Advanced Design Tools for Ocean Energy Systems Innovation, Development and Deployment

Deliverable D4.3

Testing and verification results of the Stage Gate Tool – beta version

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Revision History

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0.1	05/05/2020	Table of Contents, general introduction and specific introduction for the Stage Gate Tool	EDP CNET
0.2	30/09/2020	Updated contents	EDP CNET
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1.0	15/12/2020	Final released version for the EC	EC

EXECUTIVE SUMMARY

The objective of Task 4.3 was to carry out the testing of the Stage Gate design tool in order to verify that it meets all the previously defined requirements (in WP2 and T4.1). This report documents the outcome of T4.3 "Verification of the Stage Gate design tool."

The goal of the verification task was to ensure that the tool:

- responds correctly to a varied set of inputs;
- performs its functions in an acceptable time and reasonable use of computational resource;
- is adequate in terms of usability and
- is verified against control data.

The following actions were completed as part of the verification and are described in detail in this report:

- Definition of the Verification Cases and evaluation criteria
- Organisation of training sessions (for technical and industrial partners)
- Collection of data for each Verification Case
- Running the Verification Cases (by technical and industrial partners)
- Analysis of the results based on quantitative and qualitative assessments
- Creation of a task list of changes that could improve the tool to improve performance

A stable beta version of the tool is now available that is fully documented with a technical manual and a user manual. The tool will be further validated and demonstrated using real data from the first pilot experiences in WP7.

According to the quantitative results, the end-users involved in evaluating the SG tool are satisfied with the usability, user-friendliness, performance, and value of the software. The qualitative assessment feedback gathered some improvements that were compiled and categorised. As a result of this, 13 high priority improvement areas were selected to be implemented in the final release of the DTOceanPlus suite of design tools.

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ABBREVIATIONS AND ACRONYMS

AD	Assessment Design
BL	Business Logic
DD	Deployment Design
DO	Design Objective
DOE	Department of Energy
EA	Evaluation Area
ED	Energy Delivery
ESA	Environmental and Social Acceptance
ET	Energy Transformation
FMEA	Failure Mode and Effects Analysis
HSE	Health Safety and Environment
KPI	Key Performance Indicator
LCOE	Levelised Cost of Energy
LMO	Logistics and Marine Operations
MC	Machine Characterisation
OE	Ocean Energy
O&M	Operation and Maintenance
PTO	Power Take Off
RAMS	Reliability Availability Maintainability Survivability
RM	Reference Model
RMP	Reference Model Project
ROV	Remotely Operated Vehicle
SEF	Software Evaluation Form
SG	Stage Gate
SI	Structured Innovation
SK	Station Keeping
SLC	System Lifetime Costs
SR	Software Routes
US	User Stories
VC	Verification Case
VS	Verification Scenario
WP	Work Package

DEFINITION OF TERMS

Module/Tool	Software that can be run in standalone mode: alpha versions.
Features	The functionality provided by the software to the user and relates to the identified requirements from the user consultation exercise captured in WP2
Software route	Each of the possible trajectories to cover all the business logic of the tool (e.g., new concept/improvement cycle, …)
Verification Scenarios	A set of independent input/output data to be provided to the end-user for the verification. It comprises of the Design Objective, Verification Cases and User Stories.
User stories	Short, simple descriptions of a feature. A partial design objective (e.g., As a <type of user>, I want <some goal> so that <some reason>).
Verification Cases	Design variants covering one trajectory and ending up in one or multiple Features/User Stories.
Design Objectives	Short descriptions of a relevant design case for ocean energy, non-confidential, which has been addressed by other tools/methods, and applicable to part or all the Verification Cases.
Stages and stage gates	The key feature of the stage gate design tool is the technology development pathway split up into distinct stages, separated by stage gates. The stage gates are an opportunity for users of the tool to assess the technology and make critical decisions on whether to progress to the next stage.
Evaluation Areas	The areas in which the user measures the success of ocean energy technology to demonstrate progress and performance.
Stage activities	This is a list of the research, development and demonstration activities that should be carried out during the prescribed stages.
Metrics	The parameters used to evaluate how well a technology performs in the Evaluation Areas. These are outputs of the Deployment and Assessment tools and are summarised in the Metrics section below

1. INTRODUCTION

1.1 SCOPE AND OUTLINE

This report documents the methodology and results of the verification of the **Stage Gate (SG)** tool beta version. The verification tasks described in this report were designed to assess whether the tool:

- responds correctly to a varied set of inputs;
- performs its functions in an acceptable time and with a reasonable use of computational resource;
- is adequate in terms of usability; and
- can be verified against control data.

Verification is a critical step in software development – it determines whether the software satisfies the functional requirements and is essential to ensure the development phase is being carried out accurately.

Verification Scenarios are a set of independent input/output data to be provided to the end-user for the verification.

To perform the verification of the SG tool, eight *Verification Scenarios* (VSs) were created. After receiving demonstrations and interactive training on how to use the tool, the technical verifiers (EDP CNET) as well as the industrial verifiers (BV, CPO, EGP, ESC, Nova and Sabella) were given access to an online version of the beta version of SG tool. They were then asked to run through each of the VS and complete a Software Evaluation Form designed to perform the verification. This report describes:

- the Verification Cases (VCs), Software Evaluation Forms and associated Key Performance Indicators (KPIs) and their creation,
- the demonstration and training sessions that were provided to the verifiers of the tool,
- the results of the verification, including quantitative and qualitative assessments of each VS and
- any recommended changes or additional functionality that would add value to the tool.

The remainder of this section provides short summaries of the DTOceanPlus project and of the SG tool itself. For further information and background on the project, the reader is directed towards previous deliverables, e.g. [1, 2, 3]. Finally, Section **¡Error! No se encuentra el origen de la referencia.** d escribes the structure of the remaining sections of this report.

Section 2 outlines the methodology adopted for the verification activities, to later review the Verification Cases (VCs). Then, attention has been paid to the data used to run the VCs. The training sessions organised both for the technical and the industrial partners are also illustrated in this section. Finally, the Evaluation Criteria used to evaluate the tool's functionalities are presented.

In **Section 3** the VCs are illustrated in detail, to later proceed with the user flow and experience and the approach of the User Stories adopted to go through the features of the SG.

Section 4 illustrates the assessments resulting from the verification process, divided between quantitative and qualitative. A list of actions to improve the SG functionalities, according to the evaluations received, is also present at the end of this section.

In **Section 5** the conclusions of the verification process are listed.

1.2 SUMMARY OF DTOCEANPLUS PROJECT

The SG tool belongs to the suite of tools that DTOceanPlus project is developing for ocean energy technologies. The tools will support the entire technology innovation and advancement process from concept, through development, to deployment, and will be applicable at a range of levels: sub-system, device, and array.

At a high level, these include:

- **Structured Innovation (SI) tool,** for concept creation, selection, and design.
- **Stage Gate (SG) tool,** using metrics to measure, assess and guide technology development.
- **Deployment Design (DD) tools,** supporting optimal device and array deployment:
  - Site Characterisation (SC): to characterise the site, including metocean, geotechnical and environmental conditions;
  - Machine Characterisation (MC): to characterise the prime mover;
  - Energy Capture (EC): to characterise the device at an array level;
  - Energy Transformation (ET): to design PTO and control solutions;
  - Energy Delivery (ED): to design electrical and grid connection solutions;
  - Station Keeping (SK): to design moorings and foundations solutions;
  - Logistics and Marine Operations (LMO): to design logistical solutions and operations plans related to the installation, operation, maintenance and decommissioning operations.
- **Assessment Design (AD) tools,** used by the other tools to quantify key parameters:
  - System Performance and Energy Yield (SPEY): to evaluate projects in terms of energy performance.
  - System Lifetime Costs (SLC): to evaluate projects from the economic perspective.
  - System Reliability, Availability, Maintainability, Survivability (RAMS): to evaluate the reliability aspects of a marine renewable energy project.
  - Environmental and Social Acceptance (ESA): to evaluate the environmental and social impacts of a given wave and tidal energy projects.

The main linkages between DTOceanPlus modules are outlined in FIGURE 1-1.

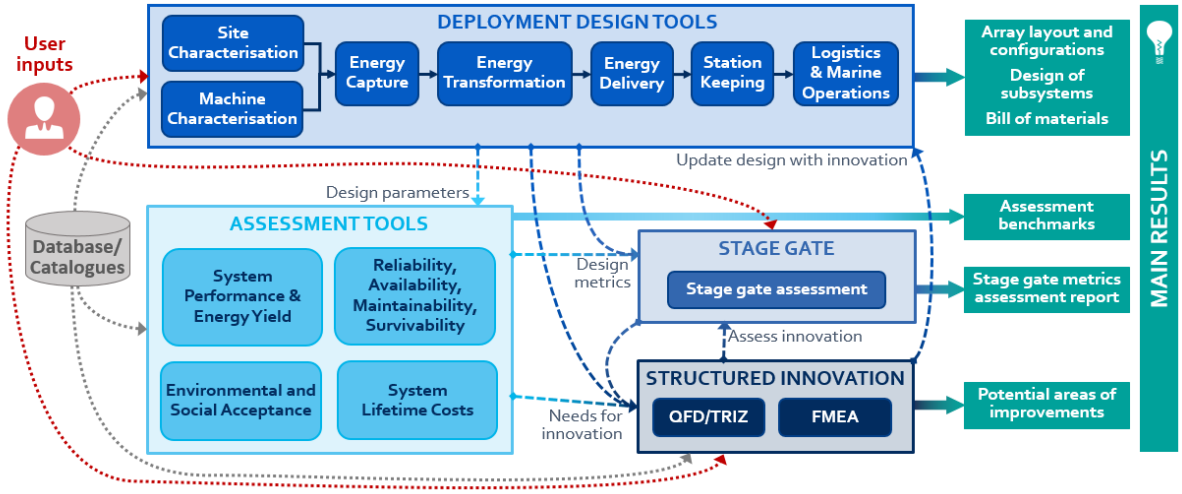


FIGURE 1-1: DTOCEANPLUS MODULES, MAIN LINKAGES AND OUTPUTS

1.3 STAGE GATE TOOL

DTOceanPlus will support the development of ocean energy technologies at all stages of the project lifecycle — from concept creation through design development to commercial deployment — with increasing level of data available and detail required at each. It has been designed to support users with differing requirements in terms of detail: from investors wishing for a high-level overview of a technology or project, to developers performing more detailed technical assessments, e.g. for project consenting [2].

The **SG tool** supports the objective assessment of technologies in the development process, ensuring a fair evaluation of sub-systems, devices and arrays from early stage concepts up to commercial deployment, guiding the technology development process. As a tool, it operates with close integration to the SI, DD and AD tools to support consistent assessment processes and ultimately guide decision making for the users of the tool. For more details on the SG tool, please refer to [3].

2. METHODOLOGY

2.1 OVERVIEW

The principal aim of the verification task was for the technical and industrial verifiers to evaluate the functionalities of the SG tool. In order to achieve this, the following actions were completed:

- **Definition of the *VCs* and *VS*** – this has been achieved by analysing the key features of the SG tool and the associated User Stories accounting for levels of complexity, standalone mode, wave and tidal scenario, array layout and network topologies (see Section 2.2).
- **Collection of data** – a collection of input/output (I/O) control data and project data (from catalogues and default data) have been defined and collected (see Section2.3).
- **Organisation of training sessions** – training sessions on the use of tool have been provided to both the technical verifiers and the industrial partners (see Section 2.4).
- **Definition of Evaluation Criteria** – a common Software Evaluation Form was developed and used in the verification of every DTOceanPlus module. The Software Evaluation Form is divided into sections assessing the Usability, User-friendliness, Performance and Accuracy and perceived Value of the tool (see Section 2.5).

After the delivery of the training sessions, the technical and industrial verifiers were provided with the VSs, reference data and Software Evaluation Form. They then assessed each of the VCs in turn, testing the appropriate features of the software and completing the Software Evaluation Form. The quantitative and qualitative results from the Software Evaluation Form completed by each verifying partner were collected, collated and analysed. The results of this analysis are presented in **Section 4**.

2.2 DEFINING THE VERIFICATION CASES

There are 7 key features of the SG tool:

1. **Framework editor** to review the framework and specify any thresholds for the SG assessment
2. **Activity checklist** to assess which stage gate the technology is eligible for
3. **Applicant Mode** complete the SG assessment with qualitative and quantitative questions
4. **Assessor Mode** to simulate the assessment of a completed application
5. **Improvement Area** identification to identify areas of improvement and link to the SI tool
6. **Study Comparison** to compare the results of two or more stage gate studies
7. **Report Generation** to produce a PDF standardised report summarising the SG assessment

For each of these key features a set of *User Stories* were defined, outlining all potential use cases of that feature. User Stories are generally formulated in users' everyday language, they should help the reader understand what the software is able to accomplish. The scope of the User Story is to delineate roles ("As a user / as a developer"), prove the utility of a certain feature ("I would like to calculate the efficiency of a tidal energy array of five turbines…") and define its purpose ("…to get the following metrics…").

A related concept is that of the *Software Routes* of each module in DTOceanPlus. Most of the individual Deployment and Assessment (D&A) modules will operate differently at different complexity levels (1, 2 or 3) and technology type (wave or tidal). It was important to identify all the different input permutations that lead to slightly different calculation methods or functions being used in the Business Logic (BL) of these tools. Each of the individual permutations and corresponding set of methods is referred to as a *Software Route*. The assessment of *Software Routes* is less applicable to the SG tool because the key features operate independently of the choice of complexity level and technology type. In other words, for the SG tool there is a one-to-one mapping between the Software Routes and the key features.

Of greater importance to the SG tool is the *stage* that a device or technology has reached. The VS needed to ensure that the SG tool works for the complete spectrum of Technology Readiness Level (TRL); from the earliest stage sub-systems to late-stage array projects.

For these reasons, the VS were developed using the 7 major features of the SG tool as the basis but including two scenarios for the *Applicant Mode* feature; one for an early-stage assessment and one for a late-stage assessment. The resulting 8 VCs are shown in **Section 3**. For each *VC*, the critical User Story associated with the feature being tested was also extracted and provided to the verifiers as extra guidance of what exactly needed to be tested. These sub-tasks within each *VC* are also described in **Section 3**.

While the SG tool operates in the same manner regardless of the technology type, it was still essential to verify that the tool is compatible with both wave and tidal energy assessments. It was also important to ensure that the tool provided value to each of the user groups expected to use the SG software (funders, investors, technology developers and project developers). Each *VS* was thus associated with a technology type and user group. Furthermore, a short description was written to add broader context and background to each scenario. All these additional details are shown in TABLE 3-1.

The *User Stories* and *Software Routes* were also used as the basis for the development of tutorials, training sessions and user manual (see the Annex for the tutorials and user manual for the SG tool).

2.3 DATA DEFINITION

VSs have been adapted in accordance with available data produced by the Reference Model Project (RMP) sponsored by the U.S Department of Energy (DOE) Wind and Water Power Technologies Program. The goal of this project is producing non-proprietary Reference Models (RMs) of marine hydrokinetic technology designs as study objects for open-source research and development programs [4].

RMs used as part of DTOceanPlus' verification activities are RM1 and RM3: for both of them power performance and velocity measurements were collected to assess their interaction with the surrounding environment. The outputs of the tests have been used as inputs for the modules developed under DTOceanPlus, as showed in FIGURE 2-1 .The use of this data was optional for the SG verification, and was provided to the verifiers as a resource if needed.

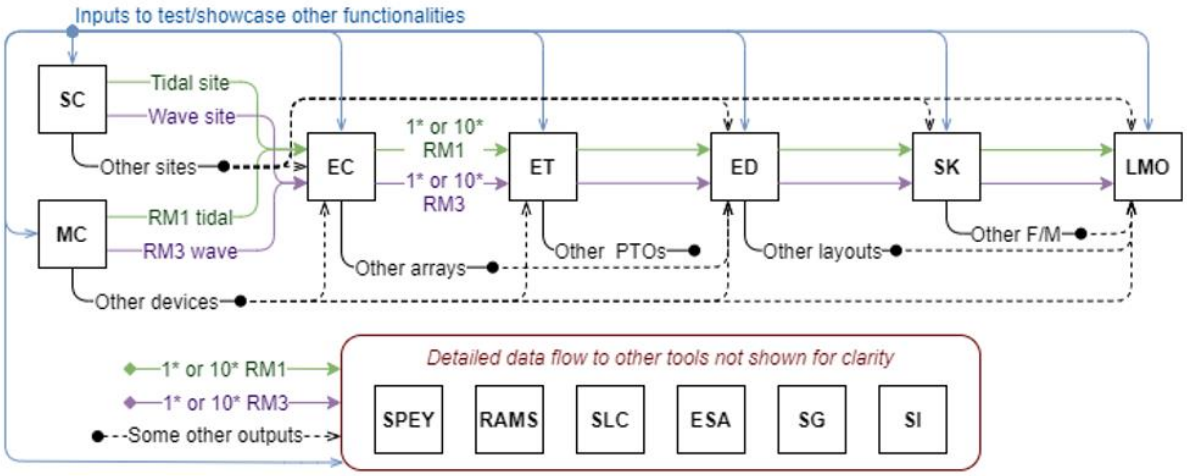


FIGURE 2-1: FLOW OF REFERENCE CASES/DATA BETWEEN THE TOOLS

2.4 DEMONSTRATION AND TRAINING SESSIONS

2.4.1 TRAINING SESSIONS FOR THE TECHNICAL PARTNERS

Before running the first round of VCs, the technical verifiers (EDP CNET) received detailed training material and tutorials. The main form of the training was provided through a set of video conference calls where a walkthrough of all the features of the tool was given. The conference calls facilitated technical discussions between the developers and the technical verifier. The *VSs* were also presented and discussed thoroughly during these training calls.

A guide describing all the potential uses of the tool was offered by 'Stage Gate tool – Alpha version' [3]. The Evaluation Areas (EAs) are listed, and for each of them it is possible to note the increasing level of complexity as the Stage progresses from 0 to 5. In the section dedicated to data input, there is a distinction between qualitative questions (for stages gates 0-1, 1-2 and 2-3) and quantitative questions for later stages gates. Subsequently, the seven major functionalities of the tool (SG Framework, Activity Checklist, Applicant Mode, Assessor Mode, Improvement Areas, Report Export Functionality and Study Comparison) are listed and explained in detail. Besides summarising the functionalities of the tool, this document also presents more technical aspects, like the implementation of the software architecture and several examples of module inputs and outputs. At the end of this user-oriented guide there are also some print screens to guide the user throughout their entire assessment.

Additionally, a webinar on how to use the SG tool is also available on the project website[1], with a focus on the tool functionalities and its potential for the different stakeholders.

[1] https://www.dtoceanplus.eu/Publications/Training/Webinar-3-Stage-Gate-Design-Tool-for-Ocean-Energy

2.4.2 TRAINING SESSIONS FOR THE INDUSTRIAL PARTNERS

A similar walkthrough of the tool was provided to the industrial partners on a separate video conference call. The industrial partners were also provided with links to the previous SG tool documentation, the *VSs* and access to the previously recorded webinar.

2.5 EVALUATION CRITERIA

Potential users and other stakeholders were consulted to identify and clarify their need, requirements and expectations of the SG tool.

The outcome of this analysis [1] has been used to inform the functional requirements for the development of the DTOceanPlus tools and subsequently set out the Evaluation Criteria.

