Communication

Is Zero Subsidy in Fixed-Bottom Offshore Wind Farms Feasible? The Case of Incheon, South Korea

Jongmin Lee 1 and George Xydis 1,2,*

1 Energy Policy and Climate Program, Krieger School of Arts & Sciences, Johns Hopkins University, Baltimore, MD 21218, USA; jlee723@jhu.edu
2 Department of Business Development and Technology, Aarhus University, Birk Centerpark 15, 7400 Herning, Denmark
* Correspondence: gxydis@gmail.com or gxydis@btech.au.dk; Tel.: +45-93508006

Abstract: It has been stated that by 2030, South Korea will have increased their capacity for wind power from 124 MW to 12 GW. According to official statements, offshore wind turbines will provide most of this wind energy. In order to determine the costs for an offshore wind energy production site, an economic analysis was performed in Incheon, South Korea, and the levelized cost of energy (LCoE) value was calculated at 129.97 USD per MWh, and the net present value and the internal rate of return were also calculated. Various scenarios were tested, and it was proven that minimum or no governmental support can lead to economically problematic projects. Is zero subsidy the future of the offshore wind industry?

Keywords: offshore; wind energy; zero subsidy; LCoE

1. Introduction

Worldwide, wind energy production is growing every year. It increased from 181 GW in 2010 to 743 GW in 2020 [1]. According to predictions, wind energy production globally in 2030 will be more than 2000 GW [2]. South Korea has declared its target is to reduce greenhouse gas emissions by 30% to meet their nationally determined contribution target by 2017 [3]. The target was updated, and it has also been announced by the government that by 2030 the country should generate 12 GW of wind power [4]. The Renewable Energy 3020 Implementation Plan (RE3020) was announced by the Korean government, with the aim of decreasing the proportion of coal and nuclear power generation and increasing power production from renewable energy sources [5]. The Third Energy Master Plan in 2019 and the Ninth Basic Plan for Power Supply Demand in 2020 were introduced to increase the share of renewable energy share in Korea [6]. In 2020, the Korean New Deal was introduced as a national development strategy to accelerate the country’s transition towards a low-carbon and eco-friendly economy. In the same year, the Ministry of Trade, Industry and Energy (MOTIE), the Ministry of Oceans and Fisheries (MOF) and the Ministry of Environment (MOE) jointly published a “Plan for Offshore Wind Power Generation in Collaboration with Local Residents and the Fishing Industry” (OSW Collaboration Plan) to share the economic benefits of offshore wind project developments and to simplify permitting and licensing procedures [7]. Furthermore, South Korea announced—only a few days after Denmark announced their energy islands worth EUR 30 billion [8]—that it has plans for 8.2-GW offshore wind power projects [9]. Consequently, these activities have resulted in greater investment for wind energy projects in South Korea.

2. Strategy and Project Aim

The paper points out that offshore wind is not the same opportunity for every investor the way it is developed today. The paper presents, via the viewpoint of the Korean
government, that there are projects that can and others that cannot be viable in the long term, depending on support and other factors.

2.1. Fixed-Bottom Wind Farm Site—Incheon

Wind energy is a zero-carbon electricity generation source, and also is an essential element in Korea’s ability to meet its ambitious greenhouse gas reduction goals together with securing energy resources. Korean offshore wind projects benefit from the three bodies of water that surround the country and offer more benefits than onshore wind projects [10]. On 17 July 2020, the MOTIE, MOF and MOE jointly published the OSW Collaboration Plan [11]. This plan prioritized five regions in South Korea in which to develop offshore wind farm activities. Their mean wind speed and mean power density of the five regions are shown in Table 1. As shown in Figure 1, these regions are Incheon, North Jeolla, South Jeolla, Ulsan and Jeju Islands. Figure 1 illustrates how the mean water depth at the Incheon sites is approximately 25 m. Since a fixed bottom foundation is generally used at water depths below approximately 60 m [12,13], it is expected that fixed-bottom offshore wind turbines will be installed in the Incheon location. Therefore, the aim of this paper is to evaluate a fixed-bottom offshore wind project (500 MW) in Incheon, South Korea, and to consider its economic feasibility for use in large-scale wind farms.

