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ENFAIT
ENABLING FUTURE ARRAYS IN TIDAL

Certification & Warranty Framework

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Contents

List of Acronyms

Acronyms	Definition
ADCP	Acoustic Doppler Current Profiler
AEP	Annual Energy Production
BSI	British Standards Institute
ERDF	European Regional Development Fund
EUWTG	European Union Wind Turbine Generator
IEC	International Electrotechnical Commission
LCOE	Levelised Cost of Energy
OEM	Original Equipment Manufacturer
UKAS	United Kingdom Accreditation Service
WTG	Wind Turbine Generator

List of Definitions

Term	Definition
Bankable	In order to successfully attract project finance to cover the cost of a project, as a whole it will have to be "bankable". In broad terms, this means that the risk presented by a project will have to be acceptable to potential lenders at the time when it is aiming to reach financial close. Bankability of a tidal turbine includes both the technology risk, and the degree to which the technology risk is mitigated by commercial measures such as warranties.

1 The Project

1.1 Introduction

A Funding Grant was awarded from the European Union's Horizon 2020 research and innovation programme in January 2017 to demonstrate a grid-connected tidal energy array at a real-world tidal energy site, propelling tidal energy towards competing on a commercial basis with alternative renewable sources of energy generation – Enabling Future Arrays in Tidal (EnFAIT). This was in response to the call *LCE-15-2016: Scaling up in the ocean energy sector to arrays* to generate significant learning through demonstration of cost-effective tidal arrays.

EnFAIT is a cutting-edge tidal energy project and is targeting the achievement of a number of industry firsts. The array, which will be deployed in a phased nature, will culminate in the cumulative deployment of a six-turbine array. In addition to the development of the Nova Innovation NM100 unit, innovative infrastructure solutions will also be tested within the context of the project. This document is produced to outline a framework for the certification of tidal arrays, including roadmaps to type and site certification. It aims to provide an overview of the activities required and a plan to achieving certification of the Nova M100 tidal device.

This report is submitted to satisfy deliverable D3.10 of the EnFAIT project and to be also made available for public dissemination. It is the authors hope that the information contained in this document will help inform future certification and warranty exercises for the nascent marine industry.

1.2 Purpose of this document

The aim of this document is to provide a high-level overview of the process of certification and a general overview of component and system warranties. The report showcases examples and experience from the wind industry to inform EnFAIT project stakeholders of the future potential for both certification and warranties within Nova Innovation's product, and the tidal energy sector in general. The document is also intended to inform the wider marine industry and provide information that is relevant to future marine energy projects. The structure of the document is as follows:

- Section 2 provides a background to the marine energy industry, as well as an introduction to Nova Innovation's tidal turbine technology. It highlights the motivation behind developing a structured certification and warranty framework, providing a brief history of the benefits of certification for the wind industry.
- Section 3 provides specific information on the certification process and aims to set out a plan/roadmap to achieve the required certification.
- Section 4 covers the various warranty requirements for a typical wind project, including component, performance and availability warranties. Similar warranty provision may be a commercial requirement for a bankable tidal energy project.
- Section 5 provides a summary of recommendations and conclusions for Nova Innovation and the EnFAIT project going forward.

2 Motivation and Background

2.1 Marine Energy Technology Background

Tidal stream energy technology developers are pioneering the development of devices to harness the kinetic energy of the ocean tides, with the industry largely focused on horizontal axis turbines. A small number of these technologies are in the early stages of project demonstration, having successfully developed and deployed prototypes and progressed on to multiple unit arrays. Tidal energy converters are not yet cost competitive with more mature renewable energy technologies such as onshore wind; however, demonstrable progress is being made in achieving cost reductions, with further cost reduction expected in the short term.

The turn of the 21st century saw a resurgence in the level of international interest for wave and tidal electricity generation at academic, industrial, and political levels – both in national (UK) and international (EU and global) environments. The EnFAIT project itself is a demonstration of the European Union's (EU) ambition to see large-scale ocean energy as part of a portfolio of clean energy technologies that can unlock carbon dioxide emission reduction and ensure energy security.

The drivers for development, and uncertainties that are characteristic of novel technology such as tidal energy converters, need to be comprehensively understood by technology developers, project developers, investors, and policy makers. There is a requirement to enhance understanding of how to address these technological and commercial uncertainties so that financiers are aware of the risks. This can be achieved by developing strategies to manage technology development and phased device and array deployment.

Early sector interest and activity from large multi-national engineering firms such as Siemens, Rolls Royce, Alstom, Andritz, Naval Energies (formerly DCNS), Lockheed Martin, SKF and ABB provided credibility to a niche market product, but ongoing development from several smaller technology developers and independent companies has been the mainstay of more recent activity in the sector. Moving from single demonstration units to deployment of arrays is bolstering the cumulative data collected on device and subsystem performance, reliability during operation, and the actual operational and maintenance costs.

Ocean energy technology test facilities have allowed the demonstration of individual devices, but there are only a few examples of array deployment. As the tidal industry moves towards array development, approaches are required to evaluate uncertainty and minimise risk. It is important for any nascent industry, on the path to commercialisation, to prove the technology concept. This is primarily achieved through design simulations, testing at scale and in-sea deployments at full scale, as discussed in Section 2.2.

One effective way to enable the impartial and unbiased assessment of technology development is through the development of standards and best-practices.

For the tidal industry, this process has already begun, and certification bodies such as DNV-GL have already published service specifications [and recommended practices] for the certification of tidal turbine arrays. Furthermore, the International Electrotechnical Committee (IEC) has established a specific technical committee (TC 114) to develop international standards for marine energy technologies, including a number of subcommittees and working groups focussed on specific areas of marine energy. The outputs from the IEC and certification bodies will be pivotal in supporting the marine industry towards commercialisation.

2.2 Nova Innovation Technology Background

Nova Innovation's M100 device, the design that constitutes the first three turbines within the EnFAIT array, has been in development since 2014. The M100 is the manifestation of technology development in an iteration of the design from an earlier 30 kW unit deployed in 2014. The M100 has been a significant evolution in the design of Nova Innovation's tidal turbine technology, following the "think big, start small" approach.

