

Article

An Integrated Assessment Framework of Offshore Wind Power Projects Applying Equator Principles and Social Life Cycle Assessment

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Abstract: This paper reviews offshore wind power project finance and provides an integrated assessment that employs Equator Principles, life cycle assessment, risk assessment, materiality analysis, credit assessment, and ISAE 3000 assurance. We have not seen any comprehensive review papers or book chapters that covers the entire offshore wind power project finance process. We also conducted an SWancor Formosa Phase 1 case study to illustrate the application of integrated assessment to better assist policymakers, wind farm developers, practitioners, potential investors and observers, and stakeholders in their decisions. We believe that this paper can form part of the effort to reduce information asymmetry and the transaction costs of wind power project finance, as well as mobilize green finance investments from the financial sector to renewable energy projects to achieve a national renewable energy policy.

Keywords: project finance; strategic environmental assessment; case study; stakeholder engagement

1. Introduction

1.1. Development of Offshore Wind Power in Taiwan

Succeeding the Framework of Taiwan's Sustainable Energy Policy [1], Taiwan announced its New Energy Policy in 2016 where one of the targets was for renewable energy in the electricity system to reach 20% by 2025. In 2016, the net energy generation was 251,434 GWh, of which renewable energy contributed 11,599 GWh, representing 4.6% of the national net energy generation [2].

In 2008, the Executive Yuan of Taiwan adopted the Framework of Taiwan's Sustainable Energy Policy to demonstrate the determination of Taiwan to reduce energy consumption and reward the development of renewable energy. This was the first attempt by Taiwan's Government to address renewable energy in a top-level governmental policy document. Following the policy, the Renewable Energy Development Act became effective in 2009. In 2011, the Taiwanese government further declared that the government would implement two national plans related to the development of renewable energy: The Thousand Wind Turbines plan, and the Million Rooftop Photovoltaic plan. The Thousand Wind Turbine plan was to install 400 onshore and 600 offshore wind turbines with a combined rated capacity of 5.2 GW by 2030 [3].

Considering the fact that Taiwan has a large population with limited land for power plant construction, insufficient natural resources, and is constrained by limited environment carrying capacity, developing abundant offshore wind power in the Taiwan Strait—one of the best wind farms in the world—has become an option for the Taiwanese authority. However, wind power only contributed 1447 GWh in 2016 [2], and of April 2017, there is only one demonstrational offshore wind

farm with two turbines in commercial operation [4]. Taiwan is obviously far behind The Thousand Wind Turbines plan of 600 offshore wind turbines by 2017, and the question of how to motivate and encourage offshore wind power development has become increasingly important and intensive in terms of turbine volumes, the financing of projects, the remaining time to target year, and the national sustainable (low carbon emission) economic growth.

The Taiwan Strait (or Formosa Strait) separates the island of Taiwan from mainland China is averaged at 180 km wide and around 300 km in length. The strait is part of the East China Sea and connects to the South China Sea to the south. The narrowest part is 130 km wide [5]. Furthermore, the Taiwan Strait has one of the best wind farm potentials in the world. According to the Global Offshore Wind Speeds Rankings, in terms of estimated wind speed at m/s, 9 out of the top 10 wind farm projects and 47 out of the top 50 in mid-2017 were located in the Taiwan Strait with an average wind speed of more than 12 m/s [6]. Aside from its landscape and wind power potential, the weather changes very often in the Strait where there are occasional monsoons, typhoons, and strong waves occurring at times, making sailing in the Strait somewhat risky. Typhoons usually occur in summer and the occasional monsoons typically happen between October and March [7].

In Taiwan, wind farm development falls in the project category listing that requires mandatory environmental impact assessment (EIA) as per the Environmental Impact Assessment Act and the Standards for Determining Specific Items and Scope of Environmental Impact Assessments for Development Activities. In 2016, the Bureau of Energy, Ministry of Economic Affairs of the Taiwanese government set up the Offshore Wind Power Block Development Policy, which proposed eight impact categories for assessment including assimilative capacity, natural ecosystems and landscape, national health and safety, use of land resource, water resource system and usage, cultural heritage, international environmental standards, and social and economic impacts [8].

However, due to a lack of regional wind power experience and extraordinary natural characteristics in the Taiwan Strait, it has taken more time for policymakers, wind farm developers, practitioners, potential investors and observers, and stakeholders to understand the impacts of wind farm development in the Taiwan Strait.

1.2. Taiwan's Demonstrational Offshore Windfarms

According to the Renewable Energy Development Act, the Offshore Wind Power Demonstration Incentive Program was formulated to encourage the industry to build offshore demonstrational wind farms with a budget subsidy of up to 50% installation expenditures, with the upper limit of the incentive fees set at NT\$250 million (approximately US\$8.3 million). Encouraged by the Renewable Energy Development Act, Taiwan has developed three demonstrational offshore wind farms: SWancor Formosa (off the coast of Zhunan Township, Miaoli County), TGC Fuhai (off the coast of Fangyuan Township, Changhua County), and TPC (west side sea area of Fangyuan Township, Changhua County). SWancor Formosa was the first commercially operated wind power that started in April 2017 and the total capacity of SWancor Formosa will be about 120 MWh [4].

The offshore wind farm consists of a wind turbine, a foundation, connectors, an ocean substation, an ocean power cable and a land power cable, and a land substation. The power generated by the wind farm is transmitted to the ocean substation and boosted. The boosted power is then transmitted to the land substation through the ocean power cable and land power cable. The offshore wind power life cycle assessment (LCA) includes manufacturing, construction, maintenance and operation (M&O), and the retirement stages. As severe weather conditions may occur in the Taiwan Strait, the risk increases the difficulty of marine construction and requires more experienced workers and the ability to conduct better weather forecasting. We also noticed a lack of laws concerning local marine workers, and formal health and safety monitoring systems in Taiwan.

