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TECHNICAL SPECIFICATION

Marine energy – Wave, tidal and other water current converters –
Part 4: Specification for establishing qualification of new technology

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INTERNATIONAL
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CONTENTS

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MARINE ENERGY – WAVE, TIDAL AND OTHER WATER CURRENT CONVERTERS –

Part 4: Specification for establishing qualification of new technology

FOREWORD

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- the required support cannot be obtained for the publication of an International Standard, despite repeated efforts, or
- the subject is still under technical development or where, for any other reason, there is the future but no immediate possibility of an agreement on an International Standard.

Technical Specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 62600-4, which is a Technical Specification, has been prepared by IEC technical committee TC 114: Marine energy – Wave, tidal and other water current converters.

The text of this Technical Specification is based on the following documents:

DTS	Report on voting
114/346/DTS	114/365A/RVDTS

Full information on the voting for the approval of this Technical Specification can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62600 series, published under the general title *Marine energy – Wave, tidal and other water current converters*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- transformed into an International standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

Certification normally qualifies technology against existing standards to confirm compliance. Technology Qualification (TQ) differs from ordinary certification in that it allows systems to be qualified that do not conform to an existing standard (or may partially conform to an existing standard). The approaches to Technology Qualification by several Certification Bodies are in the references listed in the Bibliography.

Technology Qualification is used both when the technology is completely novel and when only parts of it are novel. For example, some technologies may have been mostly demonstrated in the past, but may have some subsystems which may be novel. Technology Qualification can help developers demonstrate that the technology has been properly developed and this can be of assistance to stakeholders (such as financial institutions).

The deliverable associated with this process is the Technology Qualification Plan (TQP).

MARINE ENERGY – WAVE, TIDAL AND OTHER WATER CURRENT CONVERTERS –

Part 4: Specification for establishing qualification of new technology

1 Scope

This part of IEC 62600 specifies the requirements of the technology qualification process for marine renewable technologies. Technology Qualification is a process of providing evidence and arguments to support claims that the technology under assessment will function reliably in a target operating environment within specific limits and with an acceptable level of confidence.

The Technology Qualification process is also assumed in IEC TS 62600-2: 2019.

The objective of this document is to provide the necessary practices and technical requirements, regarding technology qualification methodology, to support the needs of the IECRE certification process for marine renewables energy systems. Technology Qualification may be performed at the beginning of the certification process to identify the uncertainties, novelties, and modes of failure, mechanisms of failure, risks and risk control measures. In addition, Technology Qualification will identify the standards that are applicable, to what extent and what adaptation to the technology is required to address the risks. The Technology Qualification Plan is the deliverable arising from this process and it will provide all necessary actions to achieve certification.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 31010:2009, *Risk management – Risk assessment techniques*

IEC 61882:2016, *Hazard and operability studies (HAZOP studies) – Application guide*

IEC TS 62600-1, *Marine energy – Wave, tidal and other water current converters – Part 1: Vocabulary*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

ISO/IEC 17065, *Conformity assessment – requirements for bodies certifying products processes and services*

ISO 17776:2016, *Petroleum and natural gas industries – Offshore production installations – Major accident hazard management during the design of new installations*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the terms and definitions given in IEC TS 62600-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1 Terms and definitions

3.1.1
application area
environmental conditions, maintenance conditions, or operating parameters which a subsystem or component within the technology is operating within

3.1.2
independent review basis
requirements for a product's components, assemblies or systems specifications including: operating conditions; performance targets and reliability targets

Note 1 to entry: These form the basis against which the product, component, assembly or system will be assessed during Technology Qualification. It covers Demonstrated, Limited field history and New or Unproven technology.

3.1.3
technology qualification plan
document created at the conclusion of the definition phase. This document covers both novel aspects and aspects which fully conform to existing codes and standards

Note 1 to entry: This includes the standards and certification levels agreed upon for the product, component, assembly and/or system, and the testing plan as defined by the qualification methods. The document contains the plan for all actions to be carried out during the certification process detailed in these procedures.

3.1.4
technology: degrees of novelty
level of maturity to which a knowhow is classified as Validated

Note 1 to entry: The degree of technology novelty combined with where/how the technology is applied (Application Area) is classified in categories to be used as input to a risk assessment.

