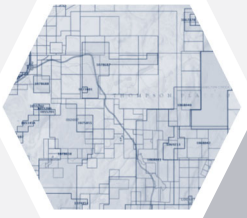

Technology Readiness Assessment

Interim Technical Guidance

August 2022
Version 02.00

BRITISH COLUMBIA
Ministry of Energy, Mines and Low Carbon Innovation

BRITISH COLUMBIA
Ministry of Environment and Climate Change Strategy

PROVINCE OF BRITISH COLUMBIA
B.C. Ministry of Energy, Mines and Low Carbon Innovation
B.C. Ministry of Environment and Climate Change Strategy

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Technology Readiness Assessment
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Table of Contents

1. Introduction

This document is intended to provide a framework to proponents for conducting a Technology Readiness Assessment (TRA) for emerging technologies proposed to control or treat effluent discharges from major mines. For the purposes of this guidance document, emerging technologies include source controls and effluent (water) treatment systems.

The information provided in this document is not intended to be exhaustive and should be used in conjunction with existing EAO, EMLI, and ENV guidance and regulatory requirements, including the Technology Readiness Levels (TRL) Interim Technical Guidance.

2. Regulatory Processes

For major mines in BC, proponents may implement measures, including source controls and/or treatment technologies, in order to meet receiving environment requirements. When technologies are proposed in applications as mitigations for project impacts, they must be demonstrated to be at a TRL suitable for implementation in accordance with the information requirements and site specificity expected as part of the respective regulatory process. As such, the TRL required for *Mines Act* (MA) and/or *Environmental Management Act* (EMA) **applications** are higher than that required for Environmental Assessment Certificate (EAC) applications under the *Environmental Assessment Act* (EA) or MA and/or EMA **planning processes**.

Technologies that have been assessed at TRL-8 or TRL-9 are considered to be proven technologies and are generally deemed acceptable to meet initial information requirements for MA and/or EMA applications, noting that additional information may be requested as part of regulatory review processes. For TRL-8 technologies, proponents likely need to conduct site-specific work to collect empirical data to support regulatory processes. For TRL-9 technologies, it is expected that the information requirements for MA and/or EMA applications can be met using scientific literature and analogue site data. However, in some cases, proponents may need to conduct site-specific work to collect empirical data to support regulatory processes.

Technologies that have been assessed at TRL-7, or below, are considered to be research and development (R&D) technologies. TRL-7 technologies may be acceptable to fulfill the information requirements for EAC applications and MA and/or EMA planning processes. However, for TRL-6 and lower technologies there is insufficient scientific literature or analogue site data to support regulatory processes due to their limited deployment and/or susceptibility to site-specific conditions, such as hydrology, climate, and source chemistry. Therefore, proponents will likely need to conduct considerable research and development activities and site-specific work to collect empirical data to meet the information requirements for EAC applications and MA and/or EMA planning processes.

If the information provided for a proposed technology does not meet the TRL criteria (e.g.TRL-7 for EAC applications and TRL-8 or TRL-9 for MA and/or EMA permitting applications) the regulatory review process may be delayed until the proponent is able to provide sufficient information, or a different technology is proposed.

A TRA is intended to support regulatory processes where an emerging technology is proposed. Where an emerging technology is proposed, following this guidance before an EAC application review process or MA and/or EMA application review process may help streamline the application review process since a robust and well-presented TRA can support common understanding of a technology's readiness by EMLI, ENV, and EAO technical reviewers and Indigenous Groups.

3. Technology Readiness Assessment (TRA)

3.1. Overview

A TRA is a systematic, evidence-based, process that evaluates the readiness of emerging technologies. A TRA may be used to identify risks and highlight critical technology information gaps. A TRA does not necessarily eliminate risk or preclude taking risks; rather, a TRA may alert interested parties to gaps in the understanding of a proposed technology that could potentially be raised during a MA, EMA, and/or EAC application review process.

A TRA should be credible, objective, reliable, and useful to proponents, their qualified professionals and/or vendors, Indigenous Groups, third parties, and EMLI, ENV, and EAO technical staff. A TRA can be conducted and updated throughout the technology's research and development process. There is no pre-determined number of TRAs that should be conducted, nor a set time interval between TRAs. The key consideration is that a technology should be evaluated during the research and development process to inform next steps and identify potential information gaps and concerns.

3.2. Objectives

The main objectives of a TRA are to identify risk, highlight critical technology information gaps, inform next steps in the development of an emerging technology, and support MA, EMA, and/or EA regulatory review processes.