Although more than three times the rated power of the first 30 kW turbine, the M100 was only double the cost. Immediate improvements due to efficiencies in fabrication and assembly, and performance improvements through enhanced yield, have allowed the company to demonstrate real cost reductions and improve investor confidence that the technology can operate autonomously and reliably. Furthermore, the real-world operation and maintenance of the three M100 devices demonstrated a trajectory towards further cost reduction optimisation and Levelised Cost of Energy (LCOE) improvement.

The EnFAIT project has allowed the technological evolution of the tidal turbine to continue, resulting in a modular turbine nacelle, optimised foundation and support structures, and improved sub-system integration. Lessons learned from the initial M100 have resulted in a next-generation device that is anticipated to enhance performance and further reduce costs, when compared to the current benchmark. The EnFAIT turbine has already been through a rigorous design review process (Document *reference D3.5 Project Verification Framework*, submitted March 2018 & *D3.6 Design Verification Report*, submitted May 2018), and has followed a Technology Qualification pathway like that identified in the DNV-GL document DNV-RP-203. The consortium is confident that, when deployed, these devices will provide evidence of robust operational performance as they become integrated into the EnFAIT array and generate electricity to the local grid.

The next stage of technology development is to look towards device certification, and component and performance warranties. While, at this stage of development, certification (for example product type certification) is premature, the steps towards achieving design consensus for a serial production model and certification of such require strategic planning – and that is the intent of this framework document.

Both device certification and component and performance warranties are important, as they provide consumer confidence in the product that is being procured. Certification provides physical documented evidence of a third-party (in this case a reputable certification body) approval that a design meets the requirements of relevant national or international standards. The design and development processes are assessed and must meet defined benchmarks in order for the technology under assessment to be considered suitable for certification. The approval relates not only to the final design, but also to the process that is undertaken on the route to certification.

Product warranties provide confidence to investors that the technology will perform to a guaranteed standard, and that any issues experienced within a warranty period will be resolved at no cost to the consumer. Warranties could be applied to the whole system, individual major components, or to the availability of the system. In some cases, a warranty may be related to specific performance aspects of the technology, such as Annual Energy Production (AEP), noise emission (such as is the case within the wind energy sector), or environmental impacts during operation such as biofouling. Warranties are provided by the Original Equipment Manufacturer (OEM) which is underpinned by the creditworthiness of the developer supplying the turbine.

2.3 A Requirement for Robust Technological Development

For any new or emerging technology, it is of fundamental importance that a structured development pathway is followed when attempting to guide the development from concept through to commercialisation. However, the benefits of a structured approach must be balanced with flexibility to allow developers to innovate and iterate their design improvements. Without a structured iterative approach to technology development, the conceptual design and product testing could result in a technology that is unsuitable for the application of technology in the desired environment, or a technology that doesn't meet any of the intended requirements set. Robust technological development will include verification that the novel technology is fit for purpose, and that it meets the specific design, performance and reliability metrics. In the case of the tidal energy sector, the operation of technology in its intended environment is not comprehensively covered by established codes and standards – approaches are needed that consider qualification of the technology in an appropriate manner.

Validation and verification are important aspects of the EnFAIT project and will feature throughout the analysis and testing phases of the project (design verification is already complete). This will provide the independent confirmation that the design, analysis, and testing has been conducted and completed in a high-quality manner, the supporting evidence is traceable, and that the product is - and will remain - fit for service.

2.4 Following in the Footsteps of Wind

Over the last three decades, the wind industry has seen rapid increases in the size and scale of individual turbines and of the largest wind farm projects. In addition to onshore wind development, offshore wind turbines are now opening up even larger unit sizes and rotor diameters. In the early stages of wind turbine generator development, small turbines were built and prototyped by experimenters, but government funded research projects in the UK, Denmark, Germany and the USA focused on multi-megawatt WTGs with large diameter rotors.

Whilst these large industrial machines were designed with correct assumptions in mind (economies of scale favour larger WTGs for lower overall LCOE), there was no ability to iterate cost effectively, or adapt designs to respond to early component or system failures.

Conversely, the commercial wind turbines found their roots through development at small scale (tens of kW) and increased slowly, through better understanding of the resource and incremental improvements in design. Since 1980, the maximum rotor diameter of the largest WTGs has doubled with each passing decade. WTG tower and hub heights have also increased correspondingly. At various stages of the industry's development, each generation of WTG was thought by many to be at the limit of physical scalability, but with advances in design, analysis, material properties, and testing and demonstration, WTGs keep evolving and surpassing previous unit benchmarks. The growth in rotor diameter and tower height has allowed WTGs to capture the stronger winds accessible at higher elevations and has allowed an improvement in unit performance to be demonstrated.

The beginning of the commercial wind industry, an industry that is now prevalent across the globe, started small. After the 'oil crisis' of the late 1970s, countries such as Denmark saw small industrial companies begin to make wind turbines. Initially this was for the domestic Danish market, but it soon began supplying a new, expanding Californian market. Among these players were Vestas, Bonus, Nordtank and Micon, who are all still active today in various guises (Bonus became Siemens Wind Power, now SiemensGamesa (SGRE) and Nordtank and Micon combined to form NEG Micon, which was later acquired by Vestas). The vibrant Californian market encouraged these small Danish players to enter into an export market long before such activity would traditionally have been advisable. American suppliers also emerged, most notably, US Windpower which subsequently became Kenetech and, after a long journey through Enron Wind, became part of General Electric (GE).

Wind benefited from the availability of small-scale experimental projects. Lessons could be learnt from testing technologies at a unit size where the costs and risks could be minimised. Failures are expected as part of the natural development of a new technology, but it is important to learn from these mistakes and make necessary improvements as the design iterates through each development phase. Failures occurred frequently in the early wind industry, the most common components of failure being the blades and gearboxes. As WTGs increased in size and capacity, the industry required coordination and convergence to ensure the devices were designed and constructed safely and reliably. Common standards and certification procedures were developed. In the early days, the certification process was fairly straightforward, however the requirement for standards and certification laid the foundations for important regulation and improvement to technology quality.

