending on the source, residual solids in this source water can be a concern. Given the simpler chemistry of municipal effluent, this avenue held new potential. They went back to the market assessment stage with this new plan, holding several discussions with the small municipalities, in collaboration with the frac service company partner. Their revised TAM was now smaller, but sufficient for a beachhead market. They realized that they would need to add additional market sectors to their business plan to achieve sufficient growth over time. For now, they focused on testing municipal effluent and achieved successful bench tests.

2.5 Assessment Questions

To facilitate completing the above initial considerations, the following Assessment Questions were developed. These can help proponents better assess specific aspects for planning the pilot test(s), refine value propositions and facilitate discussions between end users and technology proponents. A number of these aspects are also addressed in more detail in later sections within this document. Users of this document are encouraged to use these Assessment Questions as a tool by working through each in detail.

2.5.1 Value Proposition

What are the basic scientific principles that enable the proposed technology to work?

How would you explain the technology to a non-expert in the field? What basic scientific principles are involved in the technology's function? The foundational workings of the technology will need to be communicated to end users and prospective funders.

What problem does the proposed technology aim to solve? How important is this problem?

The technology needs to address a problem faced by the industry which has material impacts to the industry (e.g., in the form of regulatory burden, cost, risk, environmental impact, safety, etc.). There is a link between the importance of the problem, its severity and the total addressable market for the technology, which contributes to the business case for the technology.

Have previous efforts been undertaken to solve this problem?

Have other people/companies tried to solve this problem already? If so, why were their efforts unsuccessful? Learning from past efforts may significantly reduce piloting costs and timelines.

How is the proposed technology unique compared to existing or previous solutions?

What differentiates this technology from existing technology and processes? The proposed technology must add value in a way that is not already offered in order to be considered in favor of incumbent and competing approaches/technologies.

How will the proposed technology benefit the industry?

Is the value proposition tied to improvements in budget, time, environment, politics, sustainability disclosures, regulations, etc.? The proposed technology will need to provide measurable value to the industry. This also links to the business case.

What are the net impacts of the technology at a commercial scale?

It is critical to evaluate the potential impacts of the technology with respect to greenhouse gas emissions, water use, costs, land use, waste generation, health and safety, etc. Understanding the impacts at an early stage will be advantageous when engaging stakeholders, applying for funding and planning the commercialization process. See subsequent sections of this document for more information.

2.5.2 Technology Development

What is the current TRL of the technology?

Which third-party criteria/evaluation framework was used to assess the technology's TRL? What are the highest priority risks, performance gaps or unknowns that need to be overcome when seeking to advance this technology's maturity?

Who is/are the industrial partner(s)? What feedback has been provided by the industrial partner(s)?
Who is/are the industrial end user partner(s) that will work with the technology proponent on piloting, de-risking and eventually commercializing the technology? Has a champion within each prospective customer/partner organization been identified and engaged? What feedback has already been provided? Communication between technology proponents and industrial end users should start early in the pilot plan development process, and feedback from end users should be used to inform pilot design.

How will pilot equipment and commercialization of the proposed technology be funded?
A concrete funding plan will facilitate the technology commercialization process in the short and long term. It will also provide end users and funders with confidence to invest time and money into the technology.

How will intellectual property (IP) be managed?
Understanding the value of IP associated with the technology and planning for how this IP will be managed will inform contract/legal negotiations throughout piloting and into commercialization. In some cases, IP control can be a barrier to partnerships and piloting.

What certifications or permits are required to allow piloting of the technology at the desired location? Are different/additional certifications required for commercial operations? How will these be secured?
Securing the necessary certifications for a technology can be an expensive and lengthy process, and technology commercialization plans should account for this. Technology proponents who materially progress along this process early in development may be able to use this as a selling feature for their technology.

What does the supply chain look like?
Understanding the service and materials requirements for the technology during piloting and commercialization will help inform costs and lead times for planning purposes. Mapping out the supply chain early on may also help identify opportunities for efficiencies and time/cost savings.

2.5.3 Commercialization

Which stakeholders will be responsible for purchasing? How have all the stakeholders been engaged?
The technology proponent should speak with the purchasing stakeholders within the end user's organization to gauge interest, align on goals/expectations and establish a partnership. This will facilitate the negotiation process for piloting and future commercial sales.

Where does the proposed technology fit within existing commercial processes? How does the answer vary for greenfield and brownfield processes? Can the technology work in the conditions of the target market (e.g., with respect to remote operations, cold climates, etc.)
Understanding where the technology fits within a commercial process, and the external conditions of that process, will inform technology design, including size and operating requirements (e.g., temperature, pressure), as well as the value proposition (e.g., what unit operation(s) will the technology replace or enhance?). It will also inform piloting, since it must be demonstrated to an acceptable level that the technology can be scaled for the intended use in the intended conditions.

What are the required inputs and resulting outputs of the technology?
The technology proponent must consider the inputs required to operate the technology at both pilot and commercial scales, and the outputs that are generated as products or by-products. This will inform the costs of the inputs to operate the technology and costs of waste or by-product management once the technology is operating at commercial scale.

3.0 Regulatory Considerations

A wide range of regulations and guidelines may be applicable to a wastewater reuse project, and these vary by jurisdiction. This section is specific to the Alberta context, in which a risk-based approach is generally followed. In this approach, regulators consider the nature of the wastewater, its intended use and the potential for contaminant exposure of various receptors (e.g., people, aquatic environments). Requirements for wastewater treatment, storage and transportation are predicated on the assessed risks. Technology piloting plays an important role in demonstrating not only that a technology can achieve required numerical treatment thresholds, but also that these thresholds can be met reliably and consistently (e.g., even in cases of system failure). In other words, it must be demonstrated that the risks can be appropriately mitigated. In addition, risks related to water quantity are also evaluated by the regulators (i.e., will the use of water for this project negatively impact existing license holders and the environment by taking water, such as return flow?).

Note that both pilots and commercial applications may have regulatory requirements, and these requirements may not be the same in both cases. Differences can be driven by factors such as potential for release to the environment (e.g., a closed system pilot environment vs. a more open operating environment with discharge). The current regulatory environment for water reuse is complex, given the diversity of potential water reuse applications, and proponents should engage with the appropriate regulators at an early project stage to confirm the requirements for both piloting and commercial implementation. By doing so, proponents can avoid unnecessary delays and costs associated with working on the wrong things. Proponents should also consider that the different parties involved in piloting, including proponents, end user partners and pilot facility hosts, will have different roles and responsibilities when it comes to working through the regulatory approvals process. Early discussions with partners should occur to establish these roles and responsibilities.

Figure 2, below, is a high-level overview of regulatory considerations for a generic water reuse project concept. In all cases, the water reuse need is considered by proponents, followed by identification of an alternative water source and assessment of its quality and quantity. Informed by these characteristics and the quality requirements of the intended end use, a treatment approach will be implemented (i.e., deployment of one or more water reuse technologies). Consideration must also be given to other system elements, such as storage, transportation and disposal of waste.

Figure 3 provides several example regulatory pathways for different combinations of alternative water source and intended end use. The upper, brown set of boxes illustrates how a water reuse activity can be defined ("the why"), while the sets of blue boxes show different versions of the approvals pathway ("the how") for various alternative water sources and end uses. The pathways are presented linearly from left to right, although in practice the regulatory approvals process could progress in the opposite direction, and several iterations may be required to receive approval/acceptance from the relevant regulators.

The pathways in Figure 3 are focused on potential regulatory pathways, through the lens of the approvals required to operate. Beyond these pathways, proponents must also consider potential impacts to an operator's existing approvals, as well as any regulatory and/or end user specific requirements for certifications which may be required (e.g., ABSA pressure vessel certifications, plumbing codes). Required certifications are highly dependent on the technology and the requirements of the end user. As part of early discussions with end users and regulators, technology proponents should explore the potential certification requirements for their technology, keeping in mind once again that differences may exist between pilot and commercial scale requirements. The property line is the best separation to identify the jurisdiction for the Plumbing Code adopted in the Plumbing Code Regulation under the Safety Codes Act with Alberta Municipal Affairs. Regulations from AEPA apply outside the property. Hence, understanding the property line and how a water reuse technology interfaces with it may assist in ensuring the proposed project is regulated appropriately. Consultation with other ministries may supplement the primary regulation.

