Supporting Offshore Wind Deployment and Grid Connection in APEC Region

APEC Energy Working Group

September 2023

APEC PROJECT：EWG 06 2021A

PRODUCED BY

APEC Sustainable Energy Center (APSEC)
Tianjin University
216 Yifu Building, 92 Weijin Road, Nankai District, Tianjin 300072
China
Tel: + (86) 022-2740 0847
Email: apsec2014@126.com

and

Ove Arup & Partners Hong Kong Limited

Level 5 Festival Walk, 80 Tat Hong Kong, Chee Avenue, Kowloon Tong
Hong Kong, China
arup.com

PRODUCED FOR

Asia-Pacific Economic Cooperation Secretariat
35 Heng Mui Keng Terrace
Singapore 119616
Tel: (65) 68919 600
Fax: (65) 68919 690
Email: info@apec.org
Website: www.apec.org

APEC#223-RE-01.10

ISBN: 978-981-18-8415-3

APEC PROJECT

Supporting Offshore Wind Deployment and Grid Connection in APEC Region (EWG 06 2021A)

PROJECT OVERSEER

Prof Jinlong MA, Tianjin University /APSEC

PROJECT TEAM

Tianjin University

Prof Jinlong MA	Team Leader	Tianjin University / APSEC
Dr Yong SUN	Project Assistant	Tianjin University / APSEC
Xueshun YE	Researcher	Tianjin University
Congnan ZHANG	Research Assistant	APSEC

Project Contractor

Ove Arup & Partners Hong Kong Limited

Acknowledgement

The Project Overseer and the Project Team have been grateful for the insightful inputs and valuable comments received from the EWG member economies on the draft report. The guidance from the APEC Publication Unit for preparation of the final version of the publication has been greatly appreciated.

Supporting Offshore Wind Deployment and Grid Connection in APEC Region (EWG 06 2021A)

APEC Energy Working Group

September 2023

Table of Contents

List of Abbreviations

AC	alternative current
APEC	Asia-Pacific Economic Cooperation
BNEF	BloombergNEF
BOE	Chinese Taipei Bureau of Energy
BOEM	The Department's Bureau of Ocean Energy Management
BoP	the balance of plant
BOT	the Government under the Build-Operate-Transfer
BPLE	the South Korea Energy Masterplan and the Basic Plan for Long-term Electricity Supply and Demand
BSEE	the United States Bureau of Safety and Environmental Enforcement
BSMI	The Bureau of Standards, Metrology and Inspection
CAISO	California Independent System Operator
CES	Clean Energy Standard
CIP	Copenhagen Infrastructure Partners
CISI	Century Iron & Steel Industrial Co. Ltd
COD	commercial operation date
COPs	Construction and Operations Plans
CPPA	Corporate PPA
CPUC	the California Public Utilities Commission
CREEI	China Renewable Energy Engineering Institute
CSBC	the China Shipbuilding Corporation
CSPGC	the China Southern Power Grid Corporation
CVOWF	the Coastal Virginia Offshore Wind Farm
CWP	Century Wind Power Co Ltd
DC	direct current
DEME	Dredging, Environmental and Marine Engineering
DIP	Demonstration Incentive Program
DOC	Department of Construction
DoD	the US Department of Defence
DPPA	Direct Power Purchase Agreement
EB Act	Electricity Business Act
EBA	the Electricity Business Act
EBL	the Electric Business License
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EIA	the US Energy information Administration
EIT	Enterprise Income Tax

EPA	Chinese Taipei’s Environmental Protection Agency
EPA	US Environmental Protection Agency
EPAct	The Energy Policy Act of 2005
EPCOs	The former Electric Power Companies
ERAV	Electricity Regulatory Authority of Viet Nam
ERAV	The Electricity Regulatory Authority of Viet Nam
ERC	The Electricity Regulatory Commission
ERCOT	Electric Reliability Council of Texas
ERCOT	The Electric Reliability Council of Texas
EVN's	Viet Nam Energy’s
EVNCPC	Central Power Corporation
EVNHANOI	Hanoi Power Corporation
EVNHCMC	The Ho Chi Minh City Power Corporation
EVNNPC	Northern Power Corporation
EVNNPT	The National Power Transmission Corporation
EVNSPC	Southern Power Corporation
EWP	Korea East-West Power Co. Ltd.
FAA	Federal Aviation Administration
FDR	Facility and Design Report
FERC	The Federal Energy Regulatory Commission
FiPs	the Feed-in Premium
FIR	Fabrication and Installation Report
FiT	Feed-in Tariff
FRCC	the Florida Reliability Coordinating Council
FYP	Five-Year Plan
GCEC	Generation Cost Evaluation Committee
GENCO 1	Power Generation Corporation 1
GENCO 2	Power Generation Corporation 2
GENCO 3	Power Generation Corporation 3
GenCos	Generation Companies
GHG	greenhouse gas
GIS	gas insulated switchgear
GVA	gigavolt-ampere
HVDC	High Voltage Direct Current
IEA	the International Energy Agency’s
IMEPC	the Inner Mongolia Electric Power Corporation
IOUs	investors-owned utilities
IPPs	independent power producers
IRP	Industrial Relevance Plan
IRS	the Internal Revenue Service