The role of the classification and certification bodies, in particular GL in Germany and DNV in Denmark (now part of the same global company, DNV-GL) has been crucial in the provision of sets of rules and design appraisals for the wind industry. In parallel to the development of certification rules, comprehensive standards have been developed under the aegis of the International Electrotechnical Committee (IEC). There is now a series of standard known as IEC 61400 that cover many aspects of wind turbine design, safety and measurement. This collection of international standards is the cornerstone of the wind energy industry and has taken several decades of development to become the comprehensive resource it is now. The wind industry has set a precedent for the nascent marine energy sector to follow. This process is already underway, with the creation of the IEC Technical Committee 114, which is tasked with the preparation of international standards for marine energy.

In order for a wind energy project to be commercially viable and therefore bankable, the WTG technology used must generally acquire what is known as Type Certification. This is one of the main goals of the product certification process and is evidence of a WTG design's capability.

For early tidal technologies, it is important to understand the requirements of Type Certification, as the eventual array deployment of tidal turbines in commercial projects is likely to be analogous to wind farm development and construction. A comparison to the wind energy sector's process is beneficial. However, there are intermediate steps, before Type Certification, that are more relevant to the current stage of tidal turbine development.

Just as bankable wind energy projects must use technology with a valid type certificate, tidal energy projects will one day require similar type certification for the turbine technology type utilised within the project. The goal for tidal energy technology developers is to develop a serial-production-ready model at a commercially attractive price; one that can achieve type certification and truly begin growing the market.

Device developers active in the tidal energy sector need to establish a reputation as a commercially viable technology provider, with demonstrable technology performance, reliability, availability, and economic attractiveness if the sector is to grow into its potential as a valuable contribution to the global energy mix. This move from a niche product to a genuine industry (where technology developers / OEMs have a firm order book and sustainable revenue / cash flow) will involve overcoming hurdles that were present in the development and commercialisation of WTGs:

- Managing risk.
- Developing technology that meets design requirements and is fit for purpose.
- Provision of evidence to satisfy certification objectives.
- Demonstration of continued high performance in safety and reliability.
- Iteration, evolution, performance enhancement and product improvement.

2.5 Future Developments

While the evolution of the wind energy sector has set an important precedent for the tidal energy sector, changes in generation technology and grid infrastructure, and changes in domestic electricity markets have created new requirements that affect the dynamics of the technology development pathway.

Typically, renewable energy resource exists at the fringes of existing grid infrastructure. This is a reversal of the assumptions behind the original formation of the grid – that electricity would be generated at or near to population centres, then exported to the remainder of the network. Connection of variable-output renewable power generation facilities brings challenges in the grid integration. The predictability of generation has always been of importance; however it is inherently more difficult to forecast the output from a renewable energy generator than from a fossil fuel "baseload" power station. With an increasing proportion of the power supply being generated through inherently variable resources, grid stability, and frequency / voltage control, becomes a significant issue that requires more careful attention.

Advances in demand-side management, "smart grid" systems can alter the load or demand profile of a network. This can assist in shifting the electrical demand to a point in time where generation capacity is able to supply the needs (i.e. a period of high wind or tidal generation). This area has received much interest from governments and policy makers, and is likely to receive considerable attention in the near future as decarbonisation of the electrical, heating, and transportation systems takes place.

Supporting technologies that could be used in conjunction with fluctuating resources such as tidal also make the idea of "dispatchable renewable energy" (renewable energy on demand) a more likely reality. Two areas that should be noted in this regard are battery storage (offering the capability to time-shift power generation) and hydrogen (an energy vector that can be readily stored and transported). Both lithium-ion and flow battery technology has seen rapid advancement in recent years, and recent installations have demonstrated performance that exceeded initial expectations. The benefits of battery storage and hydrogen production through electrolysis include:

- Ability to almost instantaneously alter the local load or generation profile by:
  - Charging or discharging the batteries in response to real-time grid events. Response time is within 200ms.
  - Ramping up, or ramping down electrical hydrolysers. Response time is within 800ms for warm-start conditions (where the hydrolyser is already operational and not switching on from cold).
- Offer a dynamic load or generation that can respond to peaks and troughs in demand, and smoothing the daily peaks and troughs in electrical supply and demand profiles.
- Enable the time-shifting of power generation.
- Provide frequency control to support grid stability. This ancillary service has a response time far quicker than that of conventional fossil fuel peaking plants such as open-cycle gas turbines, or hydro power.
- Provide voltage control, and regulation to the flow of active and reactive power.
- Battery Energy Storage Systems can act as a virtual spinning reserve, providing the necessary power injection to a grid network in the event of failure of one of the other power generation components

of the system. This removes the need for conventional fossil fuel spinning reserve, and offers significant fuel and CO_2 emission savings.

The response time of integrated hybrid renewable energy systems could allow for increased penetration of renewable energy into existing grid infrastructure. Furthermore, the enhanced predictability could allow renewable energy systems to act as a form of baseload power, if the battery system and renewable energy array are sized accordingly.

These technological advances could enable a tidal energy array such as that proposed within the EnFAIT project to be integrated with a Battery Energy Storage System to provide rapid system response, and a predictable and reliable power supply. Battery storage, when coupled with a "predictably variable" resource such as tidal, could be seen to offer enhanced grid stability than what was available in the development of early wind farms.

In many markets across the globe, the coupling of renewable generation with battery storage or hydrogen production is likely to increase due to the benefits outlined above, particularly as the cost of these technologies continues to fall. Tidal energy could be particularly well placed in this regard given the location of the resource and its inherent predictability, with the prospect that tidal electricity will support the decarbonisation of heat and transport through the technologies and energy vectors mentioned above.

3 Certification

3.1 Certification Overview

Certification is a process which is designed to confirm that a product or technology is designed, documented, tested and manufactured in conformity with design assumptions, specific standards and other technical requirements. It also demonstrates that it is possible to install, operate and maintain the product or technology in accordance with the design documentation.

A certified product or technology will exhibit a greater level of technological maturity than a product without independent certification. The issuance of certification indicates that the product or technology functions (within specified limits) for its intended application and is generally recognised as a fundamental requirement in the technology selection within renewable energy projects.