Appendix C contains a series of links to potentially relevant regulatory instruments for water reuse in Alberta. These links are intended to serve as a starting point, and their site-specific application is best discussed with the appropriate regulating body, including Alberta Environment and Protected Areas (AEPA), Municipal Affairs, Alberta Health Services (AHS) and/or the Alberta Energy Regulator (AER) Regional office contact. Technology proponents are strongly encouraged to contact the appropriate regulator(s) at the earliest opportunity (e.g., at the early conceptual stage) to identify and align on regulatory requirements and potential roadblocks to technology commercialization. Indeed, the emerging Regulatory Assurance Framework developed at AEPA calls for early and frequent engagement and is a process that is intended to streamline application reviews and authorization issuance. It may also be beneficial to partner with entities with existing approvals/licenses under the *Water Act* and the *Environmental Protection and Enhancement Act (EPEA)*. These entities are likely already familiar with regulatory processes, procedures and regional contacts, and there can be a benefit.

3.1 Contacts

Below are the focus areas and contact information for the regulatory bodies in Alberta most likely to be involved in a water reuse project.

AHS – public health risks

- Website: https://ephisahs.microsoftcrmportals.com/create-case/
- Phone: 1-833-476-4743

AER – water quality and quantity impacts for energy projects (i.e., oil, oil sands, natural gas, coal resources, geothermal, and brine-hosted mineral resources).

- Please consult AER Directives or contact the local field office for site specific questions.

AEPA – water quality and quantity impacts

- https://www.alberta.ca/environment-and-water-contacts.aspx

Municipal Affairs – plumbing and cross connections within buildings.

- 780-644-1010, toll free: 1-866-421-6929 (within Canada)
- Email: safety.services@gov.ab.ca

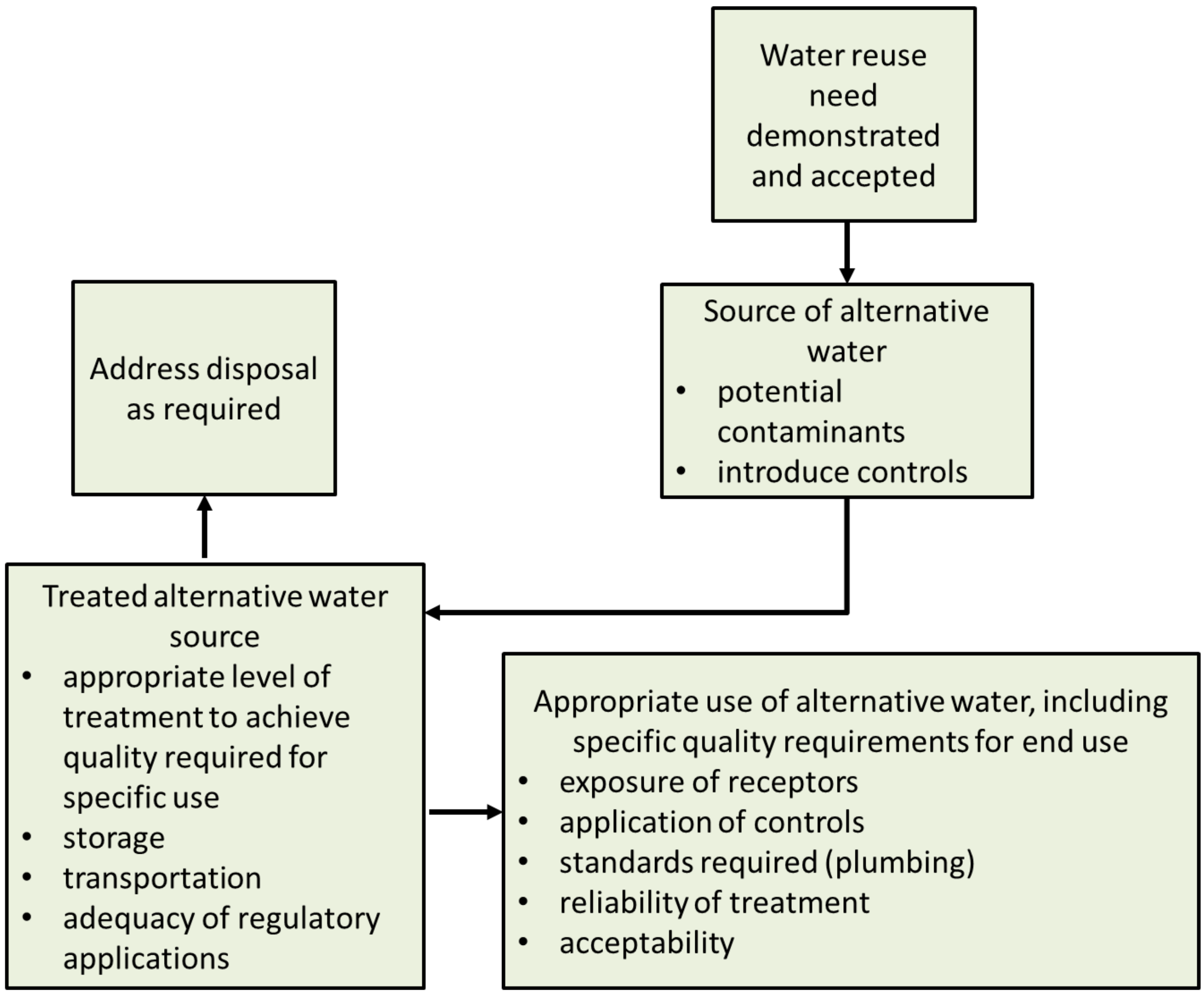
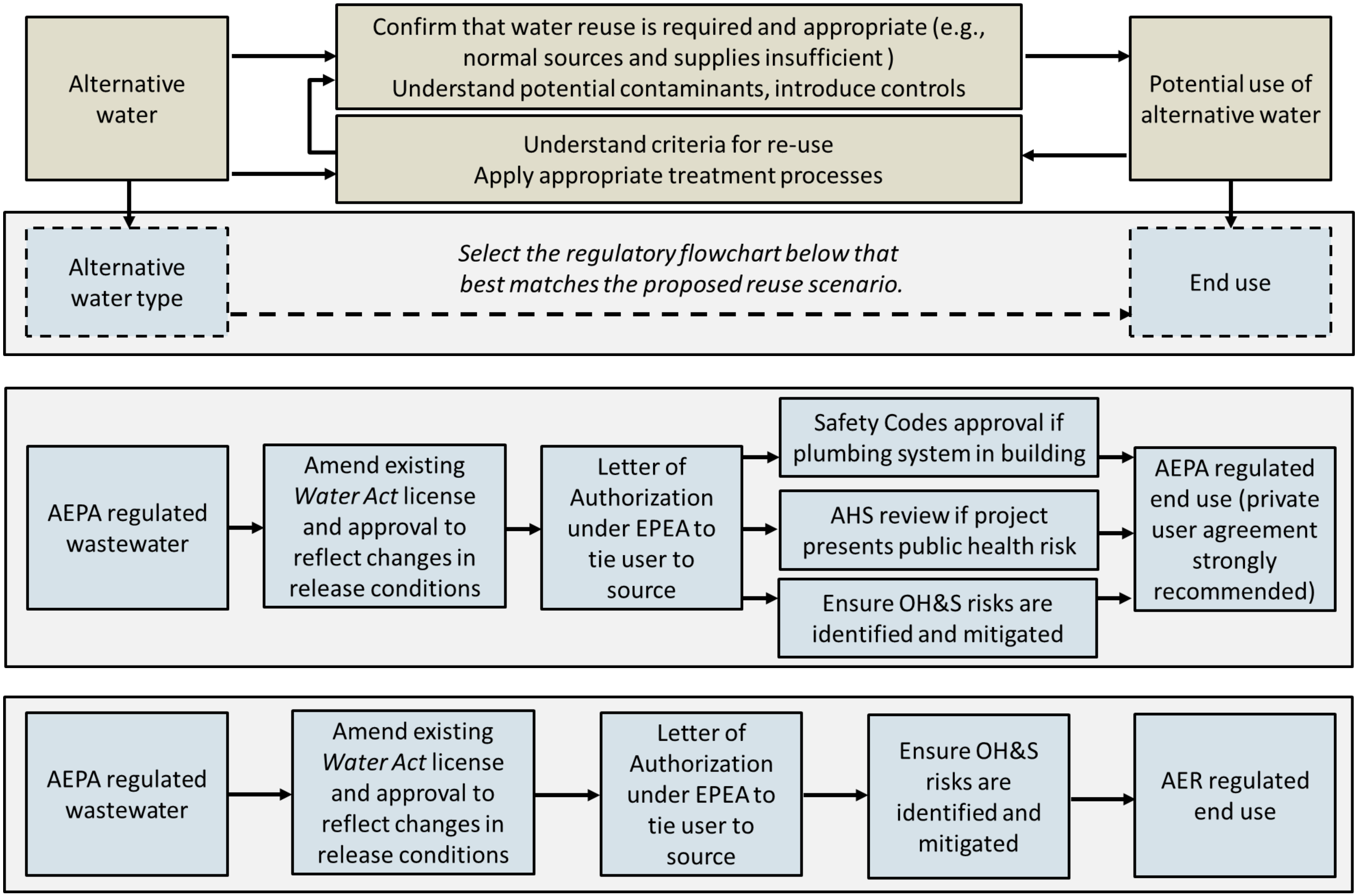