The objectives of a TRA for a specific technology depend on the state of it's research and development and proposed use by a major mine. The objectives should clearly link to and inform at least one of the following topics:

- Technology design and operation;
- Risk management and mitigation;
- Application of the technology for mitigation planning; and/or
- Information requirements for MA and/or EMA regulatory processes.

The TRA should also identify anticipated connections to MA, EMA, and/or EA regulatory processes, such as future MA, EMA, and/or EAC applications.

3.3. Components

The main components of a TRA typically include an independent peer review (IPR), a technology readiness level (TRL) determination, a technology maturation plan, a risk management approach, and a risk register. The TRA components do not have to be conducted in any particular order, nor

is each component necessarily required for every TRA. The following sections describe each component and how it supports the TRA process.

3.3.1. Independent Peer Review (IPR)

An IPR is a process that includes an independent assessment of the scientific and/or technical merit of the technology research and development by qualified persons with knowledge and expertise equal to that of the researchers whose work they are reviewing. An IPR provides recommendations that can be used to support technology research and development, MA and/or EMA planning processes, and/or MA, EMA, and/or EAC application information requirements. An IPR guidance document is provided in Appendix A.

3.3.2. Technology Readiness Level (TRL)

The TRL describes the readiness of an emerging technology. The TRL scale has nine levels and describes the different stages of technology development and the readiness (i.e. maturity) of a technology. The TRL guidance document is provided in Appendix B.

3.3.3. Technology Maturation Plan

A technology maturation plan is a management planning tool that lays out the steps, actions, and resources required to develop (i.e. mature) a technology. Key components of a technology maturation plan include:

- The objectives for a given stage of technology development;
- The development approach; and,
- The scope.

The plan should include specific tasks to be undertaken and results needed to progress to the next stage.

The objectives and the scope of the technology maturation plan should be designed to provide the information required to meet a target TRL, the EAC information requirements, and/or the MA/EMA Joint Application Information Requirements. The technology maturation plan should be designed to generate information required for the proponent to design, engineer, construct, and operate the technology at the targeted TRL level. A technology maturation plan is one of the first elements that should be developed to effectively move a technology from one TRL level to the next.

Technology maturation plans are typically outlined in the experimental plans and objectives that are included in a MA and/or EMA permit application for on-site trials of an emerging technology. However, they can also be developed and communicated separately from permit applications, depending on the objectives of the plan.

3.3.4. Risk Management Process

The main objectives of risk management are to:

- Verify that risks are consistently identified, understood, communicated, and managed; and
- Support informed decision making.

A risk management process can be used for technologies at all TRLs, and throughout the life of technologies once employed on a mine site. For the purposes of emerging technologies, the risk management process is intended to identify and address inherent risks associated with the technology and its operation. Site-specific risks associated with the implementation of a technology are managed separately as a component of MA and/or EMA permit application processes.

The risk management process generally involves three steps:

- Setting the scope and criteria;
- Conducting a risk assessment; and
- Identifying risks and developing risk controls.

Each step of the process includes communication and consultation, monitoring, review, recording, and reporting. It is best practice for the risk management process to be iterative, regularly reviewed, and updated as new data or information becomes available. Effective communication throughout the risk management process allows the proponent, Indigenous Groups, and EMLI, ENV, and EAO technical staff to understand risks and outcomes of risk assessments.

The proponent should clearly define the relevant objectives and scope of risk management activities. These should treat worker health and safety as paramount and be protective of the environment and human health. Risk criteria include the potential consequence type, severity, and likelihood (or probability) of occurrence. Potential consequence types should include impacts to worker health and safety and protection of environment and human health, at a minimum. Likelihoods and consequences generally have five categories, ranging from very unlikely to almost certain likelihood, and very low to critical severity, respectively.

In a risk assessment, the risks are identified, analyzed, and evaluated. The risk criteria form a risk matrix that rates each risk based on the consequence, severity, and likelihood. The risk controls identified and developed as part of the risk assessment should be appropriate to the likelihood and consequence of the risks.

The risk management process should be documented with a risk register, or another risk management tool, which includes each risk, risk description, consequences, consequence severity, likelihood of occurrence, risk ranking, and risk controls.

3.3.5. Risk Register

A risk register is a tool for documenting risks and associated management actions (i.e. controls). It is an important tool for understanding and evaluating the risks associated with an emerging

technology. As risks are identified, they are logged into the register and associated controls are developed. It is expected that as an emerging technology develops, the associated risks will be reduced. As such, a risk register is a living document that tracks risks and associated controls over time.