The tidal energy sector is analogous in many ways to the wind energy sector. The following types of certification should therefore be considered as applicable to tidal energy converters and arrays in the future, however the standards to which the compliance will be measured and assessed are currently still under development:

- Technology Qualification[1].
- Component Certification.
- Prototype Certification.
- Type Certification.
- Project Certification.

The process through which a specific technology will progress through the available types of certification will be guided by the relevant international standards that have to be met. As these are still under development for the tidal energy sector, the process that certification will follow will also likely evolve to incorporate relevant updates and changes. For information on current international projects addressing this issue in the short-to-medium term, see Section 3.4.1.

3.2 Technology Qualification Process

The technology development undertaken in the EnFAIT project is more appropriately aligned with DNV-GL's "Technology Qualification" process, and this is a robust initial step on the route towards certification. It should be noted, however, that Technology Qualification is not in and of itself certification. Technology Qualification can be considered as the process of providing, within an agreed and acceptable level of uncertainty, the necessary evidence to demonstrate that a technology will function within pre-determined operational limits in accordance with the design specifications.

DNVGL-RP-A203 Technology Qualification aims to provide the industry with a systematic approach to technology qualification, ensuring that the technology functions reliably within specified limits. The basic technology qualification process comprises the following main steps, as shown in Figure 3-1[2]:

[1] Technology Qualification is not a type of certification; however, the process of Technology Qualification is being considered here due to its applicability in the tidal energy sector.
[2] DNVGL-RP-A203 Technology Qualification – Recommended Practice, Edition June 2017

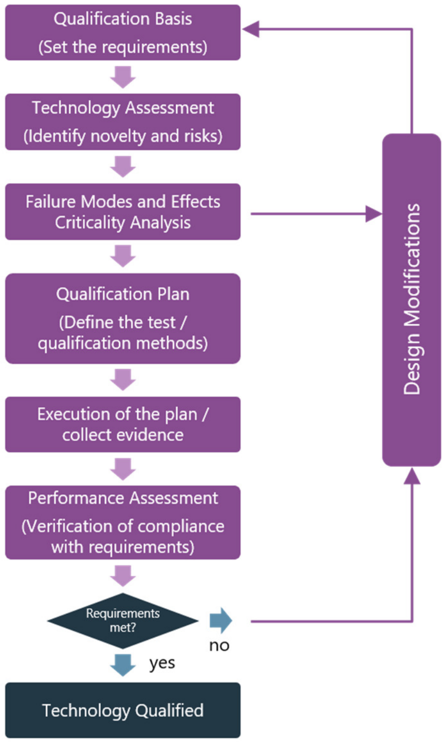

Figure 3-1: Flow diagram overview of the technology qualification process

1. The Qualification Basis - The first step is to identify the technology and define its functions and its intended use. This is typically split into a qualitative description of the expectations of the technology, as well as a description of the performance of the technology, such as reliability, availability and maintenance targets.

2. Technology Assessment - The next step aims to categorise the composition of the technology into its main functions and sub-functions. Through this, the degree of novelty of each of the functions should be identified to focus effort on addressing the key challenges and reducing uncertainties within the novel aspects of the technology.

3. Failure Modes and Effects Criticality Analysis (Threat Assessment) - The objective of this step is to identify relevant failure modes with underlying failure mechanisms for the novel technology elements and assess the associated risks. This involves evaluating the probability of the failure occurring and a prediction of the consequence of the failure. The result is the development of a detailed risk assessment matrix to highlight the most significant threats.

4. Qualification Plan - The technology qualification plan should contain detail of the qualification activities necessary to manage the critical failure modes and address the identified risks.

5. Execution of the Plan - The execution of the plan usually represents the main cost and time expense in the process. It involves, carrying out the necessary activities, collecting and documenting the data, ensuring traceability of the results and determining the performance margin for each failure mode.

6. Performance Assessment - The final step is to measure the success of the technology qualification process by assessing whether the evidence produced meets the requirement of the technology qualification basis. In the final iteration, it is necessary to confirm that the technology meets all its requirements, and both risk and uncertainty have been reduced to acceptable levels.

3.3 Certification Process

A type certificate demonstrates the completeness of the system from design to operation, verifies the correct and safe functioning of the system, with evidence reviewed by a fully independent specialist. It demonstrates that the system is designed to, and operates in accordance with, the technical state of the art. There is a significant reduction in the level of uncertainties within the technology following a type certification process, when compared to the Technology Qualification process. At a high level, the industry standard processes for certification can be broken down into discrete steps, in a similar manner to that of Technology Qualification. The same underpinning process can be used, regardless of whether the certification is component, prototype, type or project specific. The basic technology qualification process comprises the following main steps, as shown in Figure 3-2, and summarised below:

Figure 3-2: Flow diagram overview of the technology certification process

1. Design basis evaluation. The initial step in the certification process will be a review of all key information related to the technology design. This would include the relevant parameters for standard operation, and the survival parameters including fault scenarios and unplanned conditions. The evaluation would ensure that appropriate standards and codes are considered within the design. The design basis must consider conditions that cover all likely operational, and reasonably foreseeable fault loading scenarios for the design, and will confirm that proposed operating limits for the technology make it suitable for deployment in the intended locations.
2. Design evaluation. The design evaluation represents a comprehensive review of the design of the technology, including verification of any design assumptions through testing (e.g. of materials, or of components or sub-systems). The design evaluation will consider all systems and sub-systems within the technology, both individual design, and integrated operation within the wider system, assessing compliance with the required design standard. As part of the design verification process, a technology developer would be expected to provide comprehensive design documentation – including specifications, design calculations, engineering drawings, technical descriptions, and a bill of materials. The design evaluation will also consider the test plan and quality assurance for the proposed system and sub-systems. Control systems and safety systems are given careful consideration due to the essential features that ensure safety from the system and prevent injury or harm to persons from the technology.
3. Manufacturing plan evaluation. The manufacturing evaluation is undertaken to ensure that all products and components used within the system are compliant with the necessary codes and standards, technical specifications of the product, and any design documentation that was reviewed within the design evaluation (in step 2 above). The evaluation will include verification

and quality assurance of all major components supplied to the technology OEM as well as any component fabricated by the OEM themselves.