The survey highlighted the the requirement for the SG tool to be flexible for the public funding bodies who are assisted by the tool in the comparison of different technologies. Flexibility is also important for the stakeholder, who pointed out how some metrics might be more useful than others during the assessment of a technology. Detailed definitions of the various stages are required, according to several responses, including a checklist of relevant metrics for each stage. The metrics should also be standardised at international level and continuously updated.

The inputs coming from the user-groups consultation and the technical requirements set out for the SG tool [2] delineated the Evaluation Criteria used throughout the Verification activities. These criteria include a numeric (see TABLE 2-1) and qualitative assessment for each one of the tool's functionalities.

Regarding the numeric assessment, a scale ranging from 1 to 5 has been used, where 1 represents the most negative assessment and 5 the most positive one.

TABLE 2-1: SCORING SCALE USED IN THE NUMERIC ASSESSMENT

Score	1	2	3	4	5
Description	Strongly disagree	Disagree	Undecided	Agree	Strongly agree

A common Software Evaluation Form was developed and used in the verification of every DTOceanPlus module. The Software Evaluation Form was divided into four sections assessing the

- usability,
- user-friendliness,
- performance and accuracy and
- perceived value of the tool.

The individual Evaluation Criteria that were included in the Software Evaluation Form are shown in the results of the evaluation in Section 4, categorised under these four headings. When each technical or industrial verifier completed the Software Evaluation Form, they were required to assign a score of 1 – 5 (see TABLE 2-1) to each of the individual evaluation criterion.

The Evaluation Criteria for the *Performance and accuracy* section are evaluated for each feature of the software. For example, evaluation criterion 3.a.1 and 3.b.1 are the same criterion but applied to the Framework and Activity Checklist features respectively.

The completed Software Evaluation Forms are included as an Annex to this report.

3. VERIFICATION CASES

The Design Objectives for the Verification Cases of the Stage Gate tool are described below, and a summary of these are shown in TABLE 3-1.

1. The US Department of Energy wants to define thresholds for a funding call and save this new framework for applicants to use. The funding call is for early stage (TRL 3) wave energy devices. (linked to VC1)
2. A mid stage (TRL 4) tidal energy developer wants to use the Activity Checklist to assess which stage gate their 500kW tidal turbine is eligible to be assessed against. (linked to VC2)
3. An early stage (TRL 1) wave energy technology developer wants to run applicant mode stage gate assessment for their Power Take-Off (a direct electrical drive system) (linked to VC3)
4. A tidal energy developer wants to run a stage gate assessment for their late stage (TRL 7) array of 3 devices (each rated at 1MW) of horizonal axis, bottom mounted tidal turbines. (linked to VC4)
5. Wave Energy Scotland want to assess an early stage (TRL 1) wave energy Power-Take Off (a direct electrical drive system) in assessor mode as part of their PTO Programme. (linked to VC5)
6. An angel investor wants to compare the stage gate assessment results of two late stage (TRL 8) tidal energy devices (floating, one rated at 750kW, one rated at 2MW) to consider which to provide further funding to. (linked to VC6)
7. A public funder like Wave Energy Scotland want to generate a report for the stage gate assessment of a late (TRL 8) stage wave energy device (750kW, heaving buoy). (linked to VC7)
8. A technology developer wants to understand which areas of their technology need to be improved upon in order to begin using the Structured Innovation tool for concept improvement (Tidal energy, horizontal axis device, 1MW) (linked to VC8)

TABLE 3-1: SUMMARY OF STAGE GATE TOOL VERIFICATION CASES

Ref	Name	Goal	Targeted user group	Technology	Feature
VC1	Define/choose the Stage Gate Framework	Specify thresholds to be used in a SG assessment	Funder/Investor	Wave	Framework
VC2	Assess stage and outstanding activities	Complete the Activity Checklist, assess stage and review activities still to complete to be eligible for the next stage	Technology/Project developer	Tidal	Activity Checklist
VC3	Stage Gate assessment (early stage)	Complete qualitative questions to support SG assessment	Technology/Project developer	Wave	Applicant Mode
VC4	Stage Gate assessment (late stage)	Complete quantitative questions to support SG assessment, compare metric results and thresholds, identify shortfalls	Technology/Project developer	Tidal	Applicant Mode
VC5	Run Assessor Mode	Simulate SG assessment from point of view of assessor	Funder/Investor	Wave	Assessor Mode
VC6	Compare SG studies	Compare results of two or more SG studies	Funder/Investor	Tidal	Study comparison
VC7	Produce report	Generate a standardised report summarising the results of a Stage Gate analysis	Funder/Investor	Wave	Report generation
VC8	Link to SI tool	Identify improvement areas which can then be used to entering the Structured Innovation tool	Technology/Project developer	Tidal	Improvement areas

3.1 USER FLOW AND EXPERIENCE

The flow of activities to be followed when running the tool can be articulated as follows:

- **Review of the SG activities**: the user has the possibility to check off what technology development activities have been completed to date, in each of the ten available categories (Survivability, Energy Capture, Acceptability, Energy Transformation, Installability, Affordability, Reliability, Availability, Maintainability and Energy Delivery).
- **Select the SG**: based on the activities completed the user chooses which SG they would like to select.
  - *Stage 0* (with a TRL equal to 1) corresponds to 'Concept Creation', where basic principles are observed.
  - *Stage 1* (TRL 2-3) is associated with 'Concept Development'. At this stage the technology concept is formulated, and experimental proof of concept has been carried out too.
  - *Stage 2* (TRL 4) refers back to 'Design Optimisation', with the technology validated in a lab.
  - *Stage 3* (TRL 5-6) includes 'Scaled Demonstrations', under which the technology is validated and demonstrated in a real environment.
  - *Stage 4* (TRL 7-8) involves a 'Full Scale Demonstration', with a complete and qualified system and the demonstration of the prototype in an operational environment.
  - *Stage 5* shows the highest TRL (9) and includes 'Full Scale Array Demonstration' under which the system is proven in an operational environment.
- **Run the SG Assessment**: when the SG assessment is run, the user will be asked to fill out questions about their technology.
- **View the results**: the user will see a graphical representation (in percentage) depending on the questions that have been answered.
- **Generate the report**: one of the main outputs of the SG design tool is a standardised report that summarises all the input and output data of the module.

It is important to emphasise that, even though the Verification activities have been carried out by running the SG tool in *standalone mode* (i.e. the tool is not integrated with the others), it is intended to work in cooperation with the other tools developed within DTOceanPlus. For example, while running the **SG Assessment in integrated mode**, the user will be prompted to open each of the relevant DD and AD tools to calculate the metrics. In order to run the DD and AD tools, the user will be asked to provide critical input parameters about the technology being assessed. If at the end of an assessment an area of improvement is identified (e.g. running a SG assessment identifies a missing EA or if the metric results deviate significantly from the thresholds set by the user), the user will be prompted to open the SI module.

3.2 USER STORIES

As mentioned previously, the *User Stories* were used as the basis for the VCs. The eight VSs are listed below together with the critical US stories selected from each feature. These sub-tasks within each VS describe the SG tool from an end-user perspective and provided additional guidance to the verifiers on the functionalities to be tested.

1. **Framework**: view the SG Framework data and edit the framework by specifying the metric thresholds that are applied.
    1.1. **View frameworks**; as a SG user, I would like to view the *stage* and *SG* data associated with a *framework* in order to understand the activities involved in a specific *stage* and the questions that will be asked in a specific *SG* assessment.
    1.2. **View categorisation**; as a SG user, I would like to be able to categorise the *stage activity* data by either *activity category* or *EA*.
    1.3. **Edit metric thresholds**; as a SG user, I would like to edit the *metric thresholds* that will be applied in the *framework*; for each question in the *framework*, I would like to either change the value of the metric thresholds or enable/disable the threshold.
2. **Activity checklist**: assess the maturity of a technology by identifying completed and outstanding Stage Activities.
    2.1. **View checklist inputs**; as a SG user, I would like to browse through the *activities* required for each stage of a framework and mark whether that activity has been completed.
    2.2. **Change categorisation**; as a SG user, I would like to categorise the activities of the *stage activity* data by either *activity category* or *EA* when performing the activity checklist.
    2.3. **Obtain stage summary**; as a SG user, I would like to obtain the percentage of activities completed for each *stage* of a *framework*.
    2.4. **Detailed breakdown**; as a SG user, I would like to see further information on a specific *stage* in order to see the breakdown of completed activities per *activity category* and *EA*.
    2.5. **Outstanding activities**; as a SG user, I would like to see a list of the outstanding activities required for each *stage* of a *framework* and to be able to categorise the data by *activity category* or *EA*.
3. **Applicant mode (early stage)**: evaluate the overall performance of an early-stage technology (i.e. SGs 0-1, 1-2 or 2-3) using qualitative and quantitative questions (metrics), comparing results to metric thresholds if applicable.
    3.1. **Early stage applicant inputs**; as a SG user, I would like to complete a SG assessment in *applicant mode* and fill out the *metric result* and *justification* to each quantitative question or the *response* to each qualitative question in the assessment.
    3.2. **Early stage applicant mode summary**; as a SG user, I would like to view the summary results of the SG assessment in order to show the overall progress, the summary should show the *response rate* (the percentage of completed answers) and, if applicable, the *threshold success rate* (the percentage of quantitative questions that have met the required threshold).
    3.3. **Early stage metric summary**; as a SG user, I would like to view a tabular summary of the *metric results* that were achieved, along with a comparison to the metric thresholds that were defined for the chosen SG framework.
    3.4. **Early stage view responses**; as a SG user, I would like to view the answers that I submitted in a previously completed *applicant mode* assessment.
4. **Applicant mode (late stage)**: evaluate the overall performance of a late-stage technology (i.e. SGs 3-4 and 4-5), using quantitative questions (metrics), comparing results to metric thresholds if applicable.

4.1. **Late stage applicant inputs**; as a SG user, I would like to complete a SG assessment in *applicant mode* and fill out the *metric result* and *justification* to each quantitative question in the assessment.

4.2. **Late stage applicant mode summary**; as a SG user, I would like to view the summary results of the SG assessment in order to show the overall progress, the summary should show the *response rate* (the percentage of completed answers) and, if applicable, the *threshold success rate* (the percentage of quantitative questions that have met the required threshold).

4.3. **Late stage metric summary**; as a SG user, I would like to view a tabular summary of the *metric results* that were achieved, along with a comparison to the metric thresholds that were defined for the chosen SG framework.

4.4. **Late stage view responses**; as a SG user, I would like to view the answers that I submitted in a previously completed *applicant mode* assessment.

5. **Assessor mode**: simulate the evaluation of a SG assessment from the point of view of an *assessor.*

5.1. **Assessor scores**; as a SG user, I would like to review and score each of the answers that were provided in an *applicant mode* assessment.

5.2. **Assessor comments**; as a SG user, I would like to explain the score I assigned to each question by providing remarks on the *scoring criteria* associated with each question.

5.3. **Assessor summary**; as a SG user, I would like to obtain the average and weighted average score for the entire *assessor mode* assessment.

5.4. **Assessor breakdown**; as a SG user, I would like to obtain the average and weighted average scores as broken down by *question category* and *EA*.

5.5. **View responses**; as a SG user, I would like to view the scores that I submitted in a previously completed *assessor mode* assessment.

6. **Improvement areas**: identify suggested areas of improvement for a technology.

6.1. **List improvement areas**; as a SG user, I would like to obtain a list of the areas of improvement (weaknesses of the technology) that may have been identified in a SG study.

7. **Study comparison**: compare two or more technology options using previously completed SG analyses.

7.1. **Compare results**; as a SG user, I would like to compare the results of two or more SG analyses. Comparisons can include analysis results from the three main SG functionalities, namely the *Activity Checklist*, *Applicant Mode* and *Assessor Mode.*

8. **Report generation**: generate a standardised report summarising the results of a SG analysis.

8.1. **Export report**; as a SG user, I would like to generate and export a standardised report in PDF format that summarises all the information regarding a specific *SG* analysis.

4. ANALYSIS OF RESULTS

A Software Evaluation Form has been used to gather all the insights coming from the first round of VCs by the technical verifier (EDP CNET). The same document has been filled by the industrial partners, who performed the second round of VCs. A completed version of this document, with the information coming from both the technical verifier and the industrial partners, is available at the end of this report (Annexes III and IV). In this section, however, only the most relevant information will be presented.

Four characteristics have been evaluated while running the VCs for the SG tool, namely:

- Usability, which deals with the high-level software experience;
- User-friendliness, to assess how much the software is easy to use;
- Performance and Accuracy, to determine the quality of results in terms of accuracy, robustness and performance for each one of the main functionalities (features) of the software;
- Value, to assess the value perceived by the user.

The following subsections present the quantitative and qualitative results.

4.1 QUANTITATIVE ASSESSMENT

A total of 7 organisations completed the verification process for the different features of the SG tool (EDP, Corpower, Nova, BV, Sabella, ESC, EGP) and provided feedback by the Software Evaluation Form. FIGURE 4-1 shows the average scores across the 4 categories of evaluation, highlighting an overall satisfaction from using the tool, as all average scores are within the range of 3 to 5.

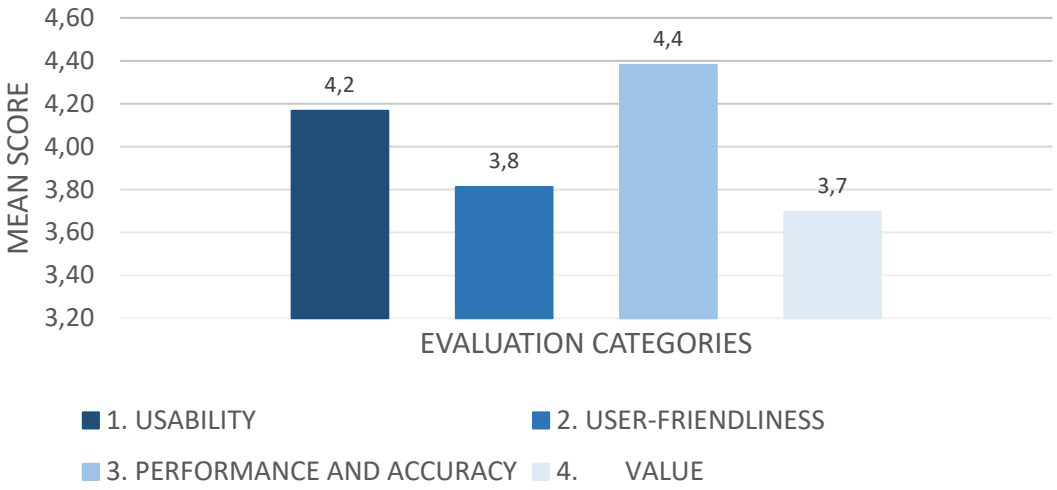


FIGURE 4-1: MEAN RATINGS OF THE EVALUATED CHARACTERISTICS

As can be seen in FIGURE 4-2, most of the participants of verification (80%) were satisfied with the usability of the SG tool. The majority of (66%) the respondents agree or strongly agree that the tool is generally user friendly. Around 80% (in average) of the respondents considered that the tool shows performance and accuracy. More than 60% of the users considered that the tool is valuable, while around 20% disagrees. A further analysis on the results is described in the following sections.

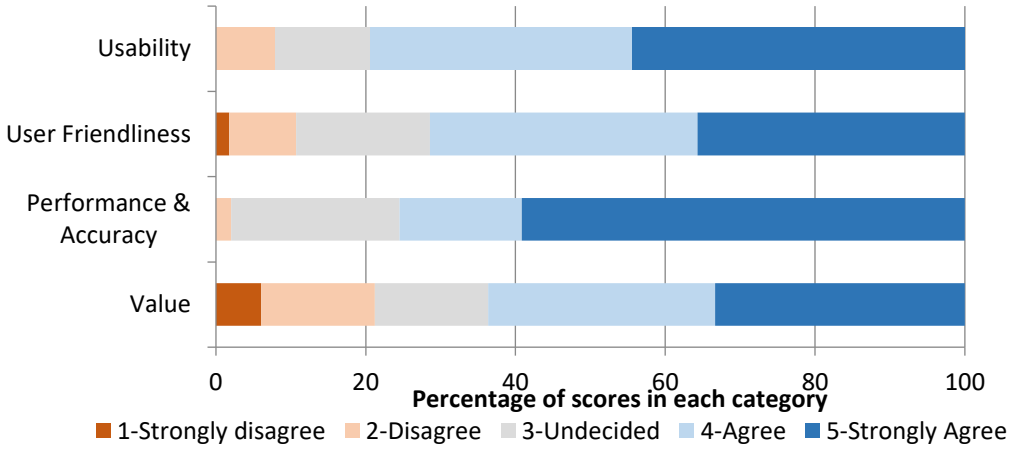


FIGURE 4-2: PERCENTAGE OF SCORES FOR THE FOUR KEY CATEGORIES

4.1.1 USABILITY

The following statements have been assessed in the *Usability* category.

TABLE 4-1: ASSESSED USABILITY CRITERIA

ID	Statement
1.1	The software is intuitive and easy to use in general
1.2	It is easy to create and delete a Study
1.3	It is easy to edit, save and export a Study
1.4	The process of inputting data is clear and efficient
1.5	Results are meaningful, easy to interpret and use
1.6	I could complete the process without errors
1.7	I am satisfied with the overall speed of computation
1.8	The software can be run from my computer without any issue
1.9	The training sessions and documentation are useful for learning how to use the software

FIGURE 4-3 presents in the form of stacked bars the user scores per each statement listed above. The same results are presented in FIGURE 4-4 using a spider chart, to highlight the mean, maximum and minimum values.

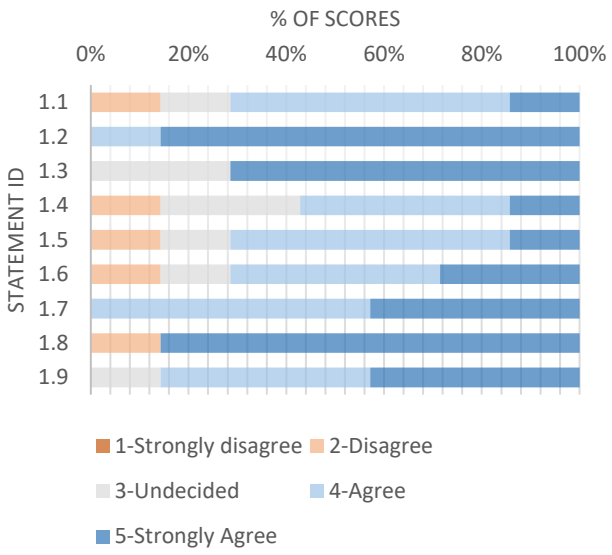


FIGURE 4-3: DISTRIBUTION OF USER SCORES PER USABILITY STATEMENT

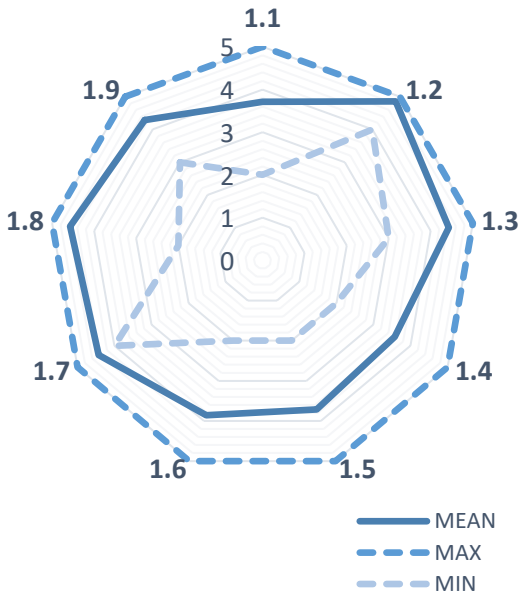


FIGURE 4-4: MEAN, MAXIMUM AND MINIMUM SCORES PER USABILITY STATEMENT

In view of the results (FIGURE 4-3) it can be said that the tool is easy to use and intuitive (ID-1.1). A high percentage (85%) of the users finds it very easy to create and delete a study (ID-1.2). The process of editing, saving and exporting a Study (ID-1.3) is also easy for more than half of the users (71%). 85% of the users are able to run the software without any issue (ID -1.8), being overall satisfied with the speed of the computation (ID-1.7). Some difficulties arise with the process of inputting data (ID-1.4): 14% of the users don't find the process sufficiently clear and efficient, 28% is undecided while the remaining users don't experience any difficulties at this stage. More than half of the users (71%) find the results obtained meaningful and easy to interpret and use (ID-1.5), while 14% of the users disagrees with this statement and the remaining 14% are undecided. Evidences of errors while running the tool (ID-1.6) have been found (14% of the total cases), but 71% of the users can run the tool without any problems.