Figure 1. Mean wind speed and mean power density of the five regions [14].
Table 1. Mean wind speed and mean power density of the five regions [14].

| At Height 100 m | Incheon | South Jeolla | North Jeolla | Ulsan | Jeju |
|----------------|---------|--------------|--------------|-------|-----|
| Mean Wind Speed (m/s) | 6.98    | 7.77         | 6.79         | 7.81  | 7.51|
| Mean Power Density (W/m²) | 439     | 538          | 469          | 722   | 525 |
| Water depth at site (m)  | 25      | 55           | -            | 140   | 105 |
| Type of Offshore Wind Farm | Fixed-bottom | Floating |

2.2. South Korea’s Renewable Energy Policies (Offshore Wind Energy)

South Korea recently declared its aim to become carbon neutral by 2050 and announced a range of strategies to meet this target in the renewable energy sector [15]. In this section, the strategies, plans and policies that are directly connected to offshore wind energy are described and analyzed.

2.2.1. Renewable Energy Portfolio Standard (RPS)

The Korean government announced its Renewable Portfolio Standard (RPS) in 2012. This was a national scheme to support offshore wind development in Korea [16]. According to the RPS, energy suppliers with a power generation capacity greater than 500 MW should produce a certain proportion of their total power from renewable sources. Figure 2 shows that the minimum proportion of RPS obligations was 3% of total power production in 2015, with a gradual increase to 25% by 2026 [17]. Energy suppliers that are not able to meet their RPS obligation are forced to pay penalties as much as 150% of the Renewable Energy Certificate (REC) price. Alternatively, they can purchase Renewable Energy Certificates (RECs) (per 1 MWh) in order to fulfill their initial targets.

Figure 2. Renewable Energy Portfolio Standard Obligations [18].

2.2.2. Renewable Energy Certificates (REC)

RECs are a market-based tool, whereby the energy suppliers can receive an economic incentive while using renewable energy sources for electricity generation in South Korea. Depending on the renewable energy sources and the location of power plants, the final REC price is decided according to the REC weighting scheme [19]. According to the RPS and REC schemes, the total energy sales from the power production is calculated according to the sum of wholesale system marginal price (SMP) of electricity and the sale of REC price [20]. Figure 3 shows the trends of mean SMP prices in South Korea between 2002 and 2021 [21], and Figure 4 indicates the trends of mean REC price in the same period [22].
Under the current PRS, energy suppliers have a fixed price contract, which is a combination of SMP and REC prices; the final REC price should be multiplied by REC weighting factors. As shown in Figure 4, the REC price has decreased since 2016. As of December 2021, the price is less than KRW 40,000 per 1 REC. As SMP and REC prices can have a critical impact on net present value (NPV), internal rate of return (IRR) and levelized cost of energy (LCoE) of renewable projects, these values are very substantial for wind developers and independent power producers in evaluating any upcoming wind projects in South Korea.

2.2.3. Renewable Energy 3020 Implementation Plan (RE3020)

The RE3020 describes the government’s target to produce 20% of energy with renewables by 2030 [23]. In 2017, MOTIE announced the Korean government’s detailed plans to increase the level of renewable energy capacity from the current levels of 7.6% (13.3 GW) to 20% (20.1 GW) of total power generation by 2030, creating relevant jobs in the renewable energy sector [24]. According to MOTIE’s report in 2017, the aim of the plan is to support the deployment of large-scale renewable energy projects, including an increase in the capacity of wind power from 1.2 GW to 17.7 GW by 2030.
2.2.4. The Third Energy Master Plan and the Ninth Basic Plan for Power Supply and Demand

The Energy Master Plan outlines the government’s main focus to tackle climate change and secure a stable energy supply. In June 2019, MOTIE published its Third Energy Master Plan with a focus on the innovative transition of the overall energy system from production and distribution to consumption [6].

In December 2020, MOTIE published the Ninth Basic Plan for Power Supply and Demand with the aim of increasing its renewable energy share from 15.8% (20.1 GW) of power capacity in 2020 to 40.9% (77.8 GW) in 2034. The total share of renewable energy is targeted to increase to 77.8 GW by 2034, which includes 45.6 GW of solar energy and 24.9 GW of wind energy. These will account for 91% of the total renewable energy share. Figure 5 illustrates the government’s plan for renewable energy development plan in South Korea by 2035 based on the Ninth Basic Plan for Power Supply and Demand.