4. Evaluation of testing and characteristic measurement. This would specifically review the test plan developed as part of the product certification, to ensure that relevant test criterion have been set for the major components and systems, and that the testing subjected to each component and system is commensurate with the load cases outlined in the product specification. This evaluation shall also ensure that evidence is being collected for all testing, with appropriately calibrated data acquisition sensors. Witnessing of specific testing may also feature.

   The verification of technology performance through testing and measurement is an essential requirement in the validation of underpinning analysis such as engineering design calculations, numerical simulations, or computational modelling. Evidence is required to demonstrate and validate that any analysis conducted accurately reflects real-world operation, and can be further used to infer design loads for additional scenarios beyond the test and measurement campaign.

   The precision and accuracy of all sensors and data recording equipment must be carefully established, and any deviation between recorded and actual values be documented appropriately.

5. A transport and installation survey will be undertaken to review the transport and installation procedures for getting the product from the point of manufacture / assembly to the point of deployment. The specific type of transportation requirements (for example road, rail, air, vessel) will be assessed together with the means by which the integrity and safety of the technology will be maintained during the period of transport. An assessment of critical risks during the transportation will be undertaken, together with inspection and monitoring of the transportation process to verify that the transportation procedures are carried out according to transportation plans and industry best practice.

6. The commissioning evaluation involves a visual inspection of major systems comprising the technology (civil, mechanical, electrical, hydraulic) to ensure that functionality of the system is as intended, and that the installation complies with the design basis, technical standards and relevant legislation. Commissioning test witnessing would also be a part of the survey to provide third party verification of the test conditions, compliance with the relevant commissioning test plans and performance criteria, and the results of the testing.

7. A final evaluation of all the requirements of certification would be carried out to ensure that all documentation relevant to the certification process has been completed and issued. The technology undergoing certification will have a cross check carried out to ensure that all relevant certification modules have been carried out on major sub systems and components. The presence of operating manuals, maintenance manuals, and relevant safety documentation shall also be reviewed to ensure that the technology is fit for operation, and that necessary documentation for training operators in its correct usage / maintenance is available.

8. Type Certificate issued. This will be issued when all certification requirements outlined above have been carried out by the certification body, and the certification body are satisfied that all conditions of certification have been met.

9. Periodic in-service inspection would be required to ensure the continued integrity of the technology under consideration. The integrity of the technology over the intended course of its service life shall be monitored to ensure the ongoing credibility of the Prototype, Type, or Project certificate issued.

3.3.1 Component Certification

Component certification generally forms an element of prototype, type, or project certification, with each major technical component of the system being evaluated in turn to ensure compliance with the relevant design standards. Multiple component certificates would be generated within a successful prototype, type, or project certification process.

3.3.2 Prototype Certification

Prototype certification is carried out to de-risk the development and testing of pre-commercial prototypes, where field testing and data collection would be used to inform the final design of a commercial production-ready product.

3.3.3 Type Certification

Type certification is carried out to confirm that the technology type under consideration is designed, documented, manufactured, quality controlled, tested, transported, installed, and maintained in conformance with design specifications, design standards, applicable legislation, and other technical requirements. The type certification process requires that the technology can be demonstrably installed, operated and maintained in accordance with the design documentation. Type certification applies to a series of a given technology, identical in design and manufacture.

3.3.4 Project Certification

Project certification is carried out to ensure that the technology under consideration meets with the specific conditions at the point of use, the project where the technology will be deployed. It is intended that project certification would identify project specific risks for the technology, and would reduce the risk profile of a given project.

3.3.5 Tidal Energy Converter Standards for Compliance

In the absence of a ratified IEC design standard for tidal turbines (analogous to the IEC 61400 series for WTGs), the predominant standard for certification of tidal turbines is considered to be DNVGL-ST-0164. This standard is used widely by technology developers in the development of tidal energy converter prototypes and concepts.

3.4 Certification Bodies

It is important for manufacturers of renewable energy technologies, seeking certification, to acquire certification from an internationally recognised certification body. These certification bodies have typically acquired accreditation from relevant accreditation organisations, which allow them to perform/assist with the certification process. It is essential that the manufactures can offer products that meet the relevant standards and codes of practice. Depending on the project location, acquiring Type Certification from an accredited certification body can be a mandatory requirement.

Table 3-1 outlines some of the certification bodies for renewable energy across the globe, as part of the International electrotechnical Committee Renewable Energy (IECRE) accreditation. There are currently no certification bodies for marine energy, however as the industry develops, it is expected that certification bodies will emerge for marine energy. Within the UK, it is the job of UK Accreditation Service (UKAS) to determine technical competence of organisations, against internationally recognised standards (e.g. ISO/IEC 17025 for testing and calibration laboratories). It should be noted that the list of organisations detailed in Table 3-1 is non-exhaustive. Other organisations, such as Lloyds Register, are not members of IECRE, but are accredited through national accreditation bodies (e.g. UKAS, BSI) to perform certification work.

Table 3-1 – IECRE Renewable Energy Certification Bodies

Certification Body Name	Country	Wind	Solar	Marine
China General Certification Center (CGC)	China	✓	✓	
China Quality Certification Centre	China	✓	✓	
Bureau Veritas Certification France	France	✓		
TÜV Rheinland LGA Products GmbH	Germany		✓	
TÜV Nord Cert GmbH	Germany	✓	✓	
DEWI-OCC Offshore and Certification Centre GmbH	Germany	✓		
DNV GL Renewable Certification Germanischer Lloyd Industrial Services GmbH	Germany	✓		
TÜV Rheinland Industrie Service GmbH	Germany	✓		
TÜV Süd Industrie Service GmbH	Germany	✓		
Tokyo Laboratory Japan Electrical Safety & Environment Technology Laboratories (JET)	Japan		✓	
Certification Entity for Renewable Energies, S.L.	Spain		✓	
UL (US)	USA		✓	

It is noted that the predominant markets emerging for tidal energy include the UK, France, Canada and Indonesia. In the future, many of the certification bodies may expand their services to include tidal turbine certification. This process has already begun for companies such as DNV GL, now offering certification to wave and tidal energy systems. In October 2015, DNV GL published a new service specification '*DNVGL-SE-0163 Certification of tidal turbines and arrays'* which is proving pivotal in assisting the maturing tidal industry.

