

Rebuttal Letter

Reviewer #1,

We thank the reviewer for their thoughtful and detailed comments, which we believe will significantly strengthen our manuscript. The reviewer's insights have helped us recognize that our initial draft, while broad in scope, lacked the necessary prioritization, analytical depth, and structural clarity to effectively address our research questions. We agree that the paper's contribution will be enhanced by moving beyond a descriptive summary to a more focused, analytical discussion that explicitly contextualizes international case studies and proposes concrete research directions relevant to Japan's floating offshore wind (FOW) landscape. We have revised the manuscript extensively to address each of the specific points raised.

R1-1: Lack of Prioritization Despite Explicit Research Question

The authors explicitly include the question “What are the gaps and what shall be prioritized?” among their three research questions (Section 1.3). While the paper identifies a wide range of technical and institutional gaps, it falls short of addressing the “prioritization” aspect. There is no framework, criteria, or comparative discussion provided to help readers understand which issues are most urgent, impactful, or feasible. A structured prioritization matrix would strengthen the paper’s contribution significantly.

Thank you for your suggestion. We agree that we need to add a structured framework to discuss prioritization. We created a subsection in the Discussion that introduces a framework for prioritizing the identified gaps and the technologies to overcome the gaps.

To systematically address the numerous challenges facing Japan's floating offshore wind sector, a structured framework is proposed to prioritize the necessary research and technological development. This framework first classifies all identified gaps and their corresponding solutions into two primary categories. "Enabling technologies" are defined as those that are absolutely essential for a project's viability; without them, a floating offshore wind farm cannot be successfully built or operated under the required technical, economic, and regulatory performance levels. All other solutions are classified as "Supporting technologies," which, while valuable, are not strictly indispensable for a project to proceed, as alternatives may exist.

The framework then further evaluates "Supporting technologies" against two critical metrics to determine their strategic importance: Cost Reduction and Scalability. Cost Reduction is the primary driver for achieving commercial viability, and activities are prioritized based on their potential to lower the Levelized Cost of Energy (LCOE) by reducing Capital Expenditures (CAPEX) or Operational Expenditures (OPEX), or by increasing Annual Energy Production

(AEP). Scalability refers to a technology's ability to support the mass deployment required to meet national energy targets, focusing on aspects like mass production, supply chain development, and logistical efficiency. This two-metric evaluation helps to distinguish between technologies that offer incremental improvements and those that are true game-changers for the industry. These classifications are synthesized into a prioritization matrix that guides strategic investment and R&D efforts.

"Enabling technologies" are categorized as non-negotiable "Must Have" activities that require immediate attention. Government-led strategic site surveys and scaling up workforce development fall in this category. For "Supporting technologies," those with high impact on both Cost Reduction and Scalability are identified as the "Holy Grail"—the top priorities for long-term research. Development of advanced survey methods and digital twins are in this category. Activities with a high impact on one metric but not the other are considered "Quick Wins," valuable for near-term projects or solving specific issues. This matrix, combined with an assessment of each technology's current readiness level (TRL), provides a clear, strategic roadmap for stakeholders to focus resources on the most critical and impactful solutions.

Modification: Add section 6.3 Prioritization of Action

R1-2: Limited Insight on Research Directions for Environmental Constraints

The review offers a thorough description of Japan's unique geological and metocean challenges—such as complex seabed topography, high geohazard risk, insufficient metocean data, and port-access limitations. However, it largely reiterates the existence of these challenges without proposing how future research might address them. Especially, Section 6.1 identifies two major gaps: (1) limited prior research and (2) lack of site-specific data. Yet it does not extend to suggesting potential directions to close these gaps. For example, no specific methodologies are proposed for enhancing site investigations, improving metocean forecasting in cyclone-prone areas, or adapting installation strategies to Japan's long-period swell conditions and port limitations. As a review paper, offering even preliminary suggestions—such as promising modeling techniques, remote sensing tools, or infrastructure planning frameworks—would help the reader better understand how these environmental constraints might be systematically addressed in future work. Including such insights would strengthen the paper's contribution to shaping Japan-specific floating offshore wind research.

Thank you for your suggestion. We agree that merely identifying challenges is insufficient and that a review paper's value lies in suggesting solutions. We have added a proposal on specific, actionable research directions.

We have revised the **summary for each section** and **Section 6.1** to go beyond simply stating the problems. For each key challenge—e.g., complex seabed topography, high geohazard risk, limited metocean data—**propose concrete research directions as follows**.

Examples added:

- **Site investigations:** We suggest specific methodologies like the use of AUVs for high-resolution bathymetric surveys, advanced geophysical techniques, data sharing scheme among other surveys conducted (such as CCS, methane hydrates), application of machine learning to predict geohazard hotspots based on historical data.
- **Metocean forecasting:** Mention the need for dedicated modeling efforts to improve typhoon and cyclone forecasting, integrating satellite remote sensing data, or adapting existing global models for Japan's specific conditions.
- **Installation strategies:** Suggest research into the development of port infrastructure planning models that optimize for limited-access ports.