![Renewable Energy Development plan in GW in South Korea by 2035](image)

**Figure 5.** Renewable energy development plan in GW in South Korea by 2035.

2.2.5. The Korean New Deal

The Korean New Deal was introduced in July 2020 by the Korean government as a national development strategy. Under the Korean New Deal, there are two main policies: the Digital New Deal and the Green New Deal [25]. The Digital New Deal promotes digital innovation and dynamics in the Korean economy, and the Green New Deal accelerates the transition towards a low-carbon and eco-friendly economy [26]. To strengthen employment and support the structural transition towards a digital and green economy, the government aims to invest KRW 160 trillion of governmental support and to create 1,901,000 jobs by 2025 [27]. It is also reported by the Ministry of Economy and Finance [28] that the total project cost for the Green New Deal is KRW 73.4 trillion. This is also expected to create 659,000 jobs in the same time frame.

2.2.6. Fishing Industry Collaboration

In July 2020, MOTIE, MOF and MOE announced their OSW Collaboration Plan, with a target of increasing the capacity of offshore wind power up to 12 GW by 2030 and sharing the economic benefits of offshore wind projects with local residents and the fishing industry. Under the current energy policy in Korea, the wind project developers are responsible for all project development activities such as permissions and application for approvals. Therefore, the process is not considered very efficient for the developers. However, as the simplification of licensing procedures is included in the plan, this implementation could reduce the potential risk for developers.

3. Methods

This work focused on identifying whether the case of Incheon was only dependent on subsidy and governmental support, or if the project could become viable with minimum
or even no support. The governmental support mechanisms were already regarding renewable energy policies and the introduced RPS, and the more recent Korean New Deal and its implementation was performed under various scenarios. The NPV, LCoE and IRR indexes were calculated based on the project’s specific particularities, such as distance from shore, REC Weighting, sea depth and the power purchase agreement (PPA), and based on these scenarios, an index-based comparison was revealed. Based on this, the viability of each scenario and the margin for profitability for such an investment were discussed. Under a clear and precise analysis of how the experiment was completed, the approach can be applied to all offshore-planned or conceptual-stage projects in the country.

4. Analysis and Results

Under the current strategies in South Korea, an extensive analysis was performed, starting from the LCoE for the Incheon wind project, shown in Figure 6.

The project is in its early planning phase and the owner is Ørsted A/S; although its capacity has not yet been fixed, it has been studied with a capacity of 500 MW.

4.1. LCoE for the Incheon Wind Project

According to Lai et al. [29] and the detailed analyses of Kocsis and Xydis [30] and Enevoldsen et al. [31], LCoE is calculated based on Equation (1):

$$LCoE = \frac{\sum_{t=1}^{n} \left( \frac{I_t + M_t}{(1+r)^t} \right)}{\sum_{t=1}^{n} \left( \frac{E_t}{(1+r)^t} \right)},$$

where:

- $I_t$ = Investment expenditures in year $t$
- $M_t$ = Operations and Maintenance expenditures in year $t$
- $E_t$ = Electricity generation in year $t$
- $r$ = Discount rate
- $n$ = Life of the wind turbine systems.

The basic information of the Incheon wind project is shown in Table 2.
Table 2. Basic Project Information.

| Category                        | Value   |
|---------------------------------|---------|
| Period                          | 2024–2053 Year |
| Capacity                        | 500 MW |
| Capital Expenditure (CAPEX) [32] | 3,837,000 USD/MW |
| Operating Expenses (OPEX) [32]  | 51.92 USD/MWh |
| Net Capacity Factor [32]        | 38.80%  |
| Tax Rate [33]                   | 22.00%  |
| Inflation [34]                  | 2.00%   |
| Discount Rate [35]              | 6.00%   |
| Debt term [33]                  | 15 Years |
| Debt Fraction [33]              | 70%     |
| Depreciation in Korea: Straight-line method [36] | 5 %/year |

Combining all the basic details of the project (Table 2), the different REC weighting schemes by the Ministry of Trade, Industry and Energy (Table 3), and knowing the SMP (taken at 80 KRW/kWh), REC at 30.2 KRW/kWh and the REC weight at 2.5—according to the basic REC weighting scheme for an offshore wind farm (Table 3)—the PPA was calculated as below (Equation (2)):

$$PPA = SMP + 1\ REC = SMP + REC \cdot (REC \ Weight),$$

(2)

Table 3. REC Weighting Scheme for Wind Farm [18].

| Category            | Criteria | REC Weighting   |
|---------------------|----------|-----------------|
| Onshore             | -        | 1.2             |
| Offshore            | -        | 2.5             |
| Offshore grid connection $\geq 5$ km and water depth $\geq 5$ m | +0.4 per 5 km and 5 m (Max. 3.5) |

The PPA is calculated at 155.5 KRW/kWh, which is equal to 130.45 USD/MWh (Table 4).