Figure 2. High-level regulatory considerations overview.


Alternative water
Confirm that water reuse is required and appropriate (e.g., normal sources and supplies insufficient)
Understand potential contaminants, introduce controls
Understand criteria for re-use
Apply appropriate treatment processes
Potential use of alternative water
Alternative water type
Select the regulatory flowchart below that best matches the proposed reuse scenario.
End use
AEPA regulated wastewater
Amend existing Water Act license and approval to reflect changes in release conditions
Letter of Authorization under EPEA to tie user to source
Safety Codes approval if plumbing system in building
AHS review if project presents public health risk
Ensure OH&S risks are identified and mitigated
AEPA regulated end use (private user agreement strongly recommended)
AEPA regulated wastewater
Amend existing Water Act license and approval to reflect changes in release conditions
Letter of Authorization under EPEA to tie user to source
Ensure OH&S risks are identified and mitigated
AER regulated end use

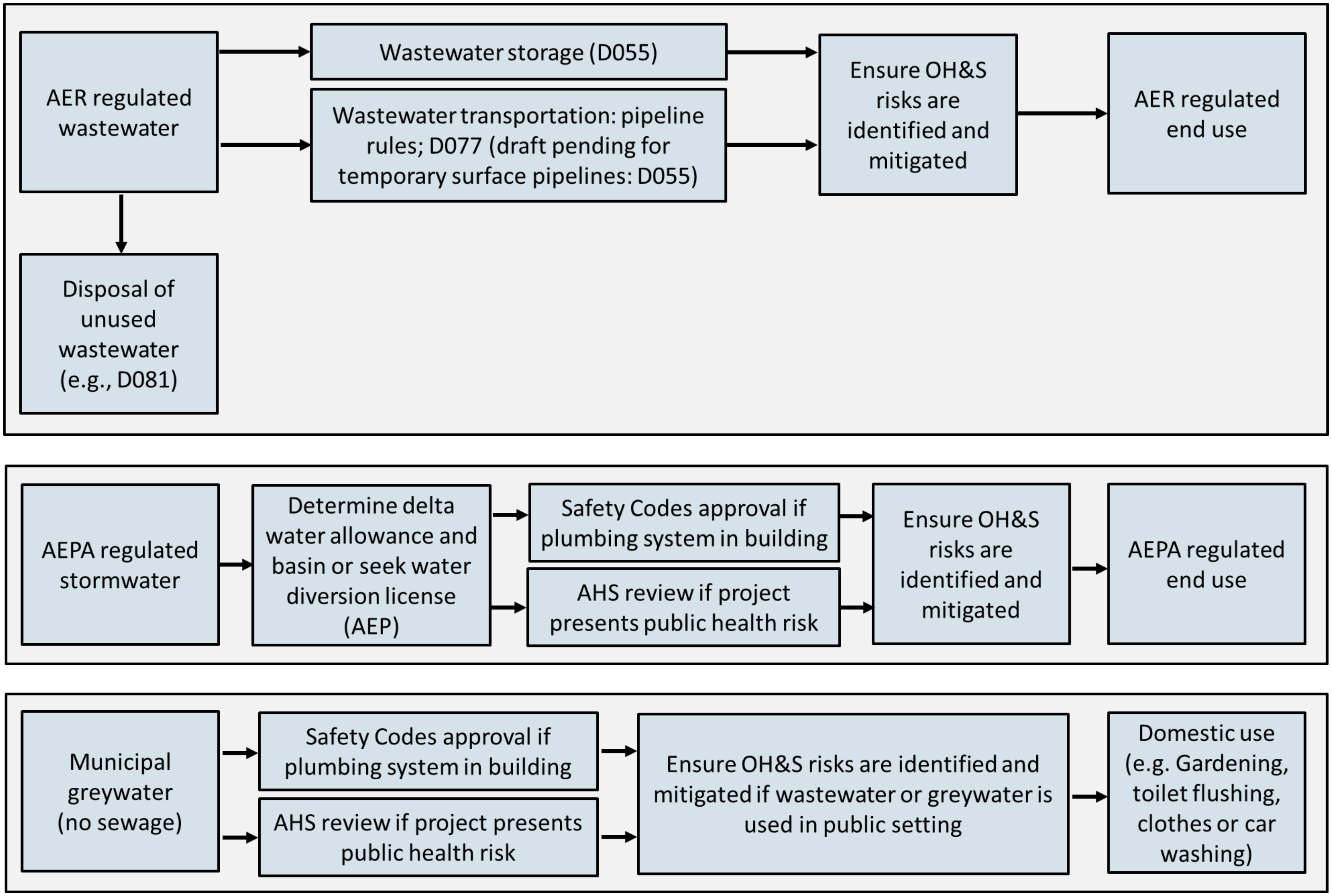


Figure 3. Example regulatory pathways for various alternative water types and end uses.

Illustrative Example

ABC Co. continued conversations with the interested parties to determine a project partner with respect to water ownership and approached AEPA and the AER. These were necessary steps to ensure all regulatory considerations were being accounted for. The water would be going from the jurisdiction of one regulator to the other with respect to end-use. Consideration was given to whether existing licenses under the Water Act would be amended to stipulate diversion or transfer due to changes in Municipal Wastewater release conditions. Consultation with appropriate regulators was also completed to determine requirements for storage, transportation, treatment and disposal of all associated waste products as per AER Bulletins. Plumbing requirements and applicable enforceable Plumbing Codes and CSA Standards were considered in project design. A letter of authorization was obtained under the Alberta Environmental Protection and Enhancement Act (EPEA).

4.0 Technical Pilots

A pilot test is meant to answer the question "*How well does this technology perform under specified conditions?".* The performance can include technical, economic and operational aspects. Pilot testing is typically done using a smaller-scale version of the technology, often sized somewhere between 10% to 50% of what the full-scale system would be. The overall intent is to perform the testing in a manner that allows the fastest determination, at the lowest cost, of potential flaws in the current design, so that the design can either be corrected or abandoned, depending on the severity of the flaws.

