Report

NorthWind Innovations 2023

Assessment of innovations

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SUMMARY
Abstract

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Table of contents

Klikk eller trykk her for å skrive inn tekst.

1 Background and approach

One of the main goals of FME NorthWind is to bring forward innovations developed in NorthWind or together with Northwind based on research performed in connection with the Centre.

The NorthWind Technology Transfer Committee and Impello Management have, together with the work package leaders of NorthWind, performed an assessment of NorthWind's first 29 innovations.

The 29 innovations were reported for the first time in the 2022 annual report. The TRL (Technology Readiness Level) of the innovations is still at a low level due to an early stage of the centre.

Impello Management was hired to help assess the innovations and to support NorthWind management.

NorthWind has five work packages, and work package leaders have been involved in the process. They were responsible for doing a self-assessment of each of the innovations belonging to their work package.

2 Overview of the Innovations

2.1 Work package 1 – Structures and Integrity

(Leader: Vigdis Olden – SINTEF, Deputy: Ana Page, NGI)

The table below shows the overview of the seven innovations of work package 1, with the associated TRL[1].

#	Innovation	About the innovation	TRL
1.1	**NICS: Numerical model for Identification of Critical Soil layers**	A new methodology for replicating early phase soil investigation field test has been developed. The proposed methodology includes a specific modification of input parameters to a large deformation finite element calculation scheme. Ultimately, the innovation can be used to identify critical soil layers and reduce uncertainties in soil properties in all stages of wind farm project development.	3
1.2	**Reliability Based Structural Design**	Main concept: To consider the probabilistic and fundamentally uncertain aspects of the design process of an offshore wind turbine support structure in order to achieve a cost-effective support structures. The design optimisation framework requires the ability to propagate uncertainties through the optimisation process.	2
1.3	**Improved health monitoring by using Acoustic Emission**	The innovation is a groundbreaking health monitoring system for early detection of micro-meter sized sub surface failures in load bearing rotating components like bearings and gears. By applying Acoustic Emission, the system will be able to detect failures at an earlier stage than by traditional vibration monitoring methods, and therefore give more time for planning of repair and replacement and possibly also avoid fatal failure by adjusting operating parameters	3
1.4	**Digital twin of the drivetrain based on more accurate material and damage data**	A Digital Twin with a physical based material model that dramatically improves the accuracy in the prediction of the remaining useful lifetime (RUL) of drivetrain components like gears and bearings. By including material mechanisms as strain localisation, microstructure evolution, crack formation and stable and unstable crack propagation, the model will reduce uncertainty in RUL predictions by reflecting the actual structural damage in gears and bearings during operation.	2
1.5	**HLAW: A cost-effective manufacturing technology for offshore wind structures**	A high-efficient and cost-effective welding method by combining laser beam welding and arc welding. HLAW can be used for manufacturing of metallic offshore wind structures, e.g., substructures, towers etc., contributing to reduce the cost of structures.	3
1.6	**AM for on-site repair and maintenance of offshore wind structures**	Additive manufacturing (AM) based method for repair and refurbishment of offshore wind components and structures. Extend structural lifetime through repairing and refurbishing damaged components and structure.	2
1.7	**AE for laser welding process monitoring**	An in-line method for fast, reliable and cost-effective defect detection during laser welding using the acoustic emission technique, which is based on the detection and conversion of high-frequency elastic waves into electrical signals.	1

[1] TRL: Technology Readyness level: https://enspire.science/trl-scale-horizon-europe-erc-explained/

2.2 Work package 2 – Marine operations and logistics

(Leader: Henning Braaten - SINTEF, Deputy: Svein Sævik - NTNU)

The table below shows the overview of the six innovations in work package 2 with the associated TRL.

#	Innovation	About the innovation	TRL
2.1	**Optimised power cable installation for coupled tension-torque behaviour**	Developing more accurate failure mechanisms for power cable dynamics considering tension-torque coupling, can be considered as a basis for improved and cost-effective installation criteria and further used for the determination of the allowable weather window for safe installation.	2
2.2	**Improved understanding of GBS installation**	For installation of gravity-based substructures (GBS) there is a lack of understanding of how uneven seabed and filter layers generate peak contact stresses and how these stress distributions change during the foundation installation process. Conservative design assumptions can result in increased base plate thickness, more reinforcement and larger base area.	1
2.3	**Methodology for wave and motion feedforward control for wind turbine blade installation**	A methodology for active motion compensation based on a feed-forward controller will be developed and illustrated via numerical simulations for blade installation using a floating vessel. This includes deterministic forecasting of waves using real-time wave surface measurements, predicting vessel and lifted blade motions, and designing a motion feed-forward controller	1
2.4	**New procedures to identify operational limits more efficiently**	W2W (Walk to Work) and crane operability studies between two floating bodies require significant computational and engineering effort to predict the operability limits using time-domain numerical simulations. This research work aims at developing procedures to perform efficient and accurate operability studies for future W2W scenarios.	3
2.5	**COSMO - Computer tool for Optimisation and Simulation of Marine Operations for installation of offshore wind farms**	A decision support tool for planning the installation operations for offshore wind farms (COSMO) is made available for testing. In addition to evaluate the impact of different industry concepts, the functionality of the tool will be extended to integrate hydrodynamic analysis as a basis for the operation criteria used in the tool.	4
2.6	**SMARTMOW - Logistics decision support tool for predictive maintenance at offshore wind farms**	A prototype for a decision support tool for predictive planning of logistics maintenance operations is being developed. The tool will build on mathematical programming techniques and identify optimal schedules based on feasibility, time, costs, weather risks and environmental risks	2

2.3 Work package 3 – Electrical Infrastructure and System Integration

(Leader: Marte Gammelsæter-SINTEF, Deputy: Magnus Korpås - NTNU)

The table below shows the overview of the six innovations in work package 3 with the associated TRL.