3.1.4.1
validated technology
knowhow that has a documented track record of operation within a defined environment

Note 1 to entry: This documentation provides confidence in the technology from practical operations (including testing), with respect to the ability of the technology to meet the specified requirements and is technology that has been used in the industry for many years with modes of failure and failure mechanisms identified and controlled by design, fabrication, testing and maintenance requirements provided in standards or industry practice.

3.1.4.2
limited field history technology
knowhow that has been used in a limited range of applications and conditions

Note 1 to entry: The technology has limited statistical basis and track record to clearly conclude that there are no new technical uncertainties to be identified. Standards and procedures may not have already been developed to address the technology.

3.1.4.3
new or unproven technology
knowhow that is not demonstrated or has no track record

Note 1 to entry: The failure modes and mechanisms of failure are not known or there is limited understanding of how the technology can fail and the safety margins needed to avoid failures. The technology has significant uncertainties.

3.1.5
Technology Qualification
TQ
process for identifying and providing the evidence that the technology will function reliably within specified limits and with an acceptable level of confidence

3.2 Abbreviated terms

API American Petroleum Institute

DOE Department of Energy (US)

ME Marine Energy

TRL Technology Readiness Levels

IRL Integration Readiness Levels

RPN Risk Priority Number

4 Independent review

ISO/IEC 17025 and ISO/IEC 17065 outline the management of the processes for independent bodies participating in TQ and certification and should be referenced, if guidance is needed.

The standards which are used as part of the independent review process should be those which are recognised by industry as being representative of current best practice.

5 Technology qualification overview

The Technology Qualification process uses a risk-based approach to verify that the technology meets its intended Qualification Basis. It is usually used for technology which is novel or technology which incorporates novel aspects. The Technology Qualification process comprises the modules as shown in Figure 1.

The subsystems / components in Table 1 are divided into the following classes:

1) Class 1: No new technical uncertainties
2) Class 2: New technical uncertainties
3) Class 3: New technical risks
4) Class 4: Demanding new technical risks

Table 1 – Technology classes

Application area	Technology: degrees of novelty		
	Validated (modified TRL 7-9)[a]	Limited field history (modified TRL 4-6)[a]	New or unproven (modified TRL 1-3)[a]
Known	1	2	3
New	2	3	4

[a] See Annex D for details.

Validated technology operating in a known application is considered technology classified as Class 1 with no new technical uncertainties. All other classes reflect varying levels of technology novelty and application uncertainty.

All systems, subsystems, components and development phases (from design and manufacturing through to decommissioning) should be considered: New technology (Classes 2 to 4) shall be subject to technology qualification: validated technology (class 1) will be subject to criticality assessment using existing standards: Class 2 items normally require only design studies to mitigate risks and Class 3 and 4 items should normally require testing in addition to design studies.