Table 4. PPA in South Korea [22].

| Category                        | Value   |
|---------------------------------|---------|
| SMP                             | 80 KRW/kWh |
| REC                             | 30.2 KRW/kWh |
| REC Weight                      | 2.5     |
| SMP + 1 REC                     | 155.5 KRW/kWh |
| PPA = SMP + 1 REC in USD        | 130.45 USD/MWh |

(exchange rate: 1 USD = 1.192 KRW).

4.2. Scenarios

Based on well-known cash flow models [37,38] the NPV and IRR indices were calculated in different scenarios. The NPV provides a comparative way to evaluate capital or financial products based on their current cash flows and is given by the formula (Equation (3)):

$$NPV = \frac{R_t}{(1+r)^t},$$

(3)

where:
\[ R_t = \text{net cash flow (inflow-outflows) in year } t \]
\[ t = \text{year of the cash flow} \]

The IRR index is another way to assess the viability of future investments. The scope is to identify the rate by which the investor will get their capital back and it is calculated via the formula (Equation (4)):

\[
IRR = \sum_{t=1}^{T} \frac{C_t}{(1 + r)^t} - C_0,
\]

where:
- \( C_t \) = Net Cash inflow in year \( t \)
- \( C_0 \) = total capital cost

Using the parameters from the project information, and in the examined case that the REC weight equals 2.5, the LCoE was calculated at 129.97 USD/MWh with a positive NPV of 147.14 KRW/kWh and a 17% IRR. After the calculations, the results of the two different scenarios are shown in the table (Table 5) and figure (Figure 7) below.

Table 5. A metric-based comparison of the different scenarios.

| PPA [USD/MWh] | NPV [KRW/kWh] | IRR [%] |
|---------------|---------------|---------|
| IF REC Weight = 1.0 | 92.45 | -207.22 | 9 |
| IF REC Weight = 0.0 | 67.11 | -443.47 | 2 |

Figure 7. Metric (PPA, NPV, IRR)–based comparison.

5. Discussion

When can such a project be regarded as a viable project? With the inclusion of the REC economic weight, the project can be considered economically competitive, as the LCoE is lower than the combination of “SMP + 1 REC”, which is 130.45 USD per MWh. However, in order to evaluate the commercial feasibility of the project [39], it is important to consider the REC weight. For example, when the REC weight is 1.0, the sum of “SMP + 1 REC” becomes 92.45 USD per MWh and IRR decreases to 9%. If the Korean government decides not to support the REC weight (REC = 0), the sum of “SMP + 1 REC” is 67.11 USD per MWh and IRR reduces down to 2%. A 2% IRR is considered rather low and most probably non-profitable [40]. This is also explained by the fact that the NPV costs in both scenarios have negative values. Practically, an investor would never go forward with an investment with such low profitability margins. On top of that, such demanding offshore projects that have a history of less than 25 years—and a lot shorter mature history—usually carry many risks [41]. Unexpected or increased faults during the 20–25 year lifetime of an offshore wind farm can completely eliminate this 2% or even end up to be a negative IRR and thus definitely not a viable project [42].

Therefore, the current Korean approach to subsidizing renewable energy development is substantial and the only viable way for foreign and domestic developers in terms of
evaluating the forthcoming large-scale offshore wind projects in South Korea. In order for subsidy to be minimal for such projects and still be viable as investments in the long term, a “coalition” with hydrogen (or methane) production and stronger links with other sectors, such as the transportation sector, is needed [43,44]. This could make offshore projects, specifically the one in Incheon, more viable. However, a detailed analysis on the topic is not included in this work and it will be the focus of a future paper.