#	Innovation	About the innovation	TRL
3.1	**Dynamic rating of inter-array cables using weather forecast**	Transmission capacity ("ampacity") of cables is limited by heating. More accurate models taking into account ambient (weather, sea, soil, etc) will allow increased ampacity and reduced LCoE. Current industry practice and standards (IEC) assumes static conditions and results in highly conservative estimates.	4
3.2	**MVDC components for ±80 kV**	System models and design of components (offshore wind generators, dynamic cables etc) for a DC turbine and DC inter array grid with subsea collectors. Enable MVDC offshore wind farms, with lower systems losses and more flexibility of power flow control compared to traditional AC systems.	1-2
3.3	**132 kV collection grids**	132 kV collection grids enable larger wind turbine generators (15-20 MW), with corresponding higher electricity production.	2
3.4	**New material model for power cables**	New material model for use in global cable dynamic analysis. Accounting for effects of hysteretic damping and the coupling to torque, axial force and external pressure during installation and operation. Improved accuracy in fatigue life assessment, and weather window for installation.	3
3.5	**Combined testing and multiscale characterisation procedure for high cycle fatigue**	Enhanced knowledge base surrounding the damage evolution and degradation mechanisms in the high and very high cycle fatigue regime of materials relevant for cable components. Improved lifetime assessment and material development for cables.	2
3.6	**Mechanical map-based real-time damage assessment**	Numerical mapping, based on 3D solid FE simulations, for the determination of correlation between local strains obtained from sensors and deformations for cable sections. Improved health monitoring and material damage estimation for cables for a more accurate lifetime assessment	2

2.4 Work package 4 – Digital twin and asset management

(Leader: Adil Rasheed – NTNU, Deputy: Kjetil Johannessen - SINTEF)

The table below shows the overview of the five innovations in work package 4 with the associated TRL.

#	Innovation	About the innovation	TRL
4.1	**Hybrid analysis and modelling**	A new approach to modelling where the best of both the physics. Common challenges associated with physics-based and data-driven models, Solid mechanics, fluid mechanics aspects of wind engineering. The method is more accurate, computationally efficient, generalisable, and self-evolving. These are the desirable features for models in a digital twin context.	2-3
4.2	**Digital Twin framework**	Virtual representation of the wind farm that accompanies the wind farm through its whole life cycle and acts as a single platform for data bundling, visualisation, real-time analysis, and decision support. Improves communication between stakeholders during planning stage, predicts power production during operation, reduces unexpected downtime through condition monitoring, provides data for future designs	?
4.3	**Non-intrusive reduced order model**	It will help to develop faster flow models for potential digital twin application. It has an online and offline phase. In the online phase, ML is used to learn the flow dynamics, and in the offline phase, the trained model is used to reconstruct the flow field for a new value of the parameter.	2
4.4	**Aroma**	Software for generating a Reduced Basis Model (RBM) from existing high-fidelity simulation setup. Addresses the 'intrusiveness' challenge: minimal expert knowledge required	4
4.5	**Multiscale wind simulation**	Framework for coupling mesoscale and microscale wind simulation platforms. Provides accurate prediction of wind taking local microscale effects into account. More accurate solutions and access to reduced order modelling frameworks	4

2.5 Work package 5 – Sustainable wind development

(Leader: Rita V. D'Oliveira Bouman – NTNU, Deputy: Roel May - NINA)

The table below shows the overview of the five innovations in work package 5 with the associated TRL.

#	Innovation	About the innovation	TRL
5.1	**Online AviSite app that visualises LCA-based cumulative effects, and screening of impacts at new sites.**	Help streamline the onshore development process while reducing unnecessary harm to birdlife, which will give industry and authorities increased predictability regarding the siting of future wind-power plants and minimised reputational and financial risk	5-6
5.2	**Online ConSite Wind app to balance socio-ecological and economy trade-offs in spatial planning of onshore and offshore wind projects**	ConSite Wind (Consensus-based Siting) helps analyse, visualise and predict scoping areas for reconciled siting of onshore/offshore wind-power plants based on user-defined decision criteria taking into account restriction areas, socio-economic activities, social and ecological values, wind resources, production potential (kWh) and levelised costs of energy production (NOK/kWh).	5-6 3-4
5.3	**Diffusion and innovation models for offshore wind technology**	Energy-economy-environment sustainability model at the industry level. Better knowledge on market diffusion of offshore wind technologies and understanding of innovation pathways	
5.4	**Sustainability assessment modes**	Sustainability assessment method for better knowledge on effects of offshore wind installation and operation on the sustainable development goals	
5.5	**SKARV: Preventing bird strikes with active control of wind turbines**	Main concept: to make small adjustments to the turbine rotor speed so that the blades and birds are not located at the same place at the same time. The control strategy requires the ability to predict the probability of distribution of the flight path ahead of time, based on current detection of the bird by a visual system	3

3 Self-assessment of the innovations

3.1 The process

The Centre Management Group (CMG) decided at its February 2023 meeting to ask Frode Iglebæk from Impello Management to perform an assessment of the innovations identified in NorthWind. At the March 2023 CMG meeting, Frode outlined about the methodology to do a self-assessment of the innovations and categorise the innovations. The responsibility to lead and follow up the process was given to the head of the Technology Transfer Committee, together with Frode Iglebæk.

The work package leaders were asked to do a self-assessment of all the innovations listed in their work package. In the self-assessment scheme, nine parameters are listed and the score table was divided into a high/low scale rated from 1 (low) to 5 (high). The parameters are listed below:

Parameters	Description/comment
1.Technology/uniqueness: High uniqueness	**High uniqueness**: The innovation is new/novel compared to existing concepts, technologies, products, systems or services. Ground-breaking vs. incremental.
2.Intellectual property rights (IP)	**Strong IP**: The innovation (or parts of it) can be claimed as 'novel'. The IP can be protected (not easily copied) by patenting, as trade secret, know-how, etc. The key concept is not published (cf. patenting). The IP ownership is clarified/agreed.
3.Industry demand	**High demand**: Expressed demand for a solution to a particular 'problem'. The demand can also be 'latent', i.e. the user/customer is not yet aware of the problem or is not aware of any existing or applicable solution.
4.Industry potential	**High potential**: The innovation addresses a large market (in the context of wind power) with multiple customers and multiple areas of applications (as opposed to expert/specialist/niche markets with very few potential users and customers).
5.Economic impact	**High economic impact**: The innovation will contribute considerably to increased revenues, reduced costs or increased profits.
6.Sustainability	**High impact**: The innovation will contribute to reach UN's Sustainability Development Goals (SDG), e.g., increased/efficient renewable energy production, reduced emissions, less use of materials, co-existence with nature, etc.
7.Safety	**High safety impact**: The innovation will contribute to improved personnel safety and safer operations.
8.Research and education	**High impact**: The innovation has a potential for developing new research areas, generating new research projects – and educate candidates and research fellows.
9.Societal/user defined	Other impact or criteria that is not covered by pt. 1 to 8.
10.Regulatory/market requirements	**High**: The innovation (concept, technology, system, service…) is legally required to meet rules and regulations, e.g. EU taxonomy, certification, license to operate requirements, or similar. **Medium**: No requirements now - but expected in the future. **Low**: No requirements now/future