3.4. Communication Framework

The communication approach should be based on the objectives of the TRA. If a TRA is intended to support a MA and/or EMA regulatory process for use of an emerging technology at a major mine, it is recommended that the proponent engages and seeks input from EMLI, ENV, EAO, and Indigenous Groups as early as possible.

It is recommended that the proponent offer a workshop for EMLI, ENV, and EAO technical staff, Indigenous Groups, and any relevant third parties, to review the components of the TRA. The workshop should be a forum to discuss the experimental data, the risk management process, identified risks and risk controls, IPR findings, and technology maturation plans that support the recommendations of the TRA. To facilitate effective discussion, attendees should be provided the TRA report in advance of the workshop.

3.5. TRA Report

A TRA is conducted by a proponent to formally document the readiness assessment, including any findings or recommendations for an emerging technology. Supporting documentation should be summarized, referenced, and included as an appendix. The TRA report should include, but not be limited to, the following sections.

3.5.1. Objective

This section describes the objectives of the TRA. As outlined in Section 3.2, this should include at least one of the following; technology design and operation; risk management and mitigation; application of the technology for mitigation planning; and/or developing information requirements for MA, EMA, and/or EA regulatory processes.

Additionally, this section should describe the reason for development of the emerging technology and the intended use of the TRA. For example, the objective may indicate that the TRA is being used to support the rationale for the inclusion of an emerging technology in a MA, EMA, and/or EAC application.

3.5.2. Technology Description

This section provides a detailed description of the technology. Sufficient detail should be included to provide a basic understanding of the technology. This section may include references to other supporting documentation, such as literature reviews, design reports, and/or performance reports.

3.5.3. TRA Components

This section references each of the components included in the TRA, outlined in Section 3.3. It should include a detailed summary of each component. Any supporting documents should be included as appendices. Additionally, a rationale should be provided for any TRA component that was not completed.

3.5.4. Communications Summary

This section provides a summary of the communication and consultation with EMLI, ENV, EAO Indigenous Groups, and any other third parties undertaken, if any, as part of the development of the TRA.

3.5.5. Conclusions

This section states the proposed TRL of the technology and provides a rationale for the determination.

3.5.6. Recommendations

This section includes any recommendations based on the current understanding of the technology and the TRL. Recommendations should be included that refer to identified objectives and next steps, including additional research and development, mitigation planning, permitting, and implementation. Recommendations could range from ceasing development of the technology to moving to implementation on a major mine through a MA and/or EMA permit application.

Because a TRA report will typically be submitted to regulators to support future MA, EMA, and/or EA regulatory process, it is recommended that TRA reports be drafted as publicly viewable documents. Any proprietary information may be referenced and submitted under separate cover as per EMLI and ENV policies.

3.6. TRA Limitations

A TRA is not a requirement of any MA, EMA, or EA regulatory processes. A proponent may include an emerging technology in a MA, EMA, and/or EA regulatory process without first conducting a TRA.

A proponent may conduct a TRA at any time to inform technology development or to support a MA, EMA, and/or EA regulatory process for a major mine. A TRA is independently initiated and developed by a proponent. A proponent can decide when and how to engage EMLI, ENV, EAO and/or Indigenous Groups in the development of a TRA but is not required to involve any additional parties.

However, it is recommended that a proponent conduct a TRA prior to including an emerging technology in a MA, EMA, and/or EA regulatory process, as the outcomes of the TRA may help inform a proponent of the technology readiness and could help inform the regulatory review process.

4. Glossary

Independent Peer Review (IPR): A process that includes an independent assessment of the technical and/or scientific merit of the technology, research and development by qualified persons with knowledge and expertise equal to that of the researchers whose work they review.

Risk Management: Coordinated activities to direct and control an organization with regard to risk.

Risk Register: A document that outlines the results of the mitigation risk analysis and risk response planning.

Source Control: An approach or measure that is intended to prevent or reduce the production and/or release of parameters of potential concern from a mined material or disturbed area into the receiving environment.

Technology Maturation Plan: A management planning tool that lays out the steps, actions, and resources needed to mature emerging technologies.

Technology Readiness Assessment (TRA): A systematic, evidence-based process that is used to evaluate the readiness of emerging technologies.

Technology Readiness Level (TRL): A scale that consists of nine levels, requiring a technology to be demonstrated at incrementally higher levels of reliability in terms of its form, the level of integration with other parts of the system, and its operating environment. At the final level the technology is described in terms of actual system performance in an operational environment. The scale is ordered according to the characteristics of the demonstration or testing environment under which a given technology may be tested at defined points in time.

Treatment: A process that improves the quality of mine contact water to make it appropriate for discharge to the environment or other specific end-uses. Types of treatment processes include chemical, biological, physical, or a combination of the three. Types of treatment technologies include active and semi-passive.