On average the users find the documentation and the training sessions led by the software developer useful (ID-1.9, see FIGURE 4-4).

4.1.2 USER FRIENDLINESS

The following criteria were used for the *User Friendliness* category:

TABLE 4-2: ASSESSED USER FRIENDLINESS CRITERIA

ID	Statement
2.1	The user interface is simple, easy to navigate and well-organised
2.2	The user interface looks professional
2.3	It responds promptly to user actions (inputs, selections, clicks, …)
2.4	It provides the user with enough help, indications and/or guidance throughout each process
2.5	The meaning of each data input/user selection is clear
2.6	The meaning of each data output is clear
2.7	Visualisation of results is clear and informative
2.8	The user can add further information to the Study through the interface

FIGURE 4-5 presents in the form of stacked bars the user scores per each statement listed above. The same results are presented in FIGURE 4-6 using a spider chart, to highlight the mean, maximum and minimum values.

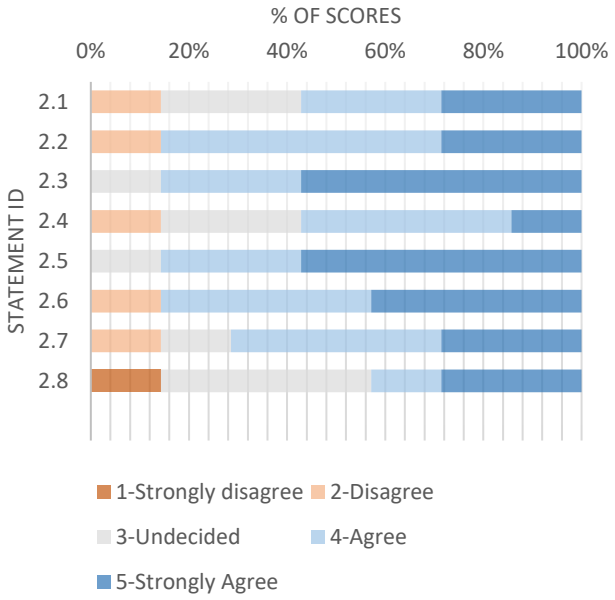


FIGURE 4-5: DISTRIBUTION OF USER SCORES PER USER-FRIENDLINESS STATEMENT

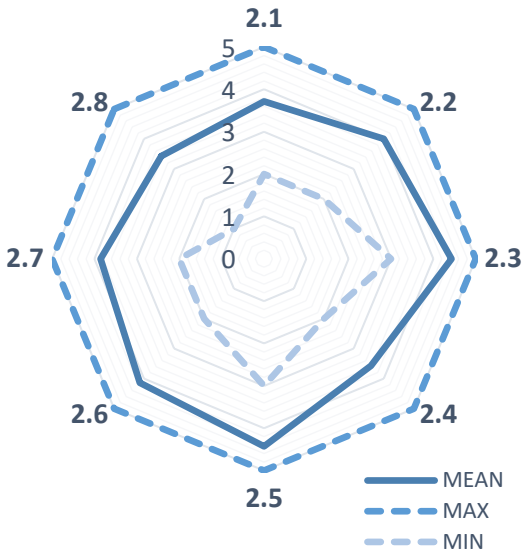


FIGURE 4-6: MEAN, MAXIMUM AND MINIMUM SCORES PER USER-FRIENDLINESS STATEMENT

As can be seen in FIGURE 4-5, 50% of the respondents agree that the user interface is simple, easy to navigate and well-organised (ID-2.1), whereas the rest are undecided or disagree. This can be an area of improvement for the final version of the tool. It can be said that the user interface looks professional and that the tool responds promptly to user actions, as over 80% of the respondents agreed with both these statements (ID-2.2 & 2.3). There is a mixed opinion on whether the tool provides the user with enough help, indications and/or guidance throughout each process (ID-2.4), with half the respondents

agreeing with this statement, and the rest undecided or disagreeing. This also can be an improvement area for the next version. The meaning of each data input/user selection and data output is clear for the users, with 80% of respondents agreeing with statements ID-2.5 and 2.6. The Visualisation of results is clear and informative according to respondents, with 66% agreeing with this statement (ID-2.7). The possibility of adding further information to the Study through the interface (ID-2.8) leaves 43% of the users undecided, with 14% of the respondents disagreeing with this statement.

The spider diagram in FIGURE 4-6 highlights a significant difference between the maximum and minimum scores, which may be due to the different levels of experience with similar tools or datasets by the users from different companies.

4.1.3 PERFORMANCE AND ACCURACY

Before the quantitative analysis is important to state that the presented results are the outcome of the test of eight different features of the tool. The features correspond to the eight verification cases previously identified: Framework, Activity Checklist, Applicant Mode [early stage], Applicant Mode [late stage], Assessor Mode, Study Comparison, Improvement Areas and Report Generation. The results represent the average values of the nine features.

The statements presented on TABLE 4-3 were assessed regarding the *Performance and Accuracy* of the tool.

TABLE 4-3: ASSESSED PERFORMANCE AND ACCURACY CRITERIA

ID	Statement
3.1	Results are robust and not sensitive to small changes of inputs
3.2	Results are credible and trustworthy for the audience
3.3	The accuracy of results is acceptable considering the granularity/complexity of data inputs used
3.4	The accuracy of results corresponds to the user expectation for the stage of technology maturity
3.5	The computational time is adequate for the level of accuracy provided
3.6	The software did not suffer from any sort of data shortage/lack of memory during the test
3.7	The software can handle errors without crashing

FIGURE 4-7 presents in the form of stacked bars the user scores per each statement listed above. The same results are presented in FIGURE 4-8 using a spider chart, to highlight the mean, maximum and minimum values.

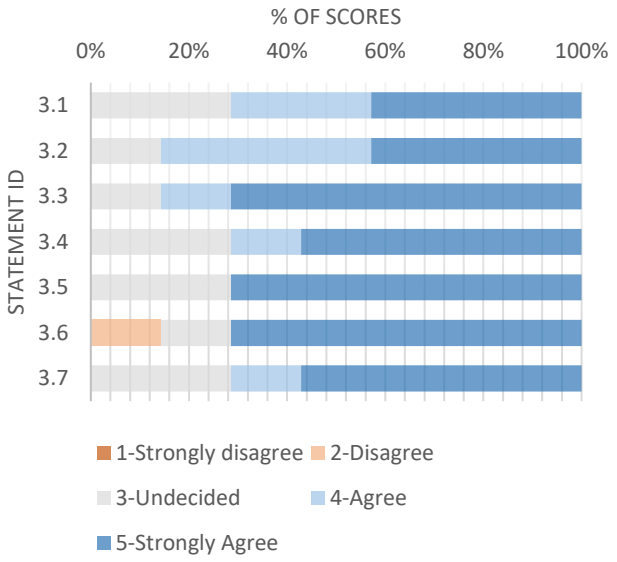


FIGURE 4-7: DISTRIBUTION OF USER SCORES PER PERFORMANCE AND ACCURACY STATEMENT

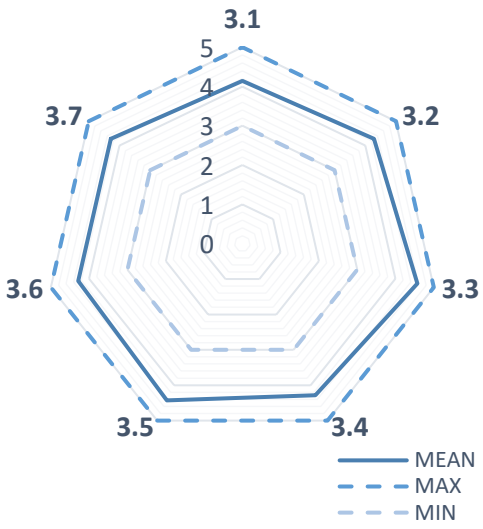


FIGURE 4-8: MEAN, MAXIMUM AND MINIMUM SCORES PER PERFORMANCE AND ACCURACY STATEMENT

FIGURE 4-7 shows that more than 70% of the testers consider that the results are robust and not sensitive to small changes of inputs. On the other hand, the remaining ones are undecided (ID-3.1). More than 80% considered that the results are credible and trustworthy while the rest are undecided about this (ID-3.2). The majority of users agree that the accuracy of the results is acceptable considering the granularity/complexity of data inputs (more than 80% - ID-3.3) and that the accuracy of the results corresponds to the user expectation for the stage of the technology maturity (more than 70% - ID 3.4). On these two criteria, around 20% and 30% remain undecided, respectively. More than 70% of the respondents strongly agree that the computational time is adequate for the level of accuracy provided, for the others this statement is undecided (ID-3.5). About the software itself, more than 70% agree in the sense that the software did not suffer from any sort of data shortage/lack of memory during the test and that the software can handle errors without crashing. Around 30% are undecided or disagree on these criteria (ID-3.6 and ID-3.7). This disagreement is only registered on ID-3.6 which may mean that the software could suffer from. data shortage/lack of memory, without crashing.

From the spider graph (FIGURE 4-8), it is possible to gauge that the mean, maximum and minimum scores are balanced regarding the performance and accuracy of this tool. The mean value is in the range of 4 and 4.7 while the maximum and minimum values are established in 5 and 3, respectively.

4.1.4 VALUE

The following criteria presented on TABLE 4-4 were assessed regarding the *Value* of the tool.

TABLE 4-4: ASSESSED VALUE CRITERIA

ID	Statement
4.1	The software allows the user full control of the design process
4.2	It produces results that allow easy comparisons
4.3	It provides a large range of alternatives to create/assess technologies
4.4	The user is informed about the internal processing (e.g. remaining time, log) and warned about potential inconsistencies
4.5	The software meets my expectations in terms of results, graphical options, interaction, and functionality
4.6	I would recommend the use of this software

FIGURE 4-9 presents in the form of stacked bars the user scores per each statement listed above. The same results are presented in FIGURE 4-10 using a spider chart, to highlight the mean, maximum and minimum values.

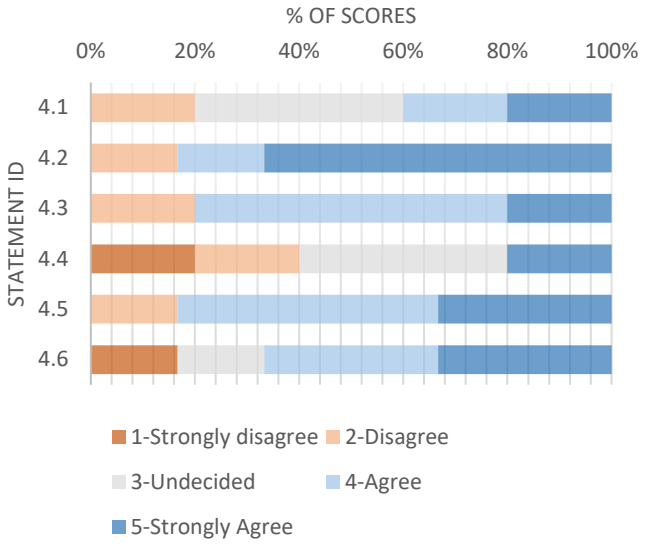


FIGURE 4-9: DISTRIBUTION OF USER SCORES PER VALUE STATEMENT

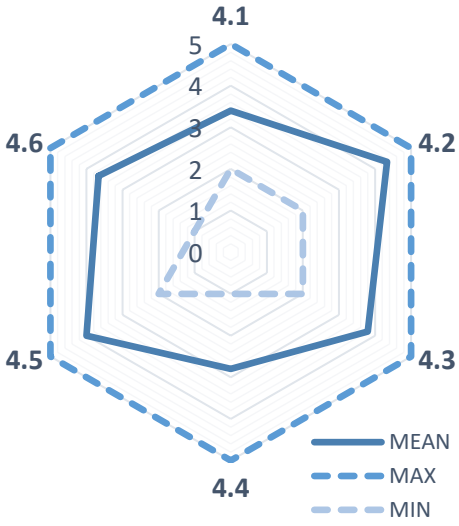


FIGURE 4-10: MEAN, MAXIMUM AND MINIMUM SCORES PER VALUE STATEMENT

Analysing FIGURE 4-9 it is possible to state that around 40% of the users consider that the software allows the user full control of the design process. Another 40% remain undecided on this, while 20% disagree on this criterion (ID-4.1). More than 80% agree that the tool produces results that allow easy comparisons, but around 20% disagree on this (ID-4.2). For the range of alternatives to create/assess technologies, 80% agree that the tool provides a large range. On the opposite side, 20% disagree on this statement (ID-4.3). Only 20% of the users agree that the tool provides information about the internal processing (e.g. remaining time, log) and warned about potential inconsistencies, 40% disagree on this and the remaining ones are undecided (ID-4.4). Almost 80% of the respondents agree that the software meets their expectations in terms of results, graphical options, interaction and functionality while the rest of them disagrees (ID-4.5). To conclude, the majority of the users would recommend the use of this tool (ID-4.6).

FIGURE 4-10 shows that there are differences between the minimum (score – 1) and maximum (score – 5) scores for the same assessment criterion that can be explained with different perspectives and expectations of the respondents. The mean scores are placed between 2,8 and 4,3.

4.2 QUALITATIVE ASSESSMENT

This section presents feedback from both technical and industrial verifiers, gathered from their Software Evaluation Forms as well as feedback given outside of the forms from consortium partners.

Comments have been grouped under three main categories: *Overall user satisfaction*, *Unintended tool performance* and *Proposals for improvement*. The aim of this last section in particular is to guide the path for improvement of the SG tool.

4.2.1 OVERALL USER SATISFACTION

Generally, the feedback indicated that the tool is easy to use and straightforward to understand. Overall user satisfaction was covered in comments such as:

- Definitely useful for public and private investors and funders. For Developers (especially early-stage) it provides a good checklist of areas to be worked on, and perhaps a framework to aspire to.
- Many early-stage developers are focussed on the 'invention' and the need to prove the concept, without a good business-plan to drive through to commercial success. This tool could provide a 'roadmap' towards this.
- Even if results were not directly ready to exploit in the way I expected for this use case, the checklist is a really interesting tool to have. Data generated and synthesized in the report would be really valuable for technology developers, especially in guiding young companies.
- Great work on the results pages where outstanding activities are clearly displayed

Comments from industrial partners which indicated improvements to the tool came under the categories of:

- Suggestions of guidance required to lead the user through the steps
- Definitions of metrics and other terminology would be helpful

- Suggestions of pop up 'Help' windows which could be useful
- Errors causing the tool to crash, which is solved by a refresh

4.2.2 UNINTENDED TOOL PERFORMANCE

A large part of this verification task was in identifying errors and bugs which could be fixed. These were discovered in:

- In Framework SG 0-1 and SG2-3 (Applicant mode), there is some extra 'none' text.
- While viewing the results, the appearance of the description of some metrics is not correct.
- Some users pressed 'Submit' before 'Save' and lost all the responses. There were other instances of the response results not showing, even after pressing 'Save' and 'Submit'.
- When running Assessor Mode, there is no room for assessor comments

All of these errors are straightforward to fix and will be addressed in the beta version of the tool.

4.2.3 PROPOSALS FOR IMPROVEMENT

4.2.3.1 CHOOSING AND DEFINING A FRAMEWORK

The overall Stage Gate evaluation is based on specific weighting of activities/evaluation areas. As thresholds can be edited, there was a suggestion that weightings be editable too.

On the Frameworks dashboard there could be a short description on the GUI to remind the user of what a framework is, for example: *"Here you can see detailed descriptions of the activities and evaluation criteria used to assess the 'Stage Gate' of development of an ocean energy technology. The default framework "DTOceanPlus Stage Gate Framework" will be used for Stage Gate studies unless a new framework is created. Create a new framework to assign metric thresholds to evaluation criteria such as X, Y, Z"*.

As for the possibility to edit metric thresholds, an overview of all the thresholds that can be edited for each *Stage* might be very useful and timesaving instead of scrolling through the "update metric threshold buttons". While fixing the threshold metrics, it is not clear which of them are supposed to be upper or lower thresholds.

There were several comments with the same point that on the list of frameworks. The 'Edit' button in the Frameworks creation section only allows the user to edit the Stage Gate Framework name, and not its content, as would be expected. The View button is used to view/edit the Frameworks, but the user may expect this.

4.2.3.2 ACTIVITY CHECKLIST

Feedback has indicated that the Activity Checklist is laborious to fill out, and there was the suggestion that it may be more user friendly to allow the user to directly go to the Stage gate they choose. This would be instead of requiring them to click on "Next Stage" multiple times. However, this may remove the benefit of ensuring the user has completed each stage fully before moving on.

Most feedback indicated that the users of the tool understand that the intention of the checklist is to ensure guidance in technology development. The completion of each stage is encouraged before moving to the next one, which ensures consistency across all Evaluation Areas in the technology development process.

There were a few comments about there being a clear diagram to show the link between Stage and TRL to help guide the user.

There were a few suggestions that pop up 'Help' windows to explain what the Evaluation Areas and metrics are would be helpful.

4.2.3.3 APPLICANT MODE

For the qualitative responses, there is no word limit to the answer boxes which may result in a large variety in the detail of the answers received. Also, the user may find it useful to input images to support their response. Some guidance on the length of answers required may help, as it would be expected that less detail is required at the earlier stages, and more as the technology has matured.

When completing the Stage Gate questions, a progression bar with live update representing the completion of each subsection could be very useful. This would better inform the user how much information they entered and how much is still required.

Depending on the type of technology being assessed (array / single device), it would be good to be able to change the units, e.g. from kWh to MWh.

4.2.3.4 ASSESSOR MODE

Feedback indicated that explanation of the scoring criteria would be useful. A description could be shown in the GUI to remind the assessor how the scoring works.

There were a few comments about there being no room for assessor comments.

4.2.3.5 COMPARE STUDIES

A comment made showed that the Study Comparison feature in its current form is not very intuitive because the fields don't look possible to be selected (because they are showed in light grey), and the results appear to be empty.

Adding studies to the comparison list was not obvious, as you can only see this is possible when selecting the studies from the Stage gate study list. It would be clearer to be able to see if you've added the study to the Study Comparison list from within the Compare Studies feature.