ISO-NE	New England Independent System Operator
ISOs	the independent system operators
ITC	Investment tax credits
JDA	the Joint Development Agreement
JERA	the joint venture of TEPCO and Chubu Electric Power Company
JPEX	Japan Electric Power Exchange
JWPA	The Japan Wind Power Association
KEPCO	the Korea Electric Power Corporation
KHNP	Korea Hydro & Nuclear Power Co. Ltd.
KNRE	The New and Renewable Energy Center
KOEN	the Korea Southeast Power
KOMIPO	Korea Midland Power Co. Ltd.
KOSPO	Korea Southern Power Co. Ltd.
KOWEPO	Korea Western Power Co. Ltd.
KPX	the Korea Electric Power Exchange
LCOE	the Levelized Cost of Electricity
LRFD	Load and Resistance Factor Design
LVRT	Low voltage ride-through
Market Rules	the Electricity Market Operation Rules
MEE	Ministry of Ecology and Environment
MIIT	Ministry of Industry and Information Technology
MISO	Midcontinent Independent System Operator
MLIT	the Ministry of Land, Infrastructure, Transport and Tourism
MOE	the Ministry of Environment
MOEA	Signed Grid Administrative Contract
MOF	the Ministry of Oceans and Fisheries
MOI	the Ministry of the Interior
MOIT	the Ministry of Industry and Trade
MONRE	The Ministry of Natural Resources and Environment
MOTIE	the Ministry of Trade, Industry and Energy
MPI	Ministry of Planning and Investment
NDC	Nationally Determined Contribution
NDC	the Japan's Nationally Determined Contribution
NDRC	the National Development and Reform Commission
NEA	the National Energy Administration
NERC	the North American Electric Reliability Corporation
NOAA	National Oceanic and Atmospheric Administration
NWPP	Northwest Power Pool
NYC DEC	New York State Department of Environmental Conservation
NYC PSC	New York State Public Service Commission

NYISO	New York Independent System Operator
NYS DOS	New York State Department of State
NYS DOT	New York State Department of Transportation
NYS OGS	New York State Office of General Services
OCCTO	Organization for Cross-regional Coordination of Transmission Operators
OCS	the Outer Continental Shelf
OEMs	the Original Equipment Manufacturers
OREC	offshore REC
OSW	offshore wind
OTC	the Over-The-Counter
OWFs	offshore wind farms
PBOC	the central bank of China
PCC	point of common coupling
PDP	Power Plan Development
PGCN	Primary Grid Connection Negotiation
PM	Prime Minister
PMSG	Permanent Magnet Synchronous Generator
POI	point of connection
PPA	Power Purchase Agreement
PTC	Production tax credits
RE3020	The Renewable Energy 3020 Implementation Plan
RECs	the Renewable Energy Certificates
REDA	the Renewable Energy Development Act
RMPA	the Rocky Mountain Power Area
RPS	Renewable Portfolio Standard
RPS	the Renewable Portfolio Standards
RTOs	The Regional Transmission Organizations
SAP	Site Assessment Plan
SBV	State Bank of Viet Nam
SCADA	Supervisory Control and Data Acquisition
SERC	the South-eastern Electric Reliability Council
SGCC	the State Grid Corporation of China
SGRE	Siemens Gamesa Renewable Energy
SIS	System Impact Study
SMP	System Marginal Price
SMP	The system marginal price
SOEs	state-owned enterprises
SPP	Southwest Power Pool
SRE	Sempra Renewables
STATCOM	Static Synchronous Compensator

SVC	Static Var Compensator
T-RECs	the Tradable Renewable Energy Certificate
T&D	transmission and distribution
Taipower	The Taiwan Power Company
TOWIA	the Taiwan Offshore Wind Industry Association
TGO	the grid operator
MOE	the Ministry of Economy
TWTP	the Thousand Wind Turbines Project
UHV	Ultra-High Voltage
UNFCCC	the United Nations Framework Convention on Climate Change
USACE	the US Army Corp of Engineers
USAID	the United States Agency for International Development
USFWS	the US Fish and Wildlife Service
VAT	value-added tax
VWEM	the wholesale market
WECC	the Western Electric Coordinating Council
WRA	Wind Resource Assessment
WSD	Working Stress Design
ZoP	zones of potential

List of Tables

List of Figures

Executive Summary

The Asia-Pacific Economic Cooperation (APEC) is a regional economic forum which consolidates the growth and prosperity of the economies in the Pacific Ocean. To achieve its goals, APEC promotes and facilitates trade, investment, economic and technical cooperation throughout the Asia-Pacific region.

Increasing numbers of economies around the world are strategizing to reduce their greenhouse gas (GHG) emissions to meet the carbon neutrality targets. A large part of decarbonization requires a shift away from fossil fuels to renewable resources of electricity generation. APEC is looking for opportunities to contribute to this movement through the promotion of offshore wind (OSW) energy. Grid connection is a key driver in determining the success of an OSW project, and as such, it is the focus of this study.

Since the beginning of the last decade, the installation of OSW capacity has been increasing globally, and in recent years, the global installed capacity has multiplied. European economies bordering the North Sea have dominated this growth, as water depth and wind resource are favourable for the deployment of the OSW technologies.

Following the success of the European economies, APEC aims to accelerate harnessing OSW resources in the region. This study provides a review and analysis of the experience in OSW development and grid connection in China; Korea; Japan; Chinese Taipei; the United States; and Viet Nam. A summary of key challenges and recommendations are provided for each member economy.

The research was organised and conducted in two stages. The first stage involved the collation of information from available online resources, government publications, research papers and in consultation with regional experts. The second stage involved the synthesis and assessment of this information into four concise report sections.

The first section focuses on the energy sector and its regulatory mechanisms. This includes an analysis of the status of each economy's electricity sector, as well as an assessment of general government regulations, policies and plans regarding climate change and renewable energy development. It also discusses specific objectives and targets for the OSW development and existing incentives and supporting mechanism.

The second section focuses on the development procedure and the stakeholder engagement for OSW projects. It includes a detailed outline of the relevant stakeholders and their responsibilities as well as the legal procedures and necessary permits and procedures required for the OSW development.

The third section describes the technical aspects of power grid connection of OSW plants to the transmission and distribution network. It starts with an outline of the member economy's current transmission network structure before detailing the steps required for the gird integration of the OSW projects. It then continues by explaining any planned upgrades, reinforcement, and expansion of the transmission networks, before providing one or two existing operational OSW farm case studies.

The final section is related to the business case for the OSW development. It explores the state of the electricity market, and reviews the provision for the ancillary services by the OSW plant.

It also describes the options for the offtake and the risk of possible energy curtailment in the related economies.

Most evaluated member economies of the current study are still largely dependent on fossil fuels for electricity generation (e.g., coal and natural gas). Of the limited contribution, the majority of non-fossil electricity generation in Korea and the US comes from nuclear power, while in other member economies, the largest portion of renewable energy is from hydropower. It is clear from this study that OSW contributes to only a small portion of electricity generation in these economies, with China having the greatest installed capacity.