3.4.1 MET-Certified Project

At present, there are no globally accepted certification schemes for marine energy. However, the Marine Energy Technology-Certified (MET-CERTIFIED) project, is the first steps towards a certification process for marine energy.

MET-CERTIFIED is a European funded project, through the European Regional Development Fund (ERDF) Interreg programme, that aims to develop internationally recognised standards and certification schemes for marine energy. The project brings together certification bodies, test centres, developers and universities in collaboration to aid the development of certification for the sector. The standards are being advanced by applying them to eight test and verification cases across the Interreg 2 Seas Region[3] and the outputs will lead to the development of standards. MET-CERTIFIED is contributing to both conformity assessment and technical committees within the International Electrotechnical Commission (IEC). The expectation is that mature standards and certification schemes will become available over the next few years.

The main partners involved in the project include:

- Dutch Marine Energy Centre (DMEC) - Netherlands
- European Marine Energy Centre (EMEC) – United Kingdom
- Lloyd's Register EMEA – United Kingdom
- Ifremer - France
- Tocardo Solutions - Netherlands
- Perpetuus Tidal Energy Centre – United Kingdom
- Dutch Standardisation Institute (NEN) - Netherlands
- DNV GL – United Kingdom
- West-Flanders Development Agency (POM) - Belgium
- Ghent University – Belgium

The outputs from the project will include mature, verified standards and certification schemes in support of IEC and IECRE developments for marine energy convertors. The EnFAIT Project is currently engaged with the MET-CERTIFIED project and are looking to align the outputs of the certification framework with the deliverables from the MET-CERTIFIED project.

3.5 EnFAIT Certification Framework

It should be noted that the intention of this document is to outline a route map which sets out the scope for certification - the EnFAIT project will not in and of itself result in a certified tidal energy converter. However, the certification processes and procedures outlined herein allow for a framework to be established for future certification of the Nova Innovation M100 tidal energy converter.

All above mentioned forms of certification will be appropriate for the technology once a confirmed series-production model has been reached, and array projects developed utilising this technology. At this stage, the EnFAIT turbine represents an evolution of technology that may not be at the final design iteration that would enter mass production. This will only be determined through successful deployment and operation of the devices and therefore a large proportion the certification process would be premature at this stage.

However, the verification process followed within the EnFAIT project has established much of the design documentation, analysis, testing, reporting, and evidence that could satisfy the requirements of a certification process, and this is the intention of the verification aspects of the EnFAIT project.

In the context of the EnFAIT project, this certification framework is intended to establish the benchmark documentation that can be utilised, updated, or adapted accordingly for future technology iterations, to submit as evidence for a future certification process. This will include:

[3] Interreg 2 Seas is a European Territorial Cooperation Programme covering England, France, the Netherland and Belgium (Flanders)

- Design basis documentation and underpinning environmental factors to be considered within the design (already completed for EnFAIT project).
- Detailed technical specifications for major systems and subsystems within the system design, detailed design documentation to outline the operating parameters of each component and sub-system, and the associated analysis and testing underpinning the design assumptions (already completed for EnFAIT project).
- Assembly and manufacturing documentation, detailed fabrication drawings, manufacturing plan, quality assurance methodology (in progress for EnFAIT project).
- Test plan, including scope of performance testing, individual test requirements, pass/fail criteria, required sensors for measurement and data acquisition, and test report templates (in progress for EnFAIT project).
- Transport methodology and deployment procedure concept finalisation. Transportation plan, detailing transport of partially assembled modules to assembly site, and transportation of assembled unit to point of deployment (in progress for EnFAIT project).
- Commissioning plan outlining the testing that is to take place following assembly, and final installation of the technology, to ensure safe operation according to specifications and relevant standards. Various stages of commissioning should be considered, for example Factory Acceptance Testing (of components and sub-systems), Assembly Acceptance Testing (of the assembled unit, prior to transportation to project site), and Site Acceptance Testing (of the installed system in-situ, a final check prior to initiating the operational phase.
- Operation and maintenance manuals to ensure that trained competent persons can safely operate, and carry out any necessary maintenance on, the system. Operations and maintenance manuals should provide a comprehensive user guide that identifies step-by-step procedures for maintenance activities to be carried out on the system, and operations for major component or module replacement.
- Awareness of other compliance requirements or certification schemes that will be applicable to products sold in domestic, European, or international markets, e.g:
    - CE marking. This process requires the determination of EU directives, and harmonised standards applicable to the product (the Machinery Directive), and the essential requirements that the product must fulfil. If an independent conformity assessment by a notified body[4] is required, this should be conducted as applicable. The product shall be tested to check its conformity with all requirements, directives, and harmonised standards. It must be determined that the product is fit for purpose and does not endanger lives or property. A technical file of all required technical documentation that demonstrates compliance with the above must be maintained. The CE marking can be applied by the OEM, and a declaration of conformity of the product drafted. This is a self-certifying process, carried out by the OEM.
    - The U.S. Department of Labor's Occupational Safety and Health Administration (OSHA) requires various types of products, devices, assemblies, or systems that are used in the workplace, to be tested and certified by a third-party organization designated as a Nationally Recognized Testing Laboratory (NRTL)[5]. Testing has to be completed according

[4] A notified body could include the certification bodies outlined in Section 3.4. A full database of notified bodies available online at http://ec.europa.eu/growth/tools-databases/nando/
[5] Current list of NRTLs available online at https://www.osha.gov/dts/otpca/nrtl/nrtllist.html

to UL (Underwriters Laboratory) testing standards. This is necessary for products being sold into the US or Canadian markets.

- CCC Certification (China Compulsory Certification). For products being sold into the Chinese market.
- Indonesian National Standard (SNI). This certification requires an independent (third–party) product certification to determine the conformity of a product with specified SNI requirements. Compliance will be assessed through initial testing of samples of the product, assessment and observation of the quality management system (and quality assurance procedures used in the manufacturing process), and observation of product testing.