Depending on end user needs, the "specified conditions" could range from typical operating conditions to the extremes of expected seasonal, flow, loading and other conditions. Often, the expected operating conditions are not clearly specified or known, and a lot of confusion can result. For example, a technology proponent could spend a significant amount of money piloting a technology under "typical" conditions, when instead potential customers are interested in a broader range of conditions.

> A pilot test is meant to answer the question "***How well** does this technology perform under specified conditions?".*

Another confounding factor can be jurisdictional differences, where successful demonstration or adoption in one region does not guarantee adoption in another region, for example due to differences in what levels or performance, reliability, etc. are required in different regions or jurisdictions. Similarly, integration into different facilities may require adjustments, even within one region or customer organization.

Another potential source of confusion can be when the target question becomes "*Does this technology work?*", which is very different than determining "*how well*" a technology works. In these cases, the pilot test becomes more of a "technology demonstration", often under ideal operating conditions. Figure 4 compares and contrasts the different types of pilot tests which may be required.

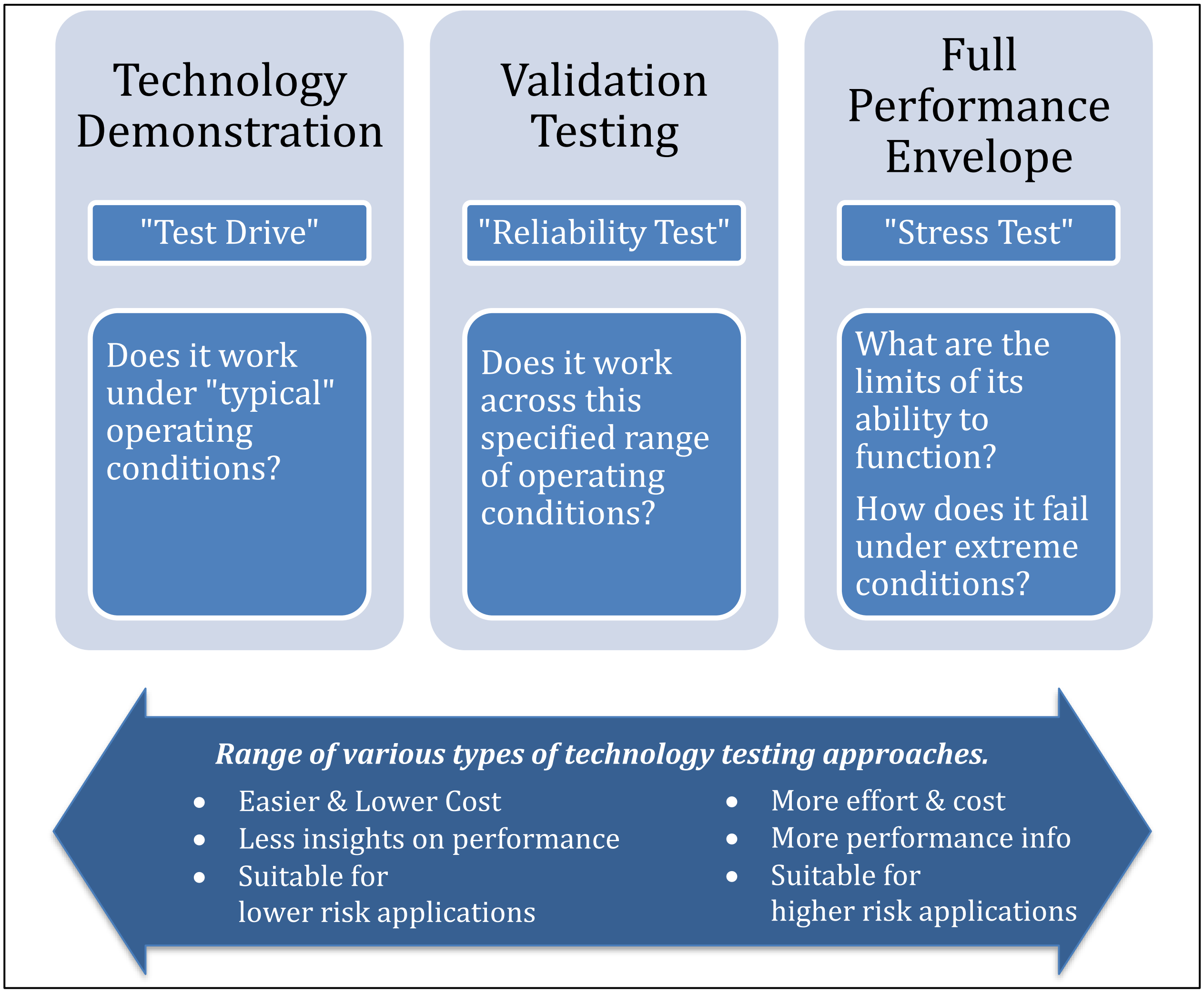


Figure 4. The range of different types of pilot testing and their testing objectives.

A Technology Demonstration is the simplest type of validation testing and is usually limited to showing that a technology performs as expected under a “typical”, or otherwise narrow, set of operating conditions. This can be likened to taking a car for a test drive under regular road conditions before buying it. While it does show that the technology “works”, it does not provide any information with regards to how it will perform under more extreme conditions or what its maintenance requirements will be. A Technology Demonstration is best suited for applications that have a quite predictable (and usually fairly narrow range) of operating conditions and where the regulatory or financial consequences for technology failure are quite low. This type of testing is usually the lowest duration and cost.

A Validation Test specifies a range of operating conditions (e.g., temperature, flow rates, loading, etc.) and asks whether the technology can function within that range of operating conditions. Using the car analogy, this would be similar to asking the manufacturer to validate that the car can reliably perform safely up to 100 km/h on both dry and wet road conditions. A Validation Test is best suited for those applications that have a known range of operating conditions and where the regulatory or financial consequences for technology failure are moderate.

Conducting pilot testing to evaluate the Full Performance Envelope is much different. It endeavors to determine the extent of conditions under which the technology is capable of continuing to operate (i.e., intentionally test it under conditions that are expected to cause the technology to fail) and then understand how those failures occur, from both the perspective of which component or subsystem failed (e.g., sealants) and which specific conditions caused the failure (e.g., temperature versus pressure). It also provides a much more comprehensive understanding of the likely maintenance and repair requirements. As an example, auto and other equipment manufacturers will undertake this comprehensive testing during development of a new model to improve design and safety, which also informs the warranty conditions they should set. Technology "proving grounds" (e.g., NASA, SpaceX, the military) are other examples of where new technologies are intentionally tested to failure.

Applications that should require new technologies to undergo Full Performance Envelope testing are those where either regulatory or financial consequences for technology failure are high or that have extreme or unpredictable operating conditions (i.e., "upset conditions"). Often, possible "upset conditions" are not well known ahead of time, hence the need to instead test the limits of performance instead, so at least subsequent operators know the limit of what they can expose the technology to without causing it to fail. Due to its comprehensive nature, Full Performance Envelope testing requires much more time and cost.

Examples of Performance Envelopes are shown in Figure 5. These simple examples show how one input or operating condition (e.g., flow rate) affects the targeted outcome (e.g., pressure). It can also show how different models or configurations of the technology are better suited for certain operating conditions. More complex performance envelopes would show the effect of multiple input parameters on the desired performance outcome.