Most member economies have announced the target of reaching carbon neutrality by 2050, and China set the goal being achieved by 2060. In addition to this, most have established a goal for renewables in the fuel mix by 2030. The most ambitious plans include China's goal for the installation of 1,200 gigawatts (GW) of wind and solar, and the US's 100% electricity generation pollution reduction goal.

Each member economy has its own targets for installed OSW capacity. China has the largest short-term target of 32GW by 2025, and is on track to exceed this by another 30GW. The remaining economies have targets of around 10GW by 2030, aside from the US which has a target of 30GW for 2030.

All member economies either currently have or have previously had a Feed-in Tariff (FiT) scheme for the promotion of renewable electricity, some of which have been specific to OSW. Some also provide the incentives such as tax exemptions, loan programs, Renewable Portfolio Standards (RPS) for the specific targets of renewable share capacity, including OSW, and green certificates.

Not all member economies have an existing competitive electricity market that allows trading of power. In economies like China, the market structure is still dominated by the government, but there are future trends of deregulating power prices and establishing wider range of electricity trading markets. Other economies, such as Viet Nam and Chinese Taipei, are transitioning to competitive electricity markets. While Korea and Japan have wholesale markets, the price in Korea is not freely set, and only part of Japan's electricity is marketed using this mechanism. The US has one of the most well-established wholesale competitive markets in the region for the trading of electricity.

The transmission network in most of the member economies is owned by government-owned companies or in the form of a monopoly. China; Korea; Chinese Taipei; and Viet Nam all have government-owned transmission companies and only a small share of power generation is owned by private business. China's grid network is managed by three different government-owned companies, and Japan's by 10 different government-owned companies, each with their own area of jurisdiction.

By the completion of the current study, not all member economies have a standard process for the OSW grid connection, although there are standards and rules for the connection of renewable power generators. In most cases it will be necessary to contact the transmission company in the area to process the connection of an OSW project. The application procedure, requirements and duration for the grid connection vary for each economy. Some require impact studies on the electrical system prior to the request, and in the most cases, it will be necessary to contact the transmission company in the area to check the specific technical details in relation to the network connection.

Apart for China, the OSW industry in most of the member economies is still at a relatively early stage of the development. Most have very less significant installed capacity, and most operational facilities are near-shore and/or demonstration projects.

Due to the early stage of the industry, the regulation and approval processes have not well-established for the specifics of the OSW technologies, and they can often be too long and complicated to incentivize the developers. The lack of capacity and track record in local supply chains also does not favour the large-scale development of the OSW technologies. As such, the development durations can be fairly long. Although most economies believe in the development of OSW as a key strategy for the decarbonization of the electricity market. These barriers can be discouraging for the possible foreign investors. Improvements in the regulatory framework or incentives, most probably at the government level, will be required to mobilise needed investment in this industry.

In general, the transmission networks in the member economies have also not fully prepared for the large-scale penetration of the OSW power from the coastal areas. In many economics, power networks are already largely congested from the recent rapid growth in solar PV capacity, and although the network upgrade plans are in place, the risk of curtailment is still significant. Grid capacity is generally seen as a bottleneck for the large penetration of OSW electricity. Strong coordination is required to ensure planned upgrades of the power network, considering the installed capacity expected for the growth in the OSW sector.

1 Development Status of the OSW in APEC Region

Europe has shown success in providing utility-scale renewable power with OSW, as well as proving market and cost compatibility to well-established forms of power generation technologies, such as combined-cycle gas turbines. The development of OSW in APEC member economies has been accelerating in the past 5 to 10 years following the success of OSW development in Europe. In the APEC region, there are a number of economies with good wind resources and potentials in developing large-scale offshore wind farms (OWFs). However, due to various reasons, especially the lack of sufficient policies, directives, and incentives from the governments on the promotion in development of OSW, the progress of OSW in these economies varies. In general, it is relatively slow with respect to achieving carbon neutrality goals.

Following the COP26 held in the UK in 2021, most of the member economies announced goals to achieve carbon neutrality by 2050 or by 2060. It is therefore expected that the development of OSW will become smoother and quicker, and the local governments will promote such development in various ways.

The following table briefly shows the development status, and the expected progress of the OSW in the six APEC member economies include in this study.

Table 1-1 Development status and expected progress in the six APEC member economies

Economies	Current installed OSW (MW)	Target OSW by 2030 (MW)	Overall OSW potential (MW)
China	26,380	>90,000	200,000~500,000 [1]
Korea	125	12,000	33,200~215,900 [2]
Japan	20	10,000	608,000 [3]
Chinese Taipei	237	15,000(by 2035)	30,000 [4]
Viet Nam	830	7,000	600,000 [5]
The US	40	30,000	2,000,000 [6]

The ambitious OSW development goals set by the six members would require stronger grid connection and integration supports. In the following sections, the current status and probable roadmap for OSW development, various aspects affecting the development of OSW, as well as the grid connection status and issues in each of these economies, will be discussed in more details.

2 China

2.1 Introduction

China is the world's second-largest economy, accounting for 16% of global GDP. It also contributes 28% of the world's electricity generation [7] [8]. Conscious of its global impact on carbon emissions, in 2021, the People's Republic of China committed to the goal of achieving carbon neutrality by 2060.

The economy's climate target is benefiting from its strong industry and the global rapid development of low-emission energy technologies. Despite an increase in coal power consumption following the global health crisis, China surpassed 1,000GW of installed renewable energy capacity in 2021. While the majority of this came from hydropower, 300GW was attributed to wind and solar energy alone, demonstrating the exponential capacity for growth within the economy.

OSW currently accounts for almost 27GW of China's installed capacity, with close to 17GW new installation in 2021 alone. According to the International Energy Agency's (IEA) Sustainable Development Scenario, China is expected to reach 175GW of installed OSW capacity by 2040, which would match the European Union's installed capacity. Achieving this scale of development would require an average investment of USD13 billion on average between 2019 and 2040, implying that about 8% of China's total power plant investment will be allocated to OSW [7].