By the conclusion of the EnFAIT project, Nova Innovation and project partners will, through the design, development, and testing of the M100 system, have increased confidence on which aspects of the M100 unit can be considered as mature in design (and could therefore be utilised within a serial production model), and which aspects require further iteration to improve the performance to cost ratio. Established documentation could be traced over future technology iterations and be supplemented by additional evidence as necessary.

No timeline is being set for target certification dates, but the groundwork will have been laid to facilitate an efficient transition to certification when the appropriate time comes. The timing is dependent on the rate of deployment and the amount of installed capacity, which relies heavily on the availability of public support. Typically, the point at which Prototype and Type certification of technology becomes relevant is the point at which iterative evolution of the design has been completed, resulting in a serial-production-ready unit, with firm system and sub-system suppliers identified and specified, where the final design can be considered suitable for commercial sale and operations. Furthermore, any certification process requires a standard to which the product is certified. Presently there is no internationally agreed standard for tidal energy converters, and there is therefore an external condition that requires development and implementation of a defined standard, which is largely outside of the control of OEMs.

4 Warranty

4.1 Warranty Overview

Warranties are designed to protect a customer purchasing a product from failure of its component parts or from underperformance. Well defined warranties can increase customer confidence in a product and encourage investment by reducing their exposure to financial risk. This is particularly relevant when considering investment in unproven or untested technologies or proven technologies in new environments.

Warranties typically seen in wind energy projects which are of relevance to tidal energy cover:

- Under-performance (further discuss in Section 4.2); and
- Lost energy production (further discussed in Section 4.3).

With no market consensus formed in the tidal energy sector at present, it is reasonable to assume that emerging tidal technologies can take guidance on warranties from the wind energy sector and other clean energy technologies, and in particular the warranty provisions offered when these technologies were at similar stages of development.

At this stage in the tidal energy sector, warranty provision can only be based on what the warranty provider is capable of underwriting. Initial warranties may be calendar based, and apply to the assembled system and individual sub-systems and components. Without a demonstrable and diverse track record of product operation, performance warranties will require underwriting from an insurance provider or similar, as it is unlikely that current OEMs will have the financial ability to provide underwriting themselves. The quantitative value of any warranty would need to be based on the confidence levels related to the realistic field performance of the technology. In time, it would be expected that performance warranties would increase in terms of the warranted levels. Confidence in the ability to provide warranties would be enhanced by strong cash flow of the OEM, and demonstrable track record of operational performance.

4.2 Performance Warranties

For the satisfaction of investors, insurers, project developers and so on, it is necessary to measure and analyse the power performance of the turbine(s) in accordance with industry standard methodologies. Currently, the industry guidance for tidal turbine power performance assessment is defined in IEC Technical Specification 62600-200:2013 - Power Performance Assessment. This technical specification is currently undergoing development by the IEC as new knowledge and experience from turbine deployments is gained by the industry.

A power curve describes the power production of a WTG for the horizontal flow speed range from cut-in to cut-out. A typical power curve warranty in the wind industry states that the purchased WTGs are guaranteed to perform to a certain level, defined by the warranted power curve and an annual nominal wind distribution.

In the wind industry power performance warranties are generally part of the turbine supply agreement, and state that the power performance may be verified through a power curve test (PCT) – almost always under IEC Standard 61400-12-1 and, often, under additional Project-specific requirements. A contractually agreed number of ‘test WTGs’ - normally, very roughly, one per ten WTGs, up to a maximum of six test WTGs - within the project will be selected as representative of the whole wind farm. These test WTGs are then tested in order to confirm that the WTGs of the wind farm meet the warranted performance levels.

Testing is be carried out using meteorological (met) masts or LiDAR. Depending on the terrain a site calibration may be required first to define the relationship between wind measured at the met mast and occurring at the test WTG location(s). IEC-compliant PCTs typically have to be performed by an independent and suitably experienced testing laboratory which has been accredited by a national accreditation body to ISO/IEC 17025 to undertake power performance measurements under IEC Standard 61400-12-1. This accreditation requires a strict level of management – of personnel, equipment and documentation – as well as technical proficiency and scientific rigour. PCTs are normally performed as a requirement (sometimes contractual) by financial institutions and/or project developers keen to ascertain the performance of their assets. Contracts generally require PCTs against the warranty to be carried out within the first two years of the project active life (after hand-over).

The power performance test measures the wind conditions and, synchronously, the power production of test turbines, and calculates the measured power curve (MPC). The MPC is then used to determine measured annual energy production (MEP), in accordance with the IEC Standard. The warranted annual energy production (WEP) is derived using the warranted power curve. These calculations give the amount of energy that would be produced in one year under the measured and warranted power curves, using a predefined nominal flow distribution.

These values can then be compared; generally an average of the MEP (MEP_{av}) of all tested turbines is used, plus the average measurement uncertainty (U_{meas}). Where the $MEP_{av} + U_{meas}$ is less than WEP, the power curve test has failed and in this case the seller is usually responsible for complying with its obligations to remedy the power performance in accordance with the agreements set out in the contract. This generally means that the turbine manufacturer will have the opportunity to make changes to the turbine(s) and re-test them.

If $MEP_{av} + U_{meas}$ is equal or greater than the WEP, then it will have been successfully verified that the power performance test of the nominated turbines - and thus all the project turbines - has satisfied the power curve warranty.

If, after all re-measurement tests allowed under the power curve warranty, the turbine(s) are found to underperform to the extent that they fail the warranty, the turbine manufacturer is liable to pay liquidated damages for the loss of earning of the entire Project lifetime to the Project developer.

The current development of industry standard power performance assessments for tidal energy follows, in many ways, the methodologies of the wind industry. Recent developments in the contractual aspect of power performance assessment in the wind industry, which aim to increase the site-representativeness and risk-sharing, are likely to also be important for the tidal energy industry and represent an opportunity for the tidal sector to learn some of the lessons from wind, thereby shortening the route to full maturity.

4.3 Availability Warranties

Availability is the term used in wind energy to define the performance of a WTG against an either time or energy-based target.

Availability figures are used for energy generation estimates which feed into revenue projections as well as forming an important element of performance tracking in service and maintenance agreements, and can take into consideration balance of plant and grid availability in addition to turbine availability.