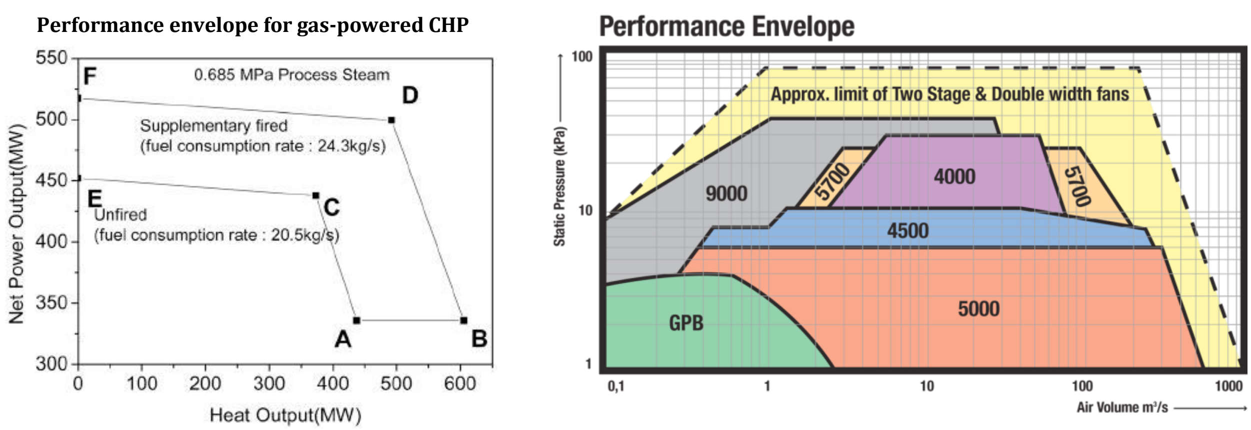


Figure 5. Examples of performance envelopes.[15]

Determining what parameters to test to define the Performance Envelope requires a solid understanding of both how the technology functions and the end user's needs and operating conditions. For example, when evaluating technologies to remove solids from wastewater, a membrane treatment technology might have very different operating constraints (e.g., presence of fouling agents) than a settling basin (e.g., insufficient residence time). It also necessitates understanding what has already been tried by others and

[15] Sources:
https://www.researchgate.net/figure/Performance-envelope-for-gas-turbine-combined-heat-and-power-system_fig4_264135719
https://www.aireng.com.au/products/centrifugal-fans/performance-envelope-centrifugal-fans/

whether that worked, or why it didn't. As discussed in Section 2.2.4 above on Intellectual Property, this information is often best accessed through partnership(s) with potential end users.

Once the type of pilot test has been selected, the pilot test plan can be developed. This Guidance Framework does not contain a "how to" manual for planning and conducting pilot tests, as there are far too many situation-specific requirements to be able to capture in this high-level document. Also, many of the larger organizations will have experienced technical specialists and preferred approaches for pilot testing. However, there are general topics that are relevant for most pilot tests which should be considered prior to detailed planning. These include considerations such as:

1. Has bench testing, which is less expensive than pilot testing, answered all the questions it can?
2. Have the technology proponents' collaborators (e.g., potential end users/customers, funders, etc.) been given an opportunity to contribute to the pilot test plan?
    a. Is it clear to all parties what type of pilot testing will be conducted (i.e., Demonstration, Validation or Performance Envelope), so expectations are aligned and incorrect perceptions of a "failed pilot" can be avoided)?
3. Does your team have the necessary expertise, facility and monitoring equipment to conduct the pilot test(s) properly and safely? Or should the end-user partner host the pilot test(s) at their site/operating facility? Or should a specialized testing facility/team be retained to conduct the pilot test? Can their experienced technical team review the pilot test plan and advise?
    a. Where are these test facilities located (e.g., refer to ecosystem maps developed by CRIN or WaterNEXT) and what logistical considerations need to be addressed to get the equipment there? What are the requirements (e.g., safety, logistical, insurance, etc.) and costs?
    b. Safety requirements, and associated training or certifications, are critical aspects to clearly document in the pilot test plan from the beginning.
    c. Note that pilot testing at an end-user's site will cause a certain level of disruption to that site/facility and its operations and maintenance teams. Therefore, mitigation of this needs to be planned for (e.g., via additional time, budget, staffing or other resources).
    d. Who will be responding to alarms, upset conditions and other equipment maintenance issues – a team from the technology developer, the test site host, or the hired testing service provider?
    e. What will the travel requirements be, and have these been budgeted for?
4. What are the key objectives for this specific pilot test – is it to evaluate technical feasibility, economic performance (re: operations and maintenance costs) or how well the technology will integrate into a facility's existing treatment train, workflow and operating procedures?
    a. Some of these aspects can sometimes be combined into a single pilot test, but in other situations these might need to be tested over several different pilot tests, each specifically designed to answer these questions separately.
    b. For larger or full-scale pilot tests, redundancy and contingency should be built into both the physical test set up (e.g., backups or spare parts) and the budget.
5. Is the testing at the correct scale to produce data relevant for the target question(s) (e.g., will the operating conditions [flow rates, reagent doses, mixing times, etc.] yield relevant results)?
    a. Has the experimental design taken into consideration what data needs to be collected, and how much, in order to achieve the data quality objectives (e.g., as informed by a statistical power analysis)? Are sufficient replicates being performed? Have quality assurance/quality control measures been built into the experimental design?
6. What are the key outputs that will be measured (e.g., % removal of a target contaminant)? What are the performance targets (e.g., minimum, maximum, average) for each key output? Is there a

priority ranking, where certain outputs are more important than others? (e.g., minimize sludge production where possible, but always ensure that the liquid discharge is below X mg/L Total Suspended Solids)?

7. Will other pilot tests be needed? How will these subsequent tests be linked to this test (for example, how will the data from this test inform the design of subsequent tests?)?
8. How will this information be shared after the pilot test(s) are complete? Is there a way to make the results (or a non-confidential summary) available to funders and future technology developers, so future innovation can build upon previous investments and efforts? (See discussion in Section 2.2.4 about the need to access previous results.)

As shown in the example in Figure 6, pilot test planning needs to consider the various factors that affect performance. It is critical to select the right test conditions. The information gathered from industry partners, technology champions, advisors and other marketplace sources is key to getting this right.

Some of these factors can be controlled (e.g., reagent dosing) and some cannot (e.g., ambient conditions). Some of the key differences between bench tests, conducted under controlled conditions, and pilot tests are caused by the introduction of uncontrolled ambient conditions that better match "real world" operating conditions. Other differences relate to how some physical or chemical phenomena change with increasing scale, which is critical and can cast doubt on the validity of pilot results if not addressed appropriately. All of this can lead to unexpected results from the pilot test, which of course is one of the key learnings that pilot tests can deliver. The pilot test plan should try to anticipate these situations as much as possible and structure the testing to maximize these learnings.

Some technology is focused on treating water, and hence has related performance indicators (e.g., treatment performance, energy used, etc.). However, other technologies, such as sensors, valves and monitoring software, are focused on measuring and controlling processes. These technologies will have different performance indicators (e.g., accuracy and precision of data or controls, service uptime, etc.). Again, the pilot test(s) will need to be designed appropriately to meet the relevant requirements.