When reviewing the SWancor Formosa, we observed that the development was subject to enforced EIA by local regulations and the Equator Principles (EPs) requested by lenders for its financing. EIA is mandatory; however, EPs are voluntary. In Taiwan, the Environmental Protection Administration

(EPA), Executive Yuan, is the executive authority of EIA. To meet the EP requirements, wind farm developers may require a more comprehensive approach other than EIA to evaluate material impact areas, particularly in social aspects. Thus, environmental assessment and financial evaluation were critical processes for the development of the SWancor Formosa wind power where LCA, stakeholder engagement, and material impact analysis were the underlying procedures in meeting the legal and financing requirements for both environmental and social aspects.

1.3. Environmental Assessment

Wind power development is typically subject to EIA, which assesses both the potential environmental and social impacts and considers a wide range (in distance or by category) of stakeholders. It also means that the inherent complexity of wind power projects is much higher than that of inland construction.

Lewis [9] mentioned that the potential challenge of EIA is whether it provided a comprehensive framework to include all phases of the project life cycle in the decision-making processes. Tang et al. [10] compared the EIA processes across Mainland China and Taiwan and pointed out that the Taiwanese EIA system faced many challenges to fine-tune its conflict resolution mechanisms. Nevertheless, public consultation and the involvement of environmental and various interest groups will increase not only the transparency of the EIA, but also the credibility of the executive authority. Recently, Li et al. [11] reviewed the Taiwanese EIA again and noticed that the process had become not only an open review, but also a more democratic forum with meaningful participation from local residents and public interest groups.

Our position is that LCA is a useful tool to include all phases of a project life cycle for material, environmental, and social impact assessment. From a project life cycle perspective, Martinez et al. [12] and Martinez et al. [13] conducted a wind power LCA based on ISO 14040 [14], ISO 14044 [15], and an LCA environmental impact sensitivity analysis. Martinez et al. defined the offshore wind power life cycle as including the manufacturing of materials and products, construction, M&O, and incineration, recycled, or landfill.

Before wind farm development, developers typically had to conduct initial surveys including location selection, equipment and product procurement, land and marine transportation arrangement, administration, and legitimate processes, and mandatory EIA. This stage usually took between one and five years; the construction stage (e.g., installation of foundation, wind turbine, substation, and cables) usually took between one and two years; the M&O stage is usually planned for 20 years, followed by retirement assessment and removal [16].

1.4. Financial Evaluation

Traditionally, financial institutions consider the 5P principles—People, Purpose, Payment, Protection and Perspective—to determine the credit line of a loan [17]. The final credit line is determined by a comprehensive evaluation that weighs the potential performance (interest rate) and the risks (such as credit risk, liquidity risk, and foreign exchange risk) of underlying assets that might undermine the profitability and collectability. To conduct credit assessments, financial institutions may, if necessary, introduce due diligence investigation as a more detailed understanding of financial, legal, and, increasingly, Environmental, Social and Governance (ESG) aspects.

The people factor is related to integrity, capability, and the management team's operational performance. Operational performance may also refer to financial statements, sustainability reports, integrated reports, etc. The purpose factor requires financial institutions to understand the borrower's business, manufacturing, and selling procedures and financial performance to determine an appropriate credit line for the borrower's real need. Payment is the basis to secure a loan, or the source of funds to pay off the loan. Protection includes two portions: one is internal protection such as adequate financial structure, collateral, and credit commitment; the other is external protection such as third-party guarantee and endorsement. Perspective refers to the future performance estimation that

requires financial institutions to evaluate not only the borrower's past performance, but into the future including industry outlook and the borrower's competitiveness.

Wind farm project finance (the financing of long-term infrastructure, industrial projects, and public services based upon a non-recourse or limited recourse financial structure where project debt and equity used to finance the project are paid back from the cash flow generated by the project and lenders have no or limited rights to claim shareholders' assets or cash flow) is a cashflow-backed loan where the source of the funds is from the generation, distribution, and sale of electricity. The financial cost of the offshore wind power project is around NT\$15–17 billion (approximately US\$0.5–0.6 billion) every MW and is further subject to the scale of the development, different skills, and the arrangement of construction [18].

However, although the 5P approach is holistic in theory, all of its elements are equally enforced and practiced. In October 2002, in a meeting of the International Finance Corporation (IFC) member commercial banks, participants decided to develop a framework that employs an environmental and social impact assessment on project finance. This framework was announced in 2003 by 10 chartered banks at the IFC headquarters and named the Equator Principles (EP), and is currently in its third edition (EP III, effective on 4 July 2013). In 2017, more than 91 Equator Principles Financial Institutions (EPFIs) across 37 countries have officially adopted the EP, covering over 70 percent of international Project Finance debt in emerging markets [19].

EPs comprise a risk management framework adopted by financial institutions for determining, assessing, and managing environmental and social risk in projects. When an EP-qualified project (such as project finance with a total project capital costs of US\$10 million or more) is proposed for financing, the Equator Principles Financial Institution (EPFI) will, as part of its internal environmental and social review and due diligence, categorize it based on the magnitude of its potential environmental and social risks and impacts. Such screening is based on the environmental and social categorization process of the IFC. Using categorization, the EPFI's environmental and social due diligence is commensurate with the nature, scale, and stage of the project, and with the level of environmental and social risks and impacts [20]. The definition of each category is as follows [20]:

1. Category A: Projects with potential significant adverse environmental and social risks and/or impacts that are diverse, irreversible or unprecedented;
2. Category B: Projects with potential limited adverse environmental and social risks and/or impacts that are few in number, generally site-specific, largely reversible, and readily addressed through mitigation measures; and
3. Category C: Projects with minimal or no adverse environmental and social risks and/or impacts.