Table 1 Explanation of the scoring from 1 to 5 (i.e., low impact scores 1 while high impact scores 5)

After the work package leaders had gone through the self-assessment it was arranged meetings with Impello, TTC and the work package leaders one by one, to go through and discuss the result of the self-assessment. A physical meeting of 1.5 hours with each of the work package leaders (and deputy if possible) was arranged. The assessment was discussed and concluded for each of the innovations.

Presentation of the results from the self-assessment for all work packages in the CMG meeting in April lead to a discussion on how to interpret and score the innovations and a more common understanding of what was expected as outcome from the self-assessment. As a follow up on this, the work package leaders updated the self-assessment and new meetings were arranged to go through the updated results of each of the innovations.

3.2 Self-assessment parameters

The tables shown in chapters 3.3, 3.4,3.6 and **Error! Reference source not found.** summarises the scores for each of the innovations.

Table 2 in chapter 3.3 gives an overview of all innovations with scores from the self-assessment set by the work package leaders for each of the parameters given in Table 1 (see previous chapter 3.1);

- Technology/uniqueness: High uniqueness
- Intellectual property rights (IP)
- Industry demand
- Industry potential
- Economic impact
- Sustainability
- Safety
- Research and education
- Societal/user defined
- Regulatory/market requirements

Table 3 shows all innovations grouped by Technology Readiness level – showing the development stage of the innovation. As can be seen from the table, eighteen of the innovations are at a development stage 2 or lower, which shows that they are at a very low level of maturity. Five of the innovations are at TRL 3 and four innovations are at stage 4. Two innovations are at TRL level 5-6, that is "Multiscale wind simulation and Avisite. These innovations are both software-based and already in use but still under further development.

Description of TRL 1 to TRL 5[2]:

- **TRL 1**. Basic principles are observed. Scientific observations of the fundamental properties of technology have been carried out and documented.
- **TRL 2.** The concept of technology is defined. Analytical studies of the technology have been carried out, where possible applications are assessed. A plan for experimentation on TRL3 is available.
- **TRL 3**. Experimental proof of concept is available. Preliminary research has been carried out to confirm possible concepts (proof of concept). Studies and laboratory measurements have been carried out to validate theories. A plan has been prepared for TRL4, validation of the technology at laboratory scale.
- **TRL 4**. The technology is validated in the laboratory. The technology has been validated on a lab scale, through systematic testing of the technology for hypothetical application. The results show that expected performance requirements for the technology may be achievable. It is ready to test the technology on TLR5, under simulated conditions.
- **TRL 5**. The technology has been tested at laboratory scale, as part of the system solution under relevant operating conditions. These are results from testing of the integrated system solution under simulated operating conditions.

Table 4 Shows the type of innovation:

[2] Reference to Innovation Norway: https://www.innovasjonnorge.no/artikkel/technology-readiness-level-(trl)

- Is it a physical device, software, method, strategy, knowledge building, other?
- What is the problem or challenge it will solve?
- Is it a key advantage and improvement to existing solutions (e.g., new features)?
- Is the innovation incremental or groundbreaking?

Table 5 shows the potential or indicated pathway for commercialisation together with the innovation's impact or potential.

Thirteen of the innovations are categorised under the topic "Licensing to partners and/or implementation in existing systems". Furthermore, sixteen of the innovations are categorised under "Internal R&D tools and/or Internal competence building".

The placement of the different innovations into tables 3, 4 and 5 is decided together with the work package leaders. For some of the innovations that are in an early stage of development, there have been discussion to agree upon the placement in the different categories, which is normal due to a lot of uncertainties in the early stage of development.

3.3 Self-assessment overall

The table below shows the results of the self-assessment for all work packages and innovations.

JUNE (updated)	WP1 Structures and Integrity						WP2 Marine Operations and Logistics						WP3 Electrical Infrastructure & System Integration						WP4 Digital Twin and Asset Management					WP 5 Sustainable Wind Development				
Innovation no.:	**1.1**	**1.3**	**1.4**	**1.5**	**1.6**	**1.7**	**2.1**	**2.2**	**2.3**	**2.4**	**2.5**	**2.6**	**3.1**	**3.2**	**3.3**	**3.4**	**3.5**	**3.6**	**4.1**	**4.2**	**4.3**	**4.4**	**4.5**	**5.1**	**5.2**	**5.3**	**5.4**	**5.5**
TRL:	3	3	2	3	2	1	2	1	1	3	4	2	4	1-2	2	3	2	2	2-4	2	2	4	6	5-6	4-6	2	–	3
1. Technology/ uniqueness	3	5	5	4	5	2	3	3	5	4	4	4	2	5	2	3	3	2	4	4	4	4	5	3	4	3	5	4
2. IP	1	5	3	3	4	2	2	2	3	3	4	3	3	4	1	1	1	1	1	3	1	3	4	-	-	-	-	4
3. Industry demand	3	5	3	3	4	2	4	2	4	4	3	4	4	4	4	3	3	4	5	5	5	5	5	2	2	3	2	5
4. Industrial potential	3	4	4	5	4	2	4	3	4	4	4	4	3	4	3	2	3	4	5	5	5	5	5	3	3	3	-	5
5. Economic impact	4	4	3	5	4	3	4	3	4	3	3	4	3	4	3	2	2	2	5	4	5	5	4	-	-	-	-	4
6. Sustainability	-	3	3	4	4	2	3	3	3	2	3	3	3	3	2	2	3	3	4	5	4	4	4	5	5	5	5	5
7. Safety	-	3	4	4	5	2	3	2	4	3	3	3	-	2	1	2	2	3	5	5	5	4	5	-	-	-	-	4
8. Research and education	5	3	5	5	1	3	4	3	5	3	4	4	2	4	1	3	3	3	5	5	5	5	5	4	4	4	4	5
9. Societal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	5	5	0	4	5	5	5	5	-
10. Regulatory/ market requirements	1	2	2	4	2	3	4	-	2	3	2	2	-	1	1	1	-	-	3	5	3	3	3	-	-	-	-	-
Final assessment	**L**	**H**	**H**	**H**	**M**	**L**	**M**	**L**	**H**	**M**	**M**	**M**	**M**	**M**	**L**	**L**	**M**	**M**	**H**	**H**	**H**	**H**	**H**	**L**	**M**	**L**	**L**	**H**