Appendix A

Independent Peer Review (IPR)

Interim Technical Guidance

August 2022

Version 02.00

PROVINCE OF BRITISH COLUMBIA
B.C. Ministry of Energy, Mines and Low Carbon Innovation
B.C. Ministry of Environment and Climate Change Strategy

Technology Readiness Assessment
Interim Technical Guidance
Independent Peer Review (IPR)
Version 02.00
Published August 2022

This document provides information regarding the Technology Readiness Assessment - Independent Peer Review (IPR) guidance for major mines in British Columbia. Although references are made to legal requirements, the content of this document should not be interpreted as legal instructions or legal advice. Users of this document should refer directly to official copies of the legislation to determine legal requirements and seek qualified legal counsel when case-specific interpretations are needed.

Technology Readiness Assessment
Interim Technical Guidance
Independent Peer Review (IPR)

Version 02.00

Table of Contents

1. Introduction

This document provides guidance on a framework for conducting an Independent Peer Review (IPR) on emerging technologies as part of a Technology Readiness Assessment (TRA).

IPRs are assessments conducted by an independent reviewer(s), who are subject matter experts not directly involved in the research and development of the emerging technology. They provide recommendations that can be used to support technology development, readiness assessment evaluations, permit application information requirements, and mine planning decisions.

Initiating an IPR process is at the discretion of the proponent, and they are responsible for its execution. However, if the proponent intends to use the IPR and TRA to support *Mines Act (MA)*, *Environmental Management* Act (EMA), and/or *Environmental Assessment Act (EA)* regulatory review processes, it is important that the proponent work with Ministry of Energy, Mines, and Low Carbon Innovation (EMLI), Ministry of Environment and Climate Change Strategy (ENV) and/or Environmental Assessment Office (EAO) technical reviewers, and Indigenous Groups.

This document is written from the perspective of an IPR being conducted to support a MA, EMA, and/or EA regulatory review process. It should be read in conjunction with the TRA guidance document developed by EMLI and ENV.

This guidance is not intended to be exhaustive and should not be used as a checklist.

2. Objective

The objective of an IPR is to provide a third-party opinion on a TRA, including the conclusions reached, the contents and comprehensiveness of the risk register or other risk management tools, and the proposed management of a technology that includes operational, health and safety, and environmental considerations.

The outcome of the IPR can be used by the proponent to assess technology readiness (e.g. maturity) and support planning and permit applications.

The results of an IPR, in conjunction with a TRA, are intended to support the review of information to meet permit application information requirements for emerging technology *in lieu* of peer-reviewed literature or appropriate analogue data.

3. Communication Framework

Effective communication throughout the IPR process is key to ensuring all parties understand the review objectives, agree with the process, and better understand the outcomes and results.

The communication framework outlined in this section is intended to provide a roadmap for effective communication and engagement, should the proponent choose to include EAO, EMLI, and/or ENV technical reviewers, and Indigenous Groups.

3.1. Structure

There are a variety of structures that can be used to engage with EAO, EMLI, and ENV technical reviewers, and Indigenous Groups during an IPR. The selected structure should be based on the objectives, scope, and timing of a specific IPR process.

One recommended structure is a working group. A proponent may engage with a new or existing working group to communicate the IPR objectives, process, and outcomes. The working group should include representation from EAO, EMLI, ENV, and Indigenous Groups.

3.2. Milestones

There are key milestones during the IPR process that should be communicated to EAO, EMLI, ENV, and Indigenous Groups. The intent of communication at these key points is to seek consensus and ensure transparency as it relates to the review process and outcomes.

To better support review objectives, the following best practices are recommended:

- Identify and communicate key milestones ahead of a review process;
- Seek consensus with respect to the key milestones and review objectives; and
- Confirm and continuously refine key milestones and review objectives throughout the IPR process.

The following are recommended communication milestones:

- **Initial Notification:** The proponent communicates the intent to initiate an IPR for an emerging technology to EAO, EMLI, and/or ENV, and Indigenous Groups.

- **Review Set-up:** The proponent communicates the details of the proposed IPR work plan, including information about the independent reviewer selection, using the agreed upon communication structure.

- **Reporting and Review:** The proponent shares the IPR final report with the working group and offers an opportunity for them to meet with the independent reviewer(s) to discuss the outcomes and recommendations. If the proponent chooses to not share the final report, the decision and rationale should be provided to the working group.

4. Review Methodology

This section describes the methodology for conducting IPRs. Each step identifies tasks and deliverables.