2.2 Overview of Offshore Wind Resource

Figure 2-1 depicts the heat maps showing the wind speed and water depth in the offshore portion of China. According to the map, wind speeds at a 100m height hub range from 1.6m/s to 11.5m/s [9], with the highest OSW resources concentrated south along the Chinese Taipei Strait. In general, the water depth of 0 to -170m below mean sea level is continuously found along the coastlines from the northern to southern portion of China [10]. Furthermore, the very deep waters below -1,000m, can be found further towards the southeast portion of the Hainan Island.

Water depths of up to -70m are generally considered suitable for bottom-fixed foundations of the OSW project, while floating foundations are more suitable for the water depths between -70m to -1,000m. Sea depths beyond -1,000m are considered ultra-deep and are less economically favourable and more complex, thus making development riskier for floating foundation. Based on the wind resource, both fixed and floating foundation OWFs can be deployed desirably along the Chinese Taipei Strait within China's Exclusive Economic Zone (EEZ) (see Figure 2-2).

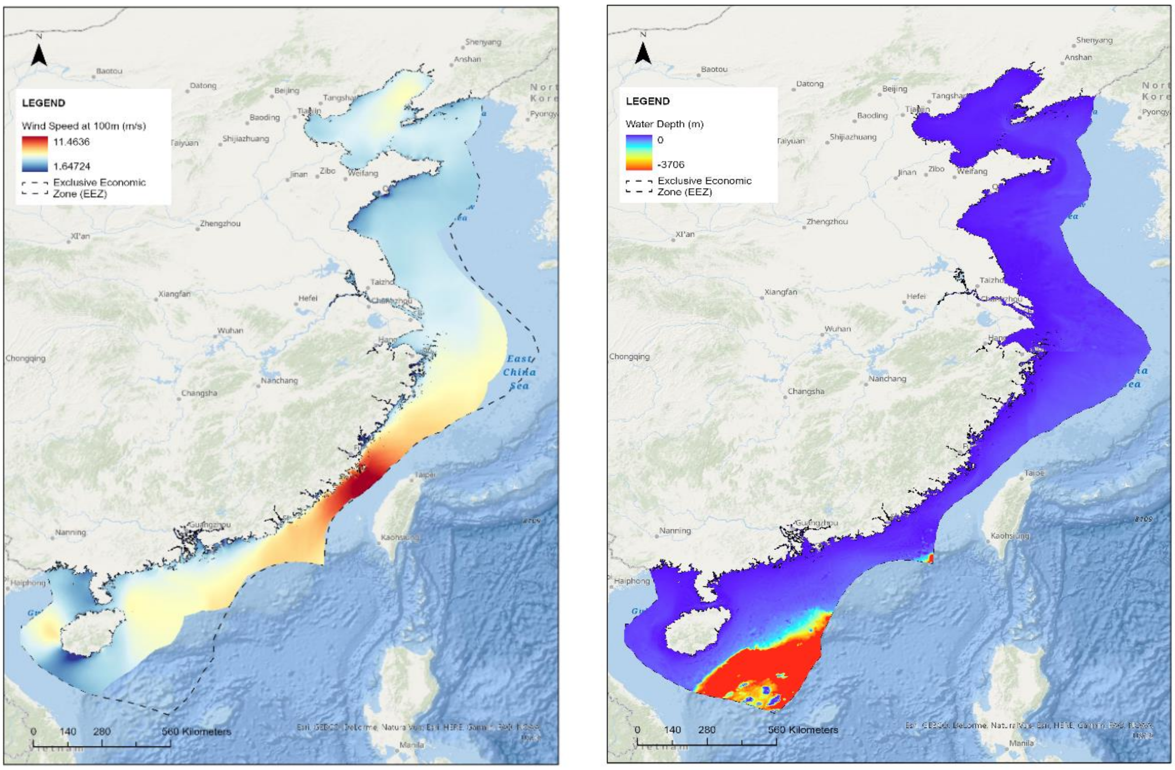


Figure 2-1 Wind speed (left) and water depth (right) of the offshore areas in China