2. Research Method

2.1. Generic Qualitative Method: Case Study

Baxter and Jack [21] reviewed the Qualitative Case Study Methodology and noted two key approaches that guide case study methodology, namely those of Stake [22] and Yin [23]. Stake [22] pointed out that the case study was defined by the interest in individual cases, while Yin [23] focused on the method and techniques that constituted a case study. For a generic qualitative case study method, the research procedures are typically as follows: (1) case study design, (2) case selection, (3) data collection, (4) data analytics, and (5) report preparation. We will discuss the context of our design of the case study, the rationale of case selection, and the data collection techniques below. Applying an integrated assessment framework, we further discuss and report our case study results in Section 3.

We observed local Taiwanese commercial banks hesitant to invest in offshore wind power and the public sector has provided little economic incentive or credit enhancement to mobilize private finance into this area and the three demonstrational offshore wind farms face similar challenges. In this context, this paper proposes a comprehensive integrated assessment to walk through the entire offshore wind

power project finance process so that each wind power development stakeholder may have clearer ideas about how each element relates to each other, and what information is relevant in wind farm project finance.

We selected SWancor Formosa Phase 1 because it was the first demonstrational offshore wind farm in commercial operation in Taiwan where mandatory EIA was required by the legal authorities and voluntary EPs were requested by lenders.

We interviewed the SWancor management, experienced consultants, and external experts as well as reviewed the literature and official EIA meeting minutes for SWancor Formosa Phase 1 to gather case study data. We found that the official EIA meeting minutes and their response papers were particularly useful to identify mandatory EIA findings, risks, issues, and challenges; on the other hand, we collected and analyzed EP requirements through interviews with SWancor management and external experts and reviewed related environmental and social performance data, if available. As discussed in Section 1, we also considered LCA as a useful tool to ensure that we reviewed the case across all phases of project life cycle for environment as well as social aspects.

2.2. Evaluation Framework: Integrated Assessment

Wind power development is an emerging market; sometimes project finance borrowers are either a start-up, or in trial operation, which means a lack of historically proven financial statements, or wind power operational experience, or integrated (financial and non-financial) reporting systems. That is, EPFI under some circumstances might need to focus on evaluating the borrower's qualifications and borrower's other unrelated industrial operational experience to make a project finance decision. Similarly, credit assessment on a borrower's business model and solvency is highly reliant on industrial-specific expertise, an in-depth knowledge of wind power, and a thorough understanding of development procedures, local regulations, and EIA (enforced by the local government). These aspects have material impacts on construction ability, the development period, the work method, and the project finance credit line amount. With regard to cash flow analysis, collateral valuation, and industry perspective, decision-makers also have to conduct very detailed studies and research the local electrical industry.

When applying EPs to project finance, categorization is essential for the overall evaluation of environmental and social impacts and EPFI will then determine whether further requirements are necessary for targeted development project(s). For all Category A and Category B projects, the EPFI will require the following [20]:

- (1) The project finance borrower conducts an assessment process to address, to the EPFI's satisfaction, the relevant environmental, social risks, and impacts of the proposed project. The assessment documentation should propose measures to minimize, mitigate, and offset adverse impacts in a manner relevant and appropriate to the nature and scale of the proposed project. For Category A and, as appropriate, Category B projects, the assessment documentation includes an Environmental and Social Impact Assessment (ESIA).
- (2) The project finance borrower develops or maintains an Environmental and Social Management System (ESMS). Furthermore, an Environmental and Social Management Plan (ESMP) will be prepared by the project finance borrower to address issues raised in the assessment process and incorporate actions required to comply with the applicable standards. Where the applicable standards are not met to the EPFI's satisfaction, the project finance borrower and the EPFI will agree on an EP Action Plan (AP). The AP is intended to outline gaps and commitments to meet EPFI requirements in line with the applicable standards.
- (3) The project finance borrower demonstrates effective stakeholder engagement as an ongoing process in a structured and culturally appropriate manner with affected communities and, where relevant, with other stakeholders.

We realized the complexity of applying different assessment standards for wind power project finance decisions. EPs also require the consideration of applicable environmental and social standards, grievance mechanisms, independent review, covenants, independent monitoring, reporting, and transparency. To integrate various applicable assessments into a more comprehensive evaluation framework, this paper proposes an integrated assessment (shown in Figure 1) for applying EPs on offshore wind power.

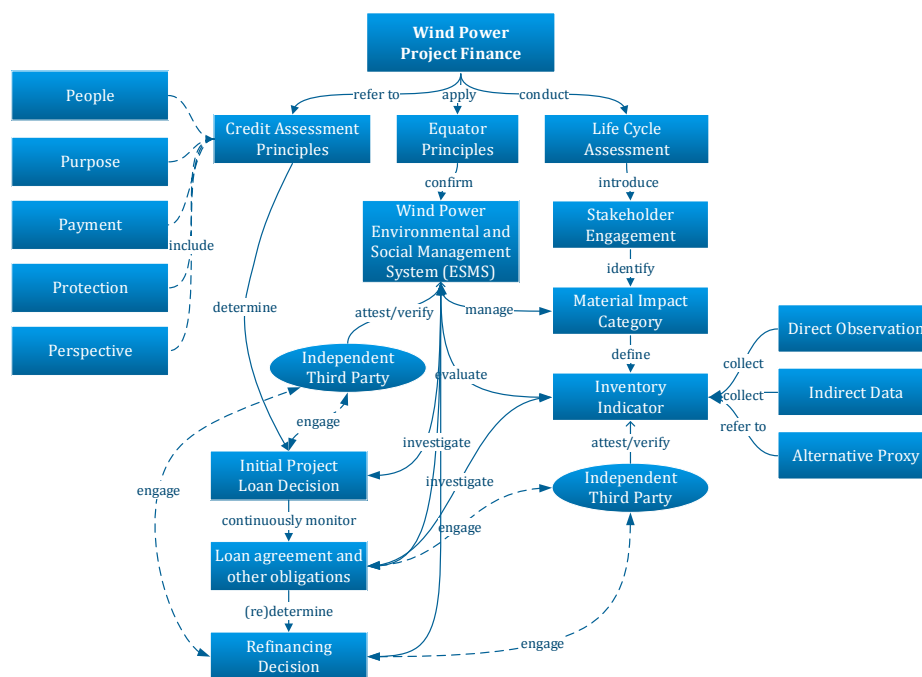


Figure 1. Integrated assessment.