4.1. Step 1: Initial Notification

Tasks	• The proponent notifies in writing EAO, EMLI, and/or ENV, and Indigenous Groups of their intent to initiate an IPR process for a specific emerging technology • The proponent coordinates a meeting to discuss and confirm a communication structure, review objectives, and timelines • The proponent develops a draft review work plan • The proponent seeks input from the working group on the workplan and makes any changes deemed necessary based on feedback received
Deliverables	• Written notification of intent to initiate an IPR process. • Communication Structure.

4.2. Step 2: Review Set-up

Tasks	• The proponent develops a detailed draft IPR workplan that:
	  ▪ Addresses the review objectives
	  ▪ Identifies review type
	  ▪ Identifies documentation for review
	• The proponent drafts a schedule
	• The proponent develops a plan for independent reviewer selection and recommends the independent reviewer(s)
	• The proponent shares the work plan, independent reviewer selection process, and recommended independent reviewer(s) with the working group and coordinates a meeting to discuss the information
	• The proponent seeks input from the working group on the workplan and makes any changes deemed necessary based on feedback received.

Deliverables	• IPR Workplan
	  ▪ Review type; and
	  ▪ List of documentation for review
	• Independent Reviewer Selection Plan
	• Schedule

4.2.1. Review Type

There are several different types of IPR reviews. The proponent should select an IPR review type based on the review objectives, technology complexity, and/or associated or perceived risk. IPR review types include:

- **Panel Review:** A group of independent reviewers share and discuss review comments. Individual comments may be prepared, or consensus advice may be provided, by the independent reviewers.

- **Letter Review:** Individual written peer review comments are requested from independent reviewers. independent reviewers do not consult with each other or participate in any collaborative peer review.

- **Desktop Review:** The independent reviewers only conduct a review of data and reports. independent reviewers are not provided access to the emerging technology.

4.2.2. Documentation for Review

It is important that the proponent identify all relevant information and documentation related to the emerging technology. This should include any supporting peer reviewed literature as well as data and performance reports from relevant stages of the technology research and development.

4.2.3. Independent Reviewer Selection

Reaching consensus with the working group on independent reviewer selection is desirable for the purpose of conducting a credible IPR process. The working group members must have confidence in the independent reviewer(s) to trust the outcomes and recommendations of the IPR. As such, it is recommended that independent reviewers be subject matter experts in disciplines relevant to the emerging technology and be as independent as possible of the proponent's research and development process. The proponent is responsible for all communication with the independent reviewer(s) throughout the IPR process development and execution.

A reviewer is considered independent if:

- They do not have a conflict of interestwith regards to the proponent's research and development process; and

- They are not influenced by someone with an interest in the proponent's research and development process.

The plan for Independent Reviewer Selection Plan should include:

- **Reviewer Criteria:** It is important that an independent reviewer be a subject matter expert in relevant and applicable fields and be independent of the proponent's research and development process. The proponent should outline the criteria that will be used to select an independent reviewer and seek input from the working group.

- **Opportunity for Nomination:** Provide an opportunity to the working group to nominate independent reviewer candidates and share candidates' curriculum vitae (CV).

- **Evaluation Methodology:** Provide a process for evaluation and selection of all nominated independent reviewer candidates.

- **Non-Consensus:** Propose a process for dealing with non-consensus, such as seeking a second round of nominations.

4.2.4. Schedule

Once an IPR type and the independent reviewer(s) have been selected, the proponent should develop a schedule outlining the review process and deliverable dates for key milestones. This schedule should be provided to the working group.

4.3. Step 3: Discovery and Analysis

Tasks	• Independent reviewers read relevant documentation • Independent reviewers conduct interviews and attend site visits (if required) • Independent reviewers summarize findings and draft final report • The proponent seeks input from the working group on the draft final report and makes any changes deemed necessary based on feedback received.
Deliverables	• Draft Final Report ▪ Conclusions ▪ Recommendations

4.4. Step 4: Reporting and Review

Tasks	• Independent reviewer(s) submits a final report to proponent • The proponent seeks input from the working group on the final report and makes any changes deemed necessary based on feedback received.
Deliverables	• Final Report • Final review presentation (if requested)

4.4.1. Final Report

The final report is the official record of the independent review.

If the IPR team and proponent cannot reach consensus on the TRL of an emerging technology, it should be presented in the TRA report as an addendum and accompanied by evidence that supports both sides. As applied in the context of this guidance document, provision is made for the proponent to provide an addendum with evidence in the event of a disagreement with the conclusions resulting from the IPR.