Modification

- Revised the **summary for each section**
- Revised **Section 6.1**

R1-3: Need for Explicit Contextualization of International Case Studies

While the manuscript introduces a range of international case studies on floating offshore wind development—particularly in Europe—these are often presented descriptively and left for the reader to interpret their relevance to Japan. In several instances (e.g., the discussion of tow-to-port maintenance in Kincardine and Hywind Scotland, or digital twin applications for predictive maintenance), there are implicit connections to Japan's environmental or infrastructural conditions, and Japanese examples are occasionally mentioned alongside. However, these links remain largely implicit rather than analytically articulated. To strengthen the paper's contribution as a review intended to inform Japan's FOW deployment, it is recommended that the authors move beyond implicit juxtaposition and provide explicit interpretation and contextualization. For example, when discussing European O&M strategies or data infrastructure challenges, what specific lessons are applicable to Japan, and what modifications or local considerations would be required? Highlighting such comparative insights more clearly—perhaps through brief analytical co

Thank you for your suggestion. Regarding learning from the Kincardine and Hywind Scotland offshore wind farms, it is important to note that these projects are the first cases of floating offshore wind turbines in the world to encounter the complexities of heavy maintenance and

the evaluation of choices such as tow-to-shore or on site repair. They offer unique opportunities of learning which is very important for FWT development in Japan considering the scarcity of FOWT maintenance experience around the world. As an example of analytical articulation/explicit interpretation and contextualization, the tow-to-port maintenance has been employed for the heavy maintenance for the Kincardine and the Hywind Scotland. These experiences have shown that the default strategy for heavy maintenance—towing the entire turbine to port—is prohibitively expensive, and downtime lasting over three months for a single turbine. For a nascent market like Japan with limited specialized port infrastructure, relying on this reactive and costly tow-to-port model may present a significant threat to project viability.

Modification: Revised Section 4.7

R1-4: Overly Lengthy and Redundant Sections

The manuscript is excessively long, and several sections could be significantly condensed without loss of content. For instance:

- The Operation & Maintenance section devotes more than four pages to describing the Hywind Scotland and Kincardine projects. While these are valuable cases, the level of detail provided (e.g., port names, tow duration, exact crane types) is excessive and not directly linked back to Japan's context.
- The Site selection and metocean challenges (e.g., typhoons, earthquakes, steep bathymetry) are described repeatedly across Sections 2, 3, and 4 without synthesis or cross-referencing.
- Similarly, the emphasis on Japan's lack of oil & gas infrastructure and limited metocean data is mentioned in multiple sections with nearly identical wording.

Reducing such repetition and consolidating related content would improve readability and focus.

Thank you for your valid suggestion. We agree that we need to improve the manuscript's readability and focus. We have significantly restructured the paper while reducing and consolidating the contents. At the same time, the paper also aims to provide information to non-experts in the field. Some of what seems to be redundant information to experts can be important to understand the context.

Modification: We have fully restructured the paper, so that the content to flow more logically, with less overlap between sections. In addition, we have shortened some of the detailed descriptive passages.

R1-5: Section 5 lacks clear linkage to the paper’s research objectives and Japanese context

Section 5 is titled in a way that suggests it will examine how floating offshore wind contributes to Japan’s societal, environmental, economic, and energy (S+3E) goals. However, this linkage is only briefly mentioned in Section 5.1 (Introduction), and not meaningfully carried through in the subsequent subsections. For example, Section 5.2 (National Security with Scale) introduces European “energy island” projects, but does not explain why these are relevant to Japan or how they relate to national security in the Japanese context. Similarly, Section 5.3 (Power-to-X (P2X) concepts) explains Power-to-X (P2X) technologies in general terms, without specifying how these technologies contribute to S+3E goals in Japan or why they are particularly important in this setting. Section 5.4 on cyber security suffers from the same lack of contextualization.

Overall, the section reads as a collection of general technical topics rather than a focused analysis. It does not provide a systematic or evidence-based discussion of how floating offshore wind supports Japan’s S+3E goals, nor does it directly contribute to answering the research question posed in the introduction. Given the already substantial length of the manuscript, I recommend removing Section 5 unless its structure and content are significantly revised to clearly support the core objectives of the paper.

Thank you for your suggestion. We agree that Section 5 was not well focused to effectively link to the paper’s core objectives. As to clarify the intention of this section we have restructured the paper and set the focused as a subsection “From Project to National Infrastructure” in the section “Industry and Economic Enablement”. It explains the “The challenge is no longer just the operational safety of a single wind farm project, but the comprehensive security of a critical national energy and industrial ecosystem. This expansion of the systemic boundary introduces new and complex challenges that require a holistic grand design.”

Modification: Condensed the section to a subsection “ From Project to National Infrastructure” in the restructured section “Industry and Economic Enablement”

R1-6: Structural Suggestion for Section 3.4

Section 3.4 contains only a single sub-section (3.4.1). Given that no additional sub-sections are provided, the hierarchical structure appears unnecessarily complex. I recommend removing the sub-section numbering and simplifying the structure to improve readability

Thank you for your suggestion. We agree that we should modify the structure to improve readability. We have modified the manuscript as follows.

Modification: Eliminate the numbering for subsection 3.4.1 and integrate the content directly under the heading of 3.4.