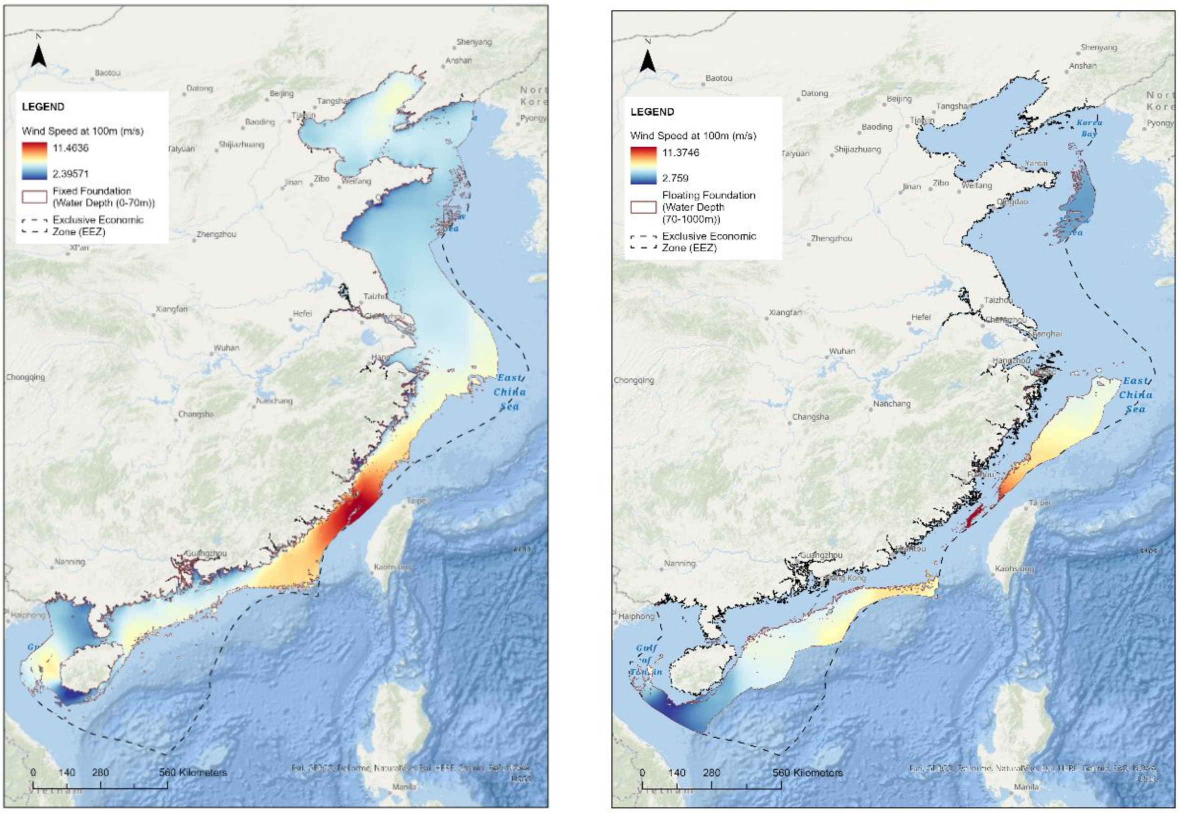


Figure 2-2 Wind speeds for fixed foundations (water depth 0 to -70m) (left) and for floating foundations (water depth -70 to -1000m) (right) in China

2.3 Energy Sector and Regulatory Mechanism

2.3.1 Structure of Electricity Supply

In 2021, China's electrical installed capacity was dominated by coal, as shown in Figure 2-3. The largest share of installed renewable electricity was from onshore wind, followed closely by large-scale hydraulic power [11]. With new sustainable development commitments, China plans to decrease its reliance on coal and increase its installation of wind and solar infrastructure.

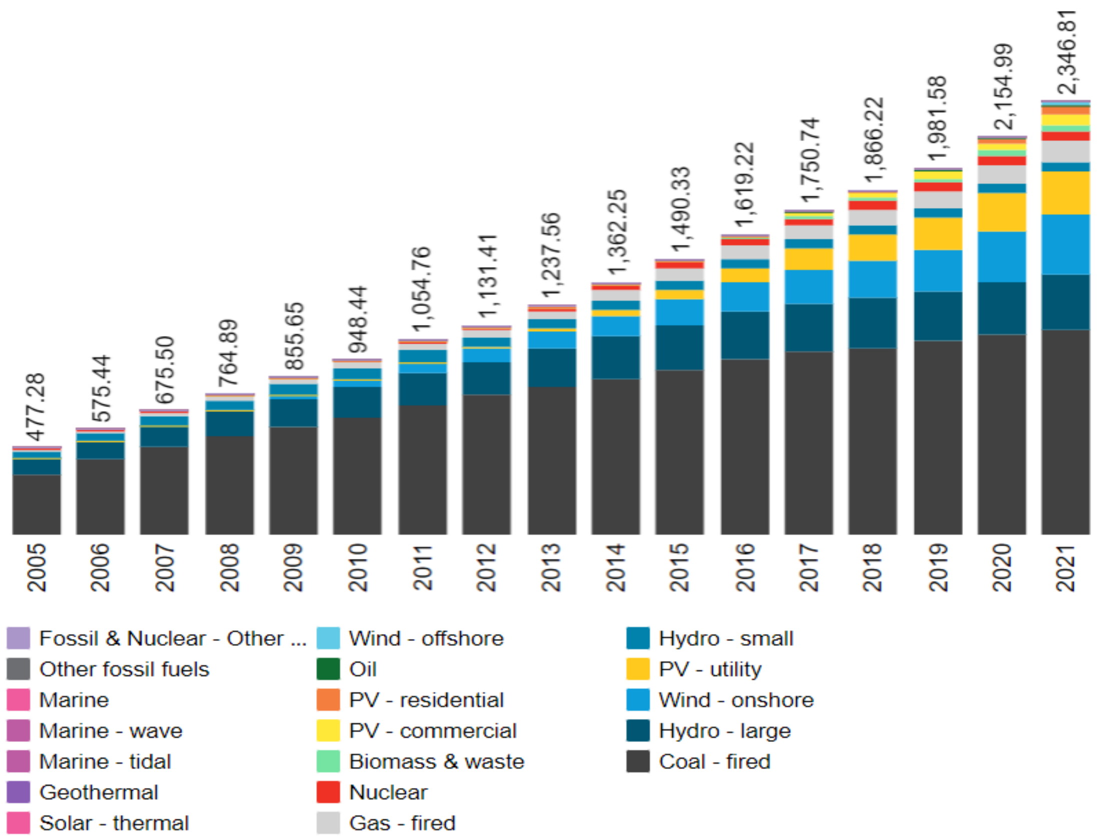


Figure 2-3 China's installed capacity (GW) by source 2005-2021

In terms of electricity generation in China, coal plants dominate, providing over 60% of the economy's electricity consumption. Onshore wind power and hydraulic power are the top renewable resources of electricity generation, accounting for more than 20% combined [11]. Figure 2-4 shows the evolution of electricity generation in the economy.

Although there are many electricity generation companies in China, the market is dominated by government-owned enterprises (SOEs) that own over half of China's generation capacity. Currently the five largest government-owned generation companies include:

- China Energy Investment Corporation
- China Huaneng Group
- China Huadian Group
- China Datang Corporation
- State Power Investment Corporation

