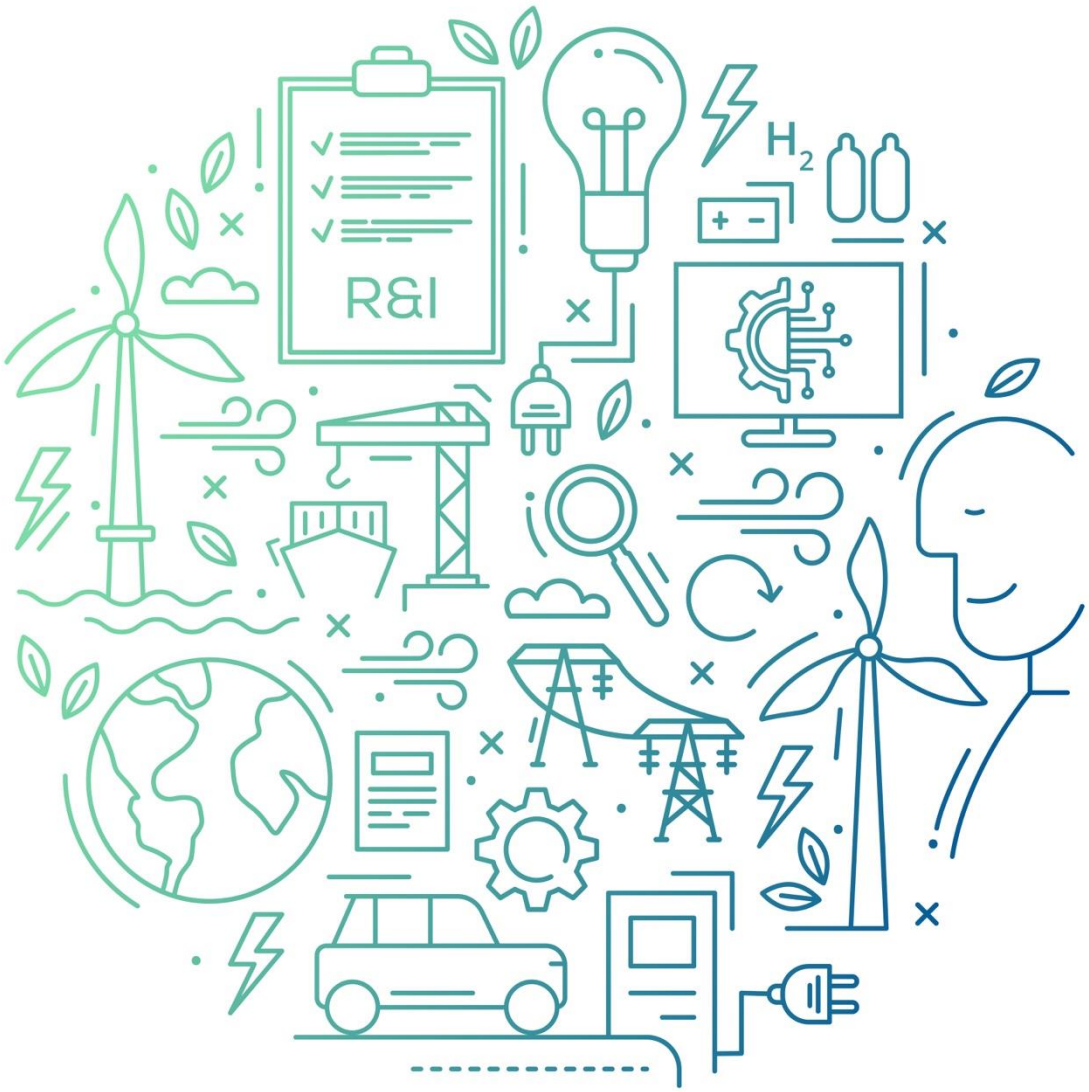
SETIP Wind



SETIPWind
Gap analysis

About SETIPWind

The SETIPWind project supports the coordination of activities of the European Technological Platform for Wind Energy (ETIPWind) and the SET Plan Implementation Working Group on Offshore Wind (IWG OW).

The objectives of the SETIPWind project are to:

- Ensure ETIPWind and the SET Plan IWG OW contribute with timely and high impact input to the EU and national R&I policies thanks to an enhanced coordination of their activities and deliverables, addressing the key technical and societal challenges of an accelerated and sustainable deployment of wind energy.
- Ensure a wider participation and engagement of key stakeholders in ETIPWind's and the IWG OW's activities, including industry, small & medium enterprises, research, and civil society organisations such as representatives from energy cooperatives, trade unions or natural protection groups, universities, associations from relevant sectors, EU Institutions, and SET Plan countries. With a particular focus on the involvement of Social Science and Humanities (SSH) experts.
- To improve the collaboration on content creation, communication, and dissemination of deliverables of ETIPWind and the IWG OW with other ETIPs and IWGs to advance towards more aligned and interconnected activities.
- To guarantee that the SET Plan initiative receives consensus-based advice from stakeholders on R&I priorities on wind energy and key areas for the energy transition, covering technical and non-technical aspects which contribute to the new SET Plan targets in the context of the EU Green Deal and Recovery Plan for Europe.
- To increase the awareness and knowledge on wind energy technology developments, the sector's state-of-play, and its impacts on the EU economy and society among the SET Plan bodies, EU policymakers, national Governments, and key decision makers.
- To maximise the impact of communication, dissemination, and exploitation of ETIPWind and IWG OW activities and deliverables, and to facilitate the dissemination of EU R&I initiatives and programmes.
- To safeguard ETIPWind's successful continuation with a finance and sustainability plan for its future beyond the lifetime of this project.

The SETIPWind project is managed by WindEurope.

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ABBREVIATIONS

Abbreviation	Description
CTOs	Chief Technology Officers
EAWE	European Academy of Wind Energy
EERA	European Energy Research Alliance
ETIPWind	European Technology and Innovation Platform
ExCo	ETIPWind Executive Committee
IWG Wind	SET-Plan Implementation Working Group on Wind energy
IWG OW	SET-Plan Implementation Working Group on Offshore wind
NECPs	National Energy & Climate Plans
R&I	Research & Innovation
SC	ETIPWind Steering Committee
SET-Plan	The EU Strategic Energy and Technology Plan
SETIPWind	Support and coordination of the European Technology and Innovation Platform on Wind Energy (ETIPWind) and the SET Plan Implementation Working Group on Wind energy (IWG Wind).
WP	Work Package

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DISCLAIMER

The SETIPWind Grant Agreement refers to the SET-Plan Implementation Working Group on Offshore Wind (IWG OW). In the perspective of the revision of the SET-Plan, which will be announced by the European Commission early 2023, the European Commission requested to extend the scope of the IWG to cover onshore wind technologies. The IWG members agreed with this request. The present document therefore refers to the Implementation Working Group on Wind energy (IWG Wind).

1. EXECUTIVE SUMMARY

The present Deliverable 4.2 has been developed by WindEurope in the framework of the Work Package 4 "Advising wind energy R&I" of the SETIPWind project.

It summarises the results from a Gap analysis conducted by the ETIPWind Steering Committee (SC) members. The analysis compares the Research & Innovation (R&I) priorities identified by ETIPWind in its 2019 Roadmap (available here) with the wind energy R&I topics addressed by the European Commission's funding programme for R&I: Horizon Europe.

This deliverable describes the methodology used to conduct the Gap analysis, the results of the analysis and the feedback from the Chief Technology Officers (or CTOs Forum) on these results.

2. METHODOLOGY

The initial objective of the Gap analysis was to compare the Horizon Europe Work programme 2023-24 against the ETIPWind 2019 Roadmap to identify the R&I topics that were addressed or not by the Horizon Europe programme.

Identifying the funding gaps is an important step that will help ETIPWind to update the R&I priorities for the wind energy sector in its new Strategic R&I Agenda (to be published by M15).

This Gap analysis was conducted from December 2022 until April 2023 by the ETIPWind SC members with the support of the SETIPWind Secretariat.

The different steps of this methodology were proposed by the SETIPWind Secretariat and discussed with the whole Steering Committee during two ETIPWind SC meetings (on 20 December 2022 and on 12 January 2023). The results of the Gap analysis were then presented and discussed during another SC meeting (on 23 March 2023).

In addition, several Working Groups were created and the SETIPWind Secretariat sent more than 120 emails to exchange with SC members on the methodology, the coordination of meetings, the assessment, and the results of the Gap analysis.

The below sections describe the different steps of the methodology used to conduct the Gap analysis.

2.1 Scope of the analysis:

The objective of the Gap analysis was to identify the R&I topics among the ETIPWind 2019 roadmap, that have not been addressed by Horizon Europe until now.

The analysis therefore compares the **49 R&I topics** identified within the 6 Pillars of the ETIPWind roadmap with:

- The wind-related projects funded by the Horizon Europe 2021-2022 Work Programme, Cluster 5
- The wind-related calls for proposals of the Horizon Europe 2023-2024 Work Programme, Cluster 5

Among the projects funded by the Horizon Europe 2021-2022 Work Programme Cluster 5, **39 projects** were identified as related to wind energy or to an enabling technology supporting wind energy (e.g. projects related to grids and system integration). In the Horizon Europe 2023-2024 Work Programme Cluster 5, **22**

calls for proposals were identified as related to wind energy or to an enabling technology supporting wind energy. The list projects and calls which were considered for the analysis is available in **Annex 2**.

It is important to note that this analysis focuses only on the Horizon Europe Cluster 5 wind energy-related topics whereas other Horizon Europe Clusters or EU funding programmes may be relevant to consider for what concerns funding for wind energy R&I. But the scope of the analysis is limited to the Horizon Europe Cluster 5.

2.2 Preliminary assessment of the Horizon Europe 2021-2022 projects and 2023-2024 calls:

As a first step the SETIPWind Secretariat did a preliminary review of the Horizon Europe projects and calls for proposal and assessed if they were linked with one or several pillars of the ETIPWind Roadmap. This exercise was done by the WindEurope's Project Management Team with the support of several members of the WindEurope's Technical Team.

In total, the scope of 39 projects and 22 calls for proposals was analysised to identify which pillar(s) of the roadmap they could match. This preliminary assessment was done through an excel table in which key information regarding the projects and calls were added (title, acronym, scope, description, website, net EU contribution, wind share, wind relevant contribution, total cost, type of action, topic code, topic description).

To facilitate the assessment of the projects and calls by the ETIPWind SC members, the Secretariat also added columns to identify:

- The Roadmap pillar(s) addressed by the project or call
- The Research area(s) addressed by the project or call
- How the research area has been addressed (what are the aspects covered, what the aspects that still need funding)

A final column was added to enable SC members to add notes and comments.

The final excel template provided to the SC members was therefore composed of three sheets:

1. Assessment of the Horizon Europe WP2021-22 projects (example in **Annex 3**)
2. Assessment of the Horizon Europe WP2023-24 calls for proposals (**example in Annex 4**)
3. A summary sheet including more detailed comments on whether the ETIPWind R&I topics have been addressed or not by Horizon Europe (example in **Annex 5**)

The development of the excel template and the preliminary assessment were done both by the WindEurope's Project management and Technical teams. This required several internal meetings and exchanges via email.

The summary sheet was added in the excel template to summarise the assessment of the SC members. For each R&I topic of the 2019 roadmap, SC members assessed:

- If the R&I topic was totally, partially, or not addressed by the Horizon Europe Work Programmes*
- If the R&I topic still needed funding in the short, medium or long-term;
- If the R&I topic was a low, medium or high priority for the wind energy sector;
- The funding amount that the R&I topic still needs to be correctly addressed in the future.

**It is important to note what is meant by totally, partially, or not addressed:*

- ***Totally addressed*** *means that the R&I topic has been addressed by Horizon Europe. Several projects have been funded on this topic or the calls for proposals will address most of the points mentioned in the topic description of the ETIPWind 2019 roadmap.*
- ***Partially addressed*** *means that some points of the Horizon Europe projects or calls are related to the R&I topic. But the SC members consider that these projects or calls won't be sufficient to efficiently tackle the R&I topic. Either because the scope of the project or call is too broadly defined, or because the budget allocated to the project or call is not enough to develop concrete solutions.*
- ***Not addressed*** *means that the R&I topic has not been addressed at all by Horizon Europe. No project or call will tackle the points mentioned in the topic description. Or the link with the R&I topic is so loose that SC members consider it won't be addressed.*

2.3 Working Groups:

To conduct the analysis, the ETIPWind Steering Committee members were divided into 6 Working Groups corresponding to the 6 R&I Pillars of the 2019 Roadmap:

1. **Working Group 1**: Grids & System integration
2. **Working Group 2**: Operations & Maintenance
3. **Working Group 3**: Next Generation Technologies
4. **Working Group 4:** Offshore balance of plant
5. **Working Group 5:** Floating Wind
6. **Working Group 6**: Skills & Human resources

Participation to these Working Groups was voluntary. Interests to take part in one or several Working Groups were gathered during the ETIPWind SC meeting on 12 January 2023. The composition of each Working Group can be found in **Annex 1**.

In each Working Group, a Chair was nominated to lead the technical discussions and 3 meetings (of around 1.5 hour) were then organised:

- The objective of the **1st meeting** was to remind the methodology to the SC members and to fill in the excel template based on the assessment of the SC members.
- The objective of the **2nd meeting** was to finalise the assessment and to fill in the "summary sheet" of the excel template.
- The **3rd meeting** was conducted only with the Working Group Chair to validate the final conclusions of the Gap analysis ton be forwarded to the Chief Technology Officers. These conclusions can be found in the Section 3.

During the meetings, the SC members did not have the time to fill in the entire excel template for their respective pillars. The excel file was therefore shared in the ETIPWind Teams repository to allow SC members to work offline on the analysis.

The final conclusions of the Gap analysis were presented to the whole Steering Committee during a meeting organised on 23 March 2023.

2.4 Feedback from the Chief Technology Officers Forum (CTOs Forum):

The Chief Technology Officers Forum (CTOs Forum[1]) also had the possibility to review the conclusions from the Gap analysis.

In this perspective, the final conclusions from the Gap analysis were shared with the CTOs Forum. And a joint meeting between the CTOs Forum and the ETIPWind Steering Committee was organised in Copenhagen on 27 April 2023.

During this meeting, the CTOs shared their feedback on the Gap analysis conclusions. They also provided ETIPWind with crucial input regarding the most urgent R&I priorities that should be addressed in the short to medium term to support the competitiveness of the European wind energy sector.

Their input is summarised in Section 4 and will be used as a basis to update the Strategic R&I Agenda of ETIPWind.