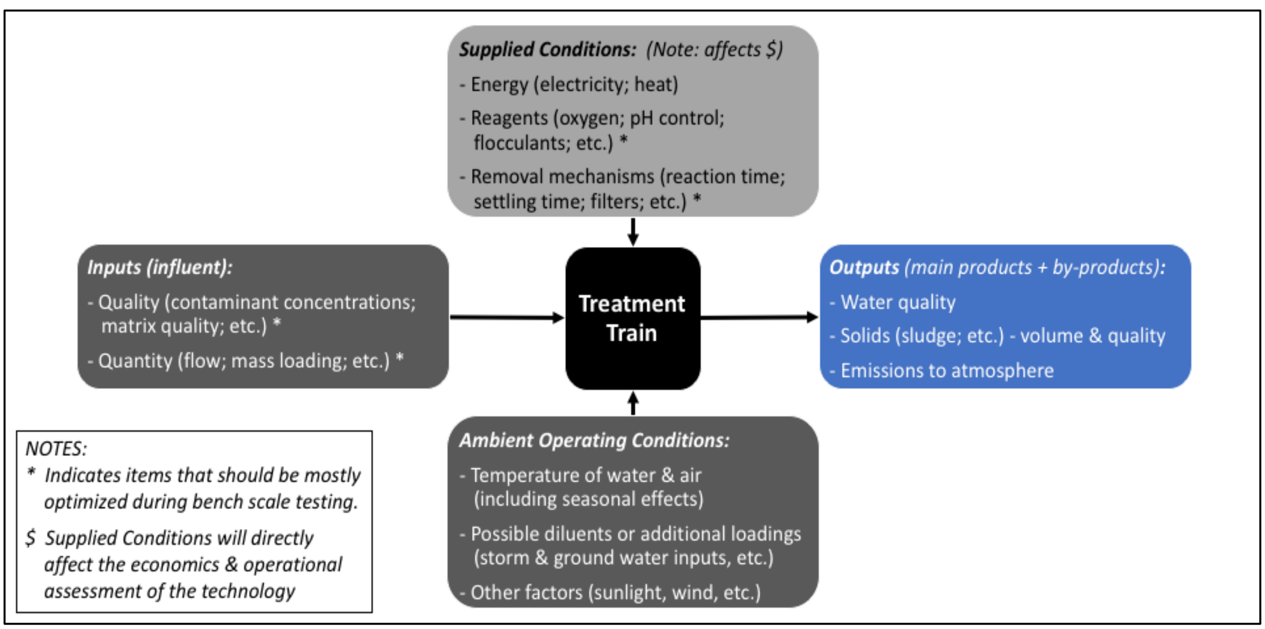


Figure 6. Various factors affect technology performance (and need to be addressed during testing).

Illustrative Example

Once the correct regulatory perspective was established, it became clear what the technical performance targets needed to be for the water treatment system. ABC Co. conducted some final bench tests and was consistently achieving this performance. The system worked well in the workshop, and the whole team at ABC Co. was eager to proceed to pilot testing and then sales. Given the extra meanders that their commercialization journey had already taken, there was growing pressure from their investors to “get to market” and start producing revenue.

So, they built a trailer-mounted field unit capable of treating 100 cubic meters of municipal effluent per day. It included the same type of membrane that they had been purchasing for the last two years of technology development, along with their proprietary mix of chemicals, tanks, a dosing pump and a control system. Their sales and technical leads worked tirelessly and were successful in securing two technology demonstrations, one with a larger hydraulic fracturing service company and one with a smaller company.

The larger service company had lots of questions and moved slowly and cautiously. However, the smaller company was nimbler and agreed to have ABC Co. come show that their technology worked. The technical team and CEO drove the trailer out to site and spent an intense 3 days, demonstrating that it worked during the frac job. An unexpected learning for the team was that their system would need to be scaled up about 100X to be able to handle the total volume of water needed for this type of job. Nevertheless, their prospective customer was impressed and placed an order for one unit, provided that they could at least increase its capacity 10X. The team was thrilled – their first sale!

Luckily, expanding the throughput 10X was simply a matter of buying a larger trailer and installing ten base modules in parallel. They did encounter some supply chain issues on the membrane and needed to scramble, switching to another membrane brand with the same nominal specs. However, everything worked well when they did the pre-delivery tests, and they shipped the unit just in time.

Unfortunately, the hydraulic fracturing service company’s operators ran the unit at pumping rates above the recommended maximum, in an effort to produce more throughput. It worked for a few hours and then the automated backwash cycle started struggling to keep up with membrane fouling that was occurring. The parallel modules also started to drift out of sequence, as each of their membranes accumulated different amounts of fouling. Midway through the second day, the unit had stopped working. ABC Co.’s technical lead tried troubleshooting over the phone with the frac operators but was unsuccessful. The site lead was quite upset because the technology “didn’t work”. Both companies argued their position, with ABC Co. maintaining the unit had been operated outside of its known performance envelope, while the service company arguing that the last-minute switch of membrane brands had not been field-validated and hence the product provided was materially different from what was promised. There was a mismatch in expectations for the unit, and the company refused to pay for it.

Illustrative Example (*continued*)

This was a huge blow to ABC Co., as not only had they spent a significant portion of their dwindling cash reserves to build both the demonstration unit and their first commercial unit, but they were also counting on this first sale to give them the reference customer they needed. Now the local industry was talking about their failure, and it was drying up their sales funnel. The investors were not happy.

Meanwhile, two of the junior technical team members had continued working with the larger service company, wading through all the questions and requests for additional information. After some very in-depth whiteboard discussions with their partner's technical specialists, they developed a plan for some validation testing, including clear performance targets. Their business accelerator coach helped them secure some additional grant funding for the testing, and they worked closely with the frac company's technical specialists and operators.

After three pilot tests, they had leveraged all the learnings from the technology showing what it could and could not do under certain operating conditions. With the technical wrinkles ironed out, the frac company then requested some additional testing and design work, this time to evaluate and optimize various economic performance thresholds...

Taking a deep breath, ABC's CEO agreed.

5.0 Pilots for Evaluating Operational and Economic Performance

The preceding section explored the importance of piloting to verify how well the *technical aspects* of a technology performed under specific conditions (e.g., could it treat the water to the specified quality). This section focuses on determining how well all the *other aspects* of a technology perform under these conditions, including how much it will cost to install and operate and how it will impact the environmental, health and safety performance of the process. This section also addresses operational and economic performance as it relates to the life cycle of the technology. Operational and economic performance are grouped in this section to reflect their strong interrelation; a technology's true costs cannot be known without an understanding of where in a process it will fit and what it will take to make it function as part of that process.

Table 1 and Table 2, below, each list several questions designed to explore these facets of how well the technology works. Each question includes a dimension which is specific to the technology's economic performance and a dimension which considers how the technology's integration into a commercial process will impact that process, either positively or negatively. For example, the technology-specific dimension for "Capital cost" reflects the costs of the technology itself, which could include pumps, vessels, instruments, membranes, proprietary components and more. For commercial integration, "Capital cost" reflects how installing the technology is expected to either increase or decrease the overall process' capital costs, for example by replacing other unit operations and equipment. Both **greenfield** and **brownfield** installations of the technology should be considered throughout Table 1 and 2.

Importantly, it may not be possible, or even necessary, to completely answer all of the questions in Table 1 and 2 during piloting. Leveraging the partnerships described earlier (e.g., with end users), technology proponents should build pilot test plans with a clear understanding of the breadth and depth of operational and economic information which is required to move to the next step of technology commercialization. For example, a particular end user may require a commercial scale, full performance envelope pilot prior to commercial deployment to confirm the anticipated operational and economic impacts to their process. In this case, a high degree of certainty would be both required and achieved for the questions below. In other situations, a technology demonstration may be sufficient to de-risk certain aspects of the technology's operational performance, while the anticipated commercial economics are estimated through a subsequent engineering design effort. The importance of collaboratively developing a pilot test plan with technology proponents, end users and other partners cannot be overstated.

There is a strong link between many of the questions below and those in the Assessment Questions in the Initial Considerations section, particularly related to the value proposition of a technology. By designing and executing one or more pilots to address the questions below, technology proponents will attempt to demonstrate and verify the technology's anticipated value proposition; that is, they will be better positioned to answer the question, "are the anticipated benefits likely to be realized at a commercial scale?". There is also potential overlap with the Technical Pilots section. Hence, all sections of this document should be considered together when preparing the technology piloting plan.

Table 1. Considerations for evaluating the economic, environmental and health and safety performance of a technology in a commercial context. These considerations link to the business case for the technology discussed under Initial Considerations.