The arrows in Figure 1 represent how each element relates to each other. Solid lines refer to main processes or critical steps; the direction of arrows show the decision-making and data flow. Dashed lines refer to either the associated principles, applicable guidance or voluntary actions such as engaging third-party auditor to perform independent evaluation. Dashed lines with double-headed arrows suggest mutual agreement between contract parties.

According to EPs [20], for a wind power development project finance, EPFI begins by determining whether a project finance is subject to EPs whose total project capital costs are US\$10 million or more. EPFI will only provide project finance to projects that meet the requirements. When reviewing EP categorization, EPFI will require the borrower to conduct ESIA to address—to the EPFI’s satisfaction—the relevant environmental and social risks, and impacts of the proposed project. The assessment documentation should propose measures to minimize, mitigate, and offset adverse impacts in a manner relevant and appropriate to the nature and scale of the proposed project.

To determine the materiality of impact categories identified by ESIA, EPs also require stakeholder engagement for social and economic impacts [20]. Through materiality analysis, evaluation is made before inventory categories and inventory indicators are identified. The integrated assessment then considers applicable environmental and social standards and ESMS to manage material impact categories. Where the applicable standards are not met to the EPFI’s satisfaction, the borrower and EPFI will agree to an AP [20].

In our integrated assessment framework, EPFI will then consider the 5P principles of credit assessment and the results of the EP evaluation to determine its initial credit line decision and, if necessary, project finance covenants which include an AP. According to EPs [20], project finance requires ongoing periodic reports as ongoing monitoring on inventory indicators for routine covenants

review and AP evaluation to monitor whether the borrower and project are continuously in compliance with requirements. To enhance the reliability of the indicators and data under certain situations, EPs also require an independent review of the EP documentation, and independent monitoring and reporting such as performing non-financial assurance based on ISAE 3000, reviewing stakeholder engagement processes, or reviewing the affected community consultation record. Finally, when the project finance expires, EPFI will reconsider the integrated assessment to determine its refinancing decision.

2.3. Materiality Assessment: Project ESIA and ISAE 3000

When ESIA has identified significant or limited project specific risk factors, EPFI may further request—for example, following ISO 14040 or S-LCA [24]—inventory indicators and inventory data. To enhance the reliability of the indicators and data, banks may perform non-financial assurance based on ISAE 3000 and, if necessary, involve third-party auditors to provide independent assurances.

After reviewing six reports analyzing the differences between the pre- and post-development activity environments of SWancor wind farm project and their responses [25,26], we concluded with the following issues: (1) marine traffic safety issues arising from conflicts in different regulations, (2) lack of underwater landscape monitoring, (3) marine organism protection, (4) noise and air pollution, (5) mitigation difficulty from smaller wind turbine to larger ones, (6) artificial reef establishment to increase fishery resources, and (7) fishery right negotiations.

Below, in Table 1, we discuss five examples about the related applicable ESMS and standards of those environmental and social issues and illustrations of ISAE 3000 assurance procedures, as well as on how those ESIA issues influence credit assessment of project finance from a 5P perspective.

Table 1. Materiality assessment.

No.	ESIA Issue	Applicable ESMS or Standards	ISAE 3000 Procedures
1.	Hazardous material management	<ul style="list-style-type: none"> ■ ISO 14001 ■ Local Environment Health and Safety (EHS) regulations 	<ul style="list-style-type: none"> ■ Review hazardous materials management system ■ Review list of hazardous materials stored and used ■ Review the emergency response plan
2.	Damaged equipment management	<ul style="list-style-type: none"> ■ ISO 14001 ■ Local EHS regulations 	<ul style="list-style-type: none"> ■ Review management of damaged equipment ■ Review waste collection, management and disposal procedures ■ Review waste collection and disposal records, or transfer manifests
3.	Process or products affecting water	<ul style="list-style-type: none"> ■ ISO 14001 ■ Local EHS regulations 	<ul style="list-style-type: none"> ■ Review wastewater pollutant monitoring report (if applicable) ■ Review wastewater treatment process ■ Inquiry on surrounding communities and understand whether negative effects
4.	EHS Risk Management	<ul style="list-style-type: none"> ■ OHSAS 18001 ■ SA 8000 ■ Local labor law ■ Local EHS regulations ■ EIA (enforced by local government) 	<ul style="list-style-type: none"> ■ Comparison of EHS policies and standards against EHS requirement or leading practice ■ Review qualification and capacity of EHS staff ■ Inquiry on estimated investment to meet Equator Principles
5.	Environmental and Social Liabilities	<ul style="list-style-type: none"> ■ Local labor law ■ Local EHS regulations ■ EIA (enforced by local government) 	<ul style="list-style-type: none"> ■ Conduct desktop analysis and site health & safety assessment ■ Review commentary surrounding material liabilities

Site management awareness in managing hazardous materials relates more to the people and protection factors rather than the rest of the 5P principles. The people factor evaluates the borrower's commitments in environmental and social issues, qualifications, and experience. This factor also evaluates broader non-financial performance in corporate social responsibility and appropriate stakeholder engagement. Protection evaluates the direct causes resulting issues ranging from hazardous materials to the physical damage of, and depreciation in the value of, collateral. This factor also evaluates the additional costs incurred by the required remedy, which could further decrease revenue earning ability or solvency with regard to assets or equity.

The quality of damaged equipment management relates more to the people and protection factors. The impacts are similar to those of site management awareness in managing hazardous materials.

Process or products affecting wastewater and water quality relates more to the people and protection factors. The impacts are similar to those of site management awareness in managing hazardous materials as mentioned above.