3. RESULTS

This section displays the results from the Gap analysis per roadmap pillar. For each pillar of the roadmap, conclusions from the Gap analysis are summarised with:

- A **summary table** showing the R&I topics that have been totally, partially, or not addressed by Horizon Europe;
- The **final conclusions** in a slide format;
- A **funding gap amount** which is an estimation of the funding amount still needed to correctly address the R&I topics within each pillar.

The Gap analysis conclusions will be published in a pdf format on the ETIPWind website. It is also available on the ETIPWind Teams repository.

3.1 Pillar 1: Grids & System integration

For the pillar 1 "Grids & System integration", one R&I topic has been totally addressed by Horizon Europe, 2 topics have not been addressed at all and 6 topics have been only partially addressed (**Table 1**).

[1] Previously known as the Advisory Board, the CTOs Forum is an independent group within WindEurope which gathers 18 Chief Technology Officers from the leading wind energy companies.

TABLE 1

Summary table of the Gap analysis for Pillar 1 topics

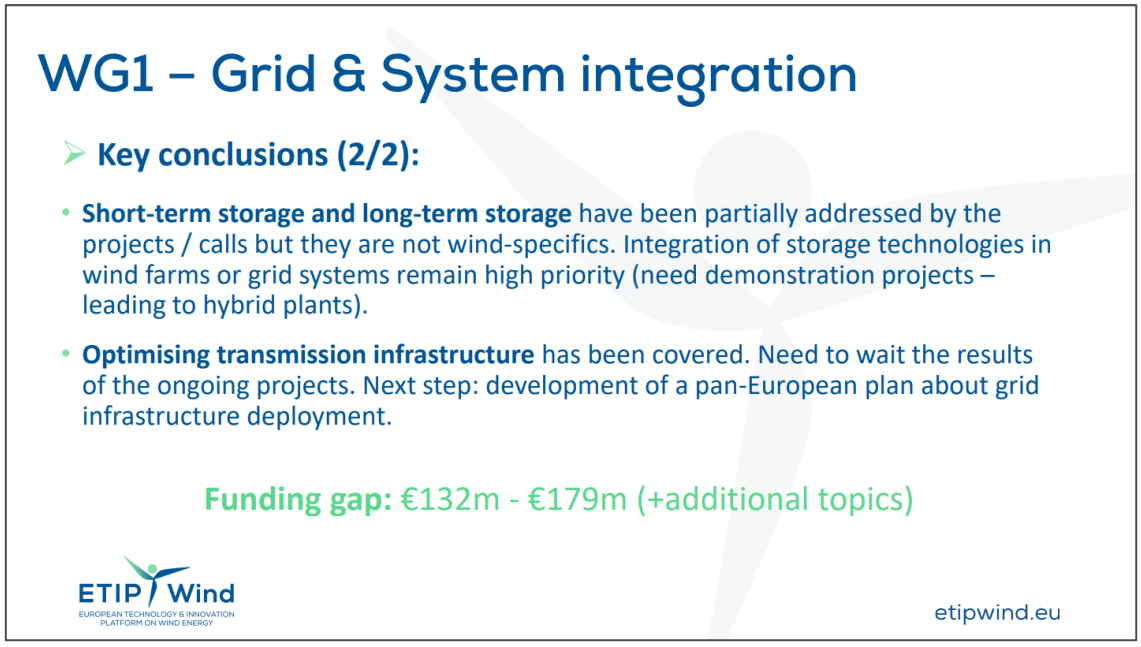
Research area	Horizon Europe WP2021-22 projects	Horizon Europe WP2023-24 calls
Integrated forecasting of power production & demand	Partially addressed	Partially addressed
Short-term energy storage	Partially addressed	Not addressed
Long-term energy storage	Partially addressed	Partially addressed
Multi-cultured wind farms	Not addressed	Not addressed
Modelling future system needs	Partially addressed	Not addressed
Optimising transmission infrastructure	Totally addressed	Partially addressed
Quantification of system services	Partially addressed	Partially addressed
Sustainable hybrid solutions	Not addressed	Not addressed
Stable system with 100% RES	Partially addressed	Partially addressed

The key conclusions from the ETIPWind Steering Committee members are summarised in the slides below.

WG1 – Grid & System integration

➢ Key conclusions (1/2):

- **Modelling future system needs** and **quantification of system services** are the most important priorities. Need funding in the short-term to work with the TSOs and utilities to understand the type of services windfarms will have to provide.
- **Developing the necessary technologies** to answer the system needs is the next urgent step.
  - **Stable system**: Need more focus on Flexibility in the transmission and generation side, hardware solutions, windfarms able to provide ancillary services such as developing grid forming capabilities, development of new converters/systems for provision of system services in the absence of large synchronous generators, etc.
  - **Hybrid plants** topics should focus on integration of flexible technologies (batteries, STATCOM, electrolizers, etc.) in a physical or virtual plant together with wind turbines
  - **Integrated forecasting of power production & demand** is still a priority but maybe not in this Pillar.



More detailed conclusions from the Gap analysis for Pillar 1 can be found in **Annex 5**.

3.2 Pillar 2: Operations & Maintenance

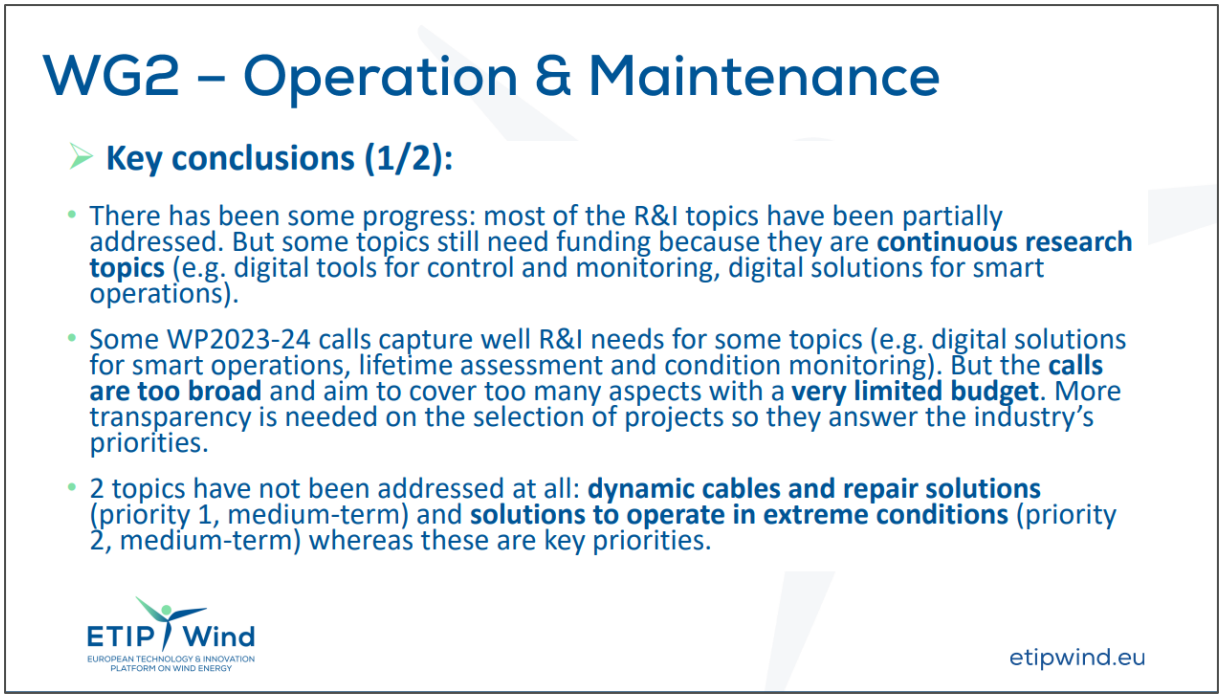
For the pillar 2 "Operations & Maintenance", 2 topics have not been addressed at all and 6 topics have been partially addressed (**Table 2**).

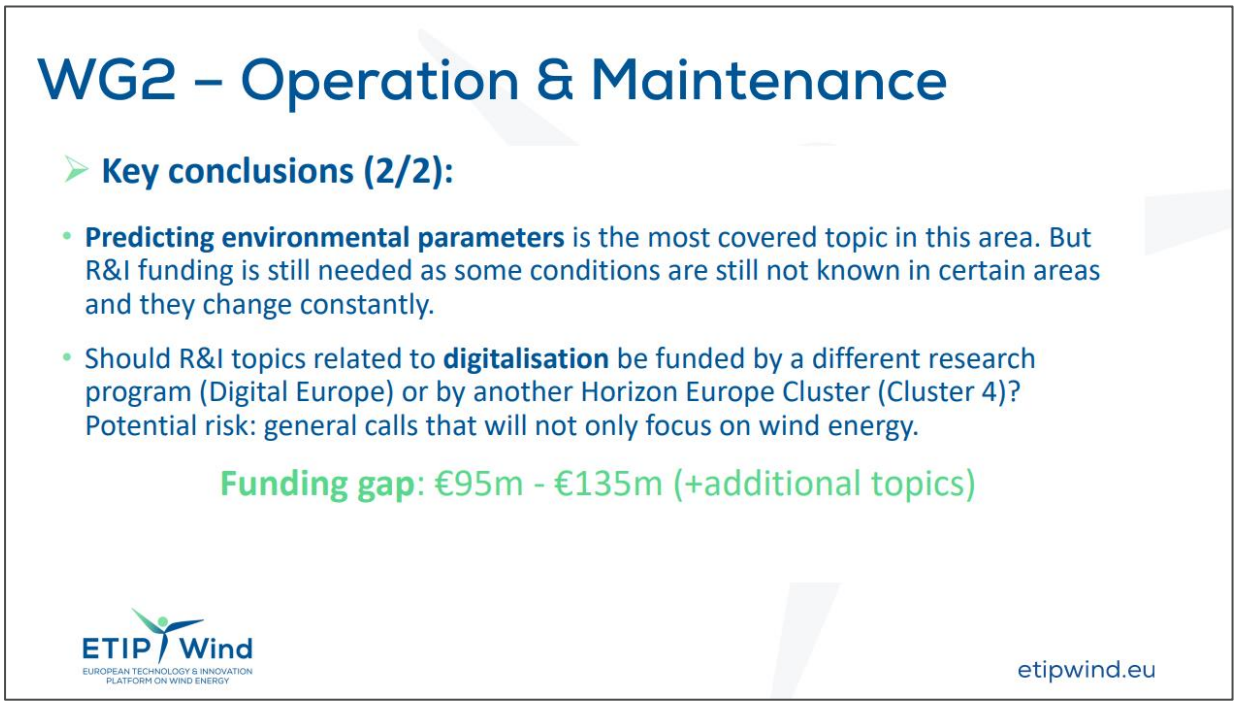
TABLE 2

Summary table of the Gap analysis for Pillar 2 topics

Research area	Horizon Europe WP2021-22 projects	Horizon Europe WP2023-24 calls
Lifetime assessment and condition monitoring	Not addressed	Partially addressed
Digital tools for control and monitoring	Partially addressed	Partially addressed
Robotic inspection and repair methods	Not addressed	Partially addressed
Dynamic cable repair solutions	Not addressed	Not addressed
Digital solutions for smart operations	Partially addressed	Partially addressed
Predicting environmental parameters	Partially addressed	Partially addressed
Decomissioning strategies and technology	Not addressed	Partially addressed
Solutions for operating in extreme conditions	Not addressed	Not addressed

The key conclusions from the ETIPWind Steering Committee members are summarised in the slides below.





More detailed conclusions from the Gap analysis for Pillar 2 can be found in **Annex 6**.

3.3 Pillar 3: Next Generation Technologies

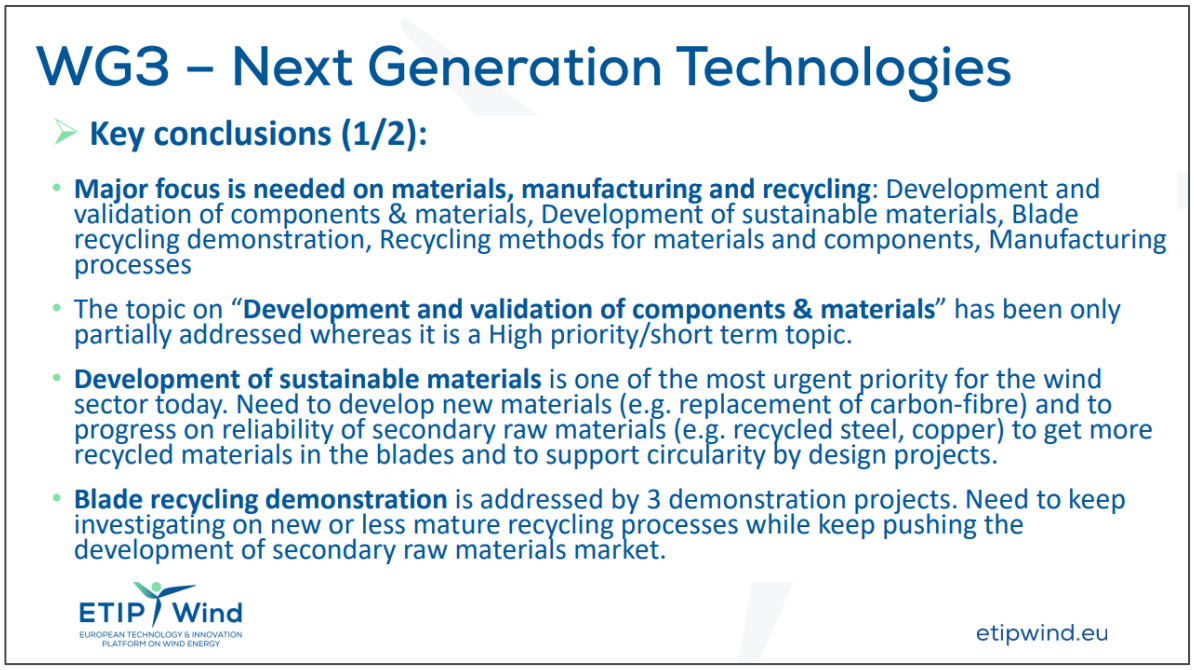
For the pillar 3 "Next Generation Technologies", 2 topics have been addressed by Horizon Europe, 2 topics have not been addressed at all and 9 topics have been partially addressed (**Table 3**).