There are two widely used methods of calculating the availability of WTGs, either time or energy based:

- Time-based availability is a ratio of the time a WTG is technically available to produce energy against the total time in a period under consideration. The total time in a period will typically be reduced by a duration permitted for contractually agreed tasks (i.e. maintenance).

- Energy-based availability calculation is the ratio of energy produced against energy potentially expected to be produced.

Where the availability (either time or energy-based) fails to meet a contractually agreed target the service provider will typically compensate for the lost production for the relevant period, with such assessment typically conducted on an annual basis.

4.4 EnFAIT Warranty Framework

The purpose of this document is not intended to serve as an exhaustive outline of the warranty strategies of a technology OEM, but rather to outline the warranty agreements that facilitate project development in other comparable renewable energy sectors.

The EnFAIT project will not result in the provision of defined or confirmed warranties from OEM or major component suppliers, but it will allow further knowledge in the level of warranty that could be provided in future iterations of the technology, based on real-world system performance.

Performance based targets have been set as project objectives, and the data produced within the EnFAIT project will allow for:

- Component wear rates to be determined, and an estimation on consumed life to be put forward (informing potential future component warranties).
- Availability data for the turbine, based on real-world operation (informing availability warranties and guarantees).
- Reliability data for system and sub-systems, based on real world operation (informing availability warranties and guarantees).
- Performance data and verified power curve (informing performance warranties and guarantees).

While formal warranty provisions will not be defined in the EnFAIT project, the project will facilitate the collection of the underpinning data on which these warranties will be based. The warranty framework therefore rests upon the collection of robust data of a sufficient resolution to enable commercial teams within relevant organisations to make decisions on product warranty offerings.

No timeline is being set for target warranty provision, but the groundwork will have been laid to facilitate an efficient benchmark level to be set for initial product warranties that can be offered to the developers of commercial projects. For a typical wind energy project, the turbine certification is completed for a specific turbine, irrespective of the project. The warranty framework is subsequently agreed on a project by project basis. This will be important to consider for tidal developers when considering the advancement of the turbine technology, as well as the deployment and development of individual projects, across the world. This process is outlined and discussed further in the following concluding section.

5 Conclusion

This document has presented an overview of the technology certification process, and an introduction to warranty provision in commercial clean energy projects. These serve as an example as to what may be expected of tidal energy technologies when commercial tidal stream energy projects are a bankable reality.

While no definitive warranty or certification obligations are expected from the outcome of the EnFAIT project, the underpinning data collected during the course of the project, the evidence prepared and presented as part of project deliverables, and the experience gained by each of the companies involved, will serve as a strong baseline on which to base both product warranties / guarantees, and a future certification campaign. The EnFAIT project is therefore a significant step in the right direction towards achieving these end goals.

It would be expected that, once a final serial-production-ready design has been reached, product certification should take place (whilst acknowledging that there are some external factors that will determine the timescales associated with the major milestones). This requires the implementation of an internationally agreed standard, on which to certify against. Certification provides confidence that design, operation and performance are in line with technical product specifications.

Whilst warranties will provide commercial comfort to project developers, the ability to underwrite warranties is more important than the confidence in being able to set a warranty on performance attributes. Given the financial position of most OEMs within the tidal energy sector, it is not envisaged that warranties will be viable for the early projects. Therefore, a certified product can provide some comfort in the design rigour, and would be recommended prior to seeking to underwrite warranties.

Early warranties will provide some confidence to project developers and customers, but there should be an expectation that early products / projects carry higher risk, and revenue inherently cannot be protected in the same way as exists within the current wind energy sector. Setting a quantitative value for performance warranties should be based on evidence from early array deployments, giving confidence that devices can exceed warranted levels.

While not intended as a detailed step by step guide, a routemap to certification is provided in Figure 5-1. This process will be monitored throughout the EnFAIT project and will be updated as necessary through the technology development pathway.

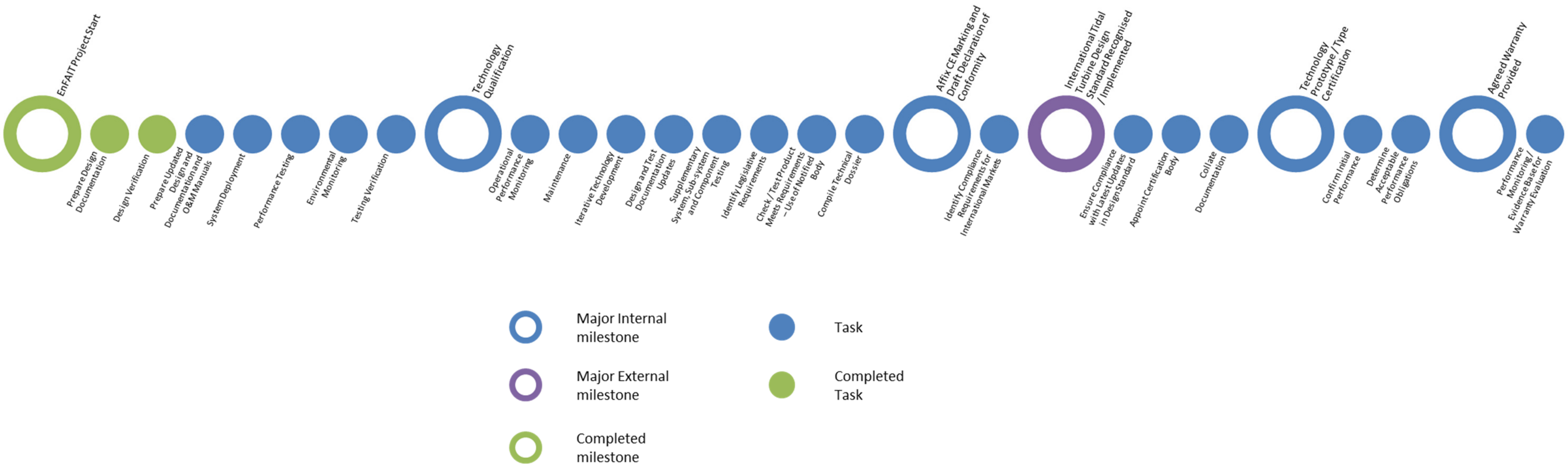

Figure 5-1: Routemap to Certification

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