



Australian Government

Australian Renewable Energy Agency

ARENA

Technology Readiness Levels for Renewable Energy Sectors

ARENA uses technology readiness levels as a tool that project proponents may want to use when considering their projects and ARENA will use to measure the technical readiness of renewable energy solutions.

1. Context

1.1 Why is a technology readiness level required?

The technology readiness level (TRL) index is a globally accepted benchmarking tool for tracking progress and supporting development of a specific technology through the early stages of the technology development chain, from blue sky research (TRL1) to actual system demonstration over the full range of expected conditions (TRL9).

The TRL methodology was developed by Stan Sadin with NASA in 1974. Since then, the process has evolved and is used across a wide range of sectors including renewable energy. An example of this is the ESB and Vattenfall classification system for evaluating the Technology Readiness for Wave Energy Projects. ARENA also uses the TRL index in the Emerging Renewables Program, for example, to help applicants in the early stages of technology development identify the stage of development of their particular innovation.

1.2 How does technology readiness relate to commercial readiness and along the technology development chain?

A pictorial representation of the TRLs and CRI is shown in Figure 1 and Figure 2.

Figure 1: TRL and CRI

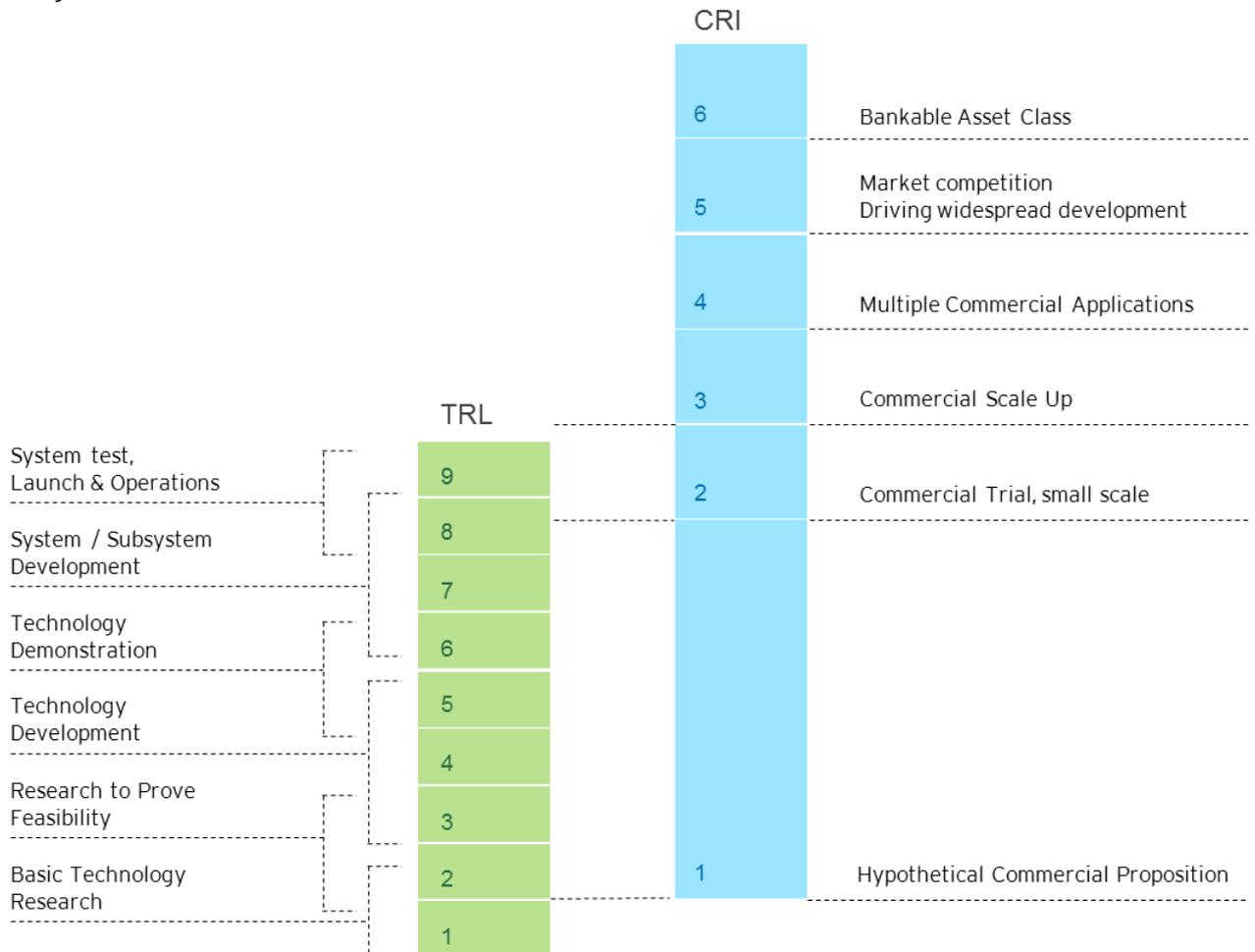
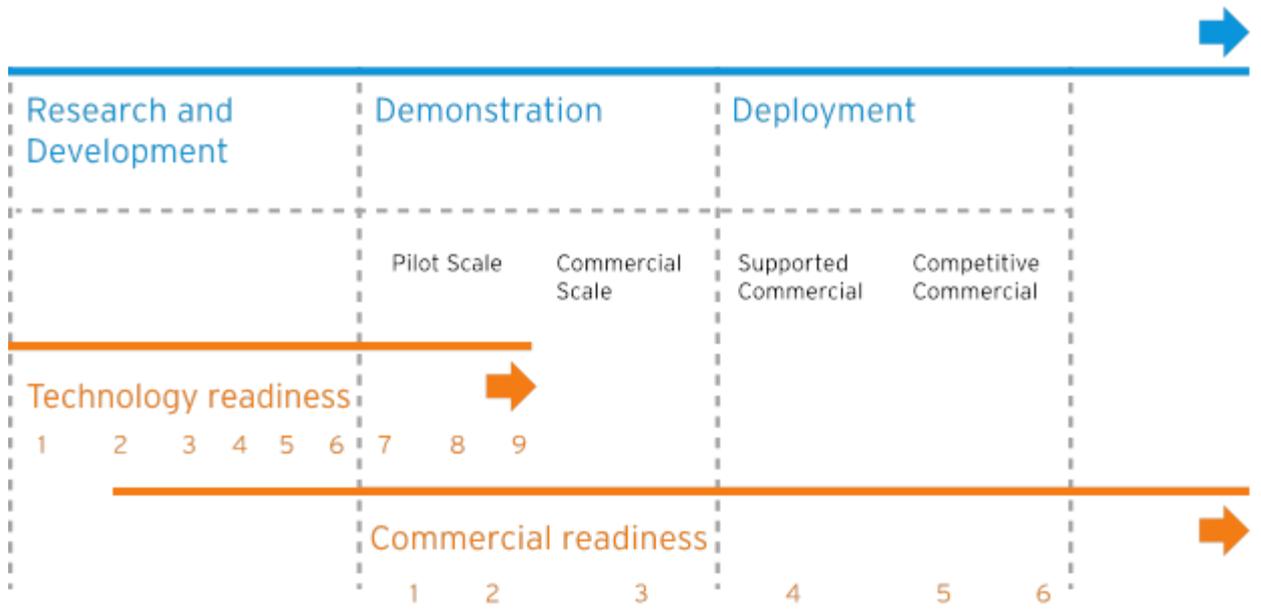