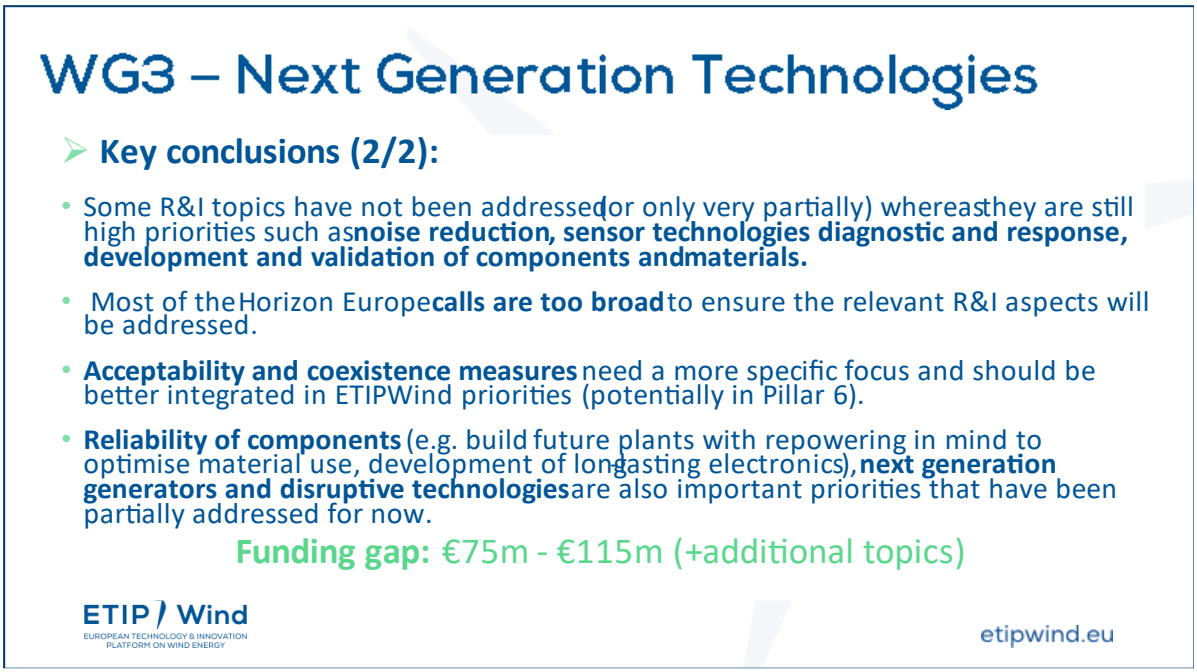
TABLE 3

Summary table of the Gap analysis for Pillar 3 topics

Research area	Horizon Europe WP2021-22 projects	Horizon Europe WP2023-24 calls
Development and validation of components & materials	Partially addressed	Partially addressed
Blade recycling demonstration	Totally addressed	Not addressed
Integrating wind energy in the surrounding natural and social environment	Partially addressed	Partially addressed
New transportation methods for large components	Not addressed	Partially addressed
Development of sustainable materials	Not addressed	Partially addressed
Standards	Not addressed	Not addressed
Manufacturing processes	Not addressed	Partially addressed
Sensor technologies diagnostics and response	Not addressed	Partially addressed
Next generation generators	Not addressed	Partially addressed
Noise reduction	Not addressed	Not addressed
Reliability of components	Not addressed	Partially addressed
Recycling methods for materials and components	Totally addressed	Partially addressed
Disruptive technologies	Not addressed	Partially addressed

The key conclusions from the ETIPWind Steering Committee members are summarised in the slides below.





More detailed conclusions from the Gap analysis for Pillar 3 can be found in **Annex 7**.

3.4 Pillar 4: Offshore balance of plant

For the pillar 4 "Offshore balance of plant", 2 topics have not been addressed at all and 6 topics have been partially addressed (**Table 4**).

TABLE 4

Summary table of the Gap analysis for Pillar 4 topics

Research area	Horizon Europe WP2021-22 projects	Horizon Europe WP2023-24 calls
Data availability and sharing	Partially addressed	Partially addressed
Serial production - analysis of substructure production processes	Not addressed	Not addressed
Cabling and connections	Partially addressed	Partially addressed
Material durability and protection	Partially addressed	Partially addressed
Cross-industry agreement and standards	Not addressed	Not addressed
Integrated optimised design plan	Not addressed	Partially addressed
Verification of methods and procedures	Not addressed	Partially addressed
Supply chain logistics (decommissioning)	Not addressed	Partially addressed

The key conclusions from the ETIPWind Steering Committee members are summarised in the slides below.

WG4 – Offshore balance of plant

➢ Key conclusions (1/2):

- Some R&I topics remain key priorities
  - **cabling and connections & material durability and protection** (in the context of reliability and lifetime extension)
  - **supply chain logistics for decommissioning** (in the context of end of lifetime solutions and minimizing lifecycle environmental impact)
  - **verification of methods and procedures** (In the context of enabling integrated design and performance prediction and monitoring of WTG and Balance of Plant).
- The **scope of the calls is too broad** and address partially the Offshore balance of plant topics with a **very limited budget**. E.g. verification of methods and procedures needs a dedicated call on **integrated verification of models** for the balance of plant and turbine.
- **Data sharing and availability** is still important topic but has a lower priority since it depends on market readiness to share data.

WG4 – Offshore balance of plant

➢ Key conclusions (2/2):

- Some topics are not relevant anymore as stand-alone topics (e.g. serial production – analysis of substructures, cross-industry agreements and standards). For serial production: funding should be more directed to **technologies that enable serial production** (e.g. optimised manufacturing processes)

Funding gap: €27m - €44m (+additional topics)

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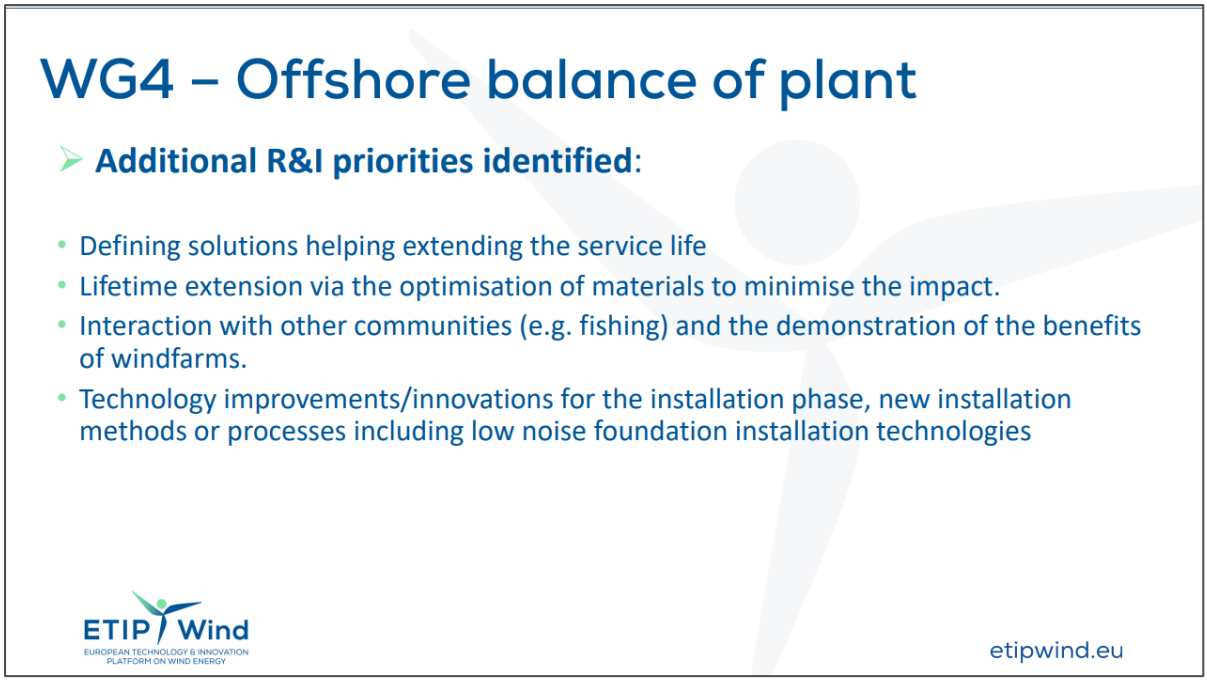

More detailed conclusions from the Gap analysis for Pillar 4 can be found in **Annex 8**.

3.5 Pillar 5: Floating wind

For the pillar 5 "Floating wind", 1 topic has not been addressed at all and 7 topics have been partially addressed (**Table 5**).

TABLE 5

Summary table of the Gap analysis for Pillar 5 topics

Research area	Horizon Europe WP2021-22 projects	Horizon Europe WP2023-24 calls
Lean production	Not addressed	Not addressed
Validation of design tools	Partially addressed	Partially addressed
Mooring and anchors	Partially addressed	Partially addressed
Dynamic electric cables	Partially addressed	Partially addressed
Control methods	Partially addressed	Not addressed
Integrated design process in supply chain	Partially addressed	Partially addressed
Floating installation, assembly and heavy maintenance	Partially addressed	Not addressed
Park level control	Not addressed	Partially addressed

The key conclusions from the ETIPWind Steering Committee members are summarised in the slides below.

WG5 – Floating wind

➢ Key conclusions (1/2):

- **Lean production** is the highest priority and has not been addressed. Need funding especially for manufacturing / high productivity tools, mass-production solutions, standardisation of transport methods and assembly.
- Some funded projects will partially address the priorities identified but focus on the demonstration of one specific technology whereas we need **validation of design tools at full-scale to ensure industrialisation**. Validation of design tools is not a priority anymore, we should move to **industrialised tools**.
- Some calls also partially address the demonstration of innovative concepts, but the **budget is too limited** to test and validate all the different technologies the call could cover.

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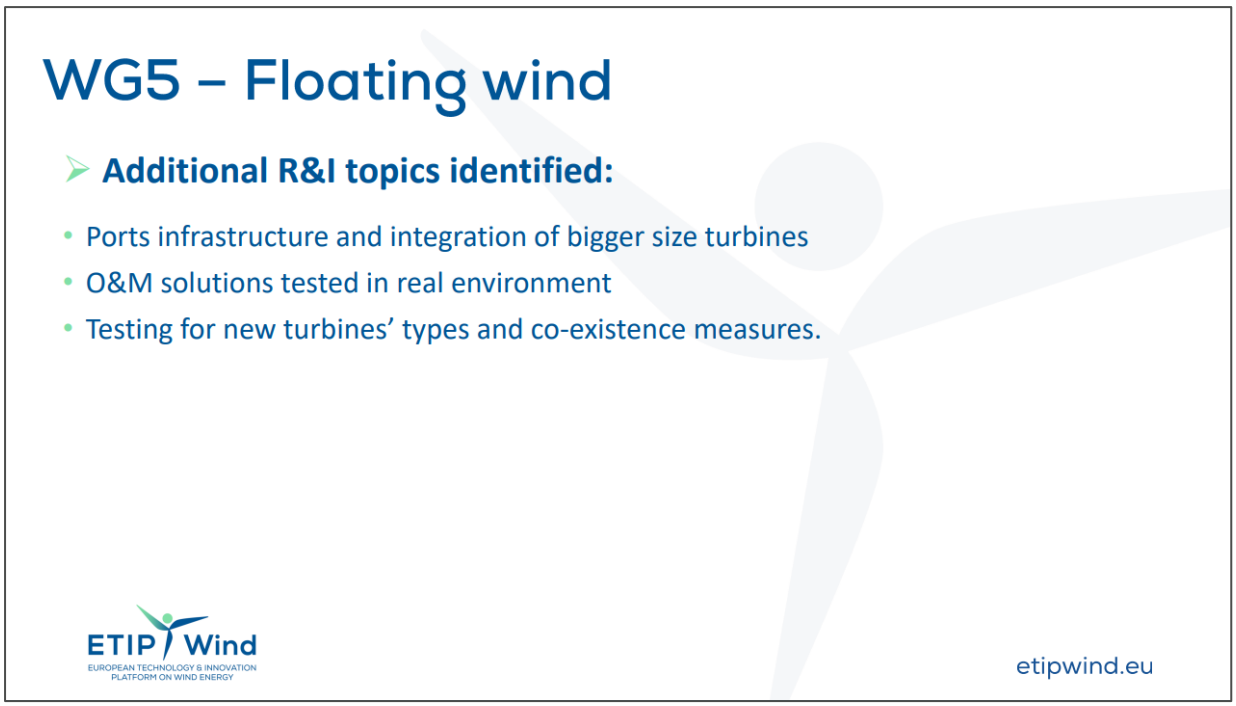
WG5 – Floating wind

➢ Key conclusions (2/2):

- **Mooring and anchors** and **Dynamic cables** are still important topics but need more mature technologies and standardisation.
- **Integrated design process in supply chain** has been partially addressed but need some tools that could help capturing the full picture.
- **Floating installation, assembly and heavy maintenance** topic: need a bigger focus on operations and major components replacement.
- **Control methods and park level control** need to be tested in real site conditions but are less urgent than other topics.

Funding gap: €135m - €190m (+additional topics)



More detailed conclusions from the Gap analysis for Pillar 5 can be found in **Annex 9**.

3.6 Pillar 6: Skills & Human resources

For the pillar 6 "Skills & Human resources", one topic has not been addressed at all and 2 topics have been partially addressed (**Table 6**).

TABLE 6

Summary table of the Gap analysis for Pillar 6 topics

Research area	Horizon Europe WP2021-22 projects	Horizon Europe WP2023-24 calls
Expand and harmonise wind energy teaching in Europe	Partially addressed	Not addressed
Boost wind energy higher education	Not addressed	Not addressed
Joint academia-industry educational programmes	Partially addressed	Not addressed

The key conclusions from the ETIPWind Steering Committee members are summarised in the slides below.

WG6 – Skills and human resources

➢ **Key conclusions:**

- The main focus should be the creation of new skilled jobs. Some projects will develop **joint academia-industry educational programmes** (upskilling and reskilling activities, mapping knowledge gap, etc) but they won't only focus on wind energy. Need funding for **wind-specific** but also **multi-disciplinary** educational and training programmes (including SSH).
- **Wind energy teaching in Europe** and **wind energy higher education** need continuous funding. Required skills are constantly changing because of technology development (e.g. wind energy curriculums, repository of skills needed, mobility of students, etc).
- Wind energy higher education should be addressed via Marie Sklodowska Curie Actions. There are already some ongoing projects on this topic but it needs **continuous funding** (e.g. PhD students)

Funding gap: €30m - €50m (+additional topics)

WG6 – Skills and human resources

➢ **Additional R&I topics identified:**

- Acceptability in general should be included in this Pillar.
- Community engagement activities (empowerment of the citizens) and regulatory issues.
- Research to better show the direct benefits of wind projects on the communities (e.g. interaction with economics, cheap electricity).