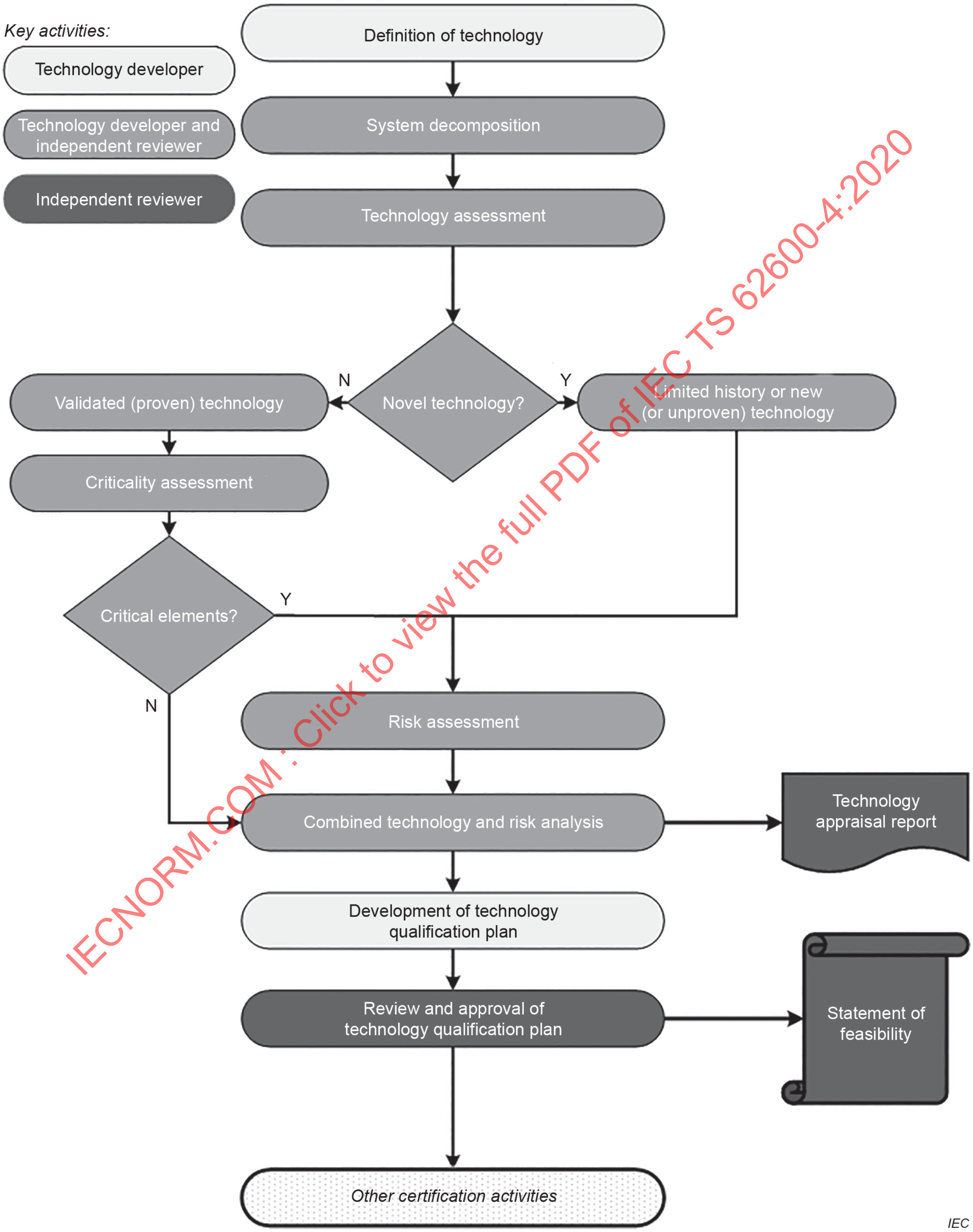

Figure 1 – Technology Qualification process

6 Stages of the Technology Qualification process

6.1 General

This clause provides explanatory guidance and the deliverables required for the activities given in Figure 1. With the exception of developing a Technology Qualification Plan, this is usually done in a workshop.

The TQ process targets the requirements, assumptions and methodologies essential for the evaluation of: design parameters, assumptions, methodologies and principles concerning a new technology. In the risk-based approach to TQ, elements such as conditions for manufacturing, transportation, installation, commissioning, operation, maintenance and decommissioning shall also be considered.

6.2 Role of independent reviewer in the process

The role of an independent reviewer should be provided prior to an independent review being conducted.

6.3 Prepare Qualification Basis

The qualification basis sets out the requirements for the device. It should document the specifications, operating conditions, performance targets and reliability targets. Examples of qualification requirements include: energy efficiency; performance; reliability; cost per unit energy; strength to stress ratio; etc. The qualification basis is used to assess the device during the technology assessment and risk assessment phases.

6.4 Prepare system decomposition

Once the Qualification Basis document has been completed, the next activity is to break down the technology into distinct subsystems / components that can be individually assessed for their maturity based upon the degree of novelty described in Annex B. The system decomposition should clarify one or more of the following:

- Subsystems and components including their functions.
- Project execution phases (e.g. manufacturing, installation, operation and decommissioning).

Each of the subsystems or components above may include hardware, firmware and software. The process outlined shall cover all phases of the life cycle of the system, subsystem or component. The only output of this step is a breakdown of the technology into distinct parts that can be individually assessed for their maturity / novelty which will enable the associated risks to be identified.