6. Conclusions

Through long-term contracts with renewable energy companies, the feed-in tariff support scheme was used in order to accelerate investments in various renewable energy technologies over the last twenty years or so; over the last decade, there has been a transition from the tariff support scheme to premium or other support schemes worldwide [45]. However, manufacturing costs for both wind turbine and solar panel projects have declined, and in most countries this support mechanism was removed and the wind and solar projects—since they started being considered mature and competitive technologies—did not require support at all. Yet, offshore wind projects did not follow exactly the same path of lower costs, and this is forecasted for much later [46]. Their cost remained higher compared to onshore projects, and still requiring governmental support [47]. In this study, the NPV and the IRR were calculated in Incheon, South Korea, proving that with limited or no governmental support the IRR could be between 2 and 9%, which could lead to negative value projects. This proves that on a large-scale, the offshore industry cannot be based on zero subsidy and one way or another it will often require support. Therefore, independent power producers are looking for ideas/concepts that could unconventionally self-support the industry. Concepts such as Denmark’s energy islands, which will also produce hydrogen that will afterwards be transported to shore, should lead to more green and viable investments in a politically and economically fragile environment [8,48]. Concepts such as hydrogen (or even methane) production in offshore sites are gaining attention and cause all developers to think that they should be building underwater pipes, not just cables. In the case of zero subsidy, there is a need to jointly develop energy sources, such as hydrogen storage, together with wind or solar energy. Such an alliance can lead the project’s IRR closer to 9% or more and minimize the payback period.

Author Contributions: Conceptualization, J.L.; validation, G.X.; formal analysis, J.L.; resources, G.X.; data curation, J.L.; writing—original draft preparation, J.L.; writing—review and editing, G.X.; visualization, J.L. and G.X.; supervision, G.X.; project administration, G.X. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The study did not report any data.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. GWEC Global Wind Report 2021. 2021. Available online: https://gwec.net/global-wind-report-2021/ (accessed on 21 December 2021).
2. IRENA. Future of Wind: Deployment, Investment, Technology, Grid Integration and Socio-Economic Aspects; International Renewable Energy Agency: Abu Dhabi, United Arab Emirates, 2019.
3. Hutfilter, U.F.; Wilson, R.; Gidden, M.; Ganti, G.; Ramalope, D.; Hare, B. Transitioning towards a Zero-Carbon Society: Science-Based Emissions Reduction Pathways for South Korea under the Paris Agreement. 2020. Available online: https://climateanalytics.org/media/climateanalytics_skorea_zerocarbontransision_2020.pdf (accessed on 5 February 2022).
4. Reve. South Korea to Increase Wind Energy Generation to 12 Gigawatts by 2030. 2020. Available online: https://www.evwind.es/2020/07/19/south-korea-to-increase-wind-energy-generation-to-12-gigawatts-by-2030/75844 (accessed on 27 December 2021).
5. Kim, J.H.; Yoo, S.H. Comparison of the economic effects of nuclear power and renewable energy deployment in South Korea. *Renew. Sustain. Energy Rev.* 2021, 135, 110236. [CrossRef]

6. Third Energy Master Plan. 2019, A New Energy Paradigm for the Future, Ministry of Trade, Industry, and Energy, South Korea. Available online: https://www.etrans.or.kr/ebook/05/files/assets/common/downloads/Third%20Energy%20Master%20Plan.pdf (accessed on 9 January 2022).

7. MOTIE (Ministry of Trade, Industry and Energy). The 9th Basic Plan for Power Supply and Demand. 2020. Available online: https://www.motie.go.kr/motie/ne/presse/press2/bbs/bbsView.do?bbs_seq_n=163670&bbs_cd_n=81 (accessed on 12 December 2021).

8. Tosatto, A.; Beseler, X.M.; Østergaard, J.; Pinson, P.; Chatzivasileiadis, S. North Sea Energy Islands: Impact on National Markets and Grids. *arXiv 2021*, arXiv:2103.17056.

9. Chu, K.H.; Lim, J.; Mang, J.S.; Hwang, M.H. Evaluation of strategic directions for supply and demand of green hydrogen in South Korea. *Int. J. Hydrog. Energy* 2022, 47, 1409–1424. [CrossRef]

10. Kim, J.H.; Nam, J.; Yoo, S.H. Public acceptance of a large-scale offshore wind power project in South Korea. *Mar. Policy* 2020, 120, 104141. [CrossRef]

11. Korea’s Offshore Wind Collaboration Plan. 2020. Available online: https://energycentral.com/news/koreas-offshore-wind-collaboration-plan (accessed on 2 December 2021).

12. Wind Europe. Floating Offshore Wind Vision Statement. 2017. Available online: https://windeurope.org/wp-content/uploads/files/about-wind/reports/Floating-offshore-statement.pdf (accessed on 2 November 2021).

13. Park, J.; Kim, B. An analysis of South Korea’s energy transition policy with regards to offshore wind power development. *Renew. Sustain. Energy Rev.* 2019, 109, 71–84. [CrossRef]

14. Global Wind Atlas. 2021. Available online: https://globalwindatlas.info/area/South%20Korea/Incheon (accessed on 5 October 2021).