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More detailed conclusions from the Gap analysis for Pillar 6 can be found in **Annex 10**.

4.CTOS FEEDBACK

To gather the feedback from the Chief Technology Officers on the Gap analysis conclusions, a meeting was organised in Copenhagen between the ETIPWind Steering Committee members and the CTOs Forum.

In total, 11 CTOs and 20 Steering Committee members attended this half-day meeting (**Picture 1** below).

PICTURE 1

ETIPWind Steering Committee + CTOs meeting in Copenhagen

The CTOs first shared their **feedback on the Gap analysis conclusions** (presented by Jacob Edmonds during the meeting). The key points they raised are summarised below:

- Several CTOs thanked the ETIPWind SC members for the clarity of the Gap analysis and its conclusions.
- A key concern was about the high number of priorities not covered by the Horizon Europe programme until now.
- The scope of the calls indeed seemed too broad and included many topics for a limited budget. This should change in the next Horizon Europe work programmes.
- When it comes to R&I needs, it was said that increasing the wind turbine size even more would be counterproductive.
- The scope of the calls is indeed too broad and is sometimes unclear according to some CTOs. The description of the calls should be clearer in the next Horizon Europe work programmes.
- It is very important to identify innovation and technology needs, but another key element is permitting. This has not been included in the Gap analysis because it is not strictly related to R&I but it should be kept in mind.
- The structure of the Working Groups (based on the Pillars of the 2019 roadmap) seems outdated and is too much based on the Levelised Cost of Energy (LCOE) reduction. The main challenge is scalability and this should be reflected in the structure of the new Working Groups.
- Another key point missing from the Gap analysis is the understanding of our ecosystems including environmental barriers but also coexistence with other communities.

In a second part, the Secretariat asked the CTOs to share their **top-3 R&I priorities** that would have a significant impact on the competitiveness of the European wind energy supply chain. This input will feed the next steps of the ETIPWind Strategic R&I Agenda's update.

The main R&I priorities mentioned by the CTOs during the meeting are summarised in the table below (**Table 7**).

TABLE 7

CTOs feedback on the top R&I priorities for the wind energy sector

Top 1 priorities	Top 2 priorities	Top 3 priorities
Grid system integration	Life Extension towards predictive maintenance	Sustainable materials
Stable 100% based on RES	Supply-chain development	Floating wind
Grid forming	Floating de-risk	Resilience
Flexibility and grid services	Quantification (and definition of system services)	Optimising transmission infrastructure
Digital balance	Human resources	Manufacturing & industrialisation
Forecasting	Supply-chain partnerships (circular economy, local supply)	Transport
Transport of large components (blades)	Energy storage	Permitting
Simulation and testing methods	Sustainable technologies	Hybrid solutions / system integration
Standardisation	Development of right skills (materials, system integration, hybrid experts, huge project execution, etc)	Education and training
Serial / mass production (e.g. floaters)	Align R&I efforts with moving expectations	Data availability
Hybrid projects including storage, Power to X		Technology development (dynamic cables for floating for example)
Industrialisation		Recycling technologies

5. ANNEXES

ANNEX 1

Composition of the Gap analysis' Working Groups

WG1: Wind energy system integration	WG2: Operations & Maintenance	WG3: Next Generation Technologies	WG4: Offshore balance of plant	WG5: Floating Wind	WG6: Skills and Human resources
Adrian Timbus (**Chair**)	Lars Landberg (**Chair**)	Marcin Luczak (**Chair**)	Wouter Dirks (**Chair**)	Benjamin Mauries (**Chair**)	Julia Zilles (**Chair**)
Mariya Trifonova	Bert Verdyck	Fabio Fugazzotto	Benjamin Mauries	Lars Landberg	Helena Solman
John Olav Tande	Adrian Timbus	Bert Verdyck	Adrian Timbus	Wouter Dirks	Tuhfe Gocmen
Ignacio Marti	Ignacio Marti	John Korsgaard	Mariya Trifonova	Adrian Timbus	Arno van Wingerde
Teresa Ojanguren	Stephan Barth	Julia Zilles	John Olav Tande	Mariya Trifonova	
	Athanasios Kolios	Ignacio Marti	Stephan Barth	John Olav Tande	
	Marcin Luczak	Arno van Wingerde	Arno van Wingerde	Ignacio Marti	
	Aidan Cronin	Stephan Barth	Aidan Cronin	Romana Hartke	
	Jacob Edmonds	Mike Anderson		Teresa Ojanguren	
	Helena Solman	Antonio Ugarte		Antonio Ugarte	
		Aidan Cronin		Hanne Wigum	
				Marcin Luczak	
				Wouter Haans	

ANNEX 2

List of Horizon Europe WP2021-2022 projects and Work Programme 2023-2024 calls for proposals

Horizon Europe Work Programme 2021-2022 projects	
AIRE	Advanced study of the atmospheric flow Integrating REal climate conditions to enhance wind farm and wind turbine power production and increase components durability
BeFlex	BOOSTING ENGAGEMENT TO INCREASE FLEXIBILITY
Blades2Build	RECYCLE, REPURPOSE AND REUSE END-OF-LIFE WIND BLADE COMPOSITES – A COUPLED PRE- AND CO-PROCESSING DEMONSTRATION PLANT
BLOW	Black sea fLoating Offshore Wind
DE-RISK	DE-RISK the adoption of Local Flexibility Markets to unlock the safe and reliable mass deployment of Renewable Energy Systems
ENFLATE	ENabling FLexibility provision by all Actors and sectors through markets and digital TEchnologies

EoLO-HUBs	Wind turbine blades End of Life through Open HUBs for circular materials in sustainable business models
Every1	Enable eVeryone's Engagemet in the eneRgY transitiON
FEDECOM	FEDErated -system of systems- approach for flexible and interoperable energy COMmunities
FlexCHESS	Flexibility services based on Connected and interoperable Hybrid Energy Storage System
FLOW	Atmospheric Flow, Loads and pOwer for Wind energy
HERMES	Highly Efficient Super Critical ZERO eMission Energy System
HiPE	High Performance Power Electronics Integrations
HVDC-WISE	HVDC-based grid architectures for reliable and resilient WIdeSprEad hybrid AC/DC transmission systems
INFINITE	INnovative oFfshore wInd techNologies In deep waTErs
IntNET	Interoperability Network for the Energy Transition
JustWind4All	Just and effective governance for accelerating wind energy
MARINEWIND	Market Uptake Measures of Floating Offshore Wind Technology Systems (FOWTs)
MERIDIONAL	Multiscale modelling for wind farm design, performance assessment and loading
Mopo	Comprehensive, fast, user-friendly and thoroughly validated open-source energy system planning framework
NEWGEN	New generation of HVDC insulation materials, cables and systems
NEXTFLOAT	Next Generation Integrated Floating Wind Optimized for Deep Waters
R2D2	Reliability, Resilience and Defense technology for the griD
READY4DC	Getting ready for multi-vendor and multi-terminal DC technology
REFRESH	Smart dismantling, sorting and REcycling of glass Fibre REinforced composite from wind power Sector through Holistic approach
RES4CITY	Renewable Energies System for Cities
SCARLET	Superconducting cables for sustainable energy transition
SENERGY NETS	Increase the Synergy among different ENERGY NETworkS
SiC4GRID	NEXT GENERATION MODULAR SIC-BASED ADVANCED POWER ELECTRONICS CONVERTERS FOR ENHANCED RENEWABLES INTEGRATION INTO THE GRID
SKILL BILL	SKILL BILL: Skill to Boost Innovation and professional fulfiLLment in a sustainable economy
SSH CENTRE	Social Sciences and Humanities for Climate, Energy aNd Transport Research Excellence
SSTAR	Innovative HV Solid-State TrAnsformer for maximizing Renewable energy penetration in energy distribution and transmission systems
STREAM	Streaming flexibility to the power system
SYMBIOSIS	SYMBIOSIS-Offshore Renewable Energy for Defence
TRANSIT	TRANSITion to sustainable future through training and education
WENDY	Multicriteria analysis of the technical, environmental and social factors triggering the PIMBY principle for Wind technologies
WHEEL	Wind Hybrid Evolution for Low-Carbon Solutions
WHISPER	Wind Energy Harvesting for Ship Propulsion Assistance and Power
WIMBY	Wind In My Backyard: Using holistic modelling tools to advance social awareness and engagement on large wind power installations in the EU

Horizon Europe Work Programme 2023-2024 calls for proposals	
HORIZON-CL5-2023-D3-01-01	Renewable Energy Valleys to increase energy security while accelerating the green transition in Europe

HORIZON-CL5-2023-D3-01-05	Critical technologies for the offshore wind farm of the future
HORIZON-CL5-2023-D3-01-10	Supporting the development of a digital twin to improve management, operations and resilience of the EU Electricity System in support to REPowerEU
HORIZON-CL5-2023-D3-01-11	Demonstration of DC powered data centres, buildings, industries and ports
HORIZON-CL5-2023-D3-01-12	Development of MVDC, HVDC and High-Power Transmission systems and components for a resilient grid
HORIZON-CL5-2023-D3-01-13	Development of novel long-term electricity storage technologies
HORIZON-CL5-2023-D3-01-15	Supporting the green and digital transformation of the energy ecosystem and enhancing its resilience through the development and piloting of AI-IoT Edge-cloud and platform solutions
HORIZON-CL5-2023-D3-02-14	Digital twin for forecasting of power production to wind energy demand
HORIZON-CL5-2023-D3-02-15	Critical technologies to improve the lifetime, efficient decommissioning and increase the circularity of offshore and onshore wind energy systems
HORIZON-CL5-2023-D3-03-04	Digital tools for enhancing the uptake of digital services in the energy market
HORIZON-CL5-2023-D3-03-05	Creation of a standardised and open-source peer-topeer energy sharing platform architecture for the energy sector
HORIZON-CL5-2023-D3-03-06	Components and interfacing for AC & DC side protection system – AC & DC grid: components and systems for grid optimisation
HORIZON-CL5-2024-D3-01-10	Next generation of renewable energy technologies
HORIZON-CL5-2024-D3-01-12	Energy Management Systems for flexibility services
HORIZON-CL5-2024-D3-01-13	DC and AC/DC hybrid transmission and distribution systems
HORIZON-CL5-2024-D3-01-14	Condition & Health Monitoring in Power Electronics (PE) - Wide Band Gap PE for the energy sector
HORIZON-CL5-2024-D3-01-15	HVAC, HVDC and High-Power cable systems
HORIZON-CL5-2024-D3-01-17	Development and integration of advanced software tools in SCADA systems for High, Medium and Low voltage AC/DC hybrid systems
HORIZON-CL5-2024-D3-02-08	Minimisation of environmental, and optimisation of socio-economic impacts in the deployment, operation and decommissioning of offshore wind farms
HORIZON-CL5-2024-D3-02-09	Demonstrations of innovative floating wind concepts
HORIZON-CL5-2024-D3-02-10	Market Uptake Measures of renewable energy systems
HORIZON-CL5-2022-D3-03-04	Integrated wind farm control

ANNEX 3

Example of the assessment of the WP2021-2022 projects in Pillar 5 (Floating wind)

HORIZON EUROPE Work Programme 2021-2022 - Funded projects

These projects have been funded by the Horizon Europe Work Programme 2021-2022. The aim is to assess whether the objectives of the project address some of the priorities identified in the ETIPWind 2019 Roadmap.

Totally addressed: all the aspects pf the Roadmap research action have been addressed by the project/call
Partially addressed: Some of the aspects of the Roadmap research action have been addressed by the project/call.
Not addressed: No aspect of the Roadmap research action have been addressed by the project/call.

Project Title	Project Acronym	Wind exclusive	More information	Website	Roadmap Pillar addressed	Research area addressed	How has the research area been addressed?	Aspects covered	Aspects that still need funding	Note	Net EU Contribution	Wind share	Wind relevant contribution	Total Cost	Type of Action	Topic Code	Topic Description
Black sea floating Offshore Wind	BLOW	Yes	https://cordis.europa.eu/project/id/101084323		**Pillar 5: Floating wind**	Validation of design tools	Partially addressed	Demonstration of one specific tech	Benchmark/validation of design tools at full scale for floating wind still needed	Project just started Jan 2023. 5MW Protototype to be built in the Black Sea.	€ 15,483,361.26	100%	€ 15,483,361.26	€ 21,242,887.50	HORIZON-IA	HORIZON-CL5-2021-D3-03-12	Innovation on floating wind energy deployment optimized for deep waters and different sea basins (Mediterranean Sea, Black Sea, Baltic Sea, North-east Atlantic Ocean)
						Floating installation, assembly and heavy maintenance	Partially addressed		Need a bigger focus on operations.								
						Mooring and anchors	Partially addressed										
						Control methods	Not addressed										
INnovative oFfshore wind techNologies in deep waTErs	INFINITE	Yes	https://cordis.europa.eu/project/id/101084321		**Pillar 5: Floating wind**	Integrated design process in supply chain	Partially addressed		Integrated design projects are needed but they need a bigger budget to be developped		€ 15,455,944.89	100%	€ 15,455,944.89	€ 22,398,250.00	HORIZON-IA	HORIZON-CL5-2021-D3-03-12	Innovation on floating wind energy deployment optimized for deep waters and different sea basins (Mediterranean Sea, Black Sea, Baltic Sea, North-east Atlantic Ocean)
						Validation of design tools	Partially addressed	Demonstration of one specific tech	Need funding for full-scale deployment projects with better testing methods to ensure industrialisation of the most competitive solution.								
						Dynamic electric cables	Partially addressed	Focusing on aluminium cables innovative aluminium dynamic cable design that is safer, lighter, cheaper and allows for more standardisation in O&M.	New materials for dynamic cables. Need funding to develop more mature technologies and standardisation								
Market Uptake Measures of Floating Offshore Wind Technology Systems (FOWTs)	MARINEWIND	Yes	https://cordis.europa.eu/project/id/101075572		**Pillar 5: Floating wind**	Not covered in roadmap	**Not covered in the roadmap**			Wider market and regulatory challenge	€ 1,380,033.75	100%	€ 1,380,033.75	€ 1,380,033.75	HORIZON-CSA	HORIZON-CL5-2021-D	Market Uptake Measures of renewable energy systems
Next Generation Integrated Floating Wind Optimized for Deep Waters	NEXTFLOAT	Yes	https://cordis.europa.eu/project/id/101084300		**Pillar 5: Floating wind**	Validation of new innovative concepts	Partially addressed	Demonstration of one specific technology	Need funding for full-scale deployment projects with better testing methods to ensure industrialisation of the most competitive solution.	X1 PivotBouy + 2BE 2-blades downwind turbine. 14 MW design	€ 15,995,130.36	100%	€ 15,995,130.36	€ 22,854,678.00	HORIZON-IA	HORIZON-CL5-2021-D3-03-12	Innovation on floating wind energy deployment optimized for deep waters and different sea basins (Mediterranean Sea, Black Sea, Baltic Sea, North-east
						Control methods	Partially addressed										
Wind Hybrid Evolution for Low-Carbon Solutions	WHEEL	Yes	https://cordis.europa.eu/project/id/101084409		**Pillar 5: Floating Wind**	Integrated design process in supply chain	Partially addressed	Major part of the supply chain involved is actually part of the consortium developing the DemoWHEEL project (inc. turbine supplier and mooring system supplier). Development of a model that can caputre the system as a whole.		Not only the demo project itself but the overall conception of the floater solution has as main focus it ssuitability to be efficiently tackled by te existing supply chain, harbor infrasytructure and contruction & installation means.							
						Validation of design tools	Partially addressed	Demonstration of one specific technology (Concrete Spar floater, 2bladed downwind tubrine, 6MW)	Need funding for full-scale deployment projects with better testing methods to ensure industrialisation of the most competitive solution.		16663950.5	1	€ 16,663,950.50	25289722.2	HORIZON-IA	HORIZON-CL5-2021-D3-03-14	Innovation on floating wind energy deployment optimized for deep waters and different sea basins (Mediterranean Sea, Black Sea, Baltic Sea, North-east Atlantic Ocean)
						Mooring and anchors	Partially addressed										
											€ 64,978,420.76						