4.2.3.6 STAGE GATE REPORT

The report page was described as neat as it provides a simple but clear overview of each stage and the flexibility of the user selecting exactly what they want included in the report. Explanations on the page are really useful to guide the user in knowing what to tick on the report section and what to expect.

Feedback included lots of formatting and structure change suggestions. A common point was that blocks of text would be clearer if displayed in a table.

Generally, comments indicated that the report should be clearer about which parts of the report are the report text, which was completed by the applicant, and which are comments by the user. A suggestion of how this could be solved is by having different coloured text for each source.

4.2.3.7 IMPROVEMENT AREAS

There was the suggestion of having a button in the integrated version to direct the user to the SI tool at the Improvement Areas feature.

Once an improvement area is flagged up, links to the relevant section of the Stage Gate tool might be helpful if the user wants to click on the relevant category and go back to the checklist or applicant mode to amend the information.

4.2.3.8 NOMENCLATURE

The initial ambiguity, in terms of nomenclature, between Stage Gate 'Study' and 'Framework' can be easily solved by adding a brief explanation for both terms, to better guide the user. The meaning of the rest of the input data is clear, and the output data are easily interpreted. The representation of output data using graphs provide the user with a global perception of the outcome of a certain assessment.

4.2.3.9 RESULTS ASSESSMENT WITH EDITED METRIC THRESHOLDS

The metric results that are not filled in are considered as results (PASS or FAIL) but should be considered as an empty field instead of assuming the value '0'.

4.3 TASK LIST

The qualitative feedback from the Software Evaluation Forms was processed as they were reviewed and compiled in a spreadsheet, sorted per feature with the frequency of each comment noted. The number of times the comment was mentioned was used as an indication of how high a priority the suggested change to the tool was. From this analysis there were 116 individual comments with feedback on the SG tool. These were sorted into 32 suggested changes to the tool to improve functionality. The suggested changes were sorted into High, Medium and Low priority changes:

- 13 out of 32 were decided to be High priority changes
- 8 out of 32 were decided to be Medium priority changes
- 11 out of 32 were decided to be Low priority changes

The High/Medium/Low allocation was split up as:

- **High**: Since there were 7 Software Evaluation Forms completed, if a comment was mentioned 4 times or more, it is likely that more than half of the reviewers discovered this issue and suggested change. This was determined to be high priority.
- **Medium**: If a comment was mentioned less than 4 times but more than once, it was determined to be a medium priority change.
- **Low**: If a comment was mentioned only once, being a one-off, it was determined to be a Low priority change.

A summary of the high priority issues is given below, with more detail Annex V.

TABLE 4-5: SUMMARY OF HIGH PRIORITY ISSUES TO ADDRESS

Issue	Resolution
There is insufficient guidance and background information provided to new users of the Stage Gate tool, applying across all functionalities of the tool.	More guidance, help buttons, additional background information and explanatory dialog boxes should be included in the final release of the Stage Gate tool, including definitions of the terminology. This will be done by incorporating the previously published documentation (e.g. D4.2) and providing links to documentation within the GUI.
Inconsistencies and typos have been identified in the underlying framework data presented in the tool.	Review activities and ensure a consistent tense in the description of activities and that descriptions make sense to all the possible users of the tool (e.g. applicants, assessors etc.)[2]
Inconsistencies in the metrics and units that make up the Stage Gate assessment component of the tool	A review of these is needed, including ▫ the suitability of certain metrics at earlier stages in the framework ▫ suitability of "array-level" metrics for the Stage Gates that are supposed to be targeting sub-system and device level technologies seemingly identical metrics are requested in multiple Stage Gates has also raised confusion
A common bug in the tool where clicking a button brought them to a blank page	This issue seems to have been resolved already, with the latest set of updates, but additional testing should be performed to ensure that this issue has been tackled adequately.
Lack of clarity in the improvement areas and how they are identified	More clarification on how the improvement areas are identified is required. Improving how the improvement areas are presented, including methods for linking the specific failed metrics to the improvement areas. An option to show the improvement areas in a tabular format has also been proposed.
Style improvements are required for the Stage Gate report	In future versions of the tool, the style and consistency of the Stage Gate report will be improved
Missing scoring criteria in the framework which means no corresponding boxes for assessor comments in Assessor Mode	Each question will be assigned a set of scoring criteria, or else a method for accepting a general assessor comment independent of the scoring criteria.

[2] The annex of this document has the updated stage activities completed in line with the IEA OES Task 12 work that WES is involved in, and this will be incorporated into the tool.

Too many collapse/expand sections in the tool which requires too much clicking by the user	Consider ways of improving the user experience. For example: ▫ Making better use of tables. ▫ "Collapse all/Expand all" buttons, ▫ Adding check boxes to entire activity categories or evaluation areas ▫ Adding a live "progression bar" to show how much of a Stage Gate assessment has been completed by the user. All of these options will be considered, along with other ideas on how to improve the UX of the Stage Gate tool.
Stage Gate report is unclear on authors of each section	To make clearer which section of the report is the description of the question, and which is the user's response. To ensure clarity in this regard, the use of tables and delineated sections will be implemented
No indication of if metric thresholds are upper or lower limits	Each location in the tool that refers to metric thresholds should mention whether the threshold is an "upper" or "lower" threshold. This is described in the metric results table but is missing in several other locations. This will be implemented in the tool.
Buttons for moving to the next stage in the Activity Checklist are confusing	These buttons can be changes so that instead of "Previous Stage", "Save", "Submit" and "Next Stage" buttons, make it possible for users to go directly to the stage that they are concerned with. Tabs or a graphical depiction along the top of the page to navigate through the stages may be used as better alternatives.
Individual buttons to edit metric thresholds is not user friendly	A single location to view and edit the metric thresholds will be more user friendly and less laborious than individual buttons and pop-up dialog boxes for each metric.
There is a need for more clarity in the Stage Gate report	To improve clarity and readability, the plan is to convert most of the data presented in the format of bullet-point lists to a tabular format.

The highest priority task that was identified called for additional guidance and help to be provided to users of the SG tool. Verification partners felt that there was a lack of background information and explanatory dialog boxes presented with the tool, and that methods such as these, to help guide the user through the Stage Gate process, would improve the SG tool significantly.

The developers of the Stage Gate tool will address this suggested improvement and implement the resolutions to the other high priority issues in the final release of DTOceanPlus. The Medium and Low priority changes are listed in the Annex and will be reviewed with as many changes implemented as possible in the remaining timeline of the project. These include issues such as:

- The user having the ability to edit the weightings of questions in the stage gate assessment
- Simplifying the charts in the Stage Gate report
- The ability to copy and paste frameworks
- Adding a glossary to help with understanding whilst using the tool

5. CONCLUSIONS

The objective of Task 4.3 was to carry out the testing of the Stage Gate design tool in order to verify that it meets all the previously defined requirements (in WP2 and T4.1). The verification task has shown that the Stage Gate tool

- responds correctly to a varied set of inputs;
- performs its functions in an acceptable time and reasonable use of computational resource;
- is adequate in terms of usability and
- is verified against control data.

The following actions were completed as part of the verification and were described throughout this report:

- Definition of the Verification Cases and evaluation criteria
- Organisation of training sessions (for technical and industrial partners)
- Collection of data for each Verification Case
- Running the Verification Cases (by technical and industrial partners)
- Analysis of the results based on quantitative and qualitative assessments
- Creation of a task list of changes that could improve the tool to improve performance

A stable beta version of the Stage Gate tool is now available. Additionally, a first draft of the technical and user manuals that will be delivered alongside the final version of the tool has been written and is included as an Annex to this report.

According to the quantitative results, the end-users involved in evaluating the SG tool were satisfied with the usability, user-friendliness, performance, and value of the software. The qualitative assessment feedback highlighted several improvements that should be made to the SG tool. Thirteen of these suggested improvements were categorised as high priority tasks and will be implemented in the final release of the DTOceanPlus suite of design tools. The highest priority task that was identified called for additional help and guidance to be provided to the users of the SG tool.

The next steps in the development of the Stage Gate tool will focus on the implementation of the suggested improvements as discussed above alongside the full integration of SG with the other DTOceanPlus tools. Further validation of the Stage Gate tool will be obtained as part of the work planned in WP7, which aims to validate the suite of tools using real-world demonstration scenarios.

6. REFERENCES

[1] DTOceanPlus, Deliverable 2.1 "Results from user-groups consultation", 2018.

[2] DTOceanPlus, "Deliverable D4.1 Technical requirements for the implementation of a world class Stage Gate Assessment Framework in Ocean Energy," 2019.

[3] WES, "Deliverable D4.2 'Stage Gate tool - Alpha version'," 2020.

[4] Hill, C., S. Neary, V., Gunawan, B., Guala, M., Sotiropoulos, F., "U.S. Department of Energy Reference Model Program RM1: Experimental Results," 2014.

ANNEX I: USER MANUAL

This annex provides an overview of the user manual that is being developed alongside the tools, firstly outlining how this will be produced, and secondly providing an early draft of the documentation content.

7.1 DOCUMENTATION FORMAT

As with the overall suite of tools, there will be an overarching main documentation, with a separate set of documentation for each module. The main documentation will cover areas including installing and running the tools; use cases and user journeys, including linkages between the various parts of the suite; and how to manage projects and studies.

To provide a dynamic and useful documentation system for the DTOceanPlus suite of tools, it is proposed that this will be developed with a linked hierarchical structure that can be viewed in a browser or exported as a document format as required. The documentation will follow an established system[3], split into four main areas preceded by a brief overview of the functionalities and workflow:

- **Tutorials** to give step-by-step instructions on using the tool for new users.
- **How-to guides** that show how to achieve specific outcomes using the tool.
- An **explanation of features and calculation methods** gives technical background on how the tool works, to give confidence in the tools.
- The **API reference section** documents the code of modules, classes, API, and GUI.

The documentation will be produced using the Sphinx Python Documentation Generator[4].

The contents of the documentation will build on the work done to date within the project and will continue to be updated alongside the code. The tutorials will build on those produced to train the partners for the verification activities described in the main report. The explanation of features and calculation methods will be based on the comprehensive details outlined in the alpha-version deliverables. Finally, the API reference section will document the code of the modules, based on the code docstrings written alongside the module code.

The results of the verification activities will be used to improve the documentation, for example the tutorials and/or how-to guides could be added or improved to address any shortcomings identified or feedback received.

For reasons of brevity, the content from the alpha version deliverables and code docstrings will not be included in this annex but will be published alongside the final software at the end of the project.

[3] The Documentation System, https://documentation.divio.com/
[4] Sphinx Python Documentation Generator https://www.sphinx-doc.org/en/master/

7.2 DRAFT DOCUMENTATION HOME PAGE

7.2.1 INTRODUCTION

The Stage Gate module (SG) is a software that supports the objective assessment of technologies in the development process, ensuring a fair assessment of sub-systems, devices and arrays from early stage concepts up to commercial deployment.

It is intended to be used by a wide variety of stakeholders, including:

- Technology developers in the evaluation of their own technology, and
- Investors and public funders to aid decision making on several technologies.

The aim of this tool is to guide the technology development process and facilitate the assessment of ocean energy technologies.

As a tool, it operates with close integration to the Structured Innovation, Deployment and Assessment tools, to support consistent assessment processes and ultimately guide decision making for the users of the tool.

7.2.2 STRUCTURE

This documentation is divided into four main sections:

- Tutorials to give step-by-step instructions on using the SG tool for new users.
- How-to guides that show how to achieve specific outcomes using the SG tool.
- An explanation of features and calculation methods gives technical background on how the SG tool works, to give confidence in the tool.
- The API reference section documents the code of modules, classes, API, and GUI.

7.2.3 FUNCTIONALITIES

The Stage Gate module has seven major functionalities:

1. Stage Gate Framework – functionality for viewing the Stage Activity and Stage Gate Question data of the Stage Gate Framework developed for DTOceanPlus. This functionality also enables the user to edit the Stage Gate Framework by specifying the metric thresholds that are applied.
2. Activity Checklist – allows the user to work through the required activities for each stage of the Stage Gate programme in turn and record whether they have been completed or not. This enables SG to identify the specific stage that a device or technology has reached.
3. Applicant Mode – the first component of the Stage Gate assessment functionality. Presents to the user a set of qualitative and quantitative questions about their technology that they must answer. Emulates the application process at the stage gate of a typical technology development programme, from the point of view of the Applicant.

4. Assessor Mode – the second component of the Stage Gate assessment functionality. Presents to the user the answers supplied by an Applicant in a previous Applicant Mode assessment and requests Assessor scores and comments. Emulates the assessment process of a Stage Gate of a typical technology development programme, from the point of view of the Assessor.
5. Improvement Areas – the methodology for identifying the improvement areas highlighted by a Stage Gate analysis. These refer to the characteristics of a device or technology that the SG module has identified as needing further development or refinement.
6. Report Export Functionality – generates a standardised report in PDF format that summarise all the key information associated with a Stage Gate analysis.
7. Study Comparison – compares the results of two or more Stage Gate Assessments that have been performed by the user.

7.3 DRAFT TUTORIALS

7.3.1 FRAMEWORK

7.3.1.1 INTRODUCTION

The Framework feature allows users to view the activity and question data that is incorporated in the Stage Gate tool. This is also the place where the user can view and edit metric thresholds.

A default framework is provided that cannot be edited, re-named or deleted. This default framework, labelled the *DTOceanPlus Stage Gate Framework*, does not contain any default metric thresholds. If a user wants to apply any metric thresholds, they must first create a new *Framework*. This section contains four tutorials:

1. Inspect the default Framework data
2. Create a new Framework
3. Edit the name and description of a Framework
4. Specify the metric thresholds to apply in a Framework

7.3.1.2 INSPECT THE DEFAULT FRAMEWORK DATA

This tutorial shows how to view the stage activity data and stage gate question data that is incorporated in the Stage Gate tool. It will use the default Framework that is provided with the Stage Gate tool to demonstrate this feature.

1. Click the main **Frameworks** button in the navigation pane on the left-hand side of the Stage Gate tool. This will bring you to the home page of the Frameworks feature.
2. You should see a list of available Frameworks that should only contain the default Framework at this stage.
3. Under the **Operations** column there are three buttons; **View, Edit** and **Delete**. Because this is the default Framework, the **Edit** and **Delete** buttons will be greyed out and disabled. Click the **View** button.

4. The name and description of the Framework are shown again at the top of the screen. Under this, there is a banner showing the six Stages (Stage 0 -- Stage 5) and the five Stage Gates that form the Stage Gate Framework. Each of the Stage and Stage Gate buttons can be selected to bring up further information for that component. Click **Stage 0** to show the activities required to be completed in Stage 0.
5. You should see a list of 9 *activity categories*, starting with *Concept creation and description*. click this activity category to expand the section and reveal the associated activities.
6. There should be 4 activities within the *Concept creation and description* section. Every activity can be expanded further to show its detailed description.
7. Above the banner showing the Stages and Stage Gates there is a switch button that is currently set to **Activity Category**. Click this button.
8. The button should switch to the **Evaluation Area** option. The list of activities should now be categorised by *Evaluation Area* rather than by the *Activity Categories* that were shown at the start. Note that this option is only applicable for the Stage activities, and not the Stage Gate questions.
9. Each of the *Evaluation Areas* can be expanded in a similar way to show the related activities. Note that the list of activities is the same, and all the switch button does is categorise the data in a different way. note also that activities can be categorised under more than one *Evaluation Area*.
10. Next, click on **Stage Gate 1 - 2**. This will bring up a list of *Question Categories*, starting with *Technology*.
11. Click the *Technology* section to reveal a description of this section, as well as a list of the four questions that form this question category.
12. Click the *Degree of novelty and innovation (I)* section. This will reveal the detailed description, the weighting and the scoring criteria for this particular question. This is an example of a qualitative question.
13. Next, click the section titled *Metrics - Installation* and then click the question *Installation duration*. This is an example of a quantitative question. It has the same description, weighting and scoring criteria that a qualitative question has but with additional information describing the metric that is being requested.
14. Under each quantitative question you will notice a button labelled **Update metric threshold**. As we are investigating the default Framework, these buttons are currently disabled. Later sections of this tutorial will describe how to set metric thresholds for non-default frameworks.
15. The user can browse through each of the Stages and Stage Gates in the same way as described above.

7.3.1.3 CREATE A NEW FRAMEWORK

In order to set metric thresholds, a new Framework entity needs to be created. this short tutorial demonstrates how to create a new Framework.

1. Click the **Frameworks** button in the navigation pane down the left-hand side to bring you to the homepage of the Frameworks feature.

2. Near the top of the screen there is a button labelled **Create a new Framework**. Click this button.
3. In the dialog box that appears, enter a name and description for the new Framework.
4. Click **Create** to create the new Framework. This creates a copy of the Stage activity and Stage Gate question data that is stored in the default framework. However, we can now use this new Framework to set metric thresholds for future Stage Gate Studies. This will be defined in *Specify the metric thresholds to apply in a Framework* tutorial.
5. Upon creating the new Framework, you should be returned to the list of Frameworks and this should include the newly created Framework entity.

7.3.1.4 EDIT THE NAME AND DESCRIPTION OF A FRAMEWORK

The name and description of any non-default Framework can be edited easily.

1. For the new Framework created in the previous tutorial, the **Edit** button in the **Operations** column should now be enabled. Click this button.
2. In the dialog box that appears, enter a new name and a new description.
3. Click the **Update** button to update and return to the Frameworks home page.
4. The second Framework should now show the updated name and description that were just set.

7.3.1.5 SPECIFY THE METRIC THRESHOLDS TO APPLY IN A FRAMEWORK

The Frameworks section is where users can set metric thresholds to be used in future Stage Gate studies. This tutorial demonstrates how to apply an example metric threshold using the new Framework created in Create a new Framework.

1. On the Frameworks homepage, click the **View** button for the new Framework that was created and edited in the preceding tutorials.
2. Next, navigate to the **Stage Gate 3 - 4** tab along the top banner.
3. Scroll down to the section titled **Metrics - Affordability** and expand this section.
4. Then expand the question labelled **LCOE**.
5. The **Update a metric threshold** button should now be enabled. Click this button.
6. In the dialog box that opens, tick the checkbox that says **Apply metric threshold**.
7. In the input number box labelled **Threshold** type the number **150**.
8. Click **Update**.
9. The dialog box should disappear and for the LCOE metric section, there should now be a new entry labelled **Threshold** that shows the threshold for this metric has been set to 150 €/kWh. This threshold will be applied for the LCOE metric in this Stage Gate for any future Stage Gate studies associated with this Framework.

7.3.2 STAGE GATE STUDY

To perform a Stage Gate analysis, you must first create a *Stage Gate study*. A Stage Gate study is the entity that is used to record and save the input and output data associated with a single analysis. Stage

Gate studies must be given a *name*. No two Stage Gate studies can have the same name. An optional *description* of the study can also be specified. Finally, each Stage Gate study must be associated with a single Framework (see previous tutorial).

This section contains three tutorials focusing on how to

- Create a Stage Gate study,
- Edit a Stage Gate study and
- Delete a Stage Gate study.