15. Oh, H.; Hong, I.; Oh, I. South Korea’s 2050 Carbon Neutrality Policy. *East Asian Policy* 2021, 13, 33–46. [CrossRef]

16. Kwon, T.H. Is the renewable portfolio standard an effective energy policy? Early evidence from South Korea. *Util. Policy* 2015, 36, 46–51. [CrossRef]

17. Ministry of Trade, Industry and Energy. Renewable Energy Portfolio Standards Weight. 2021. Available online: http://www.motie.go.kr/motie/common/download.do?fid=bbs&bbs_cd_n=81&bbs_seq_n=164641&file_seq_n=3 (accessed on 20 November 2021).

18. Ministry of Trade, Industry and Energy. Renewable Energy Portfolio Standards Obligations. 2021. Available online: http://www.motie.go.kr/motie/common/download.do?fid=bbs&bbs_cd_n=81&bbs_seq_n=164409&currentPage=1&search_key_n=title_v&cate_n=1&dept_v=&search_val_v= (accessed on 2 October 2021).

19. Kwon, T.H. Policy synergy or conflict for renewable energy support: Case of RPS and auction in South Korea. *Energy Policy* 2018, 123, 443–449. [CrossRef]

20. Yoon, J.H.; Sim, K.H. Why is South Korea’s renewable energy policy failing? A qualitative evaluation. *Energy Policy* 2015, 86, 369–379. [CrossRef]

21. Electric Power Statistics Information System (EPSIS) 2021, Mean Wholesale System Marginal Price from 2002 to 2021. Available online: https://onerec.kmos.kr/portal/selectBbsNttList.do?key=1970 (accessed on 17 November 2021).

22. Korea Power Exchange. 2021, REC Price. Available online: https://kpx.kmos.kr/portal/selectBbsNttList.do?key=1973&bbsNo=477&searchCtgry=&pageUnit=10&searchCnd=all&searchKrwd=&intebrDeptCode=&pageIndex=1 (accessed on 10 November 2021).

23. Park, S.; Yun, S.J. Multiscalar energy transitions: Exploring the strategies of renewable energy cooperatives in South Korea. *Energy Res. Soc. Sci.* 2021, 81, 102280. [CrossRef]

24. Ministry of Trade, Industry and Energy. Renewable Energy 3020 Plan. 2017. Available online: http://www.motie.go.kr/motie/common/download.do?fid=bbs&bbs_cd_n=81&bbs_seq_n=159996&file_seq_n=2 (accessed on 1 November 2021).

25. Kangarane, T. South Korea efforts to transition to a hydrogen economy. *Clean Technol. Environ. Policy* 2021, 23, 509–516. [CrossRef][PubMed]

26. Rodriguez, B.; Xydis, G. A five-target innovation discussion on low-speed wind turbine system optimization. *Energy Sources Part A Recovery Util. Environ. Eff.* 2021, 1–15. [CrossRef]

27. Cruz, K.V. Moon Jae-In’s Strategy Amid COVID-19 Pandemic: Reviving the Green in the Korean New Deal. In *Collection of Essays on Korea’s Public Diplomacy: Possibilities and Future Outlook*; Ministry of Foreign Affairs, Republic of Korea: Seoul, Korea, 2020; p. 315.

28. Ministry of Economy and Finance. Korean New Deal: National Strategy for a Great Transformation. 2020. Available online: https://english.mof.go.kr/pc/selectTbPressCenterDtl.do?boardCd=N0001&seq=4948#fn_download (accessed on 10 November 2021).

29. Lai, C.S.; Locatelli, G.; Pimm, A.; Tao, Y.; Li, X.; Lai, L.L. A financial model for lithium-ion storage in a photovoltaic and biogas energy system. *Appl. Energy* 2019, 251, 113179. [CrossRef]

30. Kocsis, G.; Xydis, G. Repair process analysis for wind turbines equipped with hydraulic pitch mechanism on the US market in focus of cost optimization. *Appl. Sci.* 2019, 9, 3230. [CrossRef]

31. Enevoldsen, P.; Permin, F.H.; Bakhtaoui, I.; von Krauland, A.K.; Jacobson, M.Z.; Xydis, G.; Sovacool, B.K.; Valentine, S.V.; Luecht, D.; Oxley, G. How much wind power potential does Europe have? Examining european wind power potential with an enhanced socio-technical atlas. *Energy Policy* 2019, 132, 1092–1100. [CrossRef]
32. AEGIR, PONDERA and COWI. Accelerating South Korean Offshore Wind Through Partnerships: A Scenario-Based Study of Supply Chain, Levelized Cost of Energy and Employment Effects. 2021. Available online: https://www.cowi.com/-/media/Cowi/Documents/Accelerating-Offshore-Wind (accessed on 29 December 2021).