Inefficient EHS Risk Management System relates to all of the 5P principles. The borrower should establish appropriate ESMS such as marine works to comply with EPs. Not only would inadequate exposure to risks impact the people and protection factors, but additional incurred costs would decrease the payment factor (overall operational and earning ability) and potentially have significant consequences for the purpose factor (requires more funds for remedy). If the non-compliance becomes a social issue, it could further impact the perspective factor and the competitiveness of the wind power industry.

Environmental and Occupational and Public Health and Safety Liabilities relate more to the payment factor, especially for cash flow analysis and the business model. When evaluating the liability dollar amount of this issue, involvement from EHS experts might be necessary to properly consider all of the applicable ESMS or standards. If liability is significant or the borrower is unable to meet the requirements, it may also impact the protection and perspective factors.

2.4. Assessment Matrix: EPs and Strategic Environmental Assessment

First, we integrated EP categorization, offshore wind power life cycle assessment (including manufacturing, construction, M&O, and retirement stages), and Block Development Policy impact categories into the assessment matrix. Then, we moved on to discuss the potential risks or impacts by using EP categorizations for each Block Development Policy impact category throughout the offshore wind farm life cycle.

As there is no generally accepted EP categorization methodology, we introduced Failure Mode and Effect Analysis (FMEA) from Kahrobaee and Asgarpoor [27] to illustrate the EP categorization and strategic environmental assessment considerations. We rewrote and calculated the Risk Priority Number (RPN) for each impact category in each life cycle stage as below:

$$\text{RPN} = \text{Probability} \times \text{Impact} \times \text{Mitigation}. \quad (1)$$

We started with the impact category and impact matrix in Block Development Policy [8] as the basis of the RPN results. The origin impact category and impact assessment were qualitatively given plus or minus in meeting the needs of strategic environmental assessment (SEA). We further reviewed the SWancor Formosa EIA meeting minutes, interviewed the environmental engineering consultant involved in the EP evaluation for SWancor Formosa, and held discussions with the SWancor management in June 2017. However, due to a limitation of national and local data availability in Taiwan, the RPN analysis remains a subjective and qualitative analysis.

By applying Equation (1), we gave scores out of 1–10 for each of the RPN factors: Probability, Impact, and Mitigation. For Probability, we gave 10 for a “higher probability”, 5 for “probable”, and 1 for “lower probability”; for Impact, we allocated 10 for “significant impact”, 5 for “limited impact”,

and 1 for “minimal impact”; and for Mitigation, we gave 10 for “mitigation is not readily available” and 1 for “mitigation is readily available”.

In Table 2, we categorized scores 500–1000 as Category A, scores of 50–250 as Category B, and scores of 1–25 as Category C. If any of the risk factors were unclear in any of the life cycle stages, the assessment result was noted as “unknown”.

Table 2. Assessment matrix. LCA: life cycle assessment; EIA: environmental impact assessment; M&O: maintenance and operation.

EIA \ LCA	Manufacturing	Construction	M&O	Retirement
	Assimilative capacity	RPN = $5 \times 5 \times 1 = 25$ Category C	RPN = $10 \times 10 \times 10 = 1000$ Category A	RPN = $10 \times 10 \times 10 = 1000$ Category A
Natural ecosystems and landscape	RPN = $1 \times 1 \times 1 = 1$ Category C	RPN = $10 \times 10 \times 10 = 1000$ Category A	RPN = $10 \times 10 \times 10 = 1000$ Category A	RPN = $1 \times 1 \times 1 = 1$ Category C
National health and safety	RPN = $1 \times 1 \times 1 = 1$ Category C	RPN = $5 \times 5 \times 10 = 250$ Category B	RPN = $1 \times 1 \times 1 = 1$ Category C	RPN = $1 \times 1 \times 1 = 1$ Category C
Use of land resource	RPN = $1 \times 1 \times 1 = 1$ Category C	RPN = $1 \times 1 \times 1 = 1$ Category C	RPN = $1 \times 1 \times 1 = 1$ Category C	RPN = $1 \times 1 \times 1 = 1$ Category C
Water resource system and usage	RPN = $1 \times 1 \times 1 = 1$ Category C	RPN = $1 \times 1 \times 1 = 1$ Category C	RPN = $1 \times 1 \times 1 = 1$ Category C	RPN = $1 \times 1 \times 1 = 1$ Category C
Cultural heritage	RPN = $1 \times 1 \times 1 = 1$ Category C	RPN = $1 \times 1 \times 1 = 1$ Category C	RPN = $1 \times 1 \times 1 = 1$ Category C	RPN = $1 \times 1 \times 1 = 1$ Category C
International environmental standard	RPN = $1 \times 1 \times 1 = 1$ Category C	RPN = $1 \times 1 \times 1 = 1$ Category C	RPN = $1 \times 1 \times 1 = 1$ Category C	RPN = $1 \times 1 \times 1 = 1$ Category C
Social and economic impacts	RPN = $1 \times 1 \times 1 = 1$ Category C	RPN = $10 \times 10 \times 10 = 1000$ Category A	RPN = $10 \times 10 \times 10 = 1000$ Category A	RPN = $1 \times 1 \times 1 = 1$ Category C

As a result, we first noted Category A had an assimilative capacity since offshore wind power includes environmental impacts in areas such as air, water, noise, and radiation. These impacts on assimilative capacity are particularly related to the construction and M&O stages.

Second, we also noted Category A in natural ecosystems and landscapes. This was due to the fact that *Sousa chinensis* or the Indo-Pacific humpback dolphin and bird habitats require careful survey and investigation where raw data might be limited and hard to obtain. Natural ecosystems and landscapes also need sound and prudent stakeholder engagement and community consultation to demonstrate appropriate management and governance commitment that may increase the development costs as well as the risks. Likewise, in social and economic impacts, fishery rights require time-consuming stakeholder engagement and community consultation; and marine and air traffic requires thorough study and research to avoid any conflict in regulations.