7.3.2.1 Create a Stage Gate study

1. Navigate to the list of Stage Gate studies by clicking the ``Stage Gate Studies`` button in the navigation pane on the left-hand side of the Stage Gate tool GUI. No default studies are provided with the tool so you should see an empty list if you have not created any studies.
2. At the top left corner of the screen there will be a button labelled **Create Stage Gate study**. Click this button.
3. On the dialog box that appears, type in a *Name* and a *Description* of the study. Note that the description is an optional parameter, but the name is not.
4. Next, use the dropdown menu to associate the Stage Gate study with a previously created Framework entity. If you want to apply metric thresholds in a Stage Gate analysis, you will need to first create a new Framework and set the metric thresholds using the Framework feature. More details are provided in the Frameworks tutorial. When creating a new Stage Gate study, you will be able to choose from the list of available frameworks, including any previously created Frameworks. For now, select the default framework *DTOceanPlus Stage Gate Framework*.
5. Click the **Create** button.
6. The list of studies should then appear, with the newly created study visible in the table of Stage Gate studies.

7.3.2.2 Edit a Stage Gate study

1. The final column of the Stage Gate studies table is labelled *Operations* and contains a set of three buttons for each Stage Gate study. Click the **Edit** button for the study created in the previous tutorial.
2. A new dialog box will pop up with the name, *Update a Stage Gate study*.
3. Enter a new name and description for the study. Note that once a study is created, it is not possible to update the Framework that was originally assigned to that study.
4. Click the **Update** button.
5. The list of studies will be displayed and the name and description of the study should be updated.

7.3.2.3 Delete a Stage Gate study

1. The last button in the *Operations* column can be used to delete any pre-existing Stage Gate study. For the study that was created in the first tutorial of this section and edited in the preceding tutorial, click the **Delete** button.
2. When the Stage Gate studies home page has loaded fully, you should see that the selected study has been deleted.

7.3.3 ACTIVITY CHECKLIST

The *Activity Checklist* helps the user identify the stage that they have reached in the technology development process. This feature presents the set of activities required to be completed at each Stage to the user in the form of a checklist. The feature can be used to quickly identify the technology readiness level of their device. It can also be used to highlight the outstanding activities that are required to complete a specific Stage. Users can use the *Activity Checklist* as an interactive reference document, saving their progress and returning to the checklist throughout the development of their technology. Note that the results of the checklist feature can also be obtained in the format of a standardised report.

7.3.3.1 COMPLETING THE CHECKLIST

1. Note that a Stage Gate study must have been created previously in order to run the checklist feature. Go to the Stage Gate studies home page by clicking the **Stage Gate Study** button in the navigation pane on the left-hand side of the tool.
2. For the previously created study, click the **Select** button in the Operations column for the study. This will bring you to the home page of that particular study.
3. Click the **Perform** button under the *Activity Checklist* heading.
4. You will be presented with the set of activities required to be completed for Stage 0. Expand the *Concept creation and description* section.
5. Next expand the first activity of this category by clicking **Device concept definition**.
6. There is a checkbox after the description of the activity. In this example, let us assume that the technology developer has completed this activity. Check the **Complete?** box for this activity.
7. Continue to navigate through the activities. For this example, mark all the activities in the **Device concept definition** and **Hydrodynamic performance assessment** categories as complete.
8. Click the **Save** button at the bottom centre of the screen. A notification saying that the checklist activities have been updated should appear. This will save the current progress so that the user can quit the programme and come back at a later time to continue the exercise.
9. There are also buttons at the bottom of the screen for navigating through the Stages of the Framework. Click the **Next Stage** button and you will see the activities for Stage 1. The heading should also change to *Stage 1*.
10. Click the **Tank testing** category and mark the **Tank testing of Power Capture technology** activity as complete.

11. Click the **Previous Stage** button at the bottom left of the page to return to the Stage 0 activities.
12. Near the top of the screen there is a switch button with the labels *Activity Category* and *Evaluation Area*. Click this switch.
13. The activities displayed on screen will now be categorised by *Evaluation Area* rather than the initial *Activity Categories*. The list of activities is the same, all that changes is the categorisation. Note that some activities can be listed under more than one *Evaluation Area*. In this case, if you check or un-check an activity under one *Evaluation Area*, the status of the activity will be reflected in each of the *Evaluation Areas* that that activity falls under.
14. Click the **Save** button once more to save the results.

7.3.3.2 VIEWING THE CHECKLIST RESULTS

1. Click the **Submit** button at the bottom centre of the screen.
2. The summary results will be displayed showing the percentage of activities completed for each stage as well as a graphical depiction of the percentages. The results should show 21% complete for Stage 0, 4% complete for Stage 1 and all the other Stages should show 0% complete.
3. Click **Stage 0** to get further details of the status of activities in Stage 0.
4. This next results page shows the percentage of activities complete for each *Activity Category* and *Evaluation Area*. For the *Concept creation and description* and *Hydrodynamic performance assessment* activity categories should both be 100% complete. The other categories should all be 0% complete. For the *Evaluation Areas*, the *Manufacturability* and *Power Capture* areas should be 100% complete, the *Installability* area should be 25% and the remaining evaluation areas should all be 0%.
5. The final section of this results pages lists the *Outstanding Activities* that are still to be completed. The user can navigate through these outstanding activities as before, categorising by either *Activity Category* or *Evaluation Area* as preferred.

7.4 DRAFT HOW-TO GUIDES

7.4.1 HOW TO USE THE SG TOOL TO IDENTIFY COMPLEXITY LEVELS

The *Activity Checklist tutorial* showed that the Stage Gate tool can be used to identify the stage of development of a device or technology. This in turn identifies the appropriate Stage Gate that the technology should be evaluated against.

A user can run each of the Deployment and Assessment tools at varying levels of complexity. A pre-defined mapping between the Stages and complexity levels of the Deployment and Assessment tools has been defined. This is referred to as the Combination Matrix and is shown in the table below.

This matrix allows the Activity Checklist functionality to inform the user of the appropriate complexity level to use for each of the Deployment and Assessment tools. Furthermore, the Stage activities have been developed in tandem with the user inputs of the Deployment and Assessment tools for each

level of complexity. As such, a user can ensure they have the user inputs required to run each tool at the appropriate level of complexity if they first use the Activity Checklist functionality in the Stage Gate module.

Note that the System Performance and Energy Yield (SPEY) tool works in the same way at each complexity level and that the complexity levels for the Machine Characterisation module (MC), a new module added since the publication of [3], have yet to be defined.

Tool	Stage 0	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Site Characterisation (SC)	1	1	2	2	3	3
Machine Characterisation (MC)	TBC	TBC	TBC	TBC	TBC	TBC
Energy Capture (EC)	1	2	2	3	3	3
Energy Transformation (ET)	1	2	2	3	3	3
Energy Delivery (ED)	1	1	1	2	3	3
Logistics and Marine Operations (LMO)	1	1	2	2	2	3
Station Keeping (SK)	1	1	1	2	3	3
Reliability, Availability, Maintainability, Survivability (RAMS)	1	1	2	2	3	3
System Performance and Energy Yield (SPEY)	-	-	-	-	-	-
System Lifetime Costs (SLC)	1	1	1	2	3	3
Environmental and Social Acceptance (ESA)	1	1	1	2	3	3

To obtain this complexity level mapping, you must do the following:

1. Create a new Stage Gate study (see *Stage Gate study* tutorial) and run the Activity Checklist mode (see *Activity Checklist* tutorial). Make sure to submit the answers.
2. The results will identify the Stage of technology development that has been reached.
3. Scroll to the bottom of the *Activity Checklist* results page, where you will see the same table shown above but with the appropriate column highlighted.
4. Click the button labelled **Start a new Deployment and Assessment design**. This button will navigate to the home page of the Site Characterisation (SC) module (the first Deployment and Assessment module in the chain). The appropriate complexity level will be pre-loaded as an input to the SC module. This will be the case for all of the subsequent Deployment and Assessment tools that are opened in turn.

ANNEX II: STAGE GATE ACTIVITIES

8.1 POWER CAPTURE

TABLE 8-1: STAGE ACTIVITIES SUPPORTING CHARACTERISATION AND EVALUATION OF POWER CAPTURE (WAVE AND TIDAL STREAM)

Stage	Stage Activities

Stage 0 – Concept creation	• Definition of technology requirements and challenges associated with Power Capture (the problem statement)
	• Concept definition and identification of physical/ functional characteristics and fundamental operating principles of the device, including:
	  ○ low/ medium/ high energy resource suitability
	  ○ deep/ shallow water
	  ○ floating/ surface piercing/ bottom mounted
	  ○ likely commercial-scale geometric size of the technology
	  ○ mode of power capture, degrees of freedom and reaction mechanism for power capture
	  ○ suitability for implementation of control systems to maximise performance
	  ○ potential benefits of control systems in terms of operating principles
	  ○ degree of reliance on control systems to achieve functionality
	• Basic estimates of hydrodynamic power capture based on:
	  ○ fundamental relationships between physical parameters (such as swept area or diameter)
	  ○ power production of comparable technologies, or
	  ○ fundamental limits (e.g. Betz or Budal limit)
	• Simple capture length ratio (wave) or power coefficient (tidal stream) calculations based on comparable technologies or consideration of fundamental limits (e.g. Betz or Budal limit)

Stage 1 – Concept development	• Evaluation of physical and functional behaviours observed in tank testing conditions. This can inform the characterisation of the device power capture functionality and suitability for the expected range of operating conditions
	• Development of a numerical model, to estimate commercial-scale power capture performance
	• Tank testing of device at approximately 1:50 - 1:20 scale with appropriate methods to mimic the behaviour of a real PTO, covering:
	  ○ a range of sea states or currents which provide scaled representation of the target commercial operating conditions to characterise the functional performance
	  ○ where appropriate, variation of controllable parameters, such as damping or device geometry and evaluation of the impact on power capture performance

Stage	Stage Activities
	• Validation of the numerical model using tank test data

Stage 2 – Design optimisation	• Further development and refinement of numerical model to estimate commercial-scale power capture performance
	• Tank testing of device at approximately 1:30 - 1:15 with damping or power take-off method implemented to mimic behaviour of a real PTO, covering:
	  ○ a range of sea-states or currents which provide scaled representation of the target commercial operating conditions to characterise the functional performance
	  ○ where appropriate, variation of controllable parameters, such as damping or device geometry and evaluation of the impact on power capture performance
	• Validation of the numerical model using tank test data
	• Engagement with PTO developers to simulate and evaluate the behaviour and performance of the device with integrated PTO

Stage 3 – Scaled demonstration	• Further development and refinement of a detailed numerical model to cover full operational envelope. The integrated fully-operational PTO must be represented
	• Open-water testing (uncontrolled environment) of device at sufficient scale and size to represent commercial-scale performance (1:6 - 1:2 depending on site selection and subsystem size). The integrated, fully functional PTO must be represented. Application of appropriate algorithms to vary controllable parameters, such as damping or device geometry must be included
	• Open-water test campaign of sufficient duration to fully evaluate the device power capture performance through sustained periods of continuous generation in representative conditions:
	  ○ for wave devices, this is should be at least 6 months to reasonably expect experience of the full range of target energy generation sea-states
	  ○ for tidal stream devices, this should cover at least one full tidal cycle (spring tide to spring tide or neap to neap)
	• Validation of the numerical model using all available appropriate data

Stage 4 – Commercial-scale single device demonstration	• Further development and refinement of a detailed numerical model with integrated subsystems to cover full operational envelope • Open-water testing (uncontrolled environment) of a single device at commercial scale in a commercially representative site, with fully functional commercial-standard subsystems • Open-water test campaign should be of sufficient duration, with no significant periods of operational interruption, to thoroughly evaluate the device power capture performance. For wave and tidal stream devices,

Stage	Stage Activities
	this should be at least 12 months in order to experience the full range of expected operating conditions. This allows inclusion of seasonal variations and the opportunity to evaluate different system and subsystem settings • Validation of the numerical model using all available appropriate data
Stage 5 – Commercial-scale array demonstration	• Additional numerical modelling and analysis to assess array-related hydrodynamic interaction between devices to reflect the installed array configuration and future array deployments • Selection of array layout based on hydrodynamic modelling and array interaction analysis • Open-water testing (uncontrolled environment) of an array of at least 2 commercial-scale devices[5], in a commercially representative site, with fully functional commercial-standard subsystems • Open-water test campaign should be of sufficient duration, with no significant periods of operational interruption, to evaluate the array power capture performance to a high degree of confidence. For wave and tidal stream devices, this should be at least 2 years in order to experience the full range of operating conditions and build statistical significance of performance characteristics • Ongoing validation of a detailed numerical model with integrated subsystems, to cover the full operational envelope • Validation and ongoing optimisation of any algorithms to vary controllable parameters, such as PTO settings (damping, force or speed restrictions) or device geometry

[5] The recommendation of "at least 2" commercial-scale devices assumes that each device represents a significant generation capacity (e.g. > 100kW). Novel generation technologies could be aggregations of large numbers of small generation capacity units and the definition of a commercial-scale array should be adapted accordingly

8.2 POWER CONVERSION

TABLE 8-2: STAGE ACTIVITIES SUPPORTING CHARACTERISATION AND EVALUATION OF POWER CONVERSION (WAVE AND TIDAL STREAM)

Stage	Stage Activities

Stage 0 – Concept creation	• Definition of technology requirements and challenges associated with Power Conversion (the problem statement)
	• Concept definition and identification of physical/functional characteristics and fundamental operating principles of PTO, including:
	  ○ suitability of the PTO to the fundamental operating principle and force of damping requirements of existing devices
	  ○ suitability for implementation of control systems to maximise performance
	  ○ potential benefits of control systems
	  ○ degree of reliance on control systems to achieve functionality
	• Energy transformation behaviour and efficiency expectations defined based on (or derived from) existing, more mature technologies

Stage 1 – Concept development	• Development of a numerical model to estimate commercial-scale Power Conversion efficiency.
	• Physical, laboratory or bench testing of main components or subsystems at an appropriate scale to represent the functional behaviour of the PTO. Proof-of-concept testing of the technology should cover:
	  ○ a representative range of PTO input conditions
	  ○ representation of inertia and other device-related phenomena
	  ○ where appropriate, variation of controllable parameters, such as damping
	  ○ assessment of potential benefits of control system implementation and reliance upon it
	• Validation of the numerical model using test data

Stage 2 – Design optimisation	• Development of a numerical model to estimate commercial-scale power conversion efficiency
	• Physical, laboratory or bench testing of complete PTO subsystem at an appropriate scale to represent the functional behaviour of the PTO technology, ideally covering:
	  ○ full range of PTO input conditions, including extremes and representation of inertia and other device-related phenomena
	  ○ complete characterisation of PTO functional performance including, where appropriate, variation of controllable parameters, such as damping
	  ○ assessment of potential benefits of control system implementation and reliance upon it
	• Validation of the numerical model using test data

Stage	Stage Activities
	• Engagement with developers to simulate and evaluate the performance of the PTO subsystem in a device

Stage 3 – Scaled demonstration	• Development of a complete numerical model to calculate commercial-scale Power Conversion efficiency, both in isolation (rig-conditions) and integrated in a device
	• Physical laboratory or rig testing of complete PTO subsystem at sufficient scale to represent commercial-scale performance, in readiness for integration with a device, covering:
	  ○ full range of PTO input conditions, including extremes and representation of inertia and other device-related phenomena
	  ○ demonstration of operational characteristics of PTO functional performance including, where appropriate, variation of controllable parameters, such as damping
	  ○ assessment of potential benefits of control system to improve performance implementation and reliance upon it
	• Validation of the numerical model using test data

Stage 4 – Commercial-scale single device demonstration	• Development of a complete, integrated numerical model to represent commercial-scale energy transformation performance across a range of input conditions and PTO settings
	• Physical testing of commercial-scale PTO subsystem, covering:
	  ○ full range of PTO input conditions, including extremes and representation of inertia and other device-related phenomena
	  ○ complete characterisation of PTO functional performance including, where appropriate, variation of controllable parameters, such as damping
	• Integration of the commercial PTO subsystem with a commercial-scale device
	• Open-water test campaign of sufficient duration, with no significant periods of operational interruption, to evaluate the Power Conversion efficiency of the PTO to a high degree of confidence. For wave and tidal stream PTOs, this should be at least 12 months in order to experience the full range of expected operating conditions (device, PTO input operating conditions and PTO settings) and to demonstrate sustained performance over an extended duration
	• Validation of the numerical model using rig and open-water test data

Stage	Stage Activities
Stage 5 – Commercial-scale array demonstration	• Integration of the commercial PTO subsystem to an array of at least 2 commercial scale devices in intended commercial deployment conditions • Open-water test campaign of sufficient duration, with no significant periods of operational interruption, to evaluate the PTO's Power Conversion efficiency to a high degree of confidence. For wave and tidal stream PTOs, this should be at least 2 years in order to experience the full range of operating conditions (device, PTO input operating conditions and PTO settings). This will build statistical significance of performance characteristics and demonstrate sustained performance over a long duration • Full validation of detailed numerical model of the PTO, integrated with the device hydrodynamic numerical model

8.3 RELIABILITY

TABLE 8-3: STAGE ACTIVITIES SUPPORTING CHARACTERISATION AND EVALUATION OF RELIABILITY (WAVE AND TIDAL STREAM)

Stage	Stage Activities
Stage 0 – Concept creation	• Definition of technology and market requirements and challenges associated with Reliability (the problem statement) • Selection of high-level reliability targets, appropriate to the technology • Evaluation of the reliability of comparable technologies and applications. This evaluation should be based on the conceptual understanding of the technology and identification of physical and functional characteristics that impact reliability, including: ○ near/ far from shore ○ deep/ shallow water ○ floating/ surface piercing/ bottom mounted ○ suitability for implementation of supervisory monitoring and control systems ○ proposed structural material considered, with respect to scale and loading scenarios and suitability for expected environmental conditions ○ concept mode of operation, moving parts, potential exposure, perceived susceptibility to damage

Stage	Stage Activities

Stage 1 – Concept development	• Development of a numerical model or structural calculations to estimate commercial-scale loads in subsystems and devices
	• Identification of likely design limit states
	• Identification of structural strength of proposed structural materials and high-level evaluation of safety factors of key structural components
	• Use of experience from similar technology in a comparable environment and application to identify key failure modes and to estimate failure rates. High-level evaluation of the sufficiency of the identified failure modes and rate
	• Evaluation of the potential for control system actions to be implemented and consideration of:
	  ○ potential benefits to Reliability
	  ○ level of reliance on control to maintain Reliability

Stage 2 – Design optimisation	• Physical, laboratory or bench testing of key components at appropriate scale to evaluate life (or cycles) capability and failure rate • Development of numerical model to estimate structural loads on a commercial-scale device, validated to the extent possible using physical testing • Quantitative assessment of likely loads (including fatigue) on a commercial-scale device in representative conditions from tank test, rig test and validated numerical modelling • Development of an FMEA based on FEED (Front End Engineering Design) activity for Stage 3 open-water test device, tank-test & modelling data. Reliability experience from similar technology in a comparable environment and application may be applied.
Stage 3 – Scaled demonstration	• Open-water testing (uncontrolled environment) of a device (or subsystems in an open-water test rig e.g. device mounted on a barge) at sufficient scale to represent commercial-scale (1:6 - 1:2) behaviour and performance with representative subsystems • Open-water test campaign should be of sufficient duration to demonstrate Reliability through sustained periods of continuous operation in representative conditions (i.e. in a operational state) ○ for wave and tidal stream devices, this should be at least 6 months. This should be sufficient time to include significant recurrence of the full range of target operational and environmental conditions. This should include any conditions of particular concern to the key failure modes • Application and evaluation of algorithms to allow variation of controllable parameters, such as damping or power capture

Stage	Stage Activities
	geometry, which could provide Reliability benefits through load reduction or mitigation • Application of structural load measurement and monitoring of system failures • Further improvement in the fidelity of numerical models to calculate commercial-scale loads, validated using open-water test data • Development of an FMEA for the technology's commercial-scale system-breakdown, informed by testing and analysis experience • Accelerated life testing at suitable scale and size to evaluate key component, subsystem, or device life (or cycles) capability and failure rates. This work should support the development of (and be coherent with) the FMEA and O&M plan
Stage 4 – Commercial-scale single device demonstration	• Open-water testing (uncontrolled environment) of a single commercial-scale device, in a commercially representative site, with fully functional commercial-standard subsystems • Open-water test campaign should be of sufficient duration to demonstrate Reliability through deployment in representative conditions with no significant periods of operational interruption. This should generate experience to support FMEA validation: o for wave and tidal stream devices, this is expected to be up to 12 months to experience of the full range of target operational and environmental conditions • On-going accelerated life testing at appropriate scale to build confidence in key component, subsystem or device life (or cycles) capability and failure rates • Monitoring capability should include a combination of: o structural loads (in device or subsystems), o operational conditions o environmental conditions, and o system failures • Further development and validation of numerical structural model to build detail and confidence in FMEA. This should include component, subsystem and device failure modes and failure rates.