Table 2 Results of the self-assessment performed by the work package leaders. (No self-assessment is performed for Innovation 1.2)

- Value 1 means low impact/potential while value 5 means high impact/potential. For most of the innovations, the TRL level is low, and low TRL is more difficult to rate than higher TRL due to a lot of uncertainties.
- The last row shows the final assessment of each of the innovations. H = high impact, M = medium impact/uncertain impact, L = low impact/ insignificant impact. All innovations' assessments are shown in attachment 1.

3.4 Technology Readiness Level (TRL) of the innovations

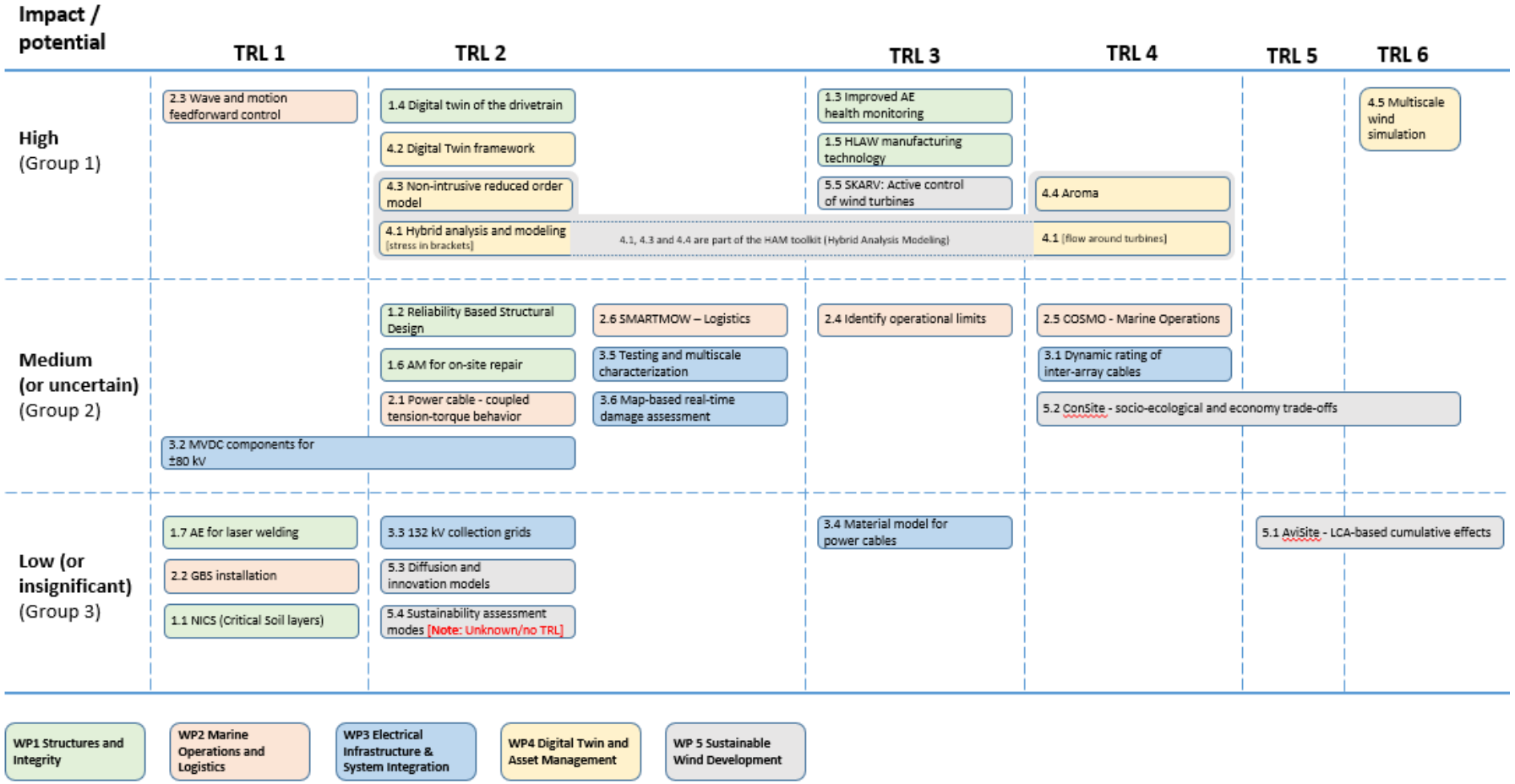


Table 3 Innovations grouped by the Technology Readiness Level (TRL)

3.5 Type of innovation – methodology, software, hardware

Impact / potential	**Methodology** (basic knowhow, improved understanding, theoretic/practical methods)	**Software** (incl. "software constituents", e.g. frameworks, numerical models, modules)	**Hardware** (incl. methods/software that will be embedded or connected to a hardware device)
High (Group 1)	1.5 HLAW manufacturing technology 4.2 Digital Twin framework 4.1 Hybrid analysis and modeling	1.4 Digital twin of the drivetrain 4.5 Multiscale wind simulation 4.3 Non-intrusive reduced order model 4.4 Aroma	1.3 Improved AE health monitoring 2.3 Wave and motion feedforward control 5.5 SKARV: Active control of wind turbines
Medium (or uncertain) (Group 2)	1.6 AM for on-site repair 1.2 Reliability Based Structural Design 3.5 Testing and multiscale characterization	2.1 Power cable - coupled tension-torque behavior 3.1 Dynamic rating of inter-array cables 2.4 Identify operational limits 3.6 Map-based real-time damage assessment 2.5 COSMO - Marine Operations 5.2 ConSite - socio-ecological and economy trade-offs 2.6 SMARTMOW – Logistics	3.2 MVDC components for ±80 kV
Low (or insignificant) (Group 3)	1.7 AE for laser welding 5.3 Diffusion and innovation models 2.2 GBS installation 5.4 Sustainability assessment modes 3.3 132 kV collection grids	1.1 NICS (Critical Soil layers) 5.1 AviSite - LCA-based cumulative effects 3.4 Material model for power cables	