4.4.2. Optional Final Report Presentation

A final report review and/or presentation offers a venue for working group members to understand findings and recommendations from the IPR. It is intended to be an opportunity for the independent reviewer(s) to summarize their key findings and respond to questions from the working group. The objective is to ensure working group members have a fulsome understanding of the final report.

Appendix B

Technology Readiness Levels (TRL)

Interim Technical Guidance

August 2022

Version 02.00

PROVINCE OF BRITISH COLUMBIA
B.C. Ministry of Energy, Mines and Low Carbon Innovation
B.C. Ministry of Environment and Climate Change Strategy

Technology Readiness Levels
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Technology Readiness Levels
Interim Technical Guidance
Version 02.00

Table of Contents

1. Introduction

This document is intended to provide guidance to proponents for determining the Technology Readiness Level (TRL) of emerging technologies proposed to control or treat effluent discharges from major mines. For the purposes of this guidance document, emerging technologies include source controls and effluent (water) treatment systems.

This document aligns TRLs with Ministry of Energy, Mines and Low Carbon Innovation (EMLI) and Ministry of Environment and Climate Change Strategy (ENV) regulatory processes. EMLI and ENV can consider the TRL of proposed technologies through one of the following processes:

- A Technology Readiness Review (TRR), or
- An *Environmental Assessment Act* (EA) Environmental Assessment Certificate (EAC) application review, or
- A *Mines Act* (MA) *and/or Environmental Management Act* (EMA) permitting application review.

2. Technology Readiness Level

The TRL scale describes the different stages of technology development and the readiness (i.e. maturity) of a technology. Determining the TRL of an emerging technology is one component of a Technology Readiness Assessment (TRA).

The primary objectives associated with a TRL determination are to:

- Support the advancement of technologies;
- Guide research and development to ensure the information required to advance the technology is collected;
- Enable consistent, uniform discussion of a technology's maturity; and
- Align TRLs with regulatory processes like environmental assessments, mine and mitigation planning, permitting, and effluent discharge, water quality and receiving environment modelling.

This document is based on Innovation Canada's TRLs (Appendix A). The TRL scale has nine levels, with TRL 1 describing a technology where only the basic principles of a concept are observed and reported and TRL 9 describing a technology that has been deployed in its final form and under expected field conditions at multiple sites. At each level, aspects of the technology are demonstrated at incrementally higher levels of dependability until the final level where the actual operation of the technology is proven through successful deployment in an operational field setting (Figure 1). When technology development is complete it may achieve a stage of being commercially available.

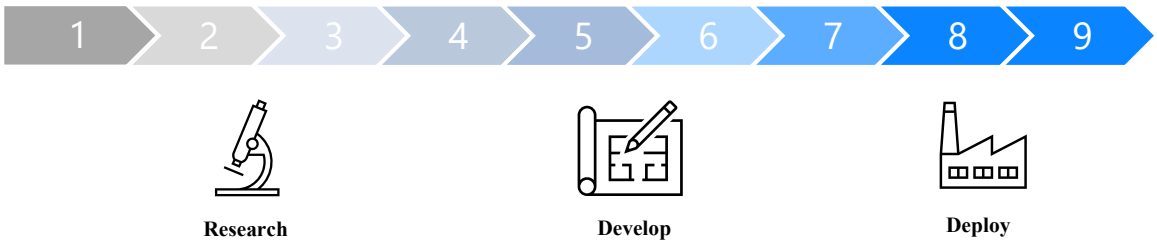

Figure 1: Technology Readiness Levels 1 to 9, from research to development to deployment in the field.

3. Regulatory Processes

For major mines in BC, proponents may implement measures, including source controls and/or treatment technologies, in order to meet receiving environment requirements. When technologies are proposed in applications as mitigations for project impacts, they must be demonstrated to be at a TRL suitable for implementation in accordance with the information requirements and site specificity expected as part of the respective regulatory process. As such, the TRL required for *Mines Act* (MA) and/or *Environmental Management Act* (EMA) **applications** are higher than that required for Environmental Assessment Certificate (EAC) applications under the *Environmental Assessment Act* (EA) or MA and/or EMA **planning processes**.

Technologies that have been assessed at TRL-8 or TRL-9 are considered to be proven technologies and are generally deemed acceptable to meet initial information requirements for MA and/or EMA applications, noting that additional information may be requested as part of regulatory review processes. For TRL-8 technologies, proponents likely need to conduct site-specific work to collect empirical data to support regulatory processes. For TRL-9 technologies, it is expected that the information requirements for MA and/or EMA applications can be met using scientific literature and analogue site data. However, in some cases, proponents may need to conduct site-specific work to collect empirical data to support regulatory processes.