ANNEX 4

Example of the assessment of the WP2023-2024 calls for proposals in Pillar 1 (Grids & System integration)

HORIZON EUROPE Work Programme 2023-2024 - Calls for proposals

These calls for proposals have been published in the Horizon Europe Work Programme 2023-2024. The aim is to assess whether the scope of the calls will address some of the priorities identified in the ETIPWind 2019 Roadmap.

Totally addressed: all the aspects pf the Roadmap research action have been addressed by the project/call
Partially addressed: Some of the aspects of the Roadmap research action have been addressed by the project/call.
Not addressed: No aspect of the Roadmap research action have been addressed by the project/call.

Call code	Type of action	Call Title	Total Budget	Number of projects	Budget / project	More information	Roadmap Pillar addressed	Research area addressed	How has the research area been addressed?	Aspects covered	Aspects that still need funding
HORIZON-CL5-2023-	HORIZON-IA	**Renewable Energy Valleys to increase energy security while accelerating the green transition in Europe**	€ 40,000,000.00	2	€ 20,000,000.00	https://ec.europa.eu/info/funding-	**Pillar 1 - Grid & System integration**	Stable system with 100% RES	**Partially addressed**	Storage systems, RES system integration to improve energy efficiency, etc.	General topic even if wind energy will be addressed.
HORIZON-CL5-2023-D3-01-10	HORIZON-IA	**Supporting the development of a digital twin to improve management, operations and resilience of the EU Electricity System in support to REPowerEU**	€ 20,000,000.00	1	€ 20,000,000.00	https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-cl5-	**Pillar 1 - Grid & System integration**	Optimising transmission infrastructure	**Partially addressed**	Contributes to the research action but focuses a lot on flexibility services which is an important topic. Dialogue between TSOs and windfarm operators.	Specifc topic on flexibility, digitalisation and cybersecurity.
HORIZON-CL5-2023-	HORIZON-IA	**Demonstration of DC powered data centres, buildings, industries and ports**	€ 18,000,000.00	2	€ 9,000,000.00	https://ec.europa.eu/info/funding-	**Pillar 1 - Grid & System integration**	Not covered in roadmap	**Not covered in the roadmap**	Not particularly applicable in the energy field.	
HORIZON-CL5-2023-D3-01-12	HORIZON-IA	**Development of MVDC, HVDC and High-Power Transmission systems and components for a resilient grid**	€ 22,000,000.00	2	€ 11,000,000.00	https://ec.europa.eu/info/funding-	**Pillar 1 - Grid & System integration**	Optimising transmission infrastructure Stable system with 100% RE	**Not addressed** **Partially addressed**	Not really about optimisation.	Need to test new converters but not fully covered by the call.
HORIZON-CL5-2023-D3-01-13	HORIZON-RIA	**Development of novel long-term electricity storage technologies**	€ 14,000,000.00	3	€ 5,000,000.00	funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-cl5-2023-d3-01-	**Pillar 1 - Grid & System integration**	Long-term energy storage	**Partially addressed**	Reduced cost and improved efficiency of sustainable renewable energy and renewable fuel technologies and their value chains.	Seems difficult for projects to address all the 3 types of impacts. Budget too low.
HORIZON-CL5-2023-D3-01-15	HORIZON-IA	**Supporting the green and digital transformation of the energy ecosystem and enhancing its resilience through the development and piloting of AI-IoT Edge-cloud and platform solutions**	€ 18,000,000.00	1	€ 18,000,000.00	tenders/opportunities/portal/screen/opportunities/topic-details/horizon-cl5-2023-d3-01-15;callCode=null;freeTextSearchKeyword=HORIZON-CL5-2023-D3-01-15;matchWholeText=true;typeCodes=1,0;statusCodes=31094501,31094502,31094503;programmePeriod=null;pro	**Pillar 1 - Grid & System integration** **Pillar 1 - Grid & System integration** **Pillar 1 - Grid & System integration**	Stable system with 100% RE Quantification of future system services Integrated forecasting of power production and	**Partially addressed** **Not addressed** **Partially addressed**	Demand side and not generation side.	Cybersecurity and digitalisation topics are not really covered by the roadmap. Need funding for quantification of future system services
HORIZON-CL5-2023-	HORIZON-RIA	**Digital twin for forecasting of power production to wind energy demand**	€ 12,000,000.00	2	€ 6,000,000.00	https://ec.europa.eu/info/funding-	**Pillar 1 - Grid & System integration**	Integrated forecasting of power production and	**Totally addressed**		
HORIZON-CL5-2023-	HORIZON-IA	**Digital tools for enhancing the uptake of digital services in the energy market**	€ 11,000,000.00	3	€ 4,000,000.00	https://ec.europa.eu/info/funding-	**Pillar 1 - Grid & System integration**	Optimising transmission infrastructure	**Partially addressed**	Demand side and not generation side. Retail consumers. More related to flexibility.	
HORIZON-CL5-2023-D3-03-05	HORIZON-IA	**Creation of a standardised and open-source peer-to peer energy sharing platform architecture for the energy sector**	€ 5,000,000.00	1	€ 5,000,000.00	https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/to	**Pillar 1 - Grid & System integration** **Pillar 1 - Grid & System integration**	Stable system with 100% RES Integrated forecasting of power production and	**Partially addressed** **Partially addressed**	Data sharing	
HORIZON-CL5-2023-	HORIZON-IA	**Components and interfacing for AC & DC side protection system – AC & DC grid: components and systems for grid optimisation**	€ 10,000,000.00	2	€ 5,000,000.00	funding-tenders/opportunities/port	**Pillar 1 - Grid & System integration**	Optimising transmission infrastructure	**Partially addressed**	Will be beneficial for offshore wind especially if the proposal relates it	
HORIZON-CL5-2024-D3-01-12	HORIZON-IA	**Energy Management Systems for flexibility services**	€ 10,000,000.00	2	€ 5,000,000.00	https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-cl5-	**Pillar 1 - Grid & System integration**	Not covered in roadmap	**Not covered in the roadmap**	Flexibility, smart buildings, smart industrial sites. More relevant for the residential buildings, households.	
HORIZON-CL5-2024-	HORIZON-RIA	**DC and AC/DC hybrid transmission and distribution systems**	€ 13,000,000.00	2	€ 6,000,000.00	https://ec.europa.eu/info/funding-	**Pillar 1 - Grid & System integration**	Optimising transmission infrastructure	**Partially addressed**		
HORIZON-CL5-2024-D3-01-14	HORIZON-RIA	**Condition & Health Monitoring in Power Electronics (PE) - Wide Band Gap PE for the energy sector**	€ 13,000,000.00	3	€ 4,000,000.00	funding-tenders/opportunities/portal/screen/opportunities/to	**Pillar 1 - Grid & System integration**	Optimising transmission infrastructure	**Partially addressed**	Electronics in transmission infrastructure (conductors, semi-conductors, materials). Very specific.	
HORIZON-CL5-2024-	HORIZON-IA	**HVAC, HVDC and High-Power cable systems**	€ 16,000,000.00	3	€ 5,000,000.00	https://ec.europa.eu/info/funding-	**Pillar 1 - Grid & System integration**	Optimising transmission infrastructure	**Not addressed**	Very specific to cables. Not really related to any energy specific application.	
HORIZON-CL5-2024-	HORIZON-RIA	**Development and integration of advanced software tools in SCADA systems for High, Medium and Low voltage AC/DC hybrid systems**	€ 12,000,000.00	2	€ 6,000,000.00	https://ec.europa.eu/info/funding-	**Pillar 1 - Grid & System integration**	Quantification of system se	**Partially addressed**		
HORIZON-CL5-2024-	HORIZON-CSA	**Market Uptake Measures of renewable energy systems**	€ 8,000,000.00	4	€ 2,000,000.00	https://ec.europa.eu/info/funding-	**Pillar 1 - Grid & System integration**	Stable system with 100% RES	**Partially addressed**	General call.	

ANNEX 5

Summary sheet of the Gap analysis for Pillar 1

Roadmap Pillar	Research action area	Recommended research actions	Covered in HEU WP2021-22 projects?	Covered in HEU WP2023-24 calls for proposals?	Do we still need funding for this research action area?	Priority	Recommended funding amount	Preliminary conclusions
Pillar 1 Grid and System Integration	Integrated forecasting of power production & demand	• Develop harmonised and standardised data models to be used for new data sets. • Create, aggregate and integrate various data sets to be used across all of the above use cases. • Adaptat and integrate existing forecasting methods to the new data sets and demand profiles	Partially addressed	Partially addressed	Medium-term	Priority 2	€2m-€4m	This R&I area is partially addressed by two WP2023-24 calls for proposals and by the BeFlexible project which will develop quicker and more powerful communication systems between grid operators and windfarm operators. But this area will still need funding in the medium-term.
	Short-term energy storage	• Economic and technical assessment of selected battery storage technologies (li-ion, flow, high temperature) with regard to their suitability in providing different requirements of grid and system services. • Model simulation and comparison of ideal versus real windfarm conditions in combination with technologies and services including variations in design and dimensioning of wind farm controller and storage system. • Implementation of measurements in combination with selected best case storage systems and analysis of the results.	Partially addressed	Not addressed	Short-term	Priority 1	€20m-€30m	This R&I area has been partially addressed by 2 projects of the WP2021-22: The FEDECOM project which will focusses on Power to X and short, mid to long term energy storage. And the FlexCHESS projec which addresses grid stability via ancillary services and long-term energy storage. But these projects are not wind-specific. The 3 recommended research actions of the roadmap still need funding in the short-term.
	Long-term energy storage	• Study requirements for long-term energy storage in the future energy system. • Research study to identify and verify the potential business cases in various regions of Europe. • Comparative concept study: integration of various seasonal storage facilities in wind farms or turbines. • Development of control algorithms of new system services provided by flexible storage (e.g. electrolysers) including prototype testing, validation and verification.	Partially addressed	Partially addressed	Medium-term	Priority 1	€30m-€50m	This R&I area has been partially covered by 3 projects in the WP2021-22: BeFlex, FEDECOM and FlexCHESS which focus on Power to X and storage infrastructures. But these projects are not wind-specific. A WP2023-24 is is dedicated to long-term storage technologies but again the call does not include any wind-specific aspects. Long-term energy storage still needs funding in the medium-term and requires a higher budget since it is more expensive than short-term (TRLs are lower for long-term storage).
	Multi-cultured wind farms	Improve models for farm layout and optimise tools for park planning of mixed wind farms with regard to multiple objectives like yields and costs. • Develop new control strategies for optimal operation of the mixed farms, taking into account interaction effects, grid stability and energy exchange price. • Research of specific turbine technologies for cost-effective turbines optimised to perform under specific wind speed regimes.	Not addressed	Not addressed	Long-term	Priority 3		Developping windfarms with different types of turbines is very challenging. This R&I topic is not a priority at the moment.
	Modeling future system needs	• Create new software/hardware packages allowing quicker and less resource consumption simulations. • Develop new simulation models representing accurate behaviour of wind turbines, wind farms and wind farm clusters. • Develop new models to simulate the power system and to pre-emptively detect new stability phenomena (e.g., harmonic instability). • Develop solutions and controls to mitigate grid instabilities related to harmonics and Phase-Locked Loop. • Develop models for power quality assessments at level of wind farm cluster. • Validate numerical models through power quality meters installed at wind farm clusters. • Economic assessment of potentially new grid requirements for renewable feed-in technology and storage technology.	Partially addressed	Not addressed	Short-term	Priority 1	€10m-€15m	This R&I area is partially addressed by the FEDECOM project that will deliver a scalable and adaptable cloud-based platform composed of analytical, modelling and optimisation services for planning, supervision and control of integrated local energy systems. But this model will not focus on wind-specific aspects. This R&I area still need funding in the short-term to work with the TSOs and utilities to understand the type of services that windfarms will have to provide. In particular given the increasing number of windfarms that will be developped to reach the RePowerEU targets.
	Optimising transmission infrastructure	• Development of quicker and more powerful communication systems between grid operators and wind farm operators. • Establish a big data information exchange platform. • Further development of HVDC technology. • Feasibility study on offshore direct current collector grids. • Optimal design and operations concepts of hybrid grids (HVDC & HVAC). • Develop, test and validate cable protection concepts for direct current and hybrid grids. • Technology development for floating platforms and suitable cabling connection concepts.	Totally addressed	Partially addressed	Short-term	Priority 3		This R&I action is addressed by 8 projects of the WP2021-22 (BeFlex, DE-RISK, FlexCHESS, HVDC-WISE, NEWGEN, RJD2, READY4DC and InterOPERA). In addition, 5 of the WP2023-24 calls will also cover some aspects related to that topic (even if they aren't specifically focusing on wind energy projects). This R&I action does not require additioanl funding at the moment.
	Quantification of system services	• Definition and characterisation (mandatory or operation capability) of system service requirements and updates to the grid codes or market rules where relevant. • Design and testing of new converters/systems for provision of system services in the absence of large synchronous generators. Including (but not limited to):Synthetic or virtual inertia; Black start; Frequency control (Fast Frequency Response, Frequency Containment reserves and Frequency Replacement Reserves); Fault-Ride-Through current contribution; and Voltage control. • Economic and technical assessment of the capabilities of power generation technologies to provide grid services. • Analysis of interdependencies between power system developments and increased system services requirements. • Demonstration of live coordination of controls provided by different sources of power generation	Partially addressed	Partially addressed	Short-term	Priority 1	€15m-€20m	The IntNET project will include the definition and characterisation of system service requirements and will therefore partially address this R&I action. It is also partially addressed by one of the WP2023-24 call. However, funding will still be needed for the harmonisation and standardisation of system services. And other recommended research actions of the ETIPWind Roadmap are still relevant. This is also an important topic in the perspective of the Market design reform.
	Sustainable hybrid solutions	• Technology development of new concepts for the electrical infrastructure of hybrid plants (e.g. dc-connections). • New tools and methods for optimal sizing and design of the hybrid plants. • Development of next generation plant control logics to optimise system operation and fulfil grid integration requirements. • Research studies into the possible future technical requirements in different regions across Europe. • Economic assessment of the system value of hybrid plants.	Not addressed	Not addressed	Medium-term	Priority 3	€5m-€10m	This topic has not been addressed by the projects or the calls. Hybird plants is not the priority at the moment eventhough it is a "nice-to-have". Wind + storage should be the focus right now.
	Stable system with 100% RES	• Research study of relevant effects in an inverter-based grid. • Impact assessment of load-characteristic and grid equipment to system stability (including possible system service out of loads). • Research into and demonstration of alternative technologies for system stabilisation (e.g. synchronous condenser). • Impact assessment of the topological distribution of stabilising sources on system stability. • Development of new system models for grids with weak voltage and frequency control. • Research study on additional and necessary system services for phases with high renewable penetration (including necessary inertia). • Research study on system interactions in grids with high shares of variable renewables. • Development and demonstration of cost-minimal-solutions, products and requirements to ensure a 100% renewables-based energy system post-2050.	Partially addressed	Partially addressed	Short-term	Priority 1	>€50m	This R&I action (mainly flexibility aspects) is partially addressed in 4 projects of the WP2021-22 (DE-RISK, ENFLATE, FEDECOM, FlexCHESS). These projects focus mainly on the market and demand side. In addition, 4 calls address this topic but only partially. The calls are general calls where various aspects can be covered or not depending on the selected projects. Additonal funding is needed for more technology oriented and wind specific topics. R&I needs to focus on flexibility in the transmission and generation side, hardware solutions, projects which make the windfarms able to provide ancillary services such as developing grid forming capabilities. The development of new converters/systems for provision of system services in the absence of large synchronous generators (Synthetic or virtual inertia; Black start;Frequency control Fault-Ride-Through current contribution; and Voltage control).