6.5 Integration of technology components/elements

For each distinct subsystem/component within a system, the integration of that distinct subsystem/component with others shall be considered. To aid this, the IRL table (Annex C) outlines distinct levels of integration that may be present between subsystems / components. Unless the IRL is high (levels 8-9), it is expected that this will have an impact on the TRL levels of subsystems/components. This assessment can be done qualitatively during a Technology Qualification workshop or a quantitative approach can be used. Methods for assessing the impact of integration readiness on the TRL levels of subsystems/ components are outlined in Annex D.

6.6 Implement technology assessment

Validated technology shall be documented in accordance with recommended practices and relevant international standards.

Temporary phases such as installation, float-out, lifting, transportation, etc., are also considered as aspects of the technology development influencing the feasibility of the concept or the integrity of the energy converter and are reflected in the operation, maintenance and repair aspects.

Concept evaluation, which is part of a technology assessment, should consider all development, deployment and retrieval phases. At minimum, this evaluation should address the following basic questions:

- Will this work?
- Is this viable?
- Will it survive?

6.7 Determining degree of novelty of technology

When considering the degree of novelty of the technology, the integration between the various technology components should be considered. For example, if a system has two subsystems which are "Validated technology" but these have never been integrated together, then the overall system cannot reasonably be considered as "Validated technology". Hence, for this technology the overall system should be considered as either "Limited field history technology" or "New or unproven technology" depending on the risks associated with the integration.

6.8 Risk assessment

While performing risk assessment the following shall be carried out:

- Define risks reflecting the level of acceptance compatible with the phase of technology development and the requirements of authorities and other stakeholders.
- Identify, where possible, relevant standards for components and subsystems.
- Assess maintenance, operations, condition monitoring and possible concept modifications to reduce the risks to an acceptable level.
- Define consequences and probability classes that align with the range of expected events and failures for the technology.
- In lieu of data obtained from specific application of the technology, the probability of the event/failure to be used during the risk assessment can be derived from relevant data from other industries, provided that an assessment of the impact of the new application in the marine renewables sector is taken into account.

Risk assessment can be done as per the risk matrix in Annex A by using several techniques (including but not limited to):

- Failure Mode Effect and Criticality Analysis (FMECA) see Annex A
- Hazard identification study (HAZID) and Hazard and operability study (HAZOP). Guidance on HAZID and HAZOP can be found in ISO 17776:2016, Annex C and IEC 61882 respectively.
- Structured What If Technique (SWIFT) which is described in ISO/IEC 31010

The risk assessment process shall be carried out by a multi-disciplinary team based on (but not limited to) the following documents:

- Technology Qualification Basis
- System decomposition
- Technology Assessment
- Detailed drawings of items subject to review
- Drawings and descriptions of control and safety systems (including software)

- Material specifications
- Outline of fabrication procedures
- Outline of installation procedures
- Outline of inspection and maintenance procedures
- Design Calculations
- Relevant test reports

6.9 Terms of reference for criticality assessment of validated technology

For technology which is not novel, the developer should identify the applicable standards that should be used for design (and if necessary, testing, reliability assessment, etc.).

6.10 Criticality assessment

The criticality assessment should allow the technology developer to prioritise the use of resources for design and testing of the technology. This could form part of the FMECA study (see Annex A). Criticality can be determined by assigning a Risk Priority Number (RPN) which is a calculation used to categorise the risks from highest to lowest.

The RPN is the product of the two scoring columns: Severity and Probability of Occurrence. Detection probability can be introduced by adjustment of the severity values.

$$\text{RPN} = \text{Severity} \times \text{Probability of Occurrence}$$

For technology which is not novel (sometimes referred to as mature), the developer should nevertheless assess if the technology is critical to the overall functioning of the device.

6.11 Develop Technology Qualification Plan

The Technology Qualification Plan consolidates the results of the studies carried out during the definition, system decomposition, technology assessment and criticality activities as shown in Figure 1. This shall include all the recommendations to reduce risks and uncertainties including the adaptation of the requirements from other industries. Mitigation strategies might include design studies and testing. The elements of a Technology Qualification Plan are available in Annex E.