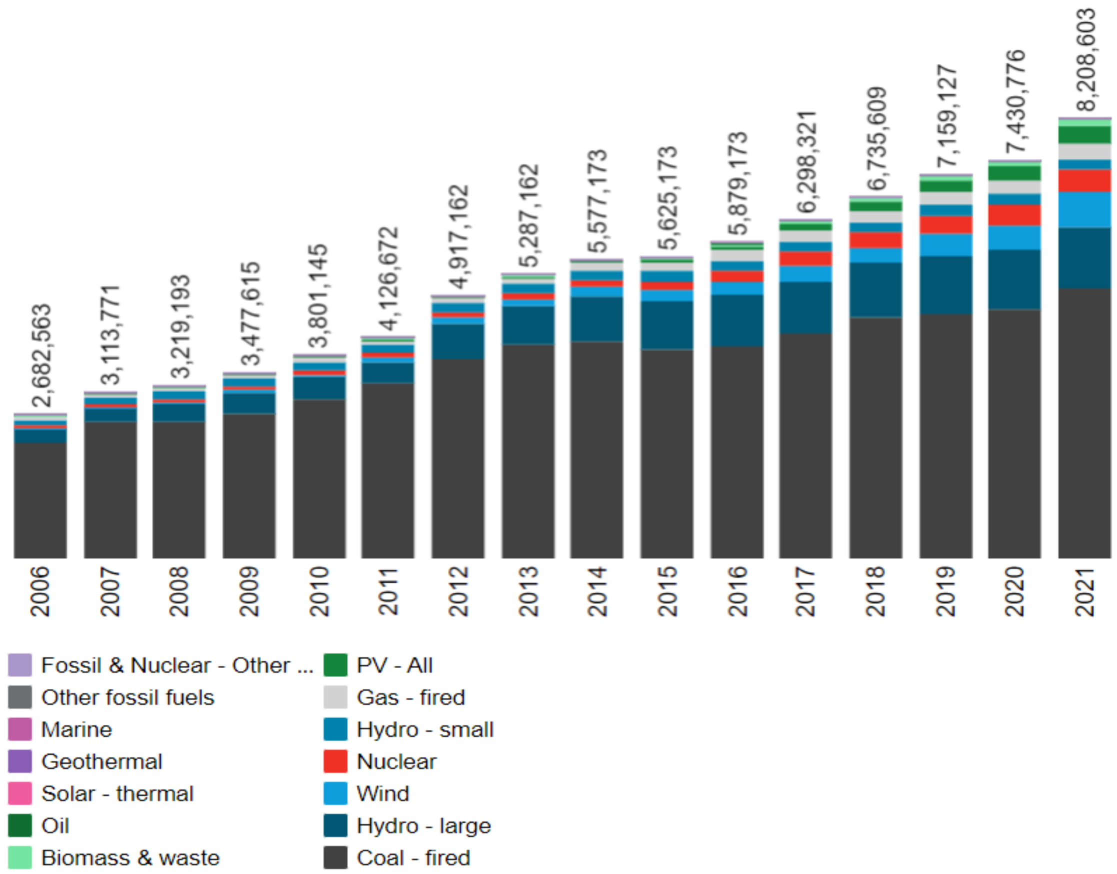


Figure 2-4 Electricity generation (GWh) by source, China 2006-2021

In the retail sector, by the end of 2017, there were over 7,000 power retail companies operating throughout China [12]. According to the latest release in 2021, the China Top 500 Energy Company List includes 137 power corporations and 93 new and renewable energy companies [13]. Although the provincial governments, local governments, private companies and foreign investors hold a share in the retail and generation sectors, the government levelled SOEs still dominate. It is noted that most wind power generation companies are owned by the government in China [14].

2.3.2 Renewable Energy and Climate Change Policies and Targets

Ahead of the COP26 on 28 October, 2021, the Chinese government officially submitted its updated Nationally Determined Contribution (NDC) [15]. The updated NDC contains the following five overarching targets:

1) Peaking carbon dioxide emissions before 2030 and achieving carbon neutrality before 2060;
2) Lower carbon intensity by over 65% in 2030 from the 2005 levels;
3) Reduce the share of non-fossil fuels in primary energy consumption to around 25% by 2030;
4) Increase forest stock volume by around 6 billion cubic meters in 2030 from the 2005 level;
5) Increase installed capacity of wind and solar power generation to over 1,200GW by 2030.

China has implemented an active domestic strategy to address climate change. In doing so, the government has established a leading group on carbon peak and carbon neutrality headed by Vice Premier of the State Council. Part of its plans are to speed up the electrification of end-use sectors by improving electrical infrastructure and promoting smart electricity distribution technologies. To satisfy the increase in demand while driving down the carbon intensity of the electricity sector, the government will accelerate the development of a new and modern energy system and vigorously develop renewables, including wind solar, biomass, marine, and nuclear energy technologies.

To reach the 1,200GW goal of renewable power generation capacity by 2030, the government has set a target of an additional 300GW of installed solar and wind power by 2025. A study conducted by BloombergNEF(BNEF) forecasts the annual installed capacity needed to reach this goal, as shown in Figure 2-5. In support of this, the *14th Five-Year Plan* (FYP) includes the construction of eight major clean energy bases, highlighting new potential OSW sites in Guangdong, Fujin, Zhejiang, Jiangshu and Shandong provinces [16].