Category		Economic-Related Considerations	Impacts to Overall Process
Capital Costs	Regulatory	What is/are the cost(s) of preparing regulatory application(s)?	By how much will the process' capital costs increase or decrease? Does the answer vary between greenfield and brownfield installations?
	Core equipment	What is/are the cost(s) of the equipment core to the technology's function? How many units will be required to achieve the desired throughput?	
	Ancillary equipment	What are the costs for ancillary equipment required to connect the technology to the process (e.g., piping, electrical transformers)?	
	Installation	How will the technology be installed in the process? What type of onsite labour is required (e.g., welding, pipe fitting)?	
Operating Costs	Operations	What operator support is required to operate the technology (e.g., number of operators, hours per shift, frequency of intervention, sampling)?	By how much will the process' operator requirements increase or decrease (e.g., in terms of fractional full-time equivalents)?
	Lab	What lab measurements are required for the technology to operate as expected? Can the required lab measurements be done on site, or is third party/external testing required?	By how much will the process' lab testing requirements increase or decrease?
	Maintenance	What amount of maintenance is required for the technology to operate as expected (e.g., frequency, hours per activity)? Do specialists need to perform the maintenance?	By how much will the process' maintenance requirements increase or decrease?
	Consumables	What consumables does the technology require, and at what frequency (e.g., chemicals, filters, etc.)?	By how much will the process' consumables requirements increase or decrease?
	Power	What are the technology's power requirements? What type of current, frequency and voltage are required?	By how much will the process' electricity requirements increase or decrease? Can the process accommodate the technology's power demands without modification?
	Natural gas	What are the technology's natural gas requirements?	By how much will the process' natural gas requirements increase or decrease?

Category		Economic-Related Considerations	Impacts to Overall Process
Physical Considerations	Footprint	How large is the technology (e.g., fit within existing footprint or require additional footprint)? How does scaling up the technology impact other required ancillary systems (e.g., input and output piping)? How will the technology's footprint change with increased scale (e.g., linearly)?	By how much will the process' land footprint increase or decrease?
	Configuration	How will the technology physically fit within the process (e.g., is there existing space in the process' configuration)? Does the answer vary between greenfield and brownfield installations?	What modifications to the process will be required to integrate the technology? What will these modifications cost?
Environment, Health, & Safety	Greenhouse Gas Emissions	What are the technology's greenhouse gas emissions?	By how much will the process' greenhouse gas emissions increase or decrease?
	Other air contaminants	Are there other air contaminants produced or avoided, either directly or indirectly, by the technology (e.g., odours, H_2S)?	By how much will the process' production of non-GHG air contaminants increase of decrease?
	Water consumption	What are the technology's water requirements, considering both make-up water (i.e., consumption) and flow-through water?	By how much will the process' water requirements increase or decrease?
	Waste materials	How much and what type of waste is generated by the technology and/or the process with the technology integrated? Is there a value to this waste or a cost to dispose of it?	By how much will the process' waste production and waste handling costs increase or decrease?
	Safety	How does the technology impact operator safety?	By how much will the process' safety risks increase or decrease?
	Public impacts	How does the technology impact public safety? How does the technology impact public perception of safety and environmental impact?	By how much will the process' public safety impacts and public image risk increase or decrease?

Table 2. Considerations for evaluating the operational performance of a technology in a commercial context.

Category	Economic-Related Considerations	Impacts to Overall Process
Reliability	What is the anticipated uptime of the technology (e.g., % of the year it will be operational)? What impacts will the technology have on the reliability of the process? Is sparing required to achieve reliability targets?	By how much will the process' uptime increase or decrease?
Production	How does the technology contribute to production/throughput from the process?	By how much will the process' production rate increase or decrease?
Installation	How long will it take to install and commission the technology? How will installation impact process productivity (e.g., production disruption)?	By how much will the process' production increase or decrease during the installation and commissioning period?
Complexity	How complex is the technology to operate? Does it require hiring or training specialized operators? How difficult is the technology to fix?	By how much does the process' complexity increase or decrease?
Remote operations	Can the technology function in remote settings (e.g., no grid connected power or wastewater management)?	What operator and/or construction interventions are required to allow the technology to function within remote processes?

Illustrative Example

The frac company's operators, maintenance team and engineers all had ideas and requests for how to improve ABC Co.'s treatment system. The two core challenges were that no one on ABC Co.'s team had done a detailed assessment on operating costs, or how their treatment system would integrate into and work with the rest of the frac equipment.

The hydraulic fracturing service company wanted to reduce the dosing of ABC Co.'s proprietary chemical additives to save costs. ABC Co. resisted this suggestion since a core contributor to their projected profit margin was chemical sales. Then their accountant pointed out that if their product was more competitive, they would secure more customers, which would more than make up the difference. So, they did some testing and were able to optimize the dosing and reduce chemical costs.

Another debate occurred around the pump ABC Co. used. When they realized that they needed to scale up their module, they selected the larger model from the pump brand they originally used. However, that brand was not commonly used in the field, and the hydraulic fracturing service company wanted them to switch to the same brand and model of pump that was used on other equipment in their fleet, to enable easier maintenance and parts interchangeability. ABC Co.'s CEO decided to do some market verification first and learned that there were two brands of pumps most commonly used in these equipment fleets. He chose to go with the more common brand. This was not the one that the hydraulic fracturing service company had originally requested, but he decided going with the general market needs made the most sense.

The pilot test plan, while subject to various updates as test results and new information became available, was a huge help in laying out a roadmap and enabling some medium- and long-term planning. It also helped everyone, including ABC Co.'s collaborators and funders, stay aware of the progress and current status as they progressed along the commercialization journey.

Ultimately, ABC Co. was able to establish themselves as a technology provider in their beachhead market, water reuse for hydraulic fracturing. Their technology contributed to the reduction of freshwater use for hydraulic fracturing. Moving to adjacent market sectors then became much easier, as they were able to build on the foundation that their now-solid technology validation had already established. They recently celebrated their tenth anniversary with a young entrepreneurs award that recognized them as an "overnight success".

6.0 Closing Comments

This Guidance Framework provides direction for water reuse technology proponents, champions and end users on how to develop and fund pilot test plans. It is intended to equip proponents and their partners with a common language and set of tools to efficiently work through the challenging and complex world of water technology piloting, from planning to execution. Users of this document are encouraged to spend time making use of the tools therein, and to initiate conversations with potential customers, partners, funders and regulators at the earliest opportunity.

Appendix A: Definitions & Acronyms

Definitions:

Beachhead market: The initial market segment into which a new product or service is initially sold, before targeting a broader market. The beachhead market is typically a niche market, with similar needs or demands amongst its customers, who are willing to try new offerings. They often have similar sales cycles or buying habits and have similar expectations for product performance. Marketing success will depend upon product performance and word-of-mouth communication, rather than formal advertising. Satisfied customers are often willing to act as references.

Bench test: Technology testing that occurs in a laboratory, workshop or similar controlled setting, on systems that are usually <10% of full-scale. Often, bench tests will be conducted on specific components, sub-systems or modules of the overall system, before these get combined together. Bench tests are a tool used from initial exploratory research through to tuning or improving technologies that have reached full commercial maturity.

Brownfield: Deploying a technology within an existing facility, usually as a replacement, expansion or redevelopment. Brownfield deployments need to account for existing/legacy infrastructure and/or operating protocols.

Compound Annual Growth Rate (CAGR): The growth rate of an investment or market, expressed as an annual average, including the effect of financial compounding.

Fit-for-purpose: A product, service or process that has sufficient design, implementation, control and maintenance to meet the needs of its intended purpose. In a water quality context, this refers to achieving the minimum required quality for the intended use, as opposed to striving to produce "pure" water.

Greenfield: Deploying a technology within a new facility. Greenfield deployments need sufficient information on the physical and operational characteristics of all the proposed components/sub-systems to enable the full facility to be designed.

Intellectual Property (IP): Intangible assets such as new designs, inventions, software or processes. These are formalized and protected via patents, copyrights, trademarks or trade secrets. During collaborative or joint venture co-development of IP, the concepts of "**Background IP**" (owned or created prior to the collaboration or joint venture) and "**Project IP**" (created during the collaboration or joint venture) are often used to determine how ownership of the various components of the IP will be assigned amongst the collaborating parties.