6.12 Updating the Technology Qualification Plan

Over time, new information and findings are likely to emerge, for example, as a result of further testing, and these should be fed back to the different modules of the Technology Qualification Plan. The new understandings learnt because of such testing may lead to the updating of the Technology Qualification Plan. This is particularly important during the in-service phase. Hence, this is an iterative process and the Technology Qualification Plan should be updated to incorporate those findings.

7 Reporting the TQ process

7.1 Report content

Reporting to accompany the Technology Qualification Plan according to this document shall contain at least the following information:

- Clear description of the systems, subsystems and components
- Name and address of the manufacturers
- This document, edition and amendments, if any

- Conditions and limitations, if any
- References to manufacturers' instructions
- Technology Qualification Basis
- System decomposition
- All applicable standards
- Technology Assessment
- Drawings of items, under review
- Drawings and descriptions of control and safety systems (including software)
- Material specifications
- Outline of fabrication procedures
- Outline of installation procedures
- Outline of inspection and maintenance procedures

The Technology Qualification Plan and accompanying documentation should clearly describe the outcomes of concept evaluation, risk assessment and criticality assessment. Annex E is offered as a guideline to the structure of the document.

7.2 Restrictions

Because reports such as test reports and others (e.g. TQ Risk Analysis) form the basis for issuing a Marine Energy Certificate of Compliance, they may not be used in any form of advertising or sales promotion to prevent the information from being misrepresented. The certification body or independent technology reviewer may have specific rules on this that should be adhered to.

Annex A
(informative)

Use of FMECA for technology qualification

A.1 General

The risk assessment stage can be performed in a workshop by a multi-disciplinary team using the Failure Mode Effects and Criticality Analysis (FMECA) methodology. For guidance, see IEC 60812. This is a technique for systematically analysing each possible failure mode within a hardware system, and identifying the resulting effect on safety, environment, operation and the system or subsystem. The Risk Ranking is a quantitative procedure which ranks failure modes according to their probability and consequences (e.g. the consequences of the failure mode on safety, environment, operation and the system or subsystem).

A.2 Risk matrix

The level of risk acceptance to be considered is defined based on the combination of probability of an event to occur and the consequence of that event. Table A.1, Table A.2 and Table A.3 provide this basis.

Table A.1 – Probability of occurrence

Class	Name	Description	Indicative annual failure rate (up to)
1	Very low	Negligible event frequency	1,0E-04
2	Low	Event unlikely to occur	1,0E-03
3	Medium	Event rarely expected to occur	1,0E-02
4	High	One or several events expected to occur during the lifetime	1,0E-01
5	Very high	One or several events expected to occur each year	1,0E+00

Table A.2 – Classification of consequence

Class	Description of consequences (impact on)				
	Safety	Environment	Operation	Assets	Cost (USD)
1	Negligible injury, effect on health	Negligible pollution or no effect on environment	Negligible effect on production (hours)	Negligible	1,5 k
2	Minor injuries, health effects	Minor pollution/slight effect on environment (minimum disruption on marine life)	Partial loss of performance (retrieval not required outside maintenance interval)	Repairable within maintenance interval	15
3	Moderate injuries and/or health effects	Limited levels of pollution, manageable/moderate effect on environment	Loss of performance requiring retrieval outside maintenance interval	Repairable outside maintenance interval	350 k
4	Significant injuries	Moderate pollution, with some clean-up costs/Serious effect on environment	Total loss of production up to 2,5 m (USD)	Significant but repairable outside maintenance interval	2,5 m
5	A fatality	Major pollution event, with significant clean-up costs/disastrous effects on the environment	Total loss of production greater than 2,5 m (USD)	Loss of device, major repair needed by removal of device and exchange of major components	13 m

The risk levels described here are compatible with the level of acceptance of risks in similar industries such as offshore wind. It is noted that for novel technology, the actual probability of failure or the actual consequence of a failure mode will be difficult to identify. For the FMECA needed in a technology qualification plan, a qualitative rather than quantitative approach is sufficient. Thus, it is recommended that an approximation of the expected probability and consequence classes are made. This can be done by reference to subject matter experts or reliability databases containing surrogate systems data.

The risk matrix categories consider the normal safety factor as defined in Table A.3.