WP1 Structures and Integrity | WP2 Marine Operations and Logistics | WP3 Electrical Infrastructure & System Integration | WP4 Digital Twin and Asset Management | WP 5 Sustainable Wind Development

Table 4 Type of innovation

3.6 Potential / indicated pathway for commercialisation

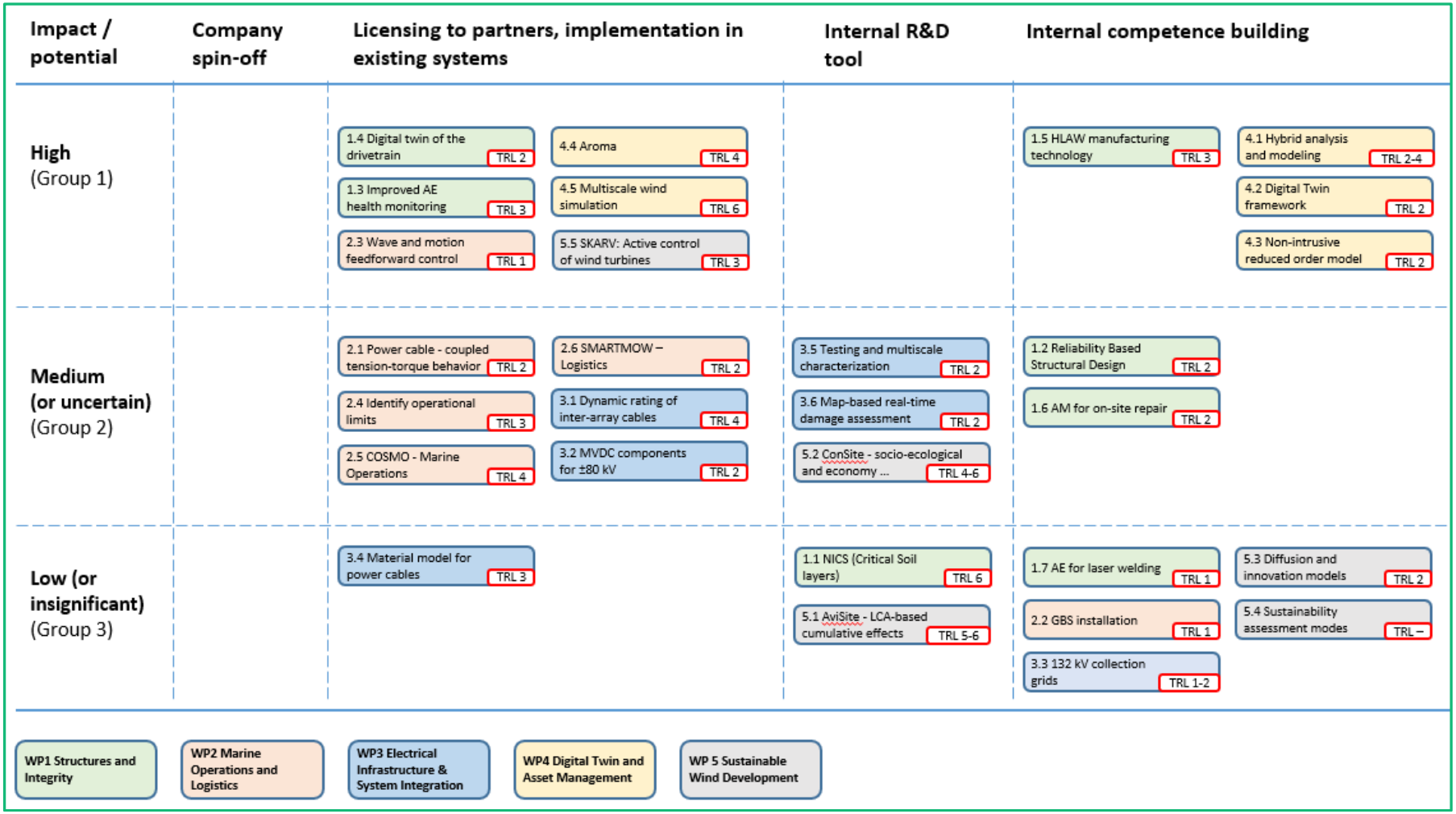


Table 5 Potential pathway for commercialisation

4 Summary

The work started in March 2023 and the task was to review and categorise 29 identified innovations in FME NorthWind with reference to the Technology Readiness level, potential route for commercialisation and utilisation and type of innovation. The categorisation of the innovations is based on a one-page project descriptions and input from the work package leaders and researchers and two rounds of self-assessment (scorecards). A final overall assessment was performed by Frode Iglebæk from Impello Management together with the head of the Technology Transfer Committee, and the summary of the innovations assessment is as follows:

- 75% of the innovations are considered to be in the early stage of development, with a range from TRL 1-3.
- Approx 40% of the innovations are considered as internal competence building.
- Around 45% of the innovations can potentially be commercialised through partners/customers (licensing, software integration, etc.)
- About 50% of the innovations are software-related (SW, numerical models, frameworks, or similar). It is difficult to draw a clear line between 'methodology' and what could become 'software'.
- ~30% of the innovations are considered to have *'high impact / high potential'.*

For most of the innovations, the goal is to improve and develop internal knowledge and expertise to be able to offer the industry the competence and knowledge they need to develop the Norwegian offshore wind industry for the future in an effective and sustainable way.

A Attachment Spider diagrams

The following pages show the self-assessments per work package and per innovation.