Figure 2: TRL and CRI mapped on the Technology Development Chain



2. Technology readiness levels

2.1 Technology Readiness Levels

There are various TRL rating scales that may be applicable to various technologies. For the purposes of its programs, ARENA uses the following scale for renewable energy technologies.

Table 1: **Technology Readiness Levels**

Level	Summary
1	Basic principles observed and reported: Transition from scientific research to applied research. Essential characteristics and behaviors of systems and architectures. Descriptive tools are mathematical formulations or algorithms.
2	Technology concept and/or application formulated: Applied research. Theory and scientific principles are focused on a specific application area to define the concept. Characteristics of the application are described. Analytical tools are developed for simulation or analysis of the application.
3	Analytical and experimental critical function and/or characteristic proof of concept: Proof of concept validation. Active research and development is initiated with analytical and laboratory studies. Demonstration of technical feasibility using breadboard or brassboard implementations that are exercised with representative data.
4	Component/subsystem validation in laboratory environment: Standalone prototyping implementation and test. Integration of technology elements. Experiments with full-scale problems or data sets.
5	System/subsystem/component validation in relevant environment: Thorough testing of prototyping in representative environment. Basic technology elements integrated with reasonably realistic supporting elements. Prototyping implementations conform to target environment and interfaces.
6	System/subsystem model or prototyping demonstration in a relevant end-to-end environment: Prototyping implementations on full-scale realistic problems. Partially integrated with existing systems. Limited documentation available. Engineering feasibility fully demonstrated in actual system application.
7	System prototyping demonstration in an operational environment: System prototyping demonstration in operational environment. System is at or near scale of the operational system with most functions available for demonstration and test. Well integrated with collateral and ancillary systems. Limited documentation available.
8	Actual system completed and qualified through test and demonstration in an operational environment: End of system development. Fully integrated with operational hardware and software systems. Most user documentation, training documentation, and maintenance documentation completed. All functionality tested in simulated and operational scenarios. Verification and Validation (V&V) completed.
9	Actual system proven through successful operations: Fully integrated with operational hardware/software systems. Actual system has been thoroughly demonstrated and tested in its operational environment. All documentation completed. Successful operational experience. Sustaining engineering support in place.

2.2 External resources

The following are various resources that may assist you with technology readiness levels.

US Department of Energy

[“Technology Readiness Assessment Guide”](#) [pdf]

NASA

[“Technology Readiness Levels Demystified”](#)

[“Technology Readiness Levels - A White Paper”](#) [pdf]

US Department of Defense

[“Technology Readiness Levels in the Department of Defense”](#) [pdf]

CSIRO

[“Unlocking Australia’s Energy Potential”](#) [pdf]

European Marine Energy Centre

[“Technology Readiness Levels for Marine Energy”](#)

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