Stage	Stage Activities
Stage 5 – Commercial-scale array demonstration	• Open-water testing (uncontrolled environment) of an array of at least 2 commercial-scale devices, in a commercially representative site, with fully functional commercial-standard subsystems • Open-water test campaign should be of sufficient duration (at least 2 years) to demonstrate and evaluate Reliability across the full range of operational and environmental conditions. Periods of operational interruption should be minimised, and primarily focussed on general maintenance, to support FMEA validation • On-going accelerated life testing at appropriate rig scale and size to build confidence in key component, subsystem or device life (or cycles) capability and failure rate • Monitoring capability should include a combination of: ○ structural loads (in device or subsystems), ○ operational conditions ○ environmental conditions, and ○ system failures • Ongoing development and validation of numerical structural model to build detail and confidence of FMEA. This should include component, subsystem, device and array failure modes, failure rates and MTTF • Definition of commercial Reliability management approach to predict and mitigate future operational interruptions, including • monitoring • prognostics/diagnostics, and • any ongoing accelerated life test and management approaches

8.4 SURVIVABILITY

TABLE 8-4: STAGE ACTIVITIES SUPPORTING CHARACTERISATION AND EVALUATION OF SURVIVABILITY (WAVE AND TIDAL STREAM)

Stage	Stage Activities
Stage 0 – Concept creation	• Definition of technology and market requirements and challenges associated with Survivability (the problem statement) • Selection of high-level Survivability targets appropriate to the technology • Evaluation of the Survivability of comparable technologies and applications. This evaluation should be based on the conceptual understanding of the technology. This should include identification of physical and functional characteristics that impact Survivability or the requirement for a specific level of Survivability • Understanding of general deployment site environmental conditions

Stage	Stage Activities
	• Clear definition of what the survival events may be, and their likely impact on systems • High-level survival strategy definition

Stage 1 – Concept development	• Critical evaluation of physical and functional characteristics of the concept that impact Survivability, including:
	  ○ modes of operation and any fundamental characteristics that improve the ability to survive extreme conditions
	  ○ suitability for implementation of protective control and monitoring systems
	• Analysis of prospective site conditions to determine likely events (within design conditions) or unlikely event (beyond design conditions)
	• Clear definition of what the survival events may be, and their likely impact on systems
	• Identification of likely design limit states & identification of structural strength of selected structural materials
	• Survival strategy definition, including suitable protective action (active and/or passive)
	• Definition of prediction, detection and alerts systems
	• Development of a numerical model to estimate extreme commercial-scale loads
	• Initial estimation of impact on LCOE of damage or loss of functionality

Stage 2 – Design optimisation	• Extensive analysis of site conditions to determine what events are likely or unlikely to occur • Review of design condition boundary based on knowledge gained from design work to date • High-level evaluation of safety factors of key structural components • Development of survival strategy including suitable protective action (active and/or passive) • Development of prediction, detection and alerts systems • Definition of actions prior to reinstatement of all normal operations (diagnostic plans, sensor information, safety checks, physical inspection) • Adaption of installation plan, O&M model and FMEA to account for protective action • Dedicated tank or rig testing to examine subsystem/device behaviour during survival events • Dedicated numerical model(s) suitable for analysing survival events and extreme environmental conditions • Validation of numerical model using data available • Measurement of key structural and pressure loads in device

Stage	Stage Activities
	• Estimate of impact on LCOE of damage or loss of functionality and implementation of protective action (cost of required systems and reduced availability) supported by outputs of modelling, testing and design

Stage 3 – Scaled demonstration	• Extensive analysis of site conditions to determine what events are likely or unlikely to occur, including combinations of environmental conditions (wind, wave, current etc.)
	• Analysis of seasonal variability and extreme conditions at site
	• Review of Design Condition Boundary based on knowledge gained to date
	• Development of an FMEA for the technology's commercial-scale system-breakdown, informed by testing and analysis experience
	• Development of process for reinstatement of all normal operations following survival event
	• Adaptation of installation plan, O&M model and FMEA to account for protective action
	• Demonstration and evaluation of the effectiveness and reliability of survival strategies at sufficient scale to represent commercial-scale device, including:
	  ○ failsafe modes
	  ○ algorithms to control protective action(s) during testing
	• Further development of increased complexity numerical model to calculate commercial-scale loads and safety factors in survival events
	• Dedicated tank or rig testing to examine component, subsystem or device behaviour and loading. This must be during survival events, expanding the range of conditions used for the testing
	• Validation of numerical model using data available from physical testing and any other appropriate available data
	• Calculation of impact on LCOE of damage or loss of functionality and implementation of protective action (cost of required systems and reduced availability)

Stage 4 – Commercial-scale single device demonstration	• Ongoing survival and extreme load analysis, taking account of component reliability and fatigue as components/subsystems age • Update installation plan, O&M model, FMEA based on open water testing experience • Update analysis of site conditions to determine what events are likely or unlikely to occur including combinations of environmental conditions (wind, wave, current etc.) • Review of Design Condition Boundary based on knowledge gained to date • Demonstration and evaluation of survival strategies on a commercial-scale device, including:

Stage	Stage Activities
	○ failsafe modes ○ algorithms to control variable parameters, such as damping or Power Capture geometry, or other active protective actions • Test of prediction, monitoring, detection and alerts systems • Update of survival strategy and protective action based on Reliability assessments • Further development of numerical model taking account of deployment experience and updated FMEA • Continued tank testing and rig testing at a scale and size sufficient for representation of survival events and extreme conditions • Update to LCOE based on available survival test and modelling data
Stage 5 – Commercial-scale array demonstration	• Update analysis of site conditions to determine likely events (within design conditions) or unlikely event (beyond design conditions), based on updated understanding of device • Structural load measurement and monitoring of system failures • Ongoing monitoring of system functionality along with Reliability actions, with update made to survival strategy if required • Ongoing use and development of prediction, monitoring, detection and alerts systems • Refinement and use of numerical model taking account of deployment experience and updated FMEA • Update to LCOE based on available survival test and modelling data, taking account of damage or loss of functionality, and implementation of protective action (cost of required systems and reduced availability)

8.5 MAINTAINABILITY

TABLE 8-5: STAGE ACTIVITIES SUPPORTING CHARACTERISATION AND EVALUATION OF MAINTAINABILITY (WAVE AND TIDAL STREAM)

Stage	Stage Activities
Stage 0 – Concept creation	• Definition of technology and market requirements and challenges associated with Reliability (the problem statement) • Selection of high-level Maintainability targets appropriate to the technology • Evaluation of the Maintainability of comparable technologies in similar applications and environmental conditions. This evaluation should be based on the conceptual understanding of the technology and identification of physical and functional characteristics that impact Maintainability, including: ○ access restrictions for device (water depth and installation type) ○ likely accessibility, modularity and transportability of components and subsystems ○ suitability for maintenance operations on-site or in a protected location (harbour) ○ potential distance from port ○ environmental conditions at prospective type of site ○ identifiable Health, Safety and Environment (HSE) risks
Stage 1 – Concept development	• Evaluation of the Maintainability characteristics of the technology, including: ○ component OEM maintenance guidance/recommendations ○ access restrictions for device (water depth and installation type) ○ likely accessibility, modularity and transportability of components and subsystems ○ suitability for maintenance operations on-site or in a protected location (harbour) ○ potential distance from port ○ environmental conditions at prospective type of site ○ identifiable Health, Safety and Environment (HSE) risks • Development of a high-level O&M process including likely planned maintenance activities in response to: ○ the identification of key failure modes based on experience from wider application of similar technology and assessment of which parts of the system will require maintenance, can be repaired or require replacement ○ HSE processes arising from identification of HSE risks

Stage	Stage Activities

Stage 2 – Design optimisation	• Optimisation of the technology in response to the fundamental Maintainability characteristics, including:
	  ○ access restrictions for device (water depth and installation type)
	  ○ likely accessibility, modularity and transportability of components and subsystems
	  ○ suitability for maintenance operations on-site or in a protected location (harbour)
	  ○ potential distance from port
	  ○ environmental conditions at intended type of site
	• Development of an initial O&M model including:
	  ○ failure modes from FMEA
	  ○ Simulation of:
	  ▪ environmental conditions
	  ▪ vessel and other infrastructure availability, capability and cost data
	  ▪ duration of maintenance actions, and estimates of component replacement cost and availability
	  ▪ marine operations limitations and restrictions
	  ○ HSE processes arising from identification of HSE risks
	• Use of O&M model to guide system design optimisation

Stage 3 – Scaled demonstration	• Development of a complete O&M model and an O&M plan in preparation for open-water deployment, incorporating:
	  ○ failure modes from FMEA
	  ○ information from technology fabrication
	  ○ simulation of:
	  ▪ environmental conditions
	  ▪ vessel and other infrastructure availability, capability and cost data
	  ▪ marine operations limitations and restrictions
	  ▪ planned and unplanned maintenance cost and repair times
	  ○ Definition of HSE actions to be implemented
	• Use of O&M model to guide O&M plan optimisation by identifying the failure modes with greatest impact on cost and availability
	• Practical demonstration of the O&M plan through operation and maintenance actions during an open-water test programme at sufficient scale to represent commercial-scale marine operations. This is likely to be 1:6 - 1:2 scale.

Stage 4 – Commercial-scale single	• Update and any required extension of the O&M model and O&M plan in preparation for open-water deployment incorporating:
	  ○ failure modes from FMEA based on commercial-scale technology design and system breakdown
	  ○ information from technology fabrication and Stage 3 deployment

Stage	Stage Activities
device demonstration	○ simulation of: ▪ environmental conditions ▪ vessel and other infrastructure availability, capability and cost data ▪ marine operations limitations and restrictions ▪ planned and unplanned maintenance cost and repair times ▪ resulting waiting times, predicted O&M activity and system availability • Definition of HSE actions to be implemented in the O&M plan • Use of O&M model to guide O&M plan optimisation by identifying the failure modes with greatest impact on cost and availability • Practical demonstration of the O&M plan through operation and maintenance actions during a 12-month open-water test programme. Evidence must be gained to validate the model inputs and assumptions.
Stage 5 – Commercial-scale array demonstration	• Update and any required extension of the O&M model and O&M plan in preparation for open-water deployment incorporating: ○ extension to represent array deployment and infrastructure ○ failure modes from array-level FMEA based on commercial-scale technology design and system breakdown ○ information from technology fabrication and Stage 4 deployment ○ planned and unplanned maintenance cost and repair time ○ simulation of: ▪ environmental conditions ▪ vessel and other infrastructure availability, capability and cost data ▪ marine operations limitations and restrictions ▪ planned and unplanned maintenance cost and repair times ▪ resulting waiting times, predicted O&M activity and system availability ▪ planned and unplanned maintenance cost and repair times • Definition of HSE actions to be implemented in the O&M plan • Use of O&M model to guide O&M plan optimisation by highlighting key failure modes • Practical demonstration of the O&M plan through operation and maintenance actions during a 2-year open-water test programme. Evidence must be gained to validate the model inputs and assumptions • Continuous update of the O&M model and plan based on open-water deployment experience

8.6 INSTALLABILITY

TABLE 8-6: STAGE ACTIVITIES SUPPORTING CHARACTERISATION AND EVALUATION OF INSTALLABILITY (WAVE AND TIDAL STREAM)

Stage	Stage Activities
Stage 0 – Concept creation	• Definition of technology and market requirements and challenges associated with Installability (the problem statement) • Selection of high-level Installability targets appropriate to the technology • Evaluation of the Installability of comparable technologies in similar applications and environmental conditions. This evaluation should be based on the conceptual understanding of the technology and identification of physical and functional characteristics that impact Installability, including: ○ environmental conditions at prospective type of site ○ water depth at prospective type of site ○ device accessibility (e.g. surface piercing/ floating/ bottom mounted) ○ installation vessel requirements ○ complexity of marine operations ○ identifiable Health, Safety and Environment (HSE) risks
Stage 1 – Concept development	• Concept characterisation of Installability characteristics of the technology, including: ○ environmental conditions at prospective type of site ○ water depth at prospective type of site ○ device accessibility (e.g. surface piercing/ floating/ bottom mounted) ○ installation vessel requirements and transit speed ○ complexity of marine operations ○ identifiable Health, Safety and Environment (HSE) risks • Development of a high-level installation plan based on the characteristics and scale of the technology. This plan may take the form of a simple storyboard and must consider the HSE implications of the process
Stage 2 – Design optimisation	• Optimisation of fundamental Installability characteristics and development of technical solutions to maximise Installability • Evaluation of HSE implications of the installation plan • Development of a detailed installation plan including: ○ vessel requirements (installation vessel, support vessel, ROV) ○ indication of vessel and equipment costs ○ consideration of marine operations complexity ○ definition of desirable installation environmental conditions

Stage	Stage Activities
	○ detailed storyboard defining the installation process, including on-shore transportation, launch method, transit to deployment site, connection (mooring and electrical) and commissioning
Stage 3 – Scaled demonstration	• Development of a complete installation plan in preparation for open-water deployment, including: ○ port requirements definition and port selection ○ launch method definition ○ specification of vessels (installation vessel, support vessel, ROV) with detailed evaluation of vessel and equipment costs ○ detailed assessment of marine operations feasibility with respect to technology characteristics, specific site conditions, vessel/operator capability and expected environmental conditions ○ specification of vessel routes from port to deployment site ○ connection and commissioning process ○ definition of HSE actions to be implemented in the installation plan • Engagement of competent persons to complete independent review of installation and operations plan • Practical demonstration of the installation plan through installation (and any retrievals/re-installations) during an open-water test programme at sufficient scale and size to represent commercial-scale marine operations. This is likely to be 1:6 - 1:2 scale
Stage 4 – Commercial-scale single device demonstration	• Adaptation and extension of the installation plan in preparation for commercial-scale open-water deployment, including: ○ port requirements definition and port selection ○ launch method definition ○ specification of vessels (installation vessel, support vessel, ROV) with detailed evaluation of vessel and equipment costs ○ detailed assessment of marine operations feasibility with respect to technology characteristics, specific site conditions, vessel/operator capability and expected environmental conditions ○ specification of vessel routes from port to deployment site ○ connection and commissioning process ○ definition of HSE actions • Engagement of external experts to complete independent review of installation plan • Practical demonstration of the installation plan through installation (and any retrievals/re-installations) during an open-water test programme of at least 12-month duration, gaining evidence to validate the plan's inputs and assumptions

8.7 AFFORDABILITY

TABLE 8-7: STAGE ACTIVITIES SUPPORTING CHARACTERISATION AND EVALUATION OF AFFORDABILITY (WAVE AND TIDAL STREAM)

Stage	Stage Activities
Stage 0 – Concept creation	• Definition of technology and market requirements and challenges associated with Affordability (the problem statement) • Selection of high-level Affordability targets appropriate to the technology • Basic estimates of CAPEX based on fundamental relationships between physical and economic parameters (e.g. material cost) and cost of similar technologies (e.g. PTO or other subsystem) • Use of typical project and technology-level cost breakdowns from wider sector experience to extrapolate costs for unknown system elements
Stage 1 – Concept development	• High-level CAPEX evaluation of key components of the commercial-scale technology • Development of an initial concept subsystem cost breakdown • Use of typical system and project cost breakdowns from wider sector experience to complete cost evaluation • Integration of high-level CAPEX and OPEX evaluations with energy yield calculated by appropriate numerical models to calculate LCOE in a proposed commercial site

Stage 2 – Design optimisation	• Development of a Levelised Cost of Energy (LCOE) model integrating:
	  ○ initial CAPEX of key components of the commercial-scale technology under development
	  ○ typical system and project cost breakdowns from wider sector experience to provide cost evaluation of other systems or subsystems
	  ○ O&M model and FMEA to evaluate OPEX and availability
	  ○ Energy yield evaluated using appropriate numerical models
	• Application of suitable learning rates and economies-of-scale to evaluate LCOE for:
	  ○ the first-of-a-kind commercial-scale prototype (Stage 4)
	  ○ a "mature sector" technology (e.g. a 10MW array at 1GW global installed capacity)

Stage 3 – Scaled demonstration	• With further knowledge gained from wider Stage 3 activities, development of a Levelised Cost of Energy (LCOE) model integrating: ○ detailed CAPEX of key components of the commercial-scale technology under development

Stage	Stage Activities
	○ typical system and project cost breakdowns from wider sector experience to provide cost evaluation of other systems or subsystems ○ Further developed O&M model and FMEA to evaluate OPEX and availability ○ Energy yield evaluated using appropriate validated numerical models • With further knowledge gained from wider Stage 3 activities, application of suitable learning rates and economies-of-scale to evaluate LCOE for: ○ the first-of-a-kind commercial-scale prototype (Stage 4) ○ a "mature sector" technology in a 10MW array at 1GW global installed capacity
Stage 4 – Commercial-scale single device demonstration	• Completion of a system-breakdown for the commercial-scale technology including all systems and subsystems • Finalisation of a Levelised Cost of Energy (LCOE) model integrating: ○ Detailed costing of the as-built commercial scale device to evaluate CAPEX ○ Refined O&M, FMEA, power capture and conversion modelling to evaluate OPEX, availability and energy yield ○ Evaluation of array infrastructure, balance of plant, learning rates, operational and finance costs • Application of suitable learning rates and economies-of-scale to evaluate LCOE for a "mature sector" technology in a 10MW array at 1GW global installed capacity
Stage 5 – Commercial-scale array demonstration	• Finalisation of system-breakdown for optimised commercial-scale technology including all systems, subsystems and array infrastructure • Finalisation of a Levelised Cost of Energy (LCOE) model integrating ○ Detailed costing of the as-built commercial-scale array system-breakdown to evaluate CAPEX ○ Refined O&M, FMEA, power capture and conversion modelling to evaluate OPEX, availability and energy yield • Application of suitable learning rates and economies-of-scale to evaluate LCOE for a "mature sector" technology in a 10MW array at 1GW global installed capacity

ANNEX III: SOFTWARE EVALUATION FORM – STANDALONE VERSION

Tool – Module: Stage Gate Design Tool

Name (user)	
Company	
Date	Pick a delivery date

Instructions

Numeric assessment

Please rate each field in the tables using a scale from 1 to 5, where 1 represents the most negative assessment and 5 the most positive one.