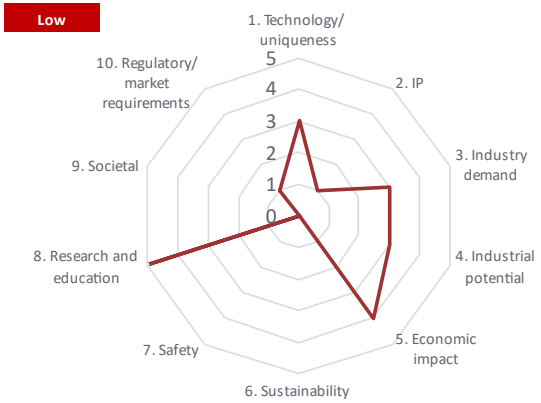
The evaluations are plotted in spider diagrams to show the distributions of the different scorings. From the example showed below:

The outer circle comprises the highest score (character 5). The example below shows an innovation which have received a high score in total. It has a high level of uniqueness, it scores high on IP (intellectual property rights), high on industry demand and potential and has a high potential for economic impact.

A.1 WP1 Structures and integrity - spider diagrams

1.1 NICS: Numerical model for identification of critical soil...

Low

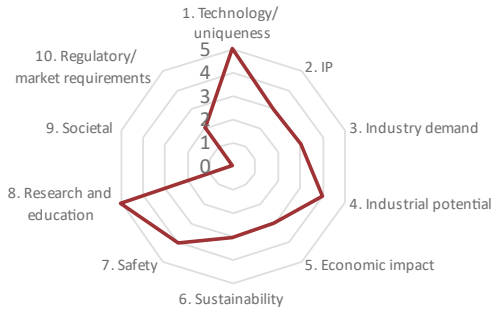


1.3 Improved health monitoring by using Acoustic Emission

High

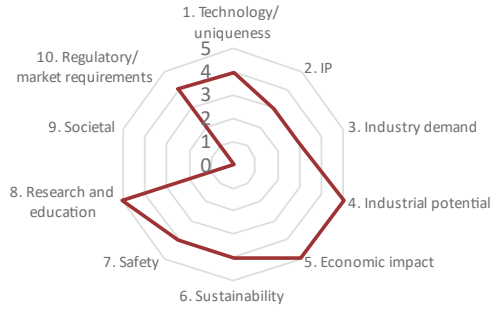
1.4 Digital twin of the drivetrain ...

High



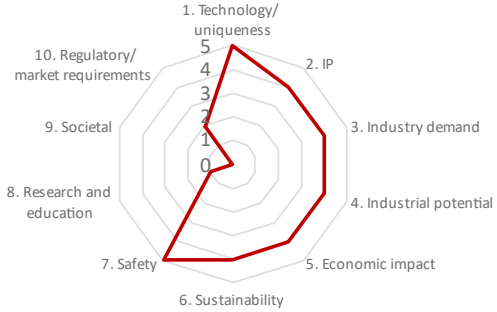
1.5 HLAW: A cost-effective manufacturing ...

High



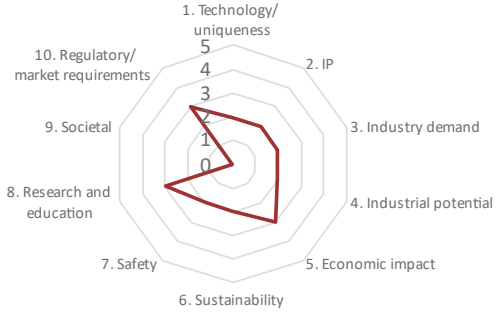
1.6 AM for on-site repair and maintenance ...

Medium



1.7 AE for laser welding process monitoring

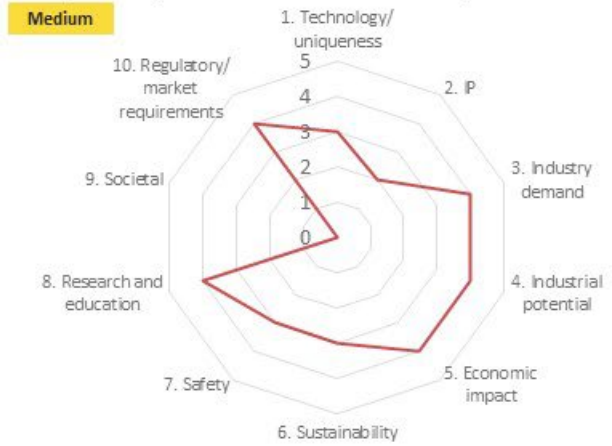
Low



A.2 WP2 Marine Operations and Logistics - spider diagrams

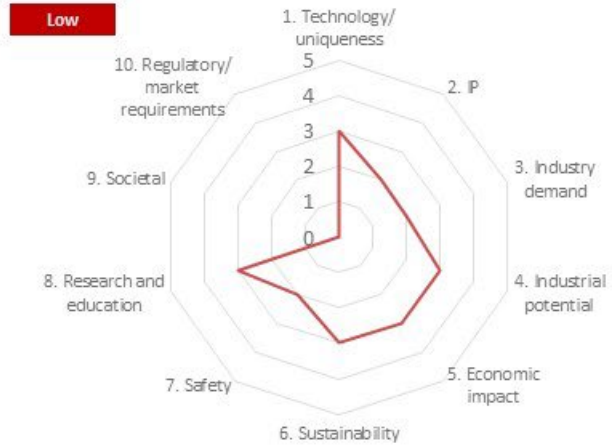
2.1 Optimized power cable installation for coupled ...