Table A.3 – Categories of risk

	Consequence				
Probability	1	2	3	4	5
5	Low	Med	High	High	High
4	Low	Med	Med	High	High
3	Low	Low	Med	Med	High
2	Low	Low	Low	Med	Med
1	Low	Low	Low	Low	Med

Low	Tolerable, no action required
Medium	Mitigation and improvement required to reduce risk to low
High	Not acceptable: mitigation and improvement required to reduce risk to low (ALARP)

Annex B
(informative)

Definition of Technology Readiness Levels (TRL)

Technology Readiness Levels as defined in US Department of Energy (DoE) document DOE G 413.3-4, see Table B.1.

Table B.1 – Description of Technology Readiness Levels

	TRL (DOE)	Definition	Description	TRL (API)
Validated technology	9	Actual system operated over the full range of expected conditions	The technology is in its final form and operated under the full range of operating conditions. Examples include using the actual system with the full range of real operations.	7
	8	Actual system completed and qualified through test and demonstration	The technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental testing and evaluation of the system in actual situations. Supporting information includes operational procedures that are virtually complete. An Operational Readiness Review (ORR) has been successfully completed prior to the start of hot testing.	7
	7	Full-scale, similar (prototypical) system demonstrated in relevant environment	This represents a major step up from TRL 6, requiring demonstration of an actual system prototype in a relevant environment. Examples include testing full-scale prototype in the field with a range of simulants in cold commissioning. Supporting information includes results from the full-scale testing and analysis of the differences between the test environment, and analysis of what the experimental results mean for the eventual operating system/environment. Final design is virtually complete.	6
Limited field history	6	Engineering/pilot-scale, similar (prototypical) system validation in relevant environment	Engineering-scale models or prototypes are tested in a relevant environment. This represents a major step up in a technology's demonstrated readiness. Examples include testing an engineering scale prototypical system with a range of simulants. Supporting information includes results from the engineering scale testing and analysis of the differences between the engineering scale, prototypical system/environment, and analysis of what the experimental results mean for the eventual operating system/environment. TRL 6 begins true engineering development of the technology as an operational system. The major difference between TRL 5 and 6 is the step up from laboratory scale to engineering scale and the determination of scaling factors that will enable design of the operating system. The prototype should be capable of performing all the functions that will be required of the operational system. The operating environment for the testing should closely represent the actual operating environment.	5
	5	Laboratory scale, similar system validation in relevant environment	The basic technological components are integrated so that the system configuration is similar to (matches) the final application in almost all respects. Examples include testing a high-fidelity, laboratory scale system in a simulated environment with a range of simulants and actual waste. Supporting information includes results from the laboratory scale testing, analysis of the differences between the laboratory and eventual operating system/environment, and analysis of what the experimental results mean for the eventual operating system/environment. The major difference between TRL 4 and 5 is the increase in the fidelity of the system and environment to the actual application. The system tested is almost prototypical.	4

	TRL (DOE)	Definition	Description	TRL (API)
	4	Component and/or system validation in laboratory environment	The basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared with the eventual system. Examples include integration of ad hoc hardware in a laboratory and testing with a range of simulants and small-scale tests of actual situations. Supporting information includes the results of the integrated experiments and estimates of how the experimental components and experimental test results differ from the expected system performance goals. TRL 4-6 represent the bridge from scientific research to engineering. TRL 4 is the first step in determining whether the individual components will work together as a system. The laboratory system will probably be a mix of on hand equipment and a few special purpose components that may require special handling, calibration, or alignment to get them to function.	3
New or unproven technology	3	Analytical and experimental critical function and/or characteristic proof of concept	Active research and development (R&D) is initiated. This includes analytical studies and laboratory-scale studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated, or representative tested with simulants. Supporting information includes results of laboratory tests performed to measure parameters of interest and comparison to analytical predictions for critical subsystems. At TRL 3 the work has moved beyond the paper phase to experimental work that verifies that the concept works as expected on simulants. Components of the technology are validated, but there is no attempt to integrate the components into a complete system. Modelling and simulation may be used to complement physical experiments.	2
	2	Technology concept and/or application formulated	Once basic principles are observed, practical applications can be invented. Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are still limited to analytic studies. Supporting information includes publications or other references that outline the application being considered and that provide analysis to support the concept. The step up from TRL 1 to TRL 2 moves the ideas from pure to applied research. Most of the work is analytical or paper studies with the emphasis on understanding the science better. Experimental work is designed to corroborate the basic scientific observations made during TRL 1 work.	1
	1	Basic principles observed and reported	This is the lowest level of technology readiness. Scientific research begins to be translated into applied R&D. Examples might include paper studies of a technology's basic properties or experimental work that consists mainly of observations of the physical world. Supporting Information includes published research or other references that identify the principles that underlie the technology.	0