Strongly disagree	Disagree	Undecided	Agree	Strongly Agree
(1)	(2)	(3)	(4)	(5)

Qualitative assessment

Please use the box in each section to add comments, overall experience, or other points that may be useful to record.

1. USABILITY

This section aims to assess the high-level software experience. A Study is a design case of an ocean energy technology that can be independently managed in DTOceanPlus.

ID	Statement	Rating
1.1	The software is intuitive and easy to use in general	[Select]
1.2	It is easy to create and delete a Study	[Select]
1.3	It is easy to edit, save and export a Study	[Select]
1.4	The process of inputting data is clear and efficient	[Select]
1.5	Results are meaningful, easy to interpret and use	[Select]
1.6	I could complete the process without errors	[Select]
1.7	I am satisfied with the overall speed of computation	[Select]
1.8	The software can be run from my computer without any issue	[Select]
1.9	The training sessions and documentation are useful for learning how to use the software	[Select]

Comments

[Please add other key points and comments]

2. USER-FRIENDLINESS

This section aims to assess the user interface of the software.

ID	Statement	Rating
2.1	The user interface is simple, easy to navigate and well-organised	[Select]
2.2	The user interface looks professional	[Select]
2.3	It responds promptly to user actions (inputs, selections, clicks, …)	[Select]
2.4	It provides the user with enough help, indications and/or guidance throughout each process	[Select]
2.5	The meaning of each data input/user selection is clear	[Select]
2.6	The meaning of each data output is clear	[Select]
2.7	Visualisation of results is clear and informative	[Select]
2.8	The user can add further information to the Study through the interface	[Select]

Comments

[Please add other key points and comments]

3. PERFORMANCE AND ACCURACY

This section aims to assess the quality of results in terms of accuracy, robustness, and performance per software Feature. A Feature is a main functionality of the software that adds value to the user.

a → Feature Tested: [Insert description of feature]

ID	Statement	Rating
3.a.1	Results are robust and not sensitive to small changes of inputs	[Select]
3.a.2	Results are credible and trustworthy for the audience	[Select]
3.a.3	The accuracy of results is acceptable considering the granularity/complexity of data inputs used	[Select]
3.a.4	The accuracy of results corresponds to the user expectation for the stage of technology maturity	[Select]
3.a.5	The computational time is adequate for the level of accuracy provided	[Select]
3.a.6	The software did not suffer from any sort of data shortage/lack of memory during the test	[Select]
3.a.7	The software can handle errors without crashing	[Select]

Comments

[Please add other key points and comments]

b → Feature Tested: [Insert description of feature]

ID	Statement	Rating
3.b.1	Results are robust and not sensitive to small changes of inputs	[Select]
3.b.2	Results are credible and trustworthy for the audience	[Select]
3.b.3	The accuracy of results is acceptable considering the granularity/complexity of data inputs used	[Select]
3.b.4	The accuracy of results corresponds to the user expectation for the stage of technology maturity	[Select]
3.b.5	The computational time is adequate for the level of accuracy provided	[Select]
3.b.6	The software did not suffer from any sort of data shortage/lack of memory during the test	[Select]
3.b.7	The software can handle errors without crashing	[Select]

Comments

[Please add other key points and comments]

c → Feature Tested: [Insert description of feature]

ID	Statement	Rating
3.c.1	Results are robust and not sensitive to small changes of inputs	[Select]
3.c.2	Results are credible and trustworthy for the audience	[Select]
3.c.3	The accuracy of results is acceptable considering the granularity/complexity of data inputs used	[Select]
3.c.4	The accuracy of results corresponds to the user expectation for the stage of technology maturity	[Select]
3.c.5	The computational time is adequate for the level of accuracy provided	[Select]
3.c.6	The software did not suffer from any sort of data shortage/lack of memory during the test	[Select]
3.c.7	The software can handle errors without crashing	[Select]

Comments

[Please add other key points and comments]

4. VALUE

This section aims to assess the perceived value to the user.

ID	Statement	Rating
4.1	The software allows the user full control of the design process	[Select]
4.2	It produces results that allow easy comparisons	[Select]
4.3	It provides a large range of alternatives to create/assess technologies	[Select]
4.4	The user is informed about the internal processing (e.g. remaining time, log) and warned about potential inconsistencies	[Select]
4.5	The software meets my expectations in terms of results, graphical options, interaction, and functionality	[Select]
4.6	I would recommend the use of this software	[Select]

Comments

[Please add other key points and comments]

5. GENERAL REMARKS

This section aims to record other qualitative aspects not mentioned above.

[Please add any final remarks]

ANNEX IV: ANONYMOUS FEEDBACK

SCORES

USABILITY

ID	Statement	Response 1	Response 2	Response 3	Response 4	Response 5	Response 6
1.1	The software is intuitive and easy to use in general	4	2	4	5	4	4
1.2	It is easy to create and delete a Study	5	5	4	5	5	5
1.3	It is easy to edit, save and export a Study	5	5	3	5	3	5
1.4	The process of inputting data is clear and efficient	4	3	4	5	2	3
1.5	Results are meaningful, easy to interpret and use	4	2	3	4	4	5
1.6	I could complete the process without errors	4	2	4	4	5	3
1.7	I am satisfied with the overall speed of computation	5	4	4	5	5	4
1.8	The software can be run from my computer without any issue	5	5	5	5	5	5
1.9	The training sessions and documentation are useful for learning how to use the software	4	4	4	5	5	3

USER-FRIENDLINESS

ID	Statement	Response 1	Response 2	Response 3	Response 4	Response 5	Response 6
2.1	The user interface is simple, easy to navigate and well-organised	4	2	3	4	3	5
2.2	The user interface looks professional	4	4	4	2	4	5
2.3	It responds promptly to user actions (inputs, selections, clicks, …)	5	4	5	3	4	5
2.4	It provides the user with enough help, indications and/or guidance throughout each process	4	2	4	5	3	3
2.5	The meaning of each data input/user selection is clear	5	3	4	5	4	5
2.6	The meaning of each data output is clear	4	2	4	5	4	5
2.7	Visualisation of results is clear and informative	5	3	4	4	2	5
2.8	The user can add further information to the Study through the interface	4	3	1	5	3	3

PERFORMANCE AND ACCURACY

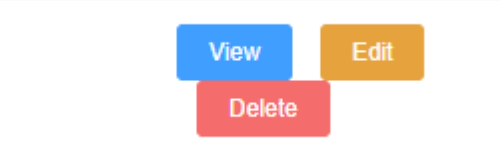
ID	Statement	Response 1	Response 2	Response 3	Response 4	Response 5	Response 6
3.1	Results are robust and not sensitive to small changes of inputs	5	3	4	5	5	4
3.2	Results are credible and trustworthy for the audience	5	3	4	5	4	4
3.3	The accuracy of results is acceptable considering the granularity/complexity of data inputs used	5	3	4	5	5	5
3.4	The accuracy of results corresponds to the user expectation for the stage of technology maturity	5	3	5	4	3	5
3.5	The computational time is adequate for the level of accuracy provided	5	3	3	5	5	5
3.6	The software did not suffer from any sort of data shortage/lack of memory during the test	5	3	5	5	5	5
3.7	The software can handle errors without crashing	4	3	5	5	5	5

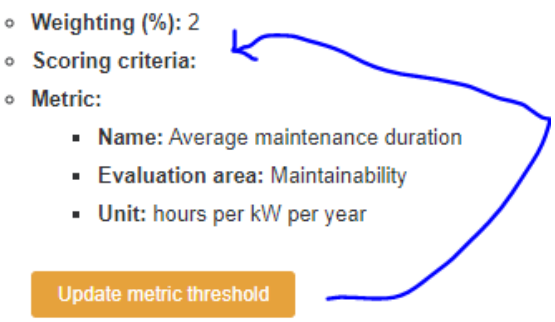
Fully aggregated results have been analysed without differentiating scores between VSs and functionalities. In all cases the average value per statement has been considered.

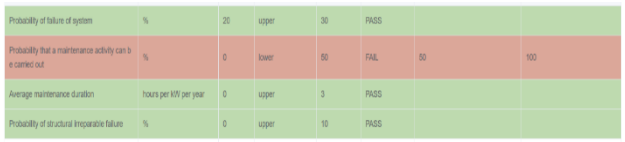
VALUE

ID	Statement	Response 1	Response 2	Response 3	Response 4	Response 5	Response 6
4.1	The software allows the user full control of the design process	4	2	3	3	5	-
4.2	It produces results that allow easy comparisons	5	2	5	5	4	5
4.3	It provides a large range of alternatives to create/assess technologies	4	2	5	4	4	-
4.4	The user is informed about the internal processing (e.g. remaining time, log) and warned about potential inconsistencies	3	3	1	5	2	-
4.5	The software meets my expectations in terms of results, graphical options, interaction, and functionality	5	2	4	4	4	5
4.6	I would recommend the use of this software	5	1	3	4	4	5

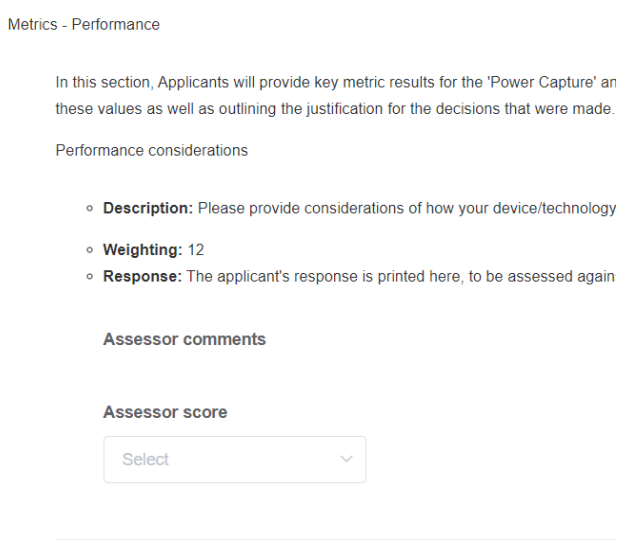
COMMENTS

ID	Feature	Subject	Comments
1	Choosing&Defining Framework	Weightings	The overall SG evaluation is based on a specific weighting of activities/evaluation areas. As thresholds can be edited, shouldn't weightings be editable too?
2	Choosing&Defining Framework	Direction of improvement	When the user quantifies the metrics, the threshold is provided. However, I haven't seen in the GUI whether the direction of improvement is shown as it is later reported in tabular form (upper/lower).
3	Choosing&Defining Framework	Framework objective	When you perform a study by creating a new "SG Study" it is not clear which the objective of the Framework is. You only understand that without selecting one of the existing frameworks, or a newly created one, you cannot save the SG Study. It could be worth to add a very brief explanation both for the SG Study and the Framework, to guide the user.
4	Choosing&Defining Framework	Thresholds	An overview of the available thresholds one can set with an explanation of their use might be useful for the user
5	Choosing&Defining Framework	Thresholds	While fixing the threshold metrics, I don't know which of them are supposed to be upper or lower thresholds./ threshold always the maximum or can be minimum?
6	Choosing&Defining Framework	Framework definition	On the Frameworks dashboard, there should be a short description on the GUI to remind the user of what a framework actually is, for example: "Here you can see detailed descriptions of the activities and evaluation criteria used to assess the 'Stage Gate' of development of an ocean energy technology. The default framework "DTOceanPlus Stage Gate Framework" will be used for Stage Gate studies unless a new framework is created. Create a new framework to assign metric thresholds to evaluation criteria such as X, Y, Z
7	Choosing&Defining Framework	Framework buttons	On the list of frameworks, the buttons shown below are misleading, because by clicking the "view" button, this is really where you view and edit metric thresholds, and the "edit" button is only where you edit the name and description of the framework. Consider changing to "View & Edit", "Rename", "Delete" for all new frameworks, and for the default framework, just "View". 

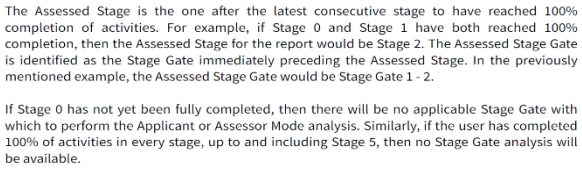
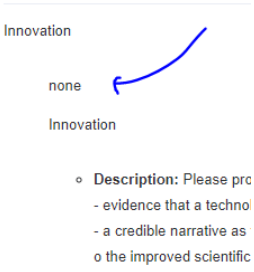
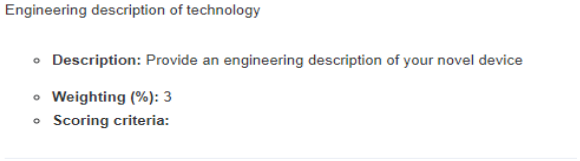
ID	Feature	Subject	Comments
8	Choosing&Defining Framework	Thresholds	Should be able to see the units of threshold in the pop up box, though I guess this is not a problem since the measuring unit is the same of the correspondent metric for which you set the threshold.
9	Choosing&Defining Framework	Thresholds	It would be good to have an overview of which metric thresholds have been changed from the default, and which ones the user is able to set, instead of scrolling through all the "update metric threshold buttons
10	Choosing&Defining Framework	Thresholds	An overview of all the thresholds one can edit for each Stage might be very useful
11	Choosing&Defining Framework	Thresholds	The objective of these thresholds should be stated somewhere: from VC3 it seems they are connected with the threshold success rate, but I didn't manage to obtain something like a visual representation of the activities for Stages 1-2, 2-3, 3-4, 4-5 that had met or not the threshold set.
12	Choosing&Defining Framework	Thresholds	If you update the metric threshold, shouldn't it automatically become the scoring criteria? 
13	Choosing&Defining Framework	Thresholds	Relating to "It is easy to create and delete a study": It may be nice to allow for copying/pasting Frameworks. Thus it would be easy to have multiple values for thresholds
14	Choosing&Defining Framework	Framework buttons	**Same as comment no. 7** Relating to "It is easy to edit, save and export a Study": The Edit button in the Frameworks creation section only allows to edit the Stage Gate Framework name, and not its content as I would expect. The View button is used to view/edit the Frameworks, but I was expecting it to only allow for viewing threshold values.
15	Choosing&Defining Framework	Thresholds	While defining a Framework, it could be interesting to highlight/guide applicants to the remaining thresholds to define (setting thresholds requires to open every single pulldown section, which is not really convenient), or at least ensure it has been seen by the applicant. It is hard, while opening and closing all the pulldown sections, to know where a threshold will need to be defined, which is

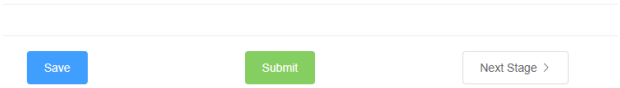
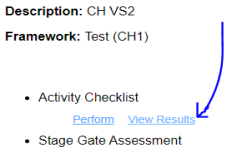
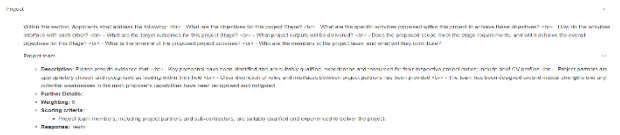
ID	Feature	Subject	Comments
			the main (and maybe only) interest in the Framework definition section.
16	Choosing&Defining Framework	Thresholds	Manipulating a slider could be better than the +/- buttons for thershold setting, adding 1 unit per click. Adapting the steps to the expected values/range of values could be good (1000 unit steps when the input magnitude is expected to be around 50000 for example) ◦ **Metric:** ▪ **Name:** Annual average delivered energy ▪ **Evaluation area:** Power Conversion ▪ **Unit:** kWh **Result** – 25002 +
17	Activity Checklist		The metric results that weren't filled in are being considered as results (PASS or FAIL) but should be considered as an empty field instead of assuming the value "0". 
18	Activity Checklist		Not that clear on the GUI how a one would select clearly the appropriate stage gate. Would be useful to have a map and description so the developer knows how their project relates or equivalated to the DTOcean+ stage gates – there would be clear where to spend the effort and which steps or stages do not need to even be filled in or looked at as they may not be relevant to the stage of the real project and technology readiness.
19	Activity Checklist		When it is about ticking Activities completed or filling the fields for the Stage Gate Assessment : it may be useful to compel the user to tick an "I saw this section" box so that every pulldown section is seen by the user. It is easy to make mistakes and not even notice it when looking at the results
20	Activity Checklist		When Performing the Activity Checklist, it may be interesting to allow the user to directly go to the Stage he wants, instead of requiring to click on "Next Stage" multiple times, when editing an existing study which is only partially filled (maybe this would remove the spirit of the exercise, as it emphasizes on subsequently filling the Stage pages ?).

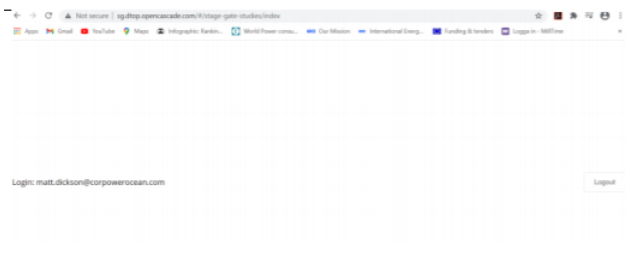
ID	Feature	Subject	Comments
21	Activity Checklist		**Same as comment 2**: It could be useful to reming the user the correspondance between stages and TRL, with a link to definitions, etc...
22	Activity Checklist		Relative to "The accuracy of results corresponds to the user expectation for the stage of technology maturity" - I filled all the Activity Checklist sections, and I expected a more specific response to this question to be given by the software, i.e. when clicking on the "View Results" button, in addition to the 6 charts, I'd have appreciated some kind of recommendations for maybe one or two stage gates the technology is eligible to be assessed against. I would expect the results for this use case to appear in the Activity Checklist Results section of the report. Even if the Assessed Stage and Assessed Stage Gate concepts are explained in the following extract from the generated report, I could not find any mention anywhere else in the document. Thus, the report synthetizes interesting results to the user, but there is no particular guidance to the next steps
23	Activity Checklist		Because the check-lists were so comprehensive, I believe that it is unlikely that every sub-section would be 100% complete by the time we need to move on to the next Stage. So not exactly a 'Gate' which implies full compliance before moving on. Some items in Stage 0 may still be incomplete / unaddressed when the device is in commercial service!
24	Activity Checklist		In many instances the same assessment was required at Stage 0, Stage 1, etc etc so maybe (say) an LCOE model is developed once – at Stage 0. It will be reviewed and refined at subsequent Stages but we couldn't say 'we're at Stage 3 LCOE' so not sure the same question is relevant at every Stage.
25	Applicant Mode	Word limit	For the qualitative responses, there is no word limit to the answer boxes, and the user is not able to input images, so there can be a huge variety of types of responses submitted – maybe this will be difficult for the evaluator to judge.
26	Applicant Mode	Too much information required	It seems to me a lot of input is required, even for a very early stage technology. when it comes to LCOE questions about subsystems – would this be answered for the whole wave energy converter?
27	Applicant Mode	Clarity of stage	When accessing the 'Applicant Mode' to continue performing a study, it is not highlighted which is the last stage you were working on. (e.g. here I had put data on Stage Gate 3-4).
28	Applicant Mode	Metrics	Cost of installation' metric seems vague. Depending on the type of technology being assessed (array / single device), would be good to be able to change the units from kWh to MWh, sometimes one could forget about the conversion in the calculations.