3. Case Study

This paper reviewed Phase 1 of the SWancor Formosa and provides an illustration of the integrated assessment (referring to Figure 1) for offshore wind farms. The case study focused on the areas of most impact such as EP Category A and Category B to discuss ESIA, the EP evaluation, and the results of the integrated assessment. This offshore wind power project was developed in accordance with the Regulation on Encouragement for Wind Power Offshore System Demonstration [28] enacted by the Bureau of Energy. This project has been in operation since April 2017. SWancor Formosa Phase 1 installed two wind turbines with a capacity of 8 MWh in total. Due to a lack of foreign-outsourcing wind power development experience, SWancor integrated various outsourced contractors and coordinated the construction. To balance the risks and development costs, SWancor involved European consultants to apply Multi-EPC (Engineering, Procurement, Construction) principles where contractors are responsible for the design, procurement, and construction. The SWancor Formosa Phase 1 was divided into four outsourced contracts: wind turbine and hoisting installation, foundation and installation, cables and layout, and the inland substation [29].

According to the Regulation on Encouragement for Wind Power Offshore System Demonstration, an offshore wind farm has to be 5 m beyond the submarine contour.

SWancor Formosa Phase 1 is located offshore from Zhunan Township, Miaoli County and is about 60 km away from the Taichung Port. The water depth is between 15 and 35 m; the batholith is between MWL 20 and 44 m; the thickness of the alluvial soil is about 2–18 m; and the maximum development area is about 10.27 km² [30]. Wu et al. [31] reviewed the wind condition and isobathic line of coastal areas from New Taipei City to Changhua County and the total wind power capacity in Taiwan was estimated at 2.2 GW. In terms of wind speed (m/s), the annual wind speed of 80 m offshore on the northwest of Miaoli County has the greatest potential in Taiwan.

3.1. ESIA and EP Evaluation

Through further detailed interview of the SWancor Formosa Phase 1, we observed intensity and complexity in certain categories regarding two stakeholder issues including the compensation of fishery rights for fishermen, and works such as assembling on docks and underwater works for land and marine workers.

These observations were consistent with our risk assessment. The compensation of fishery rights is related to social and economic impacts under construction and M&O life cycle stages where RPN is 1000, or in EP Category A. Works like assembling on dock and underwater works for land and marine workers has drawn attention, partially as Taiwan does not have an offshore exclusive port to assemble wind power for the development period of SWancor Formosa Phase 1. Assembling and marine works relate to national health and safety under the construction life cycle stage where RPN is 250, or EP Category B.

3.1.1. Compensation of Fishery Rights

Typical difficulties in negotiating fishery rights, especially at the planning stages include a lack of specific definition of fishery rights and fishing areas, a lack of measurements or monitoring systems, conflict with jurisdictional laws and regulations, and a lack of active participation from local fishermen's associations [25]. Compensation of fishery rights is mainly associated with certain LCA performance indicators such as the Global Reporting Initiative's G4 (GRI G4); EC7: Development and impact of infrastructure investments and services supported; EC8: Significant indirect economic impacts, including the extent of impacts; SO1: Percentage of operations with implemented local community engagement impact; and SO2: Operations with significant actual potential negative impacts on local communities [32].

After frequent contact with the fishermen's association and other fishermen, SWancor then signed the "SWancor Offshore Wind Farm Project's Fishery Economy Memorandum of Cooperation" with the Nanlong District Fishermen's Association. The memorandum provides specific and practicable action items such as revisions to environment protection initiatives to meet conformity with current regulations, the will of the fishermen's association and fishermen, and the feasibility of monitoring progress. A summary of the memorandum is as follows [25,26]:

- (1) Cooperate in certain fishery topics for prosperity of aquatic resource, sustainable fishery, and improvement of fishermen benefits.
- (2) At development and construction stages, provided that SWancor's needs and the will of ship owners are met, acquire ships from the Nanlong District Fishermen's Association jurisdiction.
- (3) When human resource is needed or job vacancies are available for the wind farm project in Zhunan area, hire members and members' children from the Nanlong District Fishermen's Association jurisdiction.
- (4) Provide integrated data collected by this project's ocean meteorological observation tower and set up billboards at nearby ports to display real-time ocean meteorological information for fishermen's sailing considerations.

- (5) Release fish fry within the Nanlong District Fishermen's Association jurisdictional ocean.
- (6) Execute monitoring projects for seawater quality and fishery economy and report investigation results to the Nanlong District Fishermen's Association.
- (7) Provided that current regulations are met and there are no impacts on the construction and operation, if the Nanlong District Fishermen's Association provides opportunities for fishery transformation or tourism, the project developer (SWancor) shall provide reasonable assistance.
- (8) Design fundamental and protective work methods considering the real landscape, geology, and surrounding ecological environment.

In addition to the memorandum, SWancor also signed the "Compensation of Fishery Right and Cooperation Agreement". The agreement was not only signed by both the chairman of SWancor and the director of the Nanlong District Fishermen's Association, but was also notarized at the Miaoli County Court, which made the agreement enforceable with a certain level of legal effects [33]; however, we were not able to obtain these details due to a non-disclosure agreement (NDA) [26].

We note a potential issue of precision levels of fish volume determination relating to wind farm that was also stated by "The Sixth Report Analyzing the Differences between the pre- and post-Development Activity Environments of SWancor Wind Farm Project". Due to limitations from a lack of current statutory fishery economy reports that disclosed information beyond a county-by-county basis for the local impacted area, SWancor had no authority to perform its own investigation as it may be subjective, and might possibly cause resentment from the local fishermen's association or from the fishermen themselves [25].