ANNEX 6

Summary sheet of the Gap analysis for Pillar 2

Roadmap Pillar	Research action area	Recommended research actions	Covered in HEU WP2021-22 projects?	Covered in HEU WP2023-24 calls for proposals?	Do we still need funding for this research action area?	Priority	Recommended funding amount	Preliminary conclusions
Pillar 2 - Oerations & Maintenance	Lifetime assessment and condition monitoring	• Industry assessment of instrumentation – identify what available instrumentation is not commonly used in the wind industry and which tools used need significant improvement. • New instrumentation to assess actual condition of components, including models that can predict the lifetime of a component. • Development of new measurement tools for shorter and more accurate site inspections. • Development and validation of models' remaining lifetime per component and for full system assessments based on additional Condition Monitoring Systems data. • Identification, development and assessment of new lifetime extension methods, including component replacement/repair and adjusting operational procedures. • Development of comprehensive methodology to take optimal commercial decisions based on new digital architecture using big data analytics and machine learning. • Development and validation of new models and standards to extrapolate data values from singular wind turbines to entire wind farms.	Not addressed	Partially addressed	Short-term	Priority 1	€15m-€20m	This R&I area is partially addressed by one of the WP2023-24 calls dedicated to lifetime, decommissioning and circularity of wind energy systems. The call will address new installation, decommissioning, condition monitoring technologies and O&M methodologies. However the scope of the call is very broad and it is not clear if these aspects will be tackled within the selected projects. Funding is still needed in this area because it's important to continously reduce the uncertainty and optimise the operation and lifetime of the huge investments made in wind farms across Europe.
	Digital tools for control and monitoring	• Development of new digital tools for onsite operations; • Development of new/improved digital tools for data collection, analysis and visualisation.	Partially addressed	Partially addressed	Short-term	Priority 2	€10m-€15m	Although this R&I area have not been identified as addressed in any project or call. It is linked to all projects and calls related to Pillar 2 which partially addres this topic. This topic needs continuous funding because it is an ongoing researcg topic which can contribute to a lot of different R&I topics.
	Robotic inspection and repair methods	Demonstration of testing methods to enhance understanding and knowledge about new applications of drones, robots and AUVs (not only for inspection, but also for coating, measuring, cleaning, repairing, etc). • Development of new/improved models of drones, robots and AUVs, allowing more autonomy and flexibility of (remote) operations and inspections. • Common European Regulation for the use of drones and AUVs. • Development of tools/models for better integration on maintenance activities (i.e. artificial intelligence, image treatment, new sensors and capabilities, etc.).	Not addressed	Partially addressed	Short-term	Priority 2	€10m-€15m	This R&I area is partially addressed by one WP2023-24 call dedicated to lifetime, decommissioning and circularity of wind energy systems. The call mentions remote controlled devices for in situ repairs by robots as an example of relevant action. But it is not clear if the selected projects will address this point. With the upcoming increase of windfarms in the future, robotics will be more and more needed to replace human resources. A common European Regulation for the use of drones and AUVs could be needed. This is not a research action but it needs to be taken into account.
	Dynamic cable repair solutions	• Repair methods for bottom-fixed dynamic cable failures. • Create comprehensive overview of existing repair methodologies and concepts all Technology Readiness Levels (TRL)- cable-to-cable joint damages, intra-cable damages. • Analyse advantages and disadvantages of systems to prevent damages, e.g. bend restrictors (limiting bending, increasing thermal insulation), adding "S" spring flexibility to rising cables. • Floating wind has a set of specific challenges which are addressed in the section on floating offshore wind. It suffices to say that more research is needed to: - Improve understanding of dynamic cable failures. Dedicated analysis of which floater concept will increase stress and fatigue on dynamic cables. - Identify changes in failure modes, estimate impact on failure frequency and severity and anticipate the signals in Cable Management Systems (CMS) that would provide ad-hoc and predictive failure detection.	Not addressed	Not addressed	Medium-term	Priority 1	€10m-€15m	This R&I area has not been addressed by any of the proejcts or calls. This is still a huge challenge for the industry which will become more and more important with the increasing number of windfarms. Efficient dynamic cables (especially for high voltages) still need to be developped as well as repair solutions. This is mainly a problem for the floating wind turbines but also for the bottom fixed.
	Digital solutions for smart operations	• Develop digital/AI solutions that significantly reduce costs of operations (followed by development and maintenance of onshore and offshore wind farms). • Establishing a common research framework for evaluating the risks associated with digital/AI solutions, including cyber security aspects. • Development and validation of models to verify the performance of digital/AI solutions.	Partially addressed	Partially addressed	Short-term	Priority 1	€15m-€20m	This R&I area is partially addressed by the project MERIDIONAL and the call dedicated to digital twin. Indeed it is expected that one project on offshore digital twin will be funded by this call and one on onshore digital twin. It will address aspects such as: predictive maintenance, structural health and conditional monitoring, AI / machine learning solutions. The call related to the development of a standardised and open-source peer-topeer energy sharing platform also partially addresses this topic. It includes the development of an AI-based software that uses machine learning processes to integrate core operations and local grid constraints. However, this call is very broad and one project will not be enough to cover all the aspects mentionned in the call Research funding is still needed on this ongoing research topic. The key issue in this field is to understand the uncertainties connected to the prediction and then to reduce the uncertainties. Funding for the "next generation of digital twins" is perhaps a step too far. R&I for a complete set of digital twin models is still needed (e.g. software model to make efficient use of the data available, automised with a concept that is FAIR).

Pillar 2 - Oerations & Maintenance								
	Digital solutions for smart operations	• Develop digital/AI solutions that significantly reduce costs of operations (followed by development and maintenance of onshore and offshore wind farms). • Establishing a common research framework for evaluating the risks associated with digital/AI solutions, including cyber security aspects. • Development and validation of models to verify the performance of digital/AI solutions.	Partially addressed	Partially addressed	Short-term	Priority 1	€15m-€20m	This R&I area is partially addressed by the project MERIDIONAL and the call dedicated to digital twin. Indeed it is expected that one project on offshore digital twin will be funded by this call and one on onshore digital twin. It will address aspects such as: predictive maintenance, structural health and conditional monitoring, AI / machine learning solutions. The call related to the development of a standardised and open-source peer-topeer energy sharing platform also partially addresses this topic. It includes the development of an AI-based software that uses machine learning processes to integrate core operations and local grid constraints. However, this call is very broad and one project will not be enough to cover all the aspects mentionned in the call Research funding is still needed on this ongoing research topic. The key issue in this field is to understand the uncertainties connected to the prediction and then to reduce the uncertainties. Funidng for the "next generation of digital twins" is perhaps a step too far. R&I for a complete set of digital twin models is still needed (e.g. software model to make efficient use of the data available, automised with a concept that is FAIR).
	Predicting environmental parameters	• Fundamental research in wind energy turbulence such as demonstration and validation models for out-of-boundary layer flow. • Improved measurement devices and methods for all environmental parameters (e.g. wind and wave). • Next generation models for environmental parameters (e.g. wind and wave). • Prediction models for average quantities of environmental parameters, including the associated uncertainties. • Models for the prediction of extreme values of environmental parameters, including the associated uncertainties. • Research into the application of Artificial Intelligence (AI) in the prediction of environmental conditions. • On-site experiments measuring all environmental parameters at a high temporal and spatial resolution.	Partially addressed	Partially addressed	Short-term	Priority 1	€15m-€20m	This R&I area is one of the topics related to Pillar that is the most addressed. 3 projects paretially address this topic (AIRE, FLOW, MERIDIONAL). The projects will include fundamental research in wind energy turbulence, demonstration and validation models, measurement devices for all parameters (wind, wave, etc), on-site experiment measuring, focus on situations when rotor is outside of the atmospheric boundary layer. etc. One of the call will also cover wind and weather forecast models. But some aspects still need funding such as the development of a forecast that is not focused on the weather services but more on a gobal model. R&I funding is still needed in this field beacuse there are still some areas where conditions are not known and because of climate change conditions are changing constantly. This topic is extremely complex and will become more complex with the turbines getting bigger and bigger. Research activities above TRL5 also need to be considered and a specific focus on on icing of blades and floaters could be relevant.
	Decomissioning strategies and technology	• Mapping of required scientific and technical disciplines within decommissioning technology. • Development of decommissioning methods and procedures taking the required combination of scientific and technical disciplines into account. • Development of decommissioning technologies for offshore wind. Including monopile extraction (e.g. over-pressure, vibro-extraction) and new cutting tools for subsea bed cutting. • Formulation of decommissioning demonstration projects. • Development of decommissioning vessels specifically suited to offshore wind, building on experiences from the oil & gas sector (e.g. lessons learned from "pioneering spirit" vessel). • Development of economic model for full decommissioning project cycle, including a cost/benefit analysis.	Not addressed	Partially addressed	Medium-term	Priority 2	€10m-€15m	This R&I area is partially addressed by 2 calls of the WP2023-24. The first call will cover R&I for new technologies for effective and environmentally friendly decommissioning of wind energy systems. The second call will cover R&I for minimisation of the impacts of offshore windfarms throughout their lifetime including cost-effective solutions for the decommissioning of offshore wind farms. The 2 calls seem to be too broad to cover all the aspects they include, especially with the foreseen budget. Whereas R&I funding is still needed espcially for floating wind turbines decommissioning.
	Solutions for operating in extreme conditions	• Development of new/improved coatings (hydrophobic) for an anti-icing solution. • Development of an improved and more reliable ice detection system. • Development of a more efficient and cheaper de-icing system. • Development of an improved control system able to manage unexpected loads due to extreme weather conditions.	Not addressed	Not addressed	Medium-term	Priority 2	€10m-€15m	This R&I area has not been addressed by the calls or by the projects. This is probably less relevant for the European market than elsewhere. But on the other hand, conditions are changing because of climate change so we still need research funding for this topic.