Medium



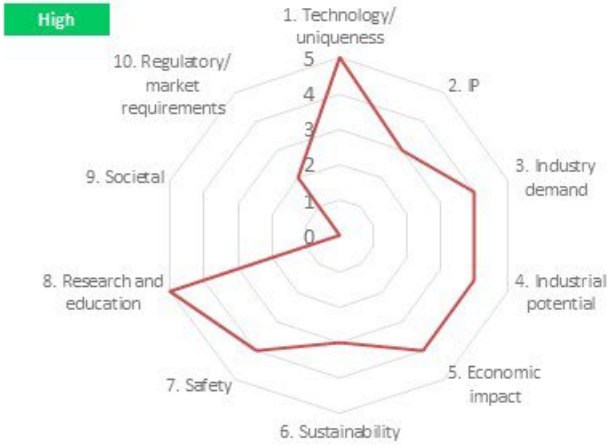
2.2 Improved understanding of GBS installation

Low



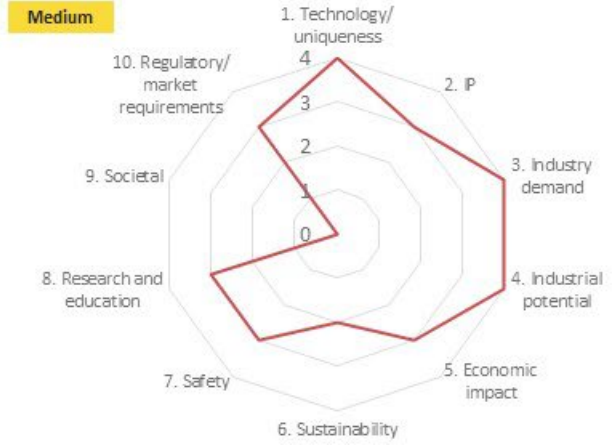
2.3 Methodology for wave and motion feedforward control

High



2.4 New procedures to identify operational limits ...

Medium

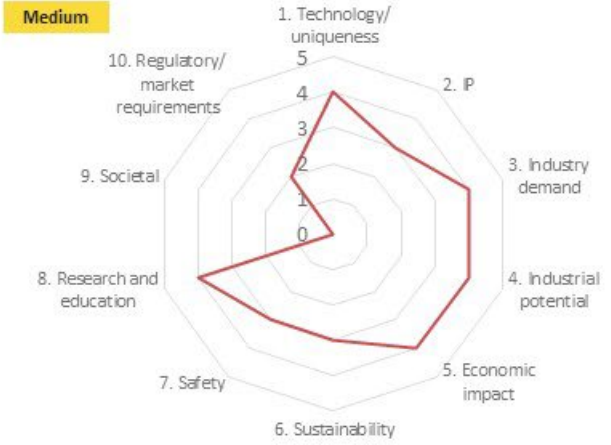


2.5 COSMO

Medium

2.6 SMARTMOW

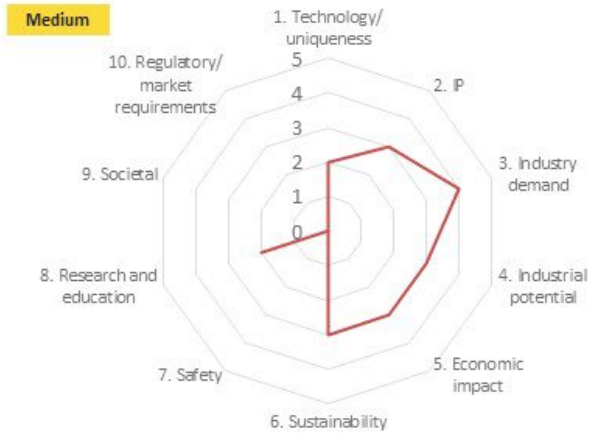
Medium



A.3 WP3 Electrical Infrastructures & System Integration - spider diagrams

3.1 Dynamic rating of inter-array cables using weather ...

Medium



3.2 MVDC components for ±80 kV

Medium

3.3 132 kV collection grids

Low

3.4 New material model for power cables

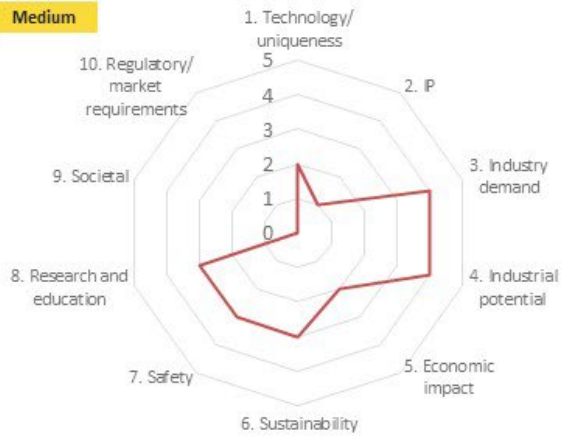
Low

3.5 Combined testing and multiscale characterization ...

Medium

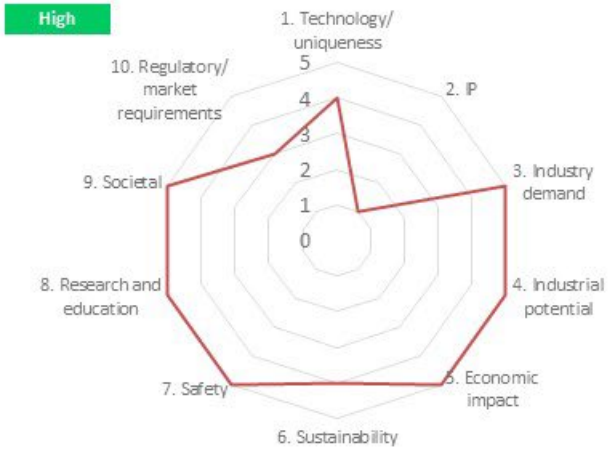
3.6 Mechanical map-based real-time damage assessment