3.1.2. Workers: Assembling on Dock and Marine Works

We observed another material social impact on the workers category where the most impacted areas were assembling on the dock and marine works. All of these risk factors influenced worker-related LCA performance indicators, including the following: GRI G4 LA6: Type of injury and rates of injury, occupational diseases, lost days, and absenteeism, and total number of work-related fatalities, by region and by gender; LA7: Workers with high incidence or high risk of diseases related to their occupation; LA10: Programs for skills management and lifelong learning that support the continued employability of employees and assist them in managing career endings; LA15: Significant actual and potential negative impacts for labor practices in the supply chain and actions taken; LA16: Number of grievances about labor practices filed, addressed, and resolved through formal grievance mechanisms [32].

We summarized these worker-specific key risk factors relating to SWancor Formosa Phase 1 for transport, at construction, and after completion as follows [25,26]:

- (1) weather forecast ability;
- (2) working environments on the dock land and in marine on the sea and under the sea when transporting to and operating at construction and installation locations;
- (3) quality of raw and packing materials and spare parts;
- (4) construction equipment and vessel capabilities;
- (5) design of boat signaling systems (to avoid marine traffic);
- (6) workers' operating skills;
- (7) appropriateness of social management systems.

For the Block Development Policy, the Taiwan EIA review committee pointed out Items 1, 4, and 5. First, the weather forecast ability required further investment in research, study and technology, and the accessibility of the forecast information was also important for fishermen to make their sailing decisions. Construction equipment and vessel capabilities are still lacking from local investments from the Taiwanese government or private sectors. We noticed that hesitation was partly due to considerable initial investment amounts to build a more qualified wind farm working vessel, which, when referring

to the European experience, could usually lift up 1,000 tons to 100 m high [34]. Second, the design of the signaling systems (to avoid traffic) was repeatedly discussed in meetings of SWancor's differences between the pre- and post-development activity environment reviews. Third, the review committee was concerned with the traffic around the installation location and prudently checked if SWancor's working vessels could be clearly recognized on radar systems for those sailing by the reviewed regions. We also noticed that current Taiwanese regulations do not allow SWancor to use buoys to avoid traffic due to a lack of authority from any current laws or regulations to do so. All other vessels are free to sail by the reviewed installation area without traffic control.

Items 2 and 6 represented significant challenges to SWancor Formosa Phase 1. Taiwan-based practices did not have sufficiently experienced marine workers with specializations in wind farm projects. To accomplish the construction, SWancor introduced international experts and organized cross-country fleet and vessels as Taiwanese engineers lacked wind farm experience. In any part of wind farm construction, the less experienced the involved workers are, the more potential risks the project will be exposed to, since the ability to maintain appropriate working environments might be limited.

In particular, Items 3 and 7 are especially about the managerial decisions and choices SWancor made for the wind farm during the procurement processes and how SWancor could successfully manage the material social impacts. Balancing the trade-off between the construction costs (including the quality of the raw and packing materials and the implementation costs of social management systems) and SWancor's commitment to targeted social performance required responsible management decisions and a well-implemented corporate social responsibility management system so that SWancor could address the material LCA issues particularly with regard to the needs of their workers.

3.1.3. EP Evaluation: Gap Analysis

This paper applied six layers of standards that a project developer might be encouraged to address for its social and environmental risks [35]. We outlined these six layers starting from the minimum requirement and ending with the best EP practice:

- (1) local law and regulation;
- (2) host governmental agreements;
- (3) international environmental and human rights law;
- (4) extra-territorial application of investor-country laws;
- (5) consumer preferences;
- (6) voluntary standards including in financing.

Items 1 and 2 represent the local law and regulation and host governmental agreements including the prevailing Block Development Policy, the required "Report Analyzing the Differences between the pre- and post-Development Activity Environments of SWancor Wind Farm Project", and other local environmental and social regulations. These standards reflect the minimum legal obligation that SWancor has to obey throughout the entire wind farm life cycle and demonstrate that any violations would most likely result in legal consequences.

Item 3 refers to higher social and environmental standards that encourage EPs in international practice beyond the local requirements. Items 4 and 5 stand for perspectives from other stakeholders such as EPFIs (either local bank or international bank) and future consumers for products and services. Item 6 is voluntary.

3.2. Integrated Assessment

Following the section above, in Table 3, we performed an integrated assessment (as shown in Figure 1) on SWancor Formosa Phase 1 and would like to particularly highlight certain LCA topics of higher priority that might need further clarification and actions from either the Taiwanese government or SWancor before moving into SWancor Formosa Phase 2.

Table 3. Equator Principle (EP) gap analysis.

No.	LCA Topics	Level of Standards	Comments and Observations	Suggested Further Action Plan
1.	Compensation of Taiwan's fishery right	Local law; and host governmental agreements	<ol style="list-style-type: none"> Lack of regional fishery data published by authority Lack of formal public consultation and community engagement policy Lack of fishery right monitoring system 	<ol style="list-style-type: none"> Setup generally accepted compensation approaches Establish formal regional fishery database for wind farm projects Introduce verification or evaluation methods Implement grievance mechanism
2.	Labor rights	Local law; host governmental agreements; and international human rights law	<ol style="list-style-type: none"> Lack of formal workers' accommodation policy Lack of labor rights monitoring system Lack of formal workers' union due to high proportion of outsourced contractors 	<ol style="list-style-type: none"> Introduce marine worker's regulation Consider a labor-related social performance reporting framework and apply an appropriate social management system Setup formal workers' union Establish formal workers' accommodation policy Implement a grievance mechanism
3.	Health and safety	International human rights law	<ol style="list-style-type: none"> Lack of local marine worker's law Lack of formal health and safety monitoring system 	<ol style="list-style-type: none"> Consider a health- and safety-related social performance reporting framework and apply an appropriate social management system Evaluate the emergency preparedness Implement a grievance mechanism

Without proper mitigation or a remedy to solve the above LCA topics, uncertainty in the social performance of the wind farm project may be raised and thus influence any project finance decision(s).

To review the impact of risk factors on credit assessment, we further discussed the application of the 5P principles in a wind power project and reviewed the processes typically performed by financial institutions in determining a line of credit. Here, we use the term "inherent risk" to represent the risk to credit assessment without mitigation or remedy whether readily available or not. Table 4 below shows how financial institutions may apply the 5P principles to wind farm projects, and the impacts of the risk factors identified by our case study.