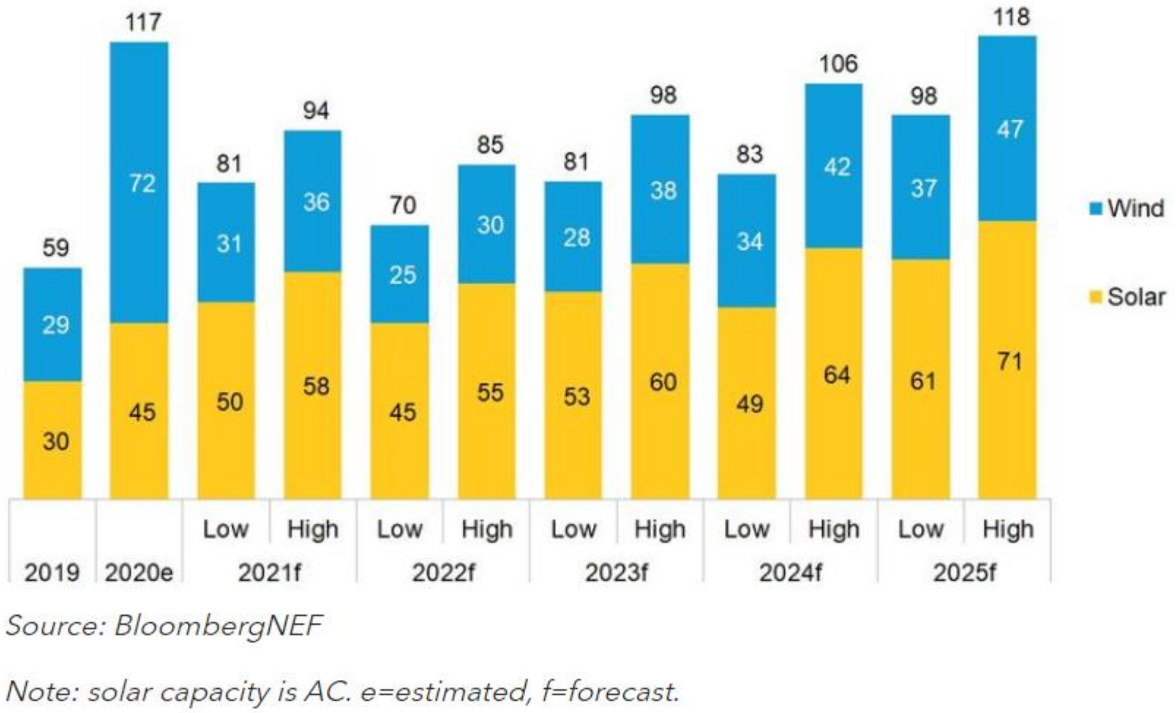


Figure 2-5 China wind and solar annual installation forecast (GW) [17]

2.3.3 Offshore Wind Power Development Policies and Targets

The offshore wind resources are rich in China's coastal provinces, particularly in Guangdong, Fujian, Zhejiang and Shandong province, as seen in Figure 2-1. These are more economically developed provinces, with continuous growth in energy consumption. The average OSW speed along the east coast of China ranges from 6.5-11.0m/s, which is relatively lower in comparison to the North Sea in Europe (9.0-12.0m/s). With lower capacity factor, this suggests for China needs to install more OSW capacity to achieve a similar level of power production as the OSW fleet in Europe [18] [19].

According to China Renewable Energy Engineering Institute (CREEI), as of December 2021, China had an installed OSW capacity of 26.93GW of in China [20]. With 16.9GW installed in 2021 alone, China saw the largest growth in OSW across the globe. Currently there is a goal to install 32GW by 2025, although predictions from the head of China Research indicate this could reach 63GW due to recent rapid developments [20] [21]. Jiangsu and Guangdong provinces are expected to account for over 60% of these deployments [20].

The designated target installed capacity for the five leading OSW development provinces by 2030 is provided in Table 2-1. Although less ambitious, other coastal provinces, such as Liaoning, Hebei, Guangxi, Hainan, and Shanghai, have also pledged the OSW development targets [22].

Table 2-1 Planned installed OSW capacity by 2030 by provinces

Province	Planned installed OSW capacity by 2030 (GW)
Guangdong	30
Jiangsu	15
Zhejiang	6.5
Fujian	5
Shandong	3

Moreover, the OSW development in Mainland China is expected to continue to grow rapidly and is also likely to see more floating platforms. The latest release from the National Development and Reform Commission (NDRC) and the National Energy Administration (NEA) in May 2022, encouraged the development of far-shore OSW farms to help reduce the coastal impact and land use [23] [24].

2.3.4 Renewable Energy and Offshore Wind Regulatory Support Mechanisms

The IEA predicts that China's OSW is estimated to reach cost parity with coal-fired generation in terms of the Levelized Cost of Electricity (LCOE) in the mid-2020s [7]. This drop is attributed to increased innovation, technological development and additional financial policy and support [11]. One of these incentives was the low-interest loan established in 2021. The loan from the central bank of China (PBOC) is estimated to be over CNY1 trillion and is expected to support the development of renewable projects across the economy. In parallel with the low-interest loan was the announcement of a 1% drop in interest rates [20].

In the late 2000s China introduced the renewable energy FiTs scheme, which successfully promoted the rapid growth of the renewable energy sector. However, despite the large growth, challenges related to the government subsidy deficits and grid integration caused the government to phase out the FiTs scheme in 2020. The government is now transitioning to other support mechanisms, including competitive auctioning, voluntary green certificate trading and the Renewable Portfolio Standards (RPS) [25]. Additionally, some local governments have established subsidies for the OSW projects in their own province. For example, the Guangdong provincial government has set to provide CNY1,500 (USD234) for each kilowatt of OSW capacity built in 2022, CNY1,000/kw for those built in 2023, and CNY500/kw for those constructed in 2024 [26].

The voluntary green certificate scheme implemented in 2017 was originally designed to complement the renewable energy FiTs. With the phase-out of the FiTs scheme, the green certificate scheme now operates as a complementary policy to the mandatory RPS scheme. One green certificate accredits 1MWh of non-hydro renewable electricity and can be traded to provide an additional revenue for renewable generators. As the green certificates scheme is increasingly identified as a channel to meet the RPS obligations, the trading volume has been raised.

The RPS was introduced in 2019 and sets annual targets on the shares of total renewables and non-hydro renewables in electricity consumption by province. This policy incentivizes both power distribution and retail companies, as well as large consumers to target the sale and purchase of renewably sourced electricity to meet with their RPS quotas [25].

Established in 2006, the Renewable Energy Law has served as the foundation for large-scale renewable development in China. It covers many fundamental elements, such as capacity targets, planning, incentives, pricing mechanisms and cost-sharing method for renewable energy development, which has guided the formulation of renewable policy in a series of five-year plans (FYPs) [27]. The 14th FYP on Renewable Energy Development was introduced in 2021, and will continue to be the focus until 2025, with a specific target for the share of non-fossil electricity generation to reach 39% by 2025. Table 2-2 summarizes the tax incentive policies relevant to OSW development [11].