Technologies that have been assessed at TRL-7, or below, are considered to be research and development (R&D) technologies. TRL-7 technologies may be acceptable to fulfill the information requirements for EAC applications and MA and/or EMA planning processes. However, for TRL-6 and lower technologies there is insufficient scientific literature or analogue site data to support regulatory processes due to their limited deployment and/or susceptibility to site-specific conditions, such as hydrology, climate, and source chemistry. Therefore, proponents will likely need to conduct considerable research and development activities and site-specific work to collect empirical data to meet the information requirements for EAC applications and MA and/or EMA planning processes.

If the information provided for a proposed technology does not meet the TRL criteria (e.g.TRL-7 for EAC applications and TRL-8 or TRL-9 for MA and/or EMA permitting applications) the regulatory review process may be delayed until the proponent is able to provide sufficient information, or a different technology is proposed.

4. Checklist

A TRL checklist has been developed to support the determination of TRLs and to align them with regulatory planning and permitting processes. The checklist is intended to guide and support major mine proponents as it relates to technology readiness and the implementation of emerging technologies, including source controls and treatment technologies, at major mines.

To be assessed by EMLI and ENV at a specific TRL, a technology should meet the criteria listed for that TRL in the checklist. Technologies that are determined to be TRL-1 to TRL-7 are considered R&D technologies. Technologies that are determined to be TRL-8 or TRL-9 are considered proven technologies.

The following information is also applicable to the TRL checklist:

- Additional, technology-specific, criteria may be required by EMLI and ENV in order to meet any of the TRLs.
- The same prototype or demonstration system could be used to demonstrate successive TRLs.
- Proponents are reminded that a TRL determination is only one component of a TRA.

Table 1: Technology Readiness Level Checklist

TECHNOLOGY READINESS LEVELS (TRL)	CRITERIA	CONNECTION TO REGULATORY PROCESSES
LEVEL 1: BASIC PRINCIPLES OBSERVED AND REPORTED	☐ Translation of scientific research into applied research and development. ☐ Literature review of technology's basic properties.	• *Research conducted by a proponent.* • *Authorization under MA and/or EMA not required.*
LEVEL 2: TECHNOLOGY CONCEPT AND/OR APPLICATION FORMULATED	☐ Activities are limited to analytical studies. ☐ Observation of basic principles.	• *Research conducted by a proponent.* • *Authorization under MA and/or EMA not required.*
LEVEL 3: ANALYTICAL AND EXPERIMENTAL CRITICAL FUNCTION AND/OR PROOF OF CONCEPT (Laboratory experiments to demonstrate basic function)	☐ Active research and development initiated. ☐ Analytical studies or laboratory studies. ☐ Testing of components that are not yet integrated or representative. ☐ Collection of empirical data.	• *Research and development conducted by a proponent.* • *Authorization under MA and/or EMA not required.*
LEVEL 4: COMPONENT VALIDATION IN A LABORATORY ENVIRONMENT (Prototype system or system component operating in a laboratory)	☐ Basic technological components are integrated to establish that they work together in the laboratory. ☐ Collection of empirical data.	• *Research and development conducted by a proponent.* • *Authorization under MA and/or EMA not required.*
LEVEL 5: COMPONENT VALIDATION IN A SIMULATED ENVIRONMENT (Prototype system or system component operating under relevant site-specific conditions)	☐ Basic technological components are integrated in the laboratory. ☐ Testing in a laboratory or simulated environment. ☐ Collection of empirical data.	• *Research and development conducted by a proponent.* • *Activity may be conducted on-site and may require authorization under MA and/or EMA.* • *Reclamation security is required for the removal of the prototype and reclamation of the disturbed area.*
LEVEL 6: PROTOTYPE DEMONSTRATION IN A SIMULATED ENVIRONMENT (Demonstration system operating under relevant site-specific conditions)	☐ Development of a prototype that represents or nearly represents the final configuration. ☐ Testing in a laboratory or simulated environment. ☐ Collection of empirical data.	• *Research and development conducted by a proponent.* • *Activity may be conducted on-site and may require authorization under MA and/or EMA.* • *Reclamation security is required for the removal of the prototype and reclamation of the disturbed area.*