Annex C
(informative)

Definition of Integration Readiness Levels (IRL)

Table C.1 – Description of Integration Readiness Levels

IRL	Description
1	An interface (i.e. physical connection) between technologies has been identified with sufficient detail to allow characterisation of the relationship
2	There is some level of specificity to characterise the interaction (i.e. ability to influence between technologies through their interface)
3	There is compatibility (i.e. common language) between technologies to orderly and efficiently integrate and interact
4	There is sufficient detail in the quality and assurance of the integration between technologies
5	There is sufficient control between technologies necessary to establish, manage, and terminate the integration
6	The integrating technologies can accept, translate and structure information for its intended application
7	The integration of technologies has been verified and validated with sufficient detail to be actionable
8	Actual integration completed and mission qualified through test and demonstration, in the system environment
9	Integration is mission-proven through successful mission operations
Source: R. Gove, B. Sauser, and J. Ramirez-Marquez, 2007, *Integration Maturity Metrics: Development of an Integration Readiness Level*, Stevens Institute of Technology.	

Annex D
(informative)

Assessing the overall Technology Readiness Levels

The overall Technology Readiness Level is a function of the TRL and IRL, in that the initial TRL of each component (and sub-component) identified should be adjusted to reflect the degree of uncertainty associated with the subsystem and components being integrated into the system.

Multiple approaches have been adopted to describe the nature of system interactions. A choice of which approach is best suited to define the quality of the interaction and accordingly determine a corresponding quantity on the IRL scale, should be agreed in the TQ workshop.

Within linear systems, as the interface between various components is relatively straightforward, the overall Technology Readiness Level for the associated components can be easily determined. For non-linear systems, as the IRL assigned to describe the interaction between the various subsystem and components is complex, a more rigorous scheme to quantify the TRL needs to be implemented.

The modified TRL assigned to each subsystem and component is modified according to the following principles:

a) The IRL should not be used to raise the TRL of subsystems and components.
b) If the IRL is 7 or higher, the TRL level should not be adjusted (i.e. the relatively high integration readiness is considered not to have an influence on the technological maturity).
c) The TRL should be halved if the associated IRL is equal to 1.
d) The adjusted TRL should be rounded down to the next integer.
e) A sliding scale should be applied to the TRL adjustment for an IRL between 1 and 7 (i.e. 1 = 50 % and 7 = 100 %) as given in the example below.

Where IRLs are assigned to the interactions between various components, the lowest IRL associated with each component shall be assumed, on the basis that the overall system performance is often only as strong as its weakest link. Subsystems and components with extremely low overall TRLs calculated because of the TRL/IRL interactions should be considered for further examination.

The following example, see Figure D.1, is provided to determine the modified TRL for component D depending upon its interaction with other components it integrates with.

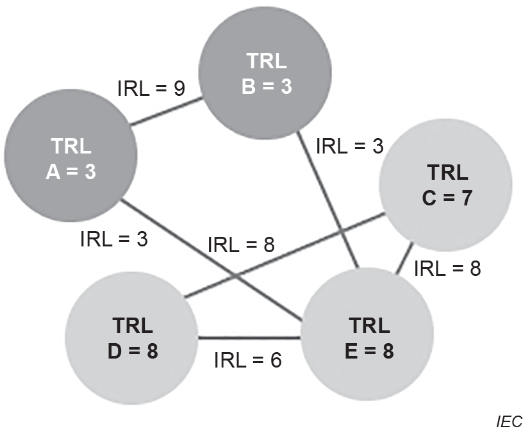

Figure D.1 – Interaction between TRL and IRL (example)