ANNEX 7

Summary sheet of the Gap analysis for Pillar 3

Research action area	Recommended research actions	Covered in HEU WP2021-22 projects?	Covered in HEU WP2023-24 calls for proposals?	Do we still need funding for this research action area?	Priority	Recommended funding amount	Preliminary conclusions
Development and validation of components & materials	• Determination of the most effective (nano-) reinforcement method specific to e.g. plydrop zones, considering the aspects of ease of application and improvement in the structural properties assessed through mechanical testing. • Investigate and evaluate a method for cost and material effective connections between components of different materials (e.g. wood, steel, concrete), including material testing and strength analyses of adjacent joints. • Developing, testing and implementing solutions for preventing unwanted effects, like surface charging, when introducing new materials. • Provide a set of benchmark experiments for fatigue-driven problems at component or subcomponent level. • Validation of simulation methods using benchmark experiments.	Not addressed	Not addressed	Medium-term	Priority 1	€15m-€20m	This R&I area has not been addressed by the projects or calls whereas it is still an important priority. Recommended research actions are still valid.
Blade recycling demonstration	• Development of financial model for recycling of wind turbine blades. • Assessment of different methods of recycling of wind turbine blades according to developed financial model. • Demonstration of industrialised recycling of wind turbine blades scalable to the coming volumes of end-of-life blades. • Demonstration of re-use of materials from recycled blades.	Totally addressed	Not addressed				This R&I area will be totally addressed by the WP2021-22 projects (Blades2build, EoLO-HUBs, REFRESH). Additional funding for blade recycling in the future but it will depend on the results of the ongoing projects. Need to keep investigating on new or less mature recycling processes while keep pushing the development of the market for secondary raw materials
Integrating wind energy in the surrounding natural and social environment	• Assessment of reliable simulation models for different sources of environmental impact, e.g. noise, vibrations to the soil, visual impact. • Development of improved design solutions for noise, vibrations, and/or visual impact reduction. • Creation of projects and campaigns to increase the culture and enhance the positive attitude of people toward wind energy. • Investigating if small wind turbines in populated/built areas could increase acceptance. • Long-term change of emissions and acceptance during lifetime.	Partially addressed	Partially addressed	Short-term	Priority 1	€10m-€15m	This R&I area has been partially addressed by 4 projects (JustWind4All dedicated to regulation and social acceptance, SYMBIOSIS and WIMBY dedicated to the creation of projects and campaigns to enhance the positive attitude of people towards wind energy, and WENDY dedicated to the development of a tool able to identify the optimal turbines' siting with the minimum environmental impact and highest social acceptance). But these projects are not addressing the technical challenges identified in this research area. And calls are too broad to know if they will tackle those aspects. The R&I area will also be partilly addressed by 2 WP2023-24 calls. Funding is still needed for more invesitgation of the benefits on the local communities, benchmarking living close to wind turbines vs. living close to coal plants. Other aspects that still need funding are: development of objective criteria, technical solutions for reduced emissions, integrating aspects of procedural and distrubtional justice. But acceptability is not only connected to Pillar 3, it needs to be transversal to all projects. Perhaps it could better be covered by Pillar 6. In the future, more specific actions for specific regions of Europe (e.g. Poland case) could be defined.
New transportation methods for large components	• Concept development • Future blade transportation requirements to be mapped (geography, cost, geometry). • Cargo airship to be further developed and financial/environmental benefits documented. • A cargo airship scale demonstration is needed to mature and validate: - Certification and flight operation legislation for cargo airships for wind power. - Technical evaluations and feasibility study. - Define conceptual deployment plans for cargo airships for wind power.	Not addressed	Partially addressed	Medium-term	Priority 3		This R&I area has been partially addressed in one of the WP2023-24 calls dedicated to minimisation of impact for offshorewindfarms. This topic is still important because transportation methods is getting to be a huge problem for the deployment of offshore wind. But it is more an industrialisation issue at the harbour level rather than a research topic. Cargo airship is not really a relevant priority anymore. Cargo airship as all the innovative transports for bigger and larger components should be better analysed and scaled through funded projects in order to all have the possibility to install larger turbirnes in the near future also onshore
Development of sustainable materials	• Mapping and evaluation of sustainable material system potential suitable for use in manufacture of wind turbine blades. • Development of new high-performance materials matching or outperforming current state of the art materials for wind turbine blades and securing full sustainable and easily recyclable blades at end of life. • Demonstration of the new developed materials in sustainable design of wind turbine blades.	Not addressed	Partially addressed	Short-term	Priority 1	€15m-€20m	This R&I area will be addressed by two WP2023-24 calls (one dedicated to offshore windfarm of the future and one dedicated to lifetime, decomissioning and circularity of offshore and onshore wind systems which covers alternatives in materials / new advanced materials). This is a key priority in the current context. We need to find solutions to get out o rare-earth materials especially for magnets. This topic still need research funding to find new materials (e.g. replacement of carbon-fibre) and to get more recycled materials in the blades which will take a long time. Funding is needed to suppprt circularity by design projects. This research area should be linked to the one on development of materials and
Standards	• Review current standards and create a roadmap for new standards like IEC, ISO to support future optimisation of turbine design. • Explore the opportunities in the use of digital twins in the verification of various turbine components. • Map the use of components that are regulated differently in different EU countries and standardise them to drive cost down (e.g. aviation lights, safety system, fire extinguish systems). • Develop a standard transportation tools for heavy equipment and harmonise regulations across the EU.	Not addressed	Not addressed				This is not a priority anymore. Perhaps an interesting topic could to develop standarised KPIs towards LCOE/LCA.

Manufacturing processes	• Develop robot technology to cope with turbine growth and to reduce manual work in e.g. blade production. • Develop further the area of utilising smart supply network with the primary goal of reducing CO2 footprint. • Develop the next generation of sensor technologies to support real-time mapping and traceability of materials in the manufacturing process. • Develop further tools and processes for 3D printing of large components. • Further develop cyber security in mobile manufacturing. • Further develop artificial intelligence to optimise manufacturing processes	Not addressed	Partially addressed	Short-term	Priority 1	€20m-€30m	This R&I area will be partially addressed by the call dedicated to offshore windfarms of the future. It will remain an issue, especially if we relocate the production in Europe. Wihtin this area, recommended research actions could be discussed with A.SPIRE (Processes4Planet Partnership) Still needed funding for this in order to help relocate teh wind industry supply chain in
Sensor technologies diagnostcs and repsone	• Development of smart rotor technologies, including necessary sensors and controllers. • Development of (big) data acquisition, storage and analysis methods based on machine learning and physical modelling. • Setting up of demonstration and testing facilities to try out new condition monitoring techniques (test rigs, test turbines, test wind farms). • Study of uncertainties and errors in measuring chains. • Improving structural health monitoring by embedding methods and sensor data in digital twins on turbine and wind farm level.	Not addressed	Partially addressed	Medium-term	Priority 2	€5m-€10m	This R&I area has been addressed only partially in the WP2023-24 call dedicated to condition & health monitoring in power electronics. It is still a key enabling technology for digital twin of the turbine. If we want a full digital twin system, it still needs technology development. Funding is also needed for projects on sensors lifetime. On this topic, ETIPWind could collaborate with the Joint Technology Initiative.
Next generation generators	• Developing new materials and generator topologies. • Researching electromagnetic coupled mechanical dynamics in wind turbine drive trains. • Research the most suitable generator topologies for modularity. • Determine the generator faults with the highest frequency rate. • Research the suitable electric drive topologies for modular generators. • Investigation of generator driver control techniques under lighter loads to maximise efficiency. • Investigation of generator driver control techniques under faults to continue operation.	Not addressed	Partially addressed				This R&I area will be partialt addressed by one of the WP2023-24 calls (the one dedicated to offshore windfarms of the future mentions compact generators, reliable dirve train). But the budet for this call seems too low to tackle all the aspects mentionned in the call description. Funding is still needed in this field for....

Noise reduction	• Assessment of more reliable simulation models for noise. • Development of improved design solutions for noise reduction. • Development of noise-based siting strategies. • Improvement and validation of the numerical tools from lab experiments and tests on the fields. • Integration of these models into the design loop. • Investigate fluid structure interaction and impact on dynamic stall and low frequency noise in and out of rated regimes. • Development of passive treatments to further reduce noise. • Long range acoustic propagation (farm level) including atmospheric and ground effects.	Not addressed	Not addressed	Short-term	Priority 1	€5m-€10m	This R&I area has not been addressed by the projects or the calls. It continues to be of high importance in onshore, as one of the key elements in the environmental effects of wind turbines
Reliability of components	• Reliability modelling with uncertainty consideration and taking into account failure mechanisms. • Development of digital twins of key components and systems. • Maturing of computational-fluid-dynamics-based aeroelastic analysis methods, backed by dedicated wind tunnel or full-scale tests. • Measuring of reliability-relevant imperfections. • Determination of model uncertainties. • Development of a virtual simulation environment for the economic quantification of material uncertainties	Not addressed	Partially addressed	Short-term	Priority 1	€10m-€15m	This R&I area will be addressed by one WP2023-24 call (dedicated to lifetime, decommissioning and circularity of onshore and offshore wind systems). But funding is still needed in this area for.... - access to the operational data for the broad research comunnity, so far it is restricted to the OEM, utilities and insurance companies - standardised assessment and evaluation KPI (downtime days/utility, failure rate/OEM), unification of the digital twins interoperability; - testing at site with the open access data
Recycling methods for materials and components	• Assessment of different recycling methods in a commercial and industrialised framework. • Identify market barriers for comercialisation of recycling of wind turbine blades and generate recommendations to eliminate those.	Totally addressed	Partially addressed				This R&I area has been addressed by the Blades2Build, EoLO-HUBs and REFRESH projects. All aspects are covered but we need to wait the results of the projects to assess what is still needed. It will also be addressed by one of the WP2023-24 call. Funding will still be needed in the future for find and validate new market streams in order to use the secondary raw material making it competitive with virgin materials
Disruptive technologies	• Conceptual design of low wind rotors aiming at light-weight low CAPEX designs. • Application of smart blade approaches (passive load reduction) and disruptive non-conventional rotor designs (downwind-free yaw/folding blades) for reduced operational and extreme loads. • Design of high voltage generators without permanent magnets. • Design of Direct Current/Direct Current (DC/DC) converter with high frequency transformers. • Development of multi-unit concepts. • Identifying markets and applications as well as feasible concepts for vertical axis, airborne and/or multi-rotor wind energy systems.	Not addressed	Partially addressed		Priority 1	€5m-€10m	This R&I area will be addressed by one WP2023-24 call (dedicated to Next generation of renewable energy technologies). It will cover new types of wind tubrines. Very well funded indeed... but includes all next generation technologies in the compûlete energy system! With no specific wind energay systems available, improvements and alternative developments for wind will likely lose out against newer and "sexier" themes in other fields. we need wind-specific calls as well!! But funding is still needed in this area for.... Multirotor set-ups

ANNEX 8

Summary sheet of the Gap analysis for Pillar 4

Roadmap Pillar	Research action area	Recommended research actions	Covered in HEU WP2021-22 projects?	Covered in HEU WP2023-24 calls for proposals?	Do we still need funding for this research action area?	Priority	Recommended funding amount	Preliminary conclusions
Pillar 4- Offshore balance of plant	Data availability & sharing	• Create common taxonomies between turbine types and mapping alarms to specific turbine components. • Design optimisation and design validation. • Lifetime assessment of components. • Quantify benefits to incentivise data-sharing activities. • Cross-sector study to find the best examples of data sharing in other sectors (e.g. Oil & Gas asset management).	Partially addressed	Partially addressed	Long-term	Priority 3	€1m-€2m	Important to have incentives but rely a lot on the readiness of the market to share data. Funding to support platform that facilitates data sharing. But the success will depend on operators willingness to share data.
	Serial production - analysis of substructure production processes	• Drive innovative processes to reduce multicity of designs to a few that use common components. • Produce a catalogue of alternatives. • Get approval for new solutions.	Not addressed	Not addressed				This R&I area has not been addressed by the projects or the calls. It is not clear whether this topic is still relevant for Horizon Europe. It can't be seen as a research topic as the market will drive the innovation processes. More funding is needed more for the production capacity / manufacturing side. However, as this is the first time we shift to serial production of heavy steel structures, development of more efficient manufacturing processes should be addressed.
	Cabling and connections	• Develop cables resistant to strain when support sand is washed away. Sensorise cables to warn of this in advance. • Optimise materials and structure of cables to make them fit for purpose and reduce the high price. • Develop automated repair systems for large array and export cables. • Develop a new cable suitable for floating wind farm connection. • Develop audio/optical-based ship monitoring and damage system to pre-warn and prevent damage and/or identify culprit of damage. • Develop lead free HVDC and HVAC cables using non-metallic seals.	Partially addressed	Partially addressed	Short-term	Priority 1	€10m-€15m	This R&I area is partially addressed by the NEWGEN project (dedicated to the construction of innovative high-voltage cables). It is also partially addressed by one of the WP2023-24 calls that will cover advanced (dynamic) cabling and connectors. However the scope of the call seems too broad to effectively address this research topic. All the recommended research actions are still very relevant today. More funding is needed to progress in this field.
	Material durability and protection	• Investigation into system reliability, operational procedures and requirements for air ventilation/water exchange to validate corrosion protection.	Partially addressed	Partially addressed	Short-term	Priority 2	€2m-€4m	This R&I area is addressed in the NEWGEN project (cable manufacturing solutions, detection methods for HVDC cables) and will also be addressed in 2 WP2023-24 calls (on offshore windfarms of the future and on lifetime, decomissioning and circularity of offshore / onshore wind energy systems). Aspects like reduced use of primary raw materials, interagation in ecosystem can be covered. But these 2 calls are very broad and the budget won't allow to cover all the aspects included in the call text. It is also very "turbine-oriented" whereas a bigger focus on offshore balance of plant is needed. Research still needs to be done in this field. E.g. it is important to get data from exisiting projects to predict corrosion, durability of cables (dynamic mechanical loads), . This topic should be linked to environmental impact as a cross-cutting issue.
	Cross-industry agreement and standards	• Standardisation of transition piece for monopiles and jackets.	Not addressed	Not addressed				This is not a stand-alone research topic.
	Integrated optimised design plan	• Coupling analyses of substructure and uncertainties of site-conditions (wind, wave, and soil). • Combined modelling of technical and economic aspects. • Incorporation of grid models. • Integration of later lifetime phases (e.g. operation) in the design process.	Not addressed	Partially addressed	Medium-term	Priority 2	€2m-€4m	This R&I area will be partially addressed by the call dedicated to digital twin and by the call on minimisation of the impacts. A lot of R&D has been done in defining uncertainties, site-conditions data. But this is still an ongoing researc topic that needs continuous funding. For example, a priority should be given to reliability of the data. The Integration of later lifetime phases is also a very important topic (hardly done in offshore).
	Verification of methods and procedures	• Model vs. model and model vs. data comparisons for components and whole system. • Well-founded definition of verification and validation procedures. • Model enhancements by means of data integration. • Model update, model calibration and system virtualisation. • Development of a large open-access data bank for validation purposes.	Not addressed	Partially addressed	Short-term	Priority 1	€10m-€15m	This R&I area will be partially addressed by one call dedicated to digital twin, which is very broad with a limited budget. The first step in this area should be the focus on offshore balance of plant bu it should not be addressed in a cross-sectoral call. It should aslo be linked to the topic of digital twin of the turbine.
	Supply chain logistics (decommissioning)	• Operating without cranes to provide useful technical export expertise. • Identification of necessary equipment and locations for storage and remanufacturing of components. • Solutions for direct reuse of materials from concept stage upwards	Not addressed	Partially addressed	Short-term	Priority 1	€2m-€4m	This R&I area will be partially addressed by 2 calls of the WP2023-24. Some aspects of this R&I area can be covered but the call scope is too broad to really tackle all the issues. Because of the increased size of the turbines and components, this is a very important topic. Decommissionning will have to be more and more considered in wind energy projects. This R&I area needs to be rephrased with more research actions. And the funding amount will depend on the definition of technology development topics.
	Additional R&I priorities:	*Defining solutions helping extending the service life. *Integrating windfarm in the balance of plant is a major challenge which is partially addressed for now. *Lifetime extension via the optimisation on the materials side to minimise the impact. * A bigger focus is needed on the interaction with other communites (e.g. fishing) and the demonstration of the benefits of windfarms. *Technology improvements/innovations at the installation phase, new installation methods or processes (e.g. for floating: methods for easier deployment). Including noise mitigation, slower hammering, underwater robots, etc.						