33. Kim, Y.K.; Chang, B.M. Real Option Valuation of a Wind Power Project Based on the Volatilities of Electricity Generation Tariff & Long Term Interest Rate. 2014. Available online: https://www.koreascience.or.kr/article/JAKO201412835857778.pdf (accessed on 6 December 2021).

34. Presidential Committee on Jobs. 2021. Available online: https://dashboard.jobs.go.kr/index/summary?pg_id=PSCT040200&data2=SCT040200&ct_type=run (accessed on 29 December 2021).

35. Kim, K.N. The Effects of Depreciation Methods on Investment Motivation for Solar Photovoltaic Systems. 2020. Available online: http://www.koreascience.or.kr/article/JAKO202009835825476.pdf (accessed on 27 December 2021).

36. Supreme Court of Korea. 2021. Available online: https://glaw.scourt.go.kr/wsjo/lawod/sjo192.do?lawodNm=%EB%B2%95%EC%9D%B8%EC%84%B8%EB%B2%95%20%EC%8B%9C%ED%96%89%EB%A0%B9&jomunNo=26&jomunGajiNo= (accessed on 7 January 2022).

37. Xydis, G. A techno-economic and spatial analysis for the optimal planning of wind energy in Kythira Island, Greece. Int. J. Prod. Econ. 2013, 146, 440–452. [CrossRef]

38. Ucal, M.; Xydis, G. Multidirectional relationship between energy resources, climate changes and sustainable development: Technoeconomic analysis. Sustain. Cities Soc. 2020, 60, 102210. [CrossRef]

39. Barutha, P.; Nahvi, A.; Cai, B.; Jeong, H.D.; Sritharan, S. Evaluating commercial feasibility of a new tall wind tower design concept using a stochastic levelized cost of energy model. J. Clean. Prod. 2019, 240, 118001. [CrossRef]

40. Broughel, A.; Wüstenhagen, R. The influence of policy risk on Swiss wind power investment. In Swiss Energy Governance; Springer: Cham, Switzerland, 2022; pp. 345–368.

41. Ucal, M.; Xydis, G. The influence of policy risk on Swiss wind power investment. In Swiss Energy Governance; Springer: Cham, Switzerland, 2022; pp. 345–368.

42. Leite, G.D.N.P.; Weschenfelder, F.; de Farias, J.G.; Ahmad, M.K. Economic and sensitivity analysis on wind farm end-of-life strategies. Renew. Sustain. Energy Rev. 2022, 160, 112273. [CrossRef]

43. Gu, Y.; Wang, D.; Chen, Q.; Tang, Z. Techno-economic analysis of green methanol plant with optimal design of renewable hydrogen production: A case study in China. Int. J. Hydrog. Energy 2022, 47, 5085–5100. [CrossRef]

44. Jaunatre, M. Renewable Hydrogen: Renewable Energy and Renewable Hydrogen APAC Markets Policies Analysis; Springer Nature: Berlin/Heidelberg, Germany, 2021.

45. Xydis, G.; Vlachakis, N. Feed-in-Premium Renewable Energy Support Scheme: A Scenario Approach. Resources 2019, 8, 106. [CrossRef]

46. Wiser, R.; Rand, J.; Seel, J.; Beiter, P.; Baker, E.; Lantz, E.; Gilman, P. Expert elicitation survey predicts 37% to 49% declines in wind energy costs by 2050. Nat. Energy 2021, 6, 555–565. [CrossRef]

47. Rubio-Domingo, G.; Linares, P. The future investment costs of offshore wind: An estimation based on auction results. Renew. Sustain. Energy Rev. 2021, 148, 111324. [CrossRef]

48. Herenčić, L.; Melnjak, M.; Capuder, T.; Androšević, I.; Rajšl, I. Techno-economic and environmental assessment of energy vectors in decarbonization of energy islands. Energy Convers. Manag. 2021, 236, 114064. [CrossRef]