Table 4. LCA topics, inherent risks to the 5P principles—People, Purpose, Payment, Protection and Perspective—and assessment procedures.

No.	LCA Topics	Inherent Risks to the 5P Principles	Applicable ISAE 3000 and Credit Assessment Procedures	Explanations
1.	Compensation of Taiwan's fishery right	Payment, Protection and Perspective	<ol style="list-style-type: none"> Review the borrower's agreement and MOU with fishermen or fishermen's association Recalculate the compensation based on original source data Review and perform on-site field work to interview with stakeholders Review estimation of compensation's contingent liabilities 	<p>Compensation of Taiwan's fishery right is one of the cash outflows for a wind farm project. Any uncertainty in estimating the compensation results in uncertainty of the wind farm's operational performance and the borrower's solvency thus represents a negative payment factor on credit assessment.</p> <p>The lack of generally accepted compensation approaches, formal public consultation, and community engagement policy or fishery right monitoring system also increases a financial institution's concerns on the perspective factor of a project and may further require a higher protection level for the targeted credit line.</p>
2.	Labor rights	People, Payment and Perspective	<ol style="list-style-type: none"> Review human rights consultation policy and stakeholder engagement record Review workers' union article, expectations, and activities, and understand the borrower's management's responses to those expectations Review and perform on-site field work to interview with stakeholders and observe workers' accommodation Review estimation of investments to meet EP requirements 	<p>To meet the EP requirements, labor rights require the borrower to perform stakeholder engagement, which is also the key to corporate social responsibility. The people factor may be assessed by the borrower's responses and actions.</p> <p>Negligence of labor rights not only results in uncertainty of operational interruption but also impacts the cost of invested capital when project is delayed or profitability is decreased when mitigation or remedy to significant labor issues are required. The more intensive concerns in labor rights are, the more uncertain the sustainable operation and perspective of a wind farm will be, which negatively affects the payment and perspective factors.</p>

Table 4. Cont.

No.	LCA Topics	Inherent Risks to the 5P Principles	Applicable ISAE 3000 and Credit Assessment Procedures	Explanations
3.	Health and safety	People and Payment	<ol style="list-style-type: none"> 1. Comparison of EHS policies and standards against EHS requirement or leading practice 2. Examine qualification and capacity of EHS staff 3. Conduct desktop analysis and site health and safety assessment 4. Review estimation of health and safety contingent liability and investments to meet EP requirements 	<p>Health and safety are important to working conditions and require the borrower to implement related monitoring systems to meet EP requirements. The people factor may be assessed by the borrower's responses and actions.</p> <p>If exposure to health and safety risks is higher than the acceptable level, operational interruption and additional recovery costs and a decrease in cashflow generation ability of a project may result, which negatively affects the payment factor. If related sites and location further deteriorate, a temporary or permanent shutdown of the wind farm may result in significant and unaffordable impacts on a project.</p>

3.3. Discussions and Further Considerations

Based on the integrated assessment results of the SWancor Formosa Phase 1 case study, we suggest that further research on effective stakeholder engagement, the life cycle risk assessment approach, materiality analysis on environmental and social impact, applicable ESMS to address certain impact category, and approaches for involvement of independent third-party evaluator for offshore wind power development are required.

For effective stakeholder engagement, applicable standards can be AA1000SES [36], S-LCA, or the Block Development Policy especially for social impacts. Sound and robust stakeholder engagement at early stages of wind power development projects can be beneficial to all project stakeholders by focusing on material issues prior to the construction stage. This introduces an opportunity of a considerable cost reduction in lead time. Stakeholder engagement is also essential for EPs, and our integrated assessment formed the basis of the materiality of economic, environment and social impacts and issues of a wind power project.

We also suggest future research is conducted in objective and quantitative EP categorization analysis and to review relationships between each factor in an integrated assessment (as shown in Figure 1) such as how the quality of inventory data would impact ESMS and project finance decisions. For example, the reliability and completeness of observed data from the LCA inventory data can be one of the quality requirements. In Taiwan, we noticed that Chun-Yu [37] reviewed the social impact assessment of Taiwan's offshore wind power development.

4. Conclusions

According to our research, we recognized that Taiwanese offshore wind power development is locally a very new industry and for offshore wind power project finance, policy-makers, wind farm developers, practitioners, and potential investors are in need of an integrated assessment framework. The lack of integrated assessment could significantly increase communication and transaction costs as well as increase the development time of offshore wind power development. The drawbacks of lacking an integrated assessment are also clear: (1) Taiwanese local commercial banks are hesitant to invest in offshore wind power public financing, (2) the public sector provides little economic incentive or credit enhancement to mobilize private finance into this area, and (3) local practitioners lack offshore wind power risk assessment ability and experience.

From the case study, we also observed that risks, including mitigation not readily available or EP gap analysis results not properly addressed by the borrower, could both further deter funds from private investors or grants from the government since the risk has not been reduced to acceptable levels. From the case study, we also observed (1) the deep discussion with fishermen and their association, and the difficulty in executing competent mechanics for offshore construction, and (2) the lack of experienced wind power construction workers or working vessels that could potentially increase both the construction risk and cost. These findings are very important for planning and construction processes; hence, the early involvement of stakeholders and public interest groups and the proper arrangement of working forces are necessary to manage wind power development.

Finally, we encourage more case studies on offshore wind power development so that information asymmetry of wind power project finance can be improved for each wind power stakeholder including policy-makers, wind farm developers, practitioners, potential investors, and observers and stakeholders, especially for their decision-making. Eliminating information asymmetry and mobilizing green finance investments from the financial sector to renewable energy projects are key factors in achieving Taiwan's New Energy Policy target where renewable energy in the electricity system reaches 20% by 2025.

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