Medium

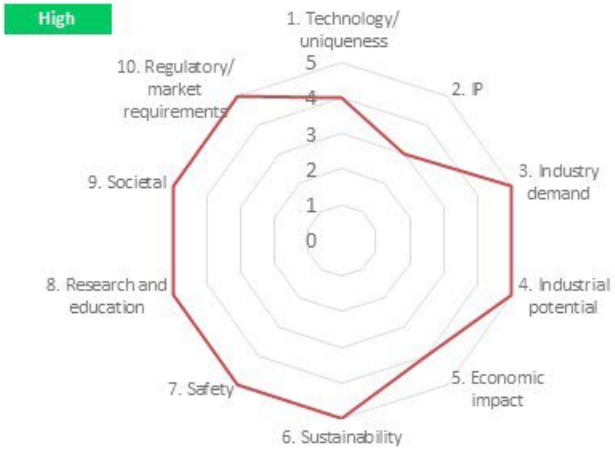


A.4 WP4 Digital twin and Asset management - spider diagrams

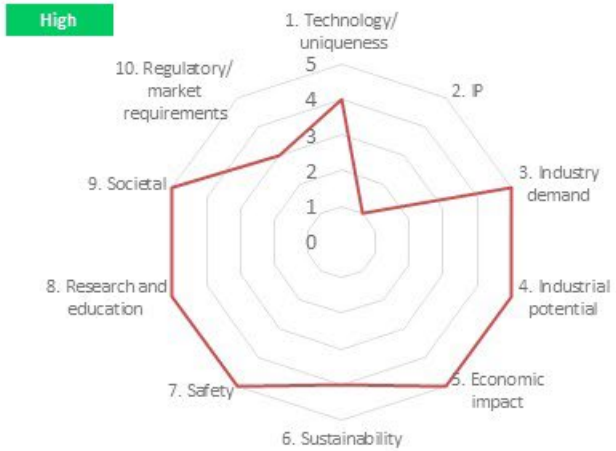
4.1 Hybrid analysis and modeling



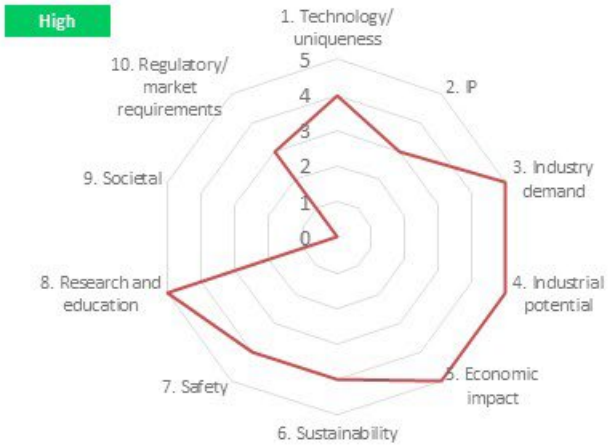
4.2 Digital Twin framework



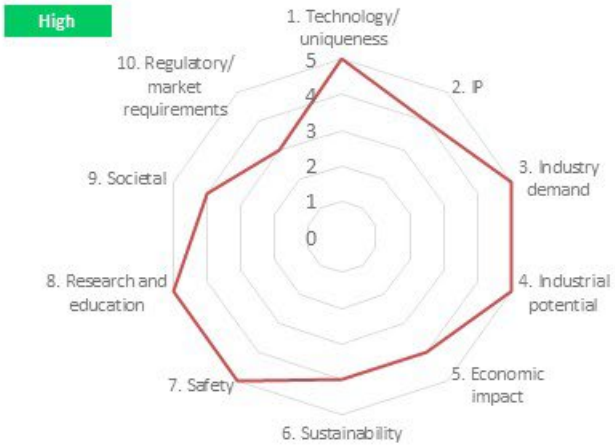
4.3 Non-intrusive reduced order model



4.4 Aroma

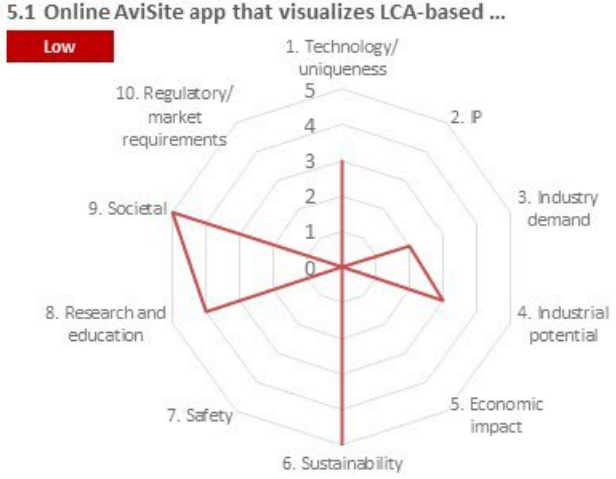


4.5 Multiscale wind simulation

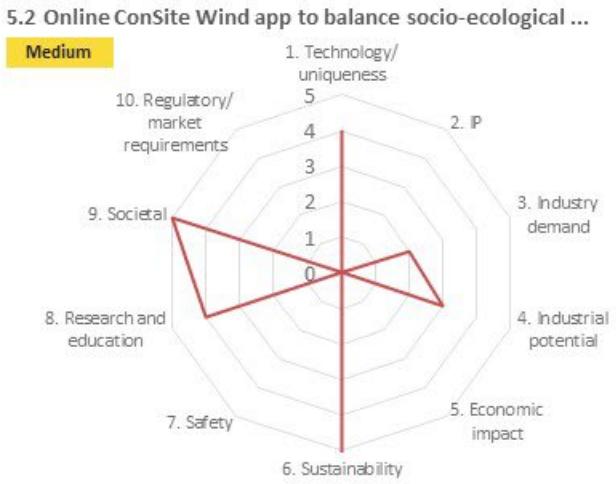


A.5 WP5 Sustainable Wind Development - spider diagrams

5.1 Online AviSite app that visualizes LCA-based ...

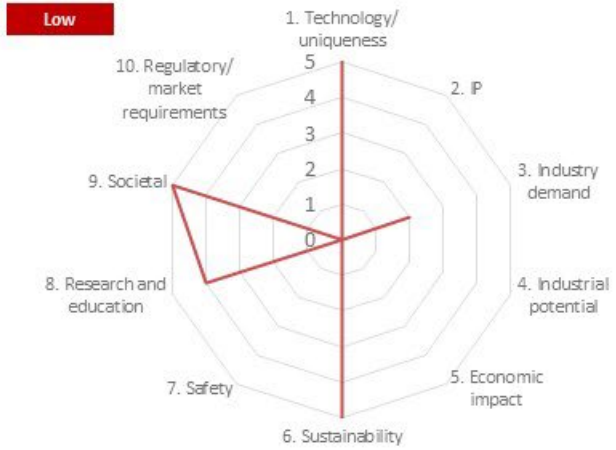


5.2 Online ConSite Wind app to balance socio-ecological ...



5.3 Diffusion and innovation models for offshore wind ...

5.4 Sustainability assessment modes



5.5 SKARV: Preventing birdstrikes with active control ...