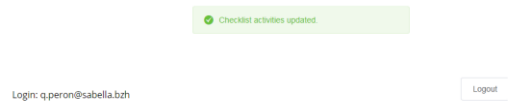
ID	Feature	Subject	Comments
29	Applicant Mode	Metrics	There are no units for Global negative& positive EIA.
30	Applicant Mode	Unclear instructions	Not clear what to input to the tool – a description? An number? How does describing AEP or availability turn into a score? Are you meant to put the score directly in the box? Very unclear.
31	Applicant Mode	Completing questions	When completing the Stage Gate questions: A progression bar, with live update, representing the completion of each subsection (e.g. Stage Gate 1-2 subsection in the Stage Gate Assessment) could be great to better inform the user how much information he entered and how much is still required
32	Applicant Mode	Clarity of stage	Related to: "It provides the user with enough help, indications and/or guidance throughout each process" - It was not really clear what the steps were to follow for the Applicant. I couldn't know if all the Activity Checklist and Stage Gate studies were needed to get results for my particular use case, in what order, etc… It would interesting to have more guidance on the process, depending on the user use case, and – maybe - the technology TRL.
33	Applicant Mode	Viewing results	Related to "Visualisation of results is clear and informative": - It may be useful to highlight that a detailed results view can be accessed through clicking on « Stage i ».
34	Assessor Mode	Assessor comments	At the Assessor Mode, when there is no room for assessor comments, that should not appear (as shown in the image below): 
35	Assessor Mode	Scoring criteria	Where does it explain the scoring criteria? Could also be shown in the GUI to remind assessor how the scoring works.
36	Assessor Mode	Assessor comments	Not able to input assessor comments

ID	Feature	Subject	Comments
37	Compare Studies	Study comparison error	The Study Comparison is not very intuitive because the fields don't look possible to be selected (because they are showed in light grey), then the results seem to be empty (because first we need to click in one of the options available):
38	Compare Studies	Study comparison	The study comparison should be possible to save in the tool./ Only by selecting the studies from the SG study list is clear that the studies will be added to the Comparison list to be compared.
39	Stage Gate Report	Overall style of report	Change from a DTO+ deliverable to a DTO+ "branded" report Change the title to the name of the SG report Remove EU flag from every page Remove contact's name from end of document Change tense to past tense/ or make more generic (I.e. remove "Shall") Put in the Introduction which sections are included in the report Take away colour as it may be printed by users in Black and White
40	Stage Gate Report	Make clear who is contributed to each section	Change "response" to "applicant response" Make clear who wrote each section: Standard report text could be greyed out – or could have 3 colours: Dark blue, medium blue, light blue for 'Standard text', 'applicant input', 'assessor input'.
41	Stage Gate Report	Extra information	We want the report to be understandable by anyone - we will explain all terms and technical language in footnotes/ Appendix
42	Stage Gate Report	Thresholds	It needs to be clear what is an upper threshold and what is a lower threshold A few inconsistencies in units
43	Stage Gate Report	Graphs	Graphs need to be more concise; take away chart title. Don't need both intro and chart title. Merge average and weighted average onto one chart
44	Stage Gate Report	Format	Right align numbers in tables inconsistent use/spacing of hyphens Inconsistent CapEx/CAPEX Change lists to tables Number headings If there are 3 levels of bullet points, change the top level to a level 3 heading e.g. Do this on page 4
45	Stage Gate Report	Specific content comments	Page 5: typo with "maintenance operations" under Installability LOW/ Med / high doesn't make sense LCOE change to cost model O&M plan not developed before O&M model? Study details could be a table (page 2) "Outstanding activities (page 4): Maybe not a table. Particularly if different responses will have different numbers of outstanding activities. If as many things are outstanding as shown here, I don't think a table will help you. "

ID	Feature	Subject	Comments
			Could work well. It would be the same every time, so I'd imagine it'd be easier to format how you'd like to see it. My main comment would be that the developers response blends into the question info. I'd change this around a bit regardless of it becoming a table or staying like this (see example on Q1) How will we manage the TRR? Can we check if it's Technology Risk Register or Technical Risk Register? List the causes in the Improvement areas and then the areas they refer to
46	Stage Gate Report	Wording	the report provides a very good overview of the Stage Gate Study performed. There are some sentences which are not very clear to me, for example:  The Assessed Stage is the one after the latest consecutive stage to have reached 100% completion of activities. For example, if Stage 0 and Stage 1 have both reached 100% completion, then the Assessed Stage for the report would be Stage 2. The Assessed Stage Gate is identified as the Stage Gate immediately preceding the Assessed Stage. In the previously mentioned example, the Assessed Stage Gate would be Stage Gate 1 - 2. If Stage 0 has not yet been fully completed, then there will be no applicable Stage Gate with which to perform the Applicant or Assessor Mode analysis. Similarly, if the user has completed 100% of activities in every stage, up to and including Stage 5, then no Stage Gate analysis will be available.
47	Stage Gate Report	General	From the 1st one it seems that the user cannot choose the Stage for which he wants to download the report, but in fact he can.
48	Stage Gate Report	Report generation	Before generating a report, I didn't find it clear what it meant « the Stage to use in the analysis ». More guidance on what the analysis will do and what it changes to select a Stage (even if we better understand once we read the report) would be great.
49	Improvement areas	Improvement areas suggestion	It would be more user-friendly to have between brackets the subcategories, for each area, which lack of information.
50	General comments	Error in text	In Framework Stage Gate 0-1, there is some extra "none" txt :  Innovation none Innovation ◦ **Description:** Please pro - evidence that a techno - a credible narrative as o the improved scientific
51	General comments	Missing text	In Framework SG 1-2, missing scoring criteria:  Engineering description of technology ◦ **Description:** Provide an engineering description of your novel device ◦ **Weighting (%):** 3 ◦ **Scoring criteria:**

ID	Feature	Subject	Comments
52	General comments	Tool crashing	The tool breaks after some actions: Creating a new Stage Gate Study; Submitting the activity checklist inputs.
53	General comments	Refreshing a study	When one saves (and closes) a SG study, when it is reopened the user should have the possibility to start from the latest stage he completed.
54	General comments	Clicking next stage	When you click 'next Stage' (shown below) it would be more user friendly to pop up to the top of the next page to enter the first input, instead of scrolling back up to the top of the page: 
55	General comments	Clicking next stage	Once the checklist was complete and 'Submit' was pressed, it took quite long to generate the output, then it doesn't automatically go to results - instead I had to go back to page (shown below) and click 'View results'. 
56	General comments	Error in text	While viewing the results, the appearance of the description of some metrics is strange: 
57	General comments	Tool crashing	"I wasn't able to get the threshold success rate" - sometimes, not all the time
58	General comments	Tool crashing	I pressed "submit" before I pressed "save" and lost all the responses. A second time the response results weren't showing, even after pressing 'save' and 'sumbit'.
59	General comments	Tool crashing	When clicking on "Submit" for any action, it works but it shows a blank page, a refresh of the window is required to continue. After refreshing, we can see that the action is completed
60	General comments	Style	Improving the design of the website to be more professional and intuitive.
61	General comments	Tool crashing	When you make a new entry from the start screen you get taken to a dead end (see below figure) and is not clear what to do next to get into the actual verification tool. You have to click "log out" to get back to the home screen which is not so intuitive.

ID	Feature	Subject	Comments
			
62	General comments	Clarity of GUI	Not enough guidance notes on the GUI or visual clues for what to do – the trining slides have been good and made things more clear but the GUI currently does not have the same clarity of direction or give the user a good overview of what to do, how data is treated, what data is required
63	General comments	n/a	**Industrial partner unable to share data:** Therefore a reviewer will have nothing to review, or the information will be so high level that a proper assessment of the technology cannot be made (which one can do with the full CPO business plan and technology road map as an example – which is shared with NDA to potential partners and customers including project developers)
64	General comments	Tool crashing	I think I completed the process without errors, but the whole process was not really clear. It may have been a choice from the developers of the tool, but to my opinion, in general, the user has to much freedom in the actions he can do (i.e. not enough guidance on what he should be doing for his particular use case, even if D4.2 is a really important source of information, but not everyone will read every tool related documentations).
65	General comments	Clarity of GUI	Related to: "The training sessions and documentation are useful for learning how to use the software": As mentioned during the 1st training session on SG Tool, what is a big complexity for new users is that it is not clear what is the concept behind each word such as Framework, Activity Category, etc… Reading D4.2, especially Section 2 and 3, was really interesting to quickly get into the SG Tool. Maybe selected extracts from this report copied to relevant sections would significantly save time to the users.

ID	Feature	Subject	Comments
66	General comments	Tool crashing	Related to "The user interface is simple, easy to navigate and well-organised" - Whenever clicking on "Submit", I had the following in my window, and could not refresh the page, which would lead to a blank page (I am using Chrome) : 
67	General comments	Style	A "Close all" button to close every pulldown sections could be useful
68	General comments	Tool crashing	The leftward arrow (previous page) button on Chrome leads to blank pages, e.g. when clicking on Perform, in a Stage Gate study (maybe not of particular interest, if the software is not intended to be used on a navigator), the "Go Back" is sometimes unavoidable
69	General comments	Error in text	**Same as comment 1**: Some sections with the "none" term in the Activity Checklist and Stage Gate Assessment pages, as well as empty areas for "Further Detail: "
70	General comments	Clarity of GUI	**Same as comment 16**: For the user who doesn't have time to read D4.2, it could be interesting to explain what the Framework is (i.e. the place where the user define if a threshold is to be used and, its value), which took me some time to understand (why to have this many pulldown sections for this few thresholds ?). This point is well explained in Section 2.3 from D4.2.C36
71	General comments	Clarity of GUI	It could be interesting to add that Activity Category and Evaluation Area are two visions of the exact same lists of items.
72	General comments	Clarity of the GUI	The stage gate assessment should be proposed by the tool e.g. If stage activities for stages 0 and 1 have been completed, the tool should inform the user that stage gate 1-2 should be completed
73	General comments	n/a	Even if results were not directly ready to exploit in the way I expected for this use case, the checklist is a really interesting tool to have, and data generated, and synthesized in the report would be really valuable for technology developers, especially in guiding young companies.
74	General comments	n/a	Referring to "Q 2.8 The user can add further information to the Study through the interface" - Comment is "I wasn't aware that I could add further info - it looked like pre-configured Scorecard or Checklist to me"
75	General comments	n/a	Definitely useful for Funders etc. For Developers (especially early-stage) it provides a good check-list of areas to be worked on, and perhaps a framework to aspire to.

ID	Feature	Subject	Comments
76	General comments	n/a	Many early-stage developers are focussed on the 'invention' and the need to prove the concept, without maybe a good business-plan to drive through to commercial success. This tool could provide a 'roadmap' towards this.
77	General comments	n/a	The tool felt like an assessment exercise for others to review or compare our results.

ANNEX V: FULL TASK LIST

Below is the list of tasks to try and include in the final version of the Stage Gate tool. It has been derived from analysis of the qualitative comments provided in the feedback forms. Tasks are presented in order of priority.

Solution	Number of comments	Priority	Description of issue
Provide guidance and help menus	20	High	There is insufficient guidance and background information provided to new users of the Stage Gate tool. This is a common issue noted several times by each verifier and applies across all functionalities of the tool, showing that this is an issue related to the user experience in general, and not one particular feature. More guidance, help buttons, additional background information and explanatory dialog boxes should be included in the final release of the Stage Gate tool. Definitions of the terminology used within the tool would also be beneficial. Most of the verifiers noted that the training they received, along with previously published documentation (e.g. D4.2) were very useful for gathering this type of information and that this material should be incorporated within the Stage Gate GUI directly. Additionally, links to the tool documentation that is being prepared as part of T4.3 should be included in the GUI itself to provide extra guidance to the user.
Implement latest Framework data	8	High	Inconsistencies and typos have been identified in the underlying framework data presented in the tool. It is particularly important to use a consistent tense in the description of activities and that these descriptions make sense to all the possible users of the tool (e.g. applicants, assessors etc.). The verification highlighted a clear need to review and solve these issues. This task has already begun, as part of the IEA OES Task 12 work that WES is involved in that has since produced a final version of the stage activity data and is currently being incorporated into the tool.
Review metrics and units	8	High	Verifiers have identified inconsistencies in the metrics and units that make up the Stage Gate assessment component of the tool. A review of these is needed. Comments relate to inconsistencies in both metric names and units. The suitability of certain metrics at earlier stages in the framework has been questioned. Several verifiers have noted that "array-level" metrics are requested for the Stage Gates that are supposed to be targeting sub-system and device level technologies. The fact that seemingly identical metrics are requested in multiple Stage Gates has also raised confusion and should be clarified.

Solution	Number of comments	Priority	Description of issue
Refresh required issue	7	High	Most identifiers identified a common bug in the tool where clicking a button brought them to a blank page. The page needed to be refreshed in order to continue using the software. It has been determined that this bug was introduced after deploying the Stage Gate tool the OCC server. This issue seems to have been resolved already, with the latest set of updates, but additional testing should be performed to ensure that this issue has been tackled adequately.
Clarify improvement areas	7	High	More clarification on how the improvement areas are identified is required. Furthermore, several suggestions for improving how the improvement areas are presented have been suggested, including methods for linking the specific failed metrics to the improvement areas. An option to show the improvement areas in a tabular format has also been proposed.
Recommended report styling	5	High	Several suggestions have been made on how to improve the style and consistency of the Stage Gate report. These changes will be added in future versions of the tool.
Missing scoring criterion	5	High	Some of the questions in the Stage Gate framework do not have associated scoring criteria. This means that there are no corresponding boxes for assessors to input their comments when using the Assessor Mode. Each question must be assigned a set of scoring criteria, or else a method for accepting a general assessor comment, independent of the scoring criteria, must be introduced.
Revamp collapse components	5	High	While the effort to avoid displaying massive amount of text at once has been appreciated by several verifiers, there is a worry that there are too many collapse/expand sections in the tool, and this will require too much clicking by the user. Need to consider ways of improving the user experience in this regard. For example, it has been suggested to make better use of tables. Additional suggestions have included, "Collapse all/Expand all" buttons, adding check boxes to entire activity categories or evaluation areas and adding a live "progression bar" to show how much of a Stage Gate assessment has been completed by the user. All of these options should be considered, along with other ideas on how to improve the UX of the Stage Gate tool.
Clarify authorship of sections	5	High	In the PDF Stage Gate report, many have remarked that it is unclear as to who is the author of various components of the report. For example, it is unclear as to which section of the report is the description of the question, and which is the user's response. Several suggestions have been made for how to ensure clarity in this regard, including the use of tables and delineated sections.

Solution	Number of comments	Priority	Description of issue
Clarify threshold types	4	High	Each location in the tool that refers to metric thresholds should mention whether the threshold is an "upper" or "lower" threshold. This is described in the metric results table but is missing in several other locations.
Improve Stage navigation	4	High	In the activity checklist, the buttons for "Previous Stage", "Save", "Submit" and "Next Stage" have caused confusion. It has been recommended to change this so that users can go directly to the stage that they are concerned with. Tabs or a graphical depiction along the top of the page to navigate through the stages have been proposed as better alternatives.
Single threshold summary/edit page	4	High	Several verifiers mentioned that a single location to view and edit the metric thresholds would be better than individual buttons and pop-up dialog boxes for each metric.
Change lists to tables	4	High	In the Stage Gate report, it has been recommended to convert most of the data presented in the format of bullet-point lists to a tabular format. This would improve clarity and readability.
Improve view/edit buttons	3	Medium	For creating, viewing and editing both a Framework and a Stage Gate study, the labels of the buttons has led to confusion. The "Edit" button in particular, only allows the name and description of the entities to be edited. Many users expected to be able to edit the metric thresholds by pressing the "Edit" button. These buttons and their labels need to be updated to avoid confusion.
Clarify framework feature	3	Medium	In addition to the single page for viewing/editing the metric thresholds, there needs to be clarification on what can be done using the Framework feature. Additionally, it has been suggested that being able to edit the weightings of the questions in each of the Stage Gate assessments would be a beneficial functionality.
Link checklist results to Stage Gate	3	Medium	The evaluation forms identified that there was an insufficient link between the Stages (the activity checklist) and the Stage Gates (the Applicant and Assessor modes). This relationship between these two needs to be clarified. For example, if all Stage 1 activities have been completed, the user should be told explicitly that they are ready to complete Stage Gate 1 - 2.
Combine bar charts	2	Medium	The bar-charts in both the GUI and the PDF report can be simplified. For instance, when describing a single study, the average and weighted average scores can be combined into a single chart. For the graphs in the report, there is no need to include a sub-section title and a graph title.

Solution	Number of comments	Priority	Description of issue
Stage Gate save/submit error	2	Medium	Several have identified a potential bug where the applicant responses are not saved or submitted properly and are lost. This relates to a bug that has already been solved in a more recent version of the tool, but tests need to be performed to ensure that the issue has been solved completely.
Save progress	2	Medium	A couple of comments suggested that it would be beneficial if the tool remembered which Stage/Stage Gate they were working on and this could be pre-loaded if the user leaves the tool and comes back to it at a later date.
Missing descriptions in framework data	2	Medium	Some question categories in the framework data have not been given a description, which leads to "none" being shown in the GUI. A similar occurrence has been noted for certain "Further details" sections. These descriptions need to be added or else a way of hiding the instances of "none" in the GUI needs to be introduced.
Simplify Study Comparison page	2	Medium	The input page for the Study Comparison is overly confusing and needs to be simplified. There is no need for having the "Transfer" component, and this should be changed to a simple list. Additionally, clear instructions should be given that only studies that use the same framework can be compared and that this is the reason for why the desired framework first needs to be chosen.
Improve threshold step size	1	Low	Manipulating a slider could be better than the +/- buttons for threshold setting and inputting metric results, which currently increment in steps of 1. Adapting the steps to the expected values/range of values would be good (1000-unit steps when the input magnitude is expected to be around 50000 for example).
Copy-paste frameworks	1	Low	It may be nice to allow for copying/pasting Frameworks, so that different sets of metric thresholds can be created more easily.
Glossary and/or footnotes	1	Low	Consider adding a glossary or several footnotes to the Stage Gate report to provide additional information and guidance to the user.
Default metric results	1	Low	The metric results that weren't filled in are being considered as results (PASS or FAIL) but should be considered as an empty field instead of assuming the value "0".
Double check text formatting	1	Low	While viewing the results, the appearance of the description of some metrics is strange:
List included sections in intro	1	Low	For the Stage Gate report, put in the Introduction which sections are included in the report (i.e. include the user input checkboxes as a reader guide at the start of the report).
Add word limit to responses	1	Low	For the qualitative responses, there is no word limit to the answer boxes, and the user is not able to input images, so there can be a huge variety of types of responses submitted – maybe this will be difficult for the evaluator to judge.

Solution	Number of comments	Priority	Description of issue
Images in qualitative responses	1	Low	For the qualitative responses, there is no word limit to the answer boxes, and the user is not able to input images, so there can be a huge variety of types of responses submitted – maybe this will be difficult for the evaluator to judge.
Number formatting	1	Low	A suggestion was made to use commas as thousand-separators when formatting numbers (both input numbers and results)
Warn not to use browser navigation	1	Low	One user tried to use the browser navigation buttons (back and forward buttons) to navigate through the tool. A recommendation should be made to avoid using these buttons.
Show rubric in assessor mode	1	Low	The rubric for what the quantitative assessor scores refers to is never presented in the GUI. This should be presented at the top of the Assessor input page and output page.

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