ANNEX 9

Summary sheet of the Pillar 5

Roadmap Pillar	Research action area	Recommended research actions	Covered in HEU WP2021-22 projects?	Covered in HEU WP2023-24 calls for proposals?	Do we still need funding for this research action area?	Priority	Recommended funding amount	Preliminary conclusions
Pillar 5 - Floting wind	Lean production	• Develop new material qualified for structure elements, mooring lines and electrical cables. • Design and develop post efficient building elements for floating offshore wind turbines. • Standardisation of transport methods and assembly. • Support the development of high precision manufacturing lines of floating platforms for more efficient mass production.	Not addressed	Not addressed	Short-term	Priority 1	>€50m	This R&I area has not been addressed by the calls or the projects. This is however a crucial topic especially when it comes to standardisation of transport methods and assembly and support the development of high precision manufacturing lines of floating platforms for more efficient mass production. Funding is still needed especially for calls related to manufacturing tools development, mass-production solutions and high productivity tools. There is also a need to reduce materials we use for windfarms (e.g. steel needs, more R&D for new materials). If the aim is to develop new tools and equipment, the budget for such a call needs to be high. As a comparison the budget of the LIFE50+ project is €10m. Experts agreed that this R&I area is the highest priority for Pillar 5.
	Validation of design tools	• Identify best practices for holistic design and optimisation of floating wind energy systems, how to co-optimise the turbines, platform, moorings, and control systems. • Develop probabilistic design methods, especially joint probabilities of operating states (wind/wakes/waves, plant control/ operator power commands, faults) and system limits (considering the interactions between components as they operate as a system). • Identify plant-scale effects on loads and control. • Validation of model tools against full scale measurements andmodel tests (need for high quality measurement data for validation, with low uncertainty. This applies both to model test and full scale measurements) to reduced uncertainty of simulation tools. • Facilitate gaining access to full-scale prototype and fleet data, in order to validate system models. • Development and deployment of experimental facilities that can be used to test and demonstrate designs. • Facilitate open access to test results from experimental tests of complicated physical phenomena. • Validation of new innovative concepts.	Partially addressed	Partially addressed	Short-term	Priority 3		This R&I area has been partially addressed by 4 projects (BLOW, INFINITE, NEXTFLOAT and WHEEL) and 1 calls. But the projects focus on the demonstration of one specific technology. Whereas what is missing is more a benchmark/validation of design tools at full scale and full-scale deployment projects with better testing methods to ensure industrialisation of the most competitive solution. Regarding the WP2023-24 call dedicated to the demonstration of innovative floating wind concepts: It seems the budget is too low to test and validate different concepts. This is key for the inudstry to identify the most competitive solution and scale it up. Funding is also needed for more specific areas such as: demonstration of dynamic cables, WTG installation and O&M concepts, scalability of the foundation (even if a lot of projects already validated some models and designs). We need to move from model development to industrialised tools and it is also important to provide access to the data gathered in previous projects (most of the time, companies do not share the relevant information).
	Mooring and anchors	• Development of new materials with required strength and stiffness (e.g. qualification of "new" fibre rope types, such as nylon). • Dynamic interaction taut leg systems and floating wind structure. • Development of cost-effective mooring system components, e.g. tensioners and new mooring systems (such as floater-to-floater mooring). • Wind controller assisted mooring (thrust & motion). • Models for dynamic behaviour of fibre ropes, and adaption of simulation tools for global analysis of fibre ropes. • Anchors for multi-axial loading. • Design tools for installation of innovative anchors (Torpedo, Deepla…) for improved installation (faster and cheaper). • Experimental validation for innovation anchors. • Assessment of the impact of extreme weather events (earthquakes and storms) on anchor design.	Partially addressed	Partially addressed	Short-term	Priority 1	€20m-€30m	This R&I area has been partially addressed by the BLOW and th WHEEL projects. In this area we still need to reduce materials, develop new materials and speed-up manufacturing processes. Maturity of technologies in that area is not that high. We need to fund projects where the anchor designs are replicable. Mooring lines and innovative installation aids also deserve a specific focus. And these solutions need real scale demonstration in real conditions.
	Dynamic electric cables	• Validated software for cross sectional analysis. • Validate and develop cable modelling tools and methods, with regards to loss estimation, harmonics and transients and long-term performance of new dynamic designs. • Qualify dynamic High Voltage Direct Current (HVDC) cable and assessment of the applicability. • Long dynamic infield cables (e.g. bellows, floater-to-floater). • Research on different configurations of dynamic cables with respect to water depth. • New materials, structure and designs (e.g. non-metallic designs for submarine dynamic power cables, cost-effective and reliable bend stiffeners). • Mechanical behaviour of bitumen, and use in cross-sectional structural analyses. • Use of monitoring data from cable response and environment for on-board cable integrity assessment. • Review non-metallic designs for submarine dynamic power cables.	Partially addressed	Partially addressed	Short-term	Priority 1	€20m-€30m	This R&I area has been partially addressed by the INFINITE project which focusing on innovative aluminium dynamic cable design that is meant to be safer, lighter, cheaper and allows for more standardisation in O&M. The call on HVAC, HVDC and High-Power cable systems also partially addresses this topic but does not focus necessarily on floating wind applications. However HVAC or HVDC dynamic cables are still important topics. The balance of plant for floating wind needs significant funding especially considering cables but also floating sub-stations. Connectors for floating also need a particular focus. New materials for dynamic cables still need to be investigated. Funding is needed to develop more mature technologies and for standardisation.
	Control methods	• Improve the use of model-based control, in combination with advanced sensors like Lidar and wave cameras, to anticipate load fluctuations and accommodate them in an optimal way. • Analyse side-to-side damping in cases of misaligned wind and waves, and in general counteracting the accumulated cycles and extremes of environmental loading, without sacrificing production. • Test and use fleet operational data to provide the foundation for adaptive, machine-learning algorithms that can supplement or perhaps transcend model-based approaches. • Explore the possibilities and limitations of machine-learning-based control algorithms, especially regarding the relationship between the data available for training and the reliability of the control response under various normal and abnormal operating conditions. • Parametrisation of the methodologies to auto-tune controllers.	Partially addressed	Not addressed	Medium-term	Priority 2	€5m-€10m	This R&I area will be partially addressed by the NEXFLOAT project. The issue with this topic is that there will be limited data availability in the short term.

	Integrated design process in supply chain	• Development of holistic models that can capture the dynamics of the entire system. • Assessment of the mechanical path from atmosphere to aerodynamics to structures to moorings. • Research into the electrical path from drivetrain to generator to cables to substation to grid, and the feedback controls at the turbine and plant levels. • Incorporation of assembly and installation needs in the glue code of the supply chain. Designs should suit scalability and should be optimised for industrialisation	Partially addressed	Partially addressed	Short-term	Priority 1	€5m-€10m	This R&I area has been partially addressed by the WHEEL project (a major part of the supply chain will be involved to develop a model that can capture the whole system) and the INFINITE project. But to fully address the topic, those projects would need a bigger budget. The WP2023-24 call dedicated to demonstration of innovative floating wind concepts may partially address this point too. Finding balance between CAPEX and OPEX is difficult today. The industry needs to find the relevant O&M strategies, cost-effective solutions to manage floating windfarms. More funding is therefore needed to develop some tools that could capture the full picture (revenues, CAPEX, OPEX for design choices).
	Floating installation, assembly and heavy maintenance	• Floating-to-floating motion compensated lifting operation. • Assess loads on components during crane/lifting operations. • Adaptable substructures for float over installation or to avoid heavy high-lifts, (e.g. telescopic designs, ... etc.). • Adapt Rotor-Nacelle-Assembly to allow for large tilting such that blades, nacelle and tower can be assembled horizontally on the ground, towed out, then flipped up vertically offshore for installation. • Flexible and Rigid Body Dynamic modelling for improved marine operations.	Partially addressed	Not addressed	Short-term	Priority 1	€30m-€50m	This R&I area has been partially addressed by the BLOW project. But it needs a bigger focus on operations. The following research actions are still relevant today: *Floating-to-floating motion compensated lifting operation *Assess loads on components during crane/lifting operations *Flexible and Rigid Body Dynamic modelling for improved marine operations The topic of major components' replacement also requires large investment in demonstrators and can be quite expensive.
	Park level control	• Develop holistic models of large-scale floating wind power plants that can be used in the design and simulation of plant control algorithms. • Increase influence of accumulated turbine control actions on the atmospheric boundary layer, in particular how perturbations to the flow propagate downstream through large plants. • Develop reduced-order models capable of predicting these effects in real-time. • Develop optimal control algorithms that can detect changes in the flow conditions, such as wake turbulence, and adapt the operation of the turbines accordingly. • Investigate and compare benefits and limitations of possible system architectures, including model-based, adaptive, and data-driven/machine-learning. • Quantify the potential benefits of additional sensor data like lidars, as well as short-term wind forecasts.	Not addressed	Partially addressed	Medium-term	Priority 2	€5m-€10m	This R&I area has been only partially addressed by the WP2023-24 call dedicated to Integrated wind farm control. Some WP202122 projects may have covered some aspects but not on floating specifically (e.g. wake effects). Floating needs specific calls and projects in this field. Control methods need to be tested in real site conditions.

Additional R&I topics:	The following additional R&I topics need to be taken into consideration: *Ports infrastructure (that could be tackled more by the Innovation Fund?) and the integration of bigger size turbines (long-term topic) are both crucial topics. *O&M solutions, tested in real environment (mid or long term). Big components' replacement should be a dedicated topic because it needs to be cost-competitive. *Co-existence: footprint of a floating windfarm is different than bottom fixed. SWe need to investigate coexistence measures (e.g. with fishermen). *Testing for developping completely new turbine types.

ANNEX 10

Summary sheet of the Pillar 6

Roadmap Pillar	Research action area	Recommended research actions	Covered in HEU WP2021-22 projects?	Covered in HEU WP2023-24 calls for proposals?	Do we still need funding for this research action area?	Priority	Recommended funding amount	Preliminary conclusions	
Pillar 6 - Skills & Human resources	Expand and harmonise wind energy teaching in Europe	• Start a structured framework programme on wind energy teaching among interested universities, with the following goals: - Promote multi-disciplinary teaching of wind energy and the understanding of the whole energy sector; - Expand the number of wind energy specific programs at European universities (this is also achieved by expanding the number of professors and academic staff actively involved in wind energy research at European universities, which is primarily obtained by boosting research funding in wind); - Expand the enrolment of students in wind energy courses, with a particular focus on the increase of female students; - Favour student mobility within and outside of the EU; - Start a structured scholarship programme to attract students from inside and outside the EU to wind energy; and - Provide funding for a detailed study on student enrolment and graduation across Europe scheme.	Partially addressed	Not addressed	Short-term	Priority 1	€20m-€30m	This R&I area is partially addressed in one WP2021-22 project: the TRANSIT project which has a general approach (not wind-specific). This topic is one of the most important priority and is an ongoing research area. The skills needs also change all the time, requirements are not the same due to ongoing technology development. Examples of some specific topics: development of good wind energy curriculum across Europe, repository of the skills needed, more support in mobility of the students and support of infrastructure for online teaching. Erasmus+ and EAWE could tackle those topics.	
	Boost wind energy higher education	• Increase EU R&I funding in wind energy, which has a cascading effect on competence in academia, number of professors and staff involved in wind energy, and consequently also on education. • Increase funding opportunities for Marie Skłodowska-Curie Actions (MSCA) in wind energy. • Include educational activities (similar to those already present in MSCAs) also in regular EU-funded research projects to improve existing education-by-research. • Fund post-doc positions, to boost the number of top researchers pursuing academic careers in wind energy, with the effect of increasing research and competence on the topic at European universities.	Not addressed	Not addressed	Short-term	Priority 2	€5m-€10m	This R&I area has not been addressed by the projects or by the calls. It is again an ongoing research area which needs continuous funding. Some activities are happening already in Marie Skłodowska-Curie Actions (e.g. ADOreD project) but we still need support for wind specific education and training (keeping in mind that PhD students can not be hired through Horizon Europe Research & Innovation Actions and the costs of their education are usually also not covered by the EU).	ADOreD project cordis: https://cordis.europa.eu/project/id/101073554
	Joint academia-industry educational programmes	• Implement a structured academia-industry framework programme (similar for example to the International Energy Agency (IEA) Wind Technology Collaboration Programme (TCP) Task) on education and training, with the following goals: - Define the required skillsets now and in the future, and update them based on the development of technology; - - Identify skills gaps with respect to peer competitors outside of Europe; - Promote industry-academia collaboration in training (at the BSc, MSc, PhD, continuing education (post-secondary) and professional levels); - Promote and help to implement joint educational programmes; - Identify needs for retraining of the workforce, for example by proposing and coordinating ad hoc continuing education activities; - Identify ways to retain trained and skilled workforce; and - Increase the attractiveness of the sector for women. • Organise dedicated regular workshops on education and training, for example every year at the WindEurope annual event.	Partially addressed	Not addressed	Medium-term	Priority 2	€5m-€10m	This R&I area is partially addressed by 3 projects (TRANSIT, SKILLBILL and RES4CITY). These projects will focus on general programmes for upskiling activities in the field of clean energy technologies, lifelong learning process, upskilling and reskilling activities, mapping of the knowledge gap, training approach to revamp industry-academic curricula, online platform for the innovative and interactive multidisciplinary programme from educational campaigns to hands-on courses. However these projects are not specifically dedicated to wind energy. We still need fudning for wind-specific educational and training programmes and perhaps an EU coordinated appoach, in particular for reskilling aspects. More focus is also needed on education programmes on social and environmental sciences in collaboration with the industry. Joint collaboration should not be limited to the wind industry: other potential stakeholders such as data science companies, fishing communities, etc should be involved.	
	Addtional R&I priorities:	*Acceptability in general should be included in this Pillar *The fact that we will have more and more turbines in our landscaps means we will need more funding for research on social acceptance aspects. *Community engagement activities are also very important to involve citizens from the beginning in wind projects. We also need research to better show the direct benefits of wind projects on the communities (e.g. interaction with economic, cheap electricity). *Regulatory issues are also important to consider (e.g. standardised regulation across Europe on citizens engagement).							