Pilot test: An operational test of technology, designed to answer the question "How well does this technology perform under specified conditions?". The performance can include technical, economic and operational aspects. Depending on end user needs, the "specified conditions" could range from typical operating conditions to the extremes of expected seasonal, flow, loading and other conditions. Pilot tests are typically conducted on a smaller-scale version of the technology, often sized somewhere between 10% to 50% of what the full-scale system would be. This technology often has a maturity of at least TRL 6.

Pilot test plan: A plan that clearly describes the various aspects that need to be addressed during pilot testing, including operational conditions, plus technical and economic performance indicators. This plan will also describe whether different pilot tests are needed to address all the objectives and lay out an experimental design for each test (e.g., what specific conditions are needed to address questions).

Pivoting: To change the direction, strategy or offering of a business when the current offering (product or service) is not meeting the needs of the marketplace.

Technology maturity: A mature technology is one that has been used long enough to resolve or remove its initial faults, and where its performance is predictable and well-established.

Technology Readiness Levels (TRLs): A method for estimating the maturity of a technology, using a series of descriptions assigned to Levels 1 (basic research) through 9 (fully mature and proven in operational environments). Originally developed by NASA in the 1970s, various organizations have since adapted the concept, including Alberta Innovates and the US Department of Energy.

Total Addressable Market (TAM): Also referred to as "Total Available Market", it is the maximum market size for a given class of solutions, assuming no competitors or market access barriers existed. A subset of the TAM will represent the "Serviceable Available Market (SAM)", which is the maximum potential reach of a specific company, and within the SAM will be the Target Market, or a realistic estimate of the % market that the current offering can capture.

Appendix B: TRL Scale and Assessment Guide

Alberta Innovates provides guidance on the TRL scale in their document, *Technology Readiness Levels*, with their definitions provided below. The document is available online:
https://albertainnovates.smartsimple.ca/files/646815/f125423/Technology-Readiness-Levels.pdf

An additional reference which may be useful is the United States Department of Energy's *Technology Readiness Assessment Guide",* available online:
https://www.directives.doe.gov/directives-documents/400-series/0413.3-EGuide-04a-admchg1/@@images/file

Level 1	**Basic principles of concept are observed and reported.** At this level scientific research begins to translated into applied research and development. Activities might include paper studies of a technology's basic properties.
Level 2	**Technology concept and/or application formulated.** At this level invention begins. Once the basic principles are observed, practical applications can be invented. Activities are limited to analytical studies.
Level 3	**Analytical and experimental critical function and/or proof of concept.** At this level active research and development is initiated. Activities might include components that are not yet integrated or representative.
Level 4	**Component and/or validation in a laboratory environment.** At this level basic technological components are integrated to establish that they will work together. Activities include integration of "ad hoc" hardware in the laboratory.
Level 5	**Component and/or validation in a simulated environment.** At this level the basic technological components are integrated for testing in a simulated environment. Activities include laboratory integration of components.
Level 6	**System/subsystem model or prototype demonstration in a simulated environment.** At this level a model or prototype is developed that represents a near desired configuration. Activities include testing in a simulated operational environment or laboratory.
Level 7	**Prototype ready for demonstration in an appropriate operational environment.** At this level the prototype should be at planned operational level and is ready for demonstration of an actual prototype in an operational environment. Activities include prototype field testing.
Level 8	**Actual technology completed and qualified through tests and demonstrations.** At this level the technology has been proven to work in its final form and under expected conditions. Activities include developmental testing and evaluation of whether it will meet operational requirements.
Level 9	**Actual technology proven through successful deployment in an operational setting.** At this level there is actual application of the technology in its final form and under real-life conditions, such as those encountered in operational test and evaluations. Activities include using the innovation under operational conditions.

Appendix C: Current Legislation and Guidance Documents

Links are provided below to key guidance documents and legislation relevant for Alberta water reuse.

Alberta Health Services

[Public health guidelines for water reuse and stormwater use]

Alberta Environment and Protected Areas

[Interim guidance to authorize reuse of municipal and industrial wastewater]

[Alberta's Water Act (WA)]

[Alberta Environmental Protection and Enhancement Act (EPEA), Section 67(3)]

[Activities Designation Regulation]

[Drinking Water/Wastewater Applications Info]

[Wastewater and storm Drainage Regulation]

[Standards and Guidelines for Municipal Waterworks]

[Wastewater and Storm Drainage Systems (Alberta Environment, 2006)]

[Classification of Land for Irrigation Guidelines for Municipal Wastewater Irrigation Water Quality Based Effluent Limits Procedures Manual]

[Environmental quality guidelines for Alberta surface waters [2018]]

[Guidance for deriving site-specific water quality objectives for Alberta rivers. Version 1.0]

[Municipal policies and procedures manual (section 2)]

Alberta Municipal Affairs

[Plumbing Code Regulation (Safety codes Act)]

[2020 National Plumbing Code]

[2020 National Building Code]

[Canadian Guidelines for Domestic Reclaimed Water for use in Toilet and Urinal Flushing]

[Notice: alternative solutions guide for small system water reuse and stormwater use]

[B128.1 - Design and installation of non-potable water systems/ Maintenance and field testing of non-potable water systems]

[B128.2 - Maintenance and field testing of non-potable water systems]

B128.3 - Performance of non-potable water treatment systems

Safety Codes Council – Where to Get a Permit

Alberta Energy Regulator

ID 2000-03 (plus Memorandum of Understanding): Harmonization of Waste Management

Interim guidance to authorize reuse of municipal and industrial wastewater

New Guidance on Applications Under the Water Conservation Policy for Upstream Oil & Gas Operations

Directive 081: Water Disposal Limits and Reporting Requirements for Thermal In Situ Oil Sands Schemes

New Edition of Manual 002: Drilling Waste Inspections

Geothermal Resource Development Rules and Directive 089: Geothermal Resource Development

Directive 051: Injection and Disposal Wells – Well Classifications, Completions, Logging, and Testing

Directive 055: Storage Requirements for the Upstream Petroleum Industry

Tailings Performance Criteria and Requirements for Oil Sands Mining Schemes [Rescinded by Directive 085: Fluid Tailings Management for Oil Sands Mining Projects]

Directive 081: Water Disposal Limits and Reporting Requirements for Thermal In Situ Oil Sands Schemes

Fluid Tailings Management for Oil Sands Mining Projects

Acts, Regulations and Rules

Codes of Practice under the Water Act or the Environmental Protection and Enhancement Act

Specified Enactments (Jurisdiction) Regulation

Environmental Protection and Enhancement Act

Activities Designation Regulation

Approvals and Registration Procedures Regulation

Conservation and Reclamation Regulation

Disclosure of Information Regulation

Environmental Assessment Regulation

Environmental Assessment (Mandatory and Exempted Activities) Regulation

Environmental Protection and Enhancement (Miscellaneous) Regulation

Remediation Regulation

Waste Control Regulation

Wastewater and Storm Drainage Regulation

Wastewater and Storm Drainage (Ministerial) Regulation

Water Act

Oldman River Basin Water Allocation Order

Water allocation policy for closed river basins in the South Saskatchewan River Basin directive

Surface water allocation directive

Administrative Guideline for Transfer of Water Allocations (and Agreements to Assign Water, and License Amendments)

Guide to compelling reasons to not take the 10% holdback for water transfers within the South Saskatchewan River Basin

Water (Ministerial) Regulation

Water (Offences and Penalties) Regulation

Codes of Practice under the Water Act and the Environmental Protection and Enhancement Act

Code of Practice for a Waterworks System Consisting Solely of a Water Distribution System

Code of Practice for Wastewater Systems Consisting Solely of a Wastewater Collection System

Code of Practice for Wastewater Systems Using a Wastewater Lagoon

Code of Practice for Waterworks Systems Using High Quality Groundwater