TECHNOLOGY READINESS LEVELS (TRL)	CRITERIA	CONNECTION TO REGULATORY PROCESSES
LEVEL 7: PROTOTYPE DEMONSTRATION IN SITE-SPECIFIC ENVIRONMENT (Demonstration system operating at near full-scale under relevant site-specific conditions)	☐ Development of a prototype representative of the final configuration. ☐ Testing in the actual field setting. ☐ Empirical data supports the implementation of the technology to meet receiving environment requirements under a range of conditions representative of the expected life and application of the technology. ☐ A risk management approach and risk register have been developed. Identified risks have proposed mitigations through operational and management actions. ☐ MA and EMA Joint Application Information Requirements for the technology, excluding capital and operating costs, that are technology-specific can be met (JAIR Section 5.6.4). An independent peer review may be used *in lieu* of literature and analogue data.	• *Research and development conducted by a proponent.* • *Activity may be conducted on-site and may require authorization under MA and/or EMA.* • *The technology may be proposed for use in MA and/or EMA planning processes.* • *The technology may be included in EAC applications.* • *Reclamation security is required for the removal of the prototype and reclamation of the disturbed area.* • *Reclamation security may be required for the provision of an alternative, proven, technology.*
LEVEL 8: ACTUAL TECHNOLOGY COMPLETED AND QUALIFIED THROUGH TEST AND DEMONSTRATIONS (First-of-a-kind system complete and proven at full-scale)	☐ A risk management approach and risk register have been developed/updated. Identified risks have proposed mitigations through operational and management actions. ☐ The technology is transferable and can conceptually be implemented at any site, subject to site-specific conditions. ☐ The operational and replacement costs of the technology can be calculated for bonding requirements. ☐ MA and EMA Joint Application Information Requirements for the technology are fully met (JAIR Section 5.6.4) using an appropriate combination of literature, analogue data, and empirical data for the technology.	• *The technology may be proposed for use in MA and/or EMA planning processes.* • *The technology may be included in EAC applications.* • *The technology may be included in MA and/or EMA permit applications as a proven technology.* • *MA/EMA Joint Application Information Requirements can be met with empirical data.* • *Reclamation security is required for the technology's capital and operating costs and reclamation of the disturbed area.*
LEVEL 9: ACTUAL TECHNOLOGY PROVEN THROUGH SUCCESSFUL DEPLOYMENT IN OPERATIONAL SETTINGS (System complete and proven at full-scale in multiple settings)	☐ MA and EMA Joint Application Information Requirements for the technology are met (JAIR Section 5.6.4) using an appropriate combination of literature and analogue data for the technology. Empirical data may not be required.	• *The technology may be proposed for use in MA and/or EMA planning processes.* • *The technology may be included in EAC applications.* • *The technology may be included in MA and/or EMA permit applications as a proven technology.* • *MA/EMA Joint Application Information Requirements can be met without empirical data.* • *Reclamation security is required for the technology's capital and operating costs and removal and reclamation of the disturbed area.*

5. Glossary

Prototype: The first design of a technology or part of a technology from which other forms are copied or developed.

Source Control: An approach or measure that is intended to prevent or reduce the production and/or release of parameters of potential concern from a mined material or disturbed area into the receiving environment.

Technology Readiness Assessment (TRA): A systematic, evidence-based process that is used to evaluate the readiness of emerging technologies.

Technology Readiness Level (TRL): A scale that consists of nine levels, requiring a technology to be demonstrated at incrementally higher levels of reliability in terms of its form, the level of integration with other parts of the system, and its operating environment. At the final level the technology is described in terms of actual system performance in an operational environment. The scale is ordered according to the characteristics of the demonstration or testing environment under which a given technology may be tested at defined points in time.

Treatment: A process that improves the quality of mine contact water to make it appropriate for discharge to the environment or other specific end-uses. Types of treatment processes include chemical, biological, physical, or a combination of the three. Types of treatment technologies include active and semi-passive.

Appendix A – Innovation Canada Technology Readiness Levels[1]

Level 1: Basic principles of concept are observed and reported
Scientific research begins to be 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
Invention begins. Once basic principles are observed, practical applications can be invented. Activities are limited to analytic studies.

Level 3: Analytical and experimental critical function and/or proof of concept
Active research and development is initiated. This includes analytical studies and/or laboratory studies. Activities might include components that are not yet integrated or representative

Level 4: Component and/or validation in a laboratory environment
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
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
A model or prototype 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
Prototype at planned operational level and is ready for demonstration in an operational environment. Activities include prototype field testing.

Level 8: Actual technology completed and qualified through tests and demonstrations
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
Actual application of the technology in its final form and under real-life conditions, such as those encountered in operational tests and evaluations. Activities include using the innovation under operational conditions.

[1] Innovation, Science and Economic Development Canada, Innovation Canada. Technology readiness levels. 2018-01-23. (https://www.ic.gc.ca/eic/site/080.nsf/eng/00002.html)

Technology Readiness Assessment
Interim Technical Guidance

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