Table 2-2 Tax incentives for OSW development in China [11]

Policy	Content	Start date
China Renewable Energy Technology Enterprise Income Tax Reduction	Renewable energy equipment manufacturers and companies qualified as the "high and new technology enterprises" are entitled to a preferential Enterprise Income Tax (EIT) rate of 15% for three years, while other corporate income tax rate is 25%. Businesses that maintain their "high and new technology enterprise" status qualification can continue to enjoy the 15% EIT.	01 Jan 2008
China Income Tax Reduction for Renewable Energy Developers	Renewable energy project developers are qualified for the enterprise income tax exemption for the first three years of the project operation, followed by another three years with a preferential tax rate of 12.5%, compared to the normal tax rate of 25%.	01 Jan 2008
China VAT Reduction on Wind Power	A reduced value-added tax (VAT) rate of 8.5% applies to the project developers in China for power generation from wind energy.	01 Jul 2008
China VAT Exemption for Renewable Power Generation	A halved VAT rate of 8.5% applies to the project developers in China for electricity generated from wind or solar.	01 Feb 2013
China Strategic Emerging Industries Key Product Catalogue	Products and services that are classified as Strategic Emerging Industries (OSW included) can get the funding support from the government or enjoy the preferential tax benefits.	22 Feb 2013

Another significant support mechanism was the introduction of tax incentives for renewable energy generation in China.

2.4 Offshore Wind Development Procedure and Stakeholder Engagement

2.4.1 Stakeholders and Their Responsibilities

Established in 2013 the NEA serves under the NDRC as the regulator of the power industry in China. The NEA is responsible for [28]:

- Formulating policies and standards related to energy, such as coal, oil, natural gas, electricity, new and renewable energy;
- Managing the administration of nuclear power;
- Supporting energy saving and utilization of resources;
- Supervising and regulating the operation of the electric power market;
- Overseeing electricity safety, reliability and emergency management including formulation of regulations;
- Organizing international corporation by negotiating and signing agreements with foreign energy administration and international energy organizations.

Table 2-3 summaries the different ministries and authorities relating to the OSW development in China.

2.4.2 Offshore Wind Approval Procedures

To streamline the development of OSW, the State Oceanic Administration and the NEA jointly released the guideline – *Measures for Offshore Wind Establishment* in 2017. The guideline highlights the rules for the installation of new OWFs. Meanwhile, it specifies distance from the shore, water depth and sea area requirements under different conditions and in different locations along the Chinese coast. The guideline also clarifies that no OSW is permitted to be built in protected areas and fragile biological zones [29].

The approval procedure for an OSW project in China can generally be arranged into four stages [30]. Table 2-4 summarizes these stages, and Figure 2-6 shows a flow chart of the entire approval process [31].

Table 2-3 Summary of the authorities related to OSW development in China

Ministry and authority	Functions and responsibilities
National Development and Reform Commission (NDRC)	Setting the economy's development direction and the strategic energy plan. Facilitating sustainable development and coordinating environmental protection and restoration. Formulating policy for energy, renewable energy, coal, electricity development. Initiating, approving and regulating large energy infrastructure projects.
National Energy Administration (NEA)	Serving under the NDRC. Setting standards and overseeing the operation of the electricity market. Organising and approving large energy projects and investment. Regulating the economy's energy industry and projects. Facilitating international energy cooperation.
State Administration for Market Regulation	Registering electricity companies.
Ministry of Natural Resources	Approving land use rights and sea use rights and granting relevant certificates. Regulating and monitoring sea use and shore area development.
Ministry of Ecology and Environment (MEE)	Overseeing the execution of CO_2 emission reduction targets. Ensuring the compliance with the environmental regulations related to electricity generation plants. Formulating the strategic plans and policies on climate change and emission reduction in accordance with the United Nations Framework Convention on Climate Change (UNFCCC).
Ministry of Industry and Information Technology (MIIT)	Formulating plans and mentoring emission reduction and energy saving on energy intensive industry such as iron and steel, cement, aluminium, and chemicals.
Ministry of Finance	Approving and distributing the subsidies to renewable energy plant.
State Oceanic Administration	Regulating the use of sea area.

Table 2-4 Stages for OSW development in China [30]

Stage	Description	Referencing technical standard
Stage 1: Planning	Preparing the required specifications for early-stage OSW development.	• Preparation Rules of Offshore Wind Power Farm Projects Planning Report (Trial) (FD 005-2008) • Code for Preparation of Safety Pre-assessment Report of Wind Power Farm Projects (NB/T 31028-2012) • Code for Preparation of Offshore Wind Power Farm Projects Pre-feasibility Study Report (NB/T 31031-2012) • Code for Preparation of Offshore Wind Power Farm Projects Feasibility Study Report (NB/T 31032-2012) • Code for Wind Energy Resource Measurement and Marine Hydrological Observation of Offshore Wind Farm Projects (NB/T 31029-2012) • Technical Specification for Construction Organization Plan of Offshore Wind Power Farm Projects (NB/T 31033-2012)
Stage 2: Design	Following design codes, including Load and Resistance Factor Design(LRFD)/Working Stress Design(WSD) structural design, structural load, aseismatic design, structural steel, pile foundation design, anti-corrosion technology and other aspects as issued by the relevant Design Institute.	• Wind Turbine Systems Design Requirements (GB/T 18451.1-2012) • Design Code of 110kV-220kV Offshore Boosting Substation in Wind Power Farm (NB/T 31115-2017) • Guide for Selection and Laying of AC Submarine Cables for Offshore Wind Power Projects (NB/T 31117-2017) • Technical Standard for Anti-corrosion of Offshore Wind Farm Steel Structures (NB/T 31006-2011) • Standard for Design of Offshore Wind Power Farm (GBT 51308-2019)
Stage 3: Offshore construction	Following the requirements for construction preparation, construction transportation, foundation engineering construction, installation of wind power equipment, laying of submarine cables, engineering observation and detection, the commissioning and trial run of OSW farms, construction management, etc.	• Code for Construction of Offshore Wind Power Project (GB/T 50571-2010) • Technical Code for Construction Safety of Offshore Wind Power Farm Projects (NB/T 10393-2020)
Stage 4: Operation and Maintenance	The operation and maintenance of wind turbine are managed by the wind turbine manufacturer. The owning enterprise will later take charge of the maintenance and operation, following the manufacturer's instructions.	• Offshore Wind Turbines-Requirements for Operation and Maintenance (GB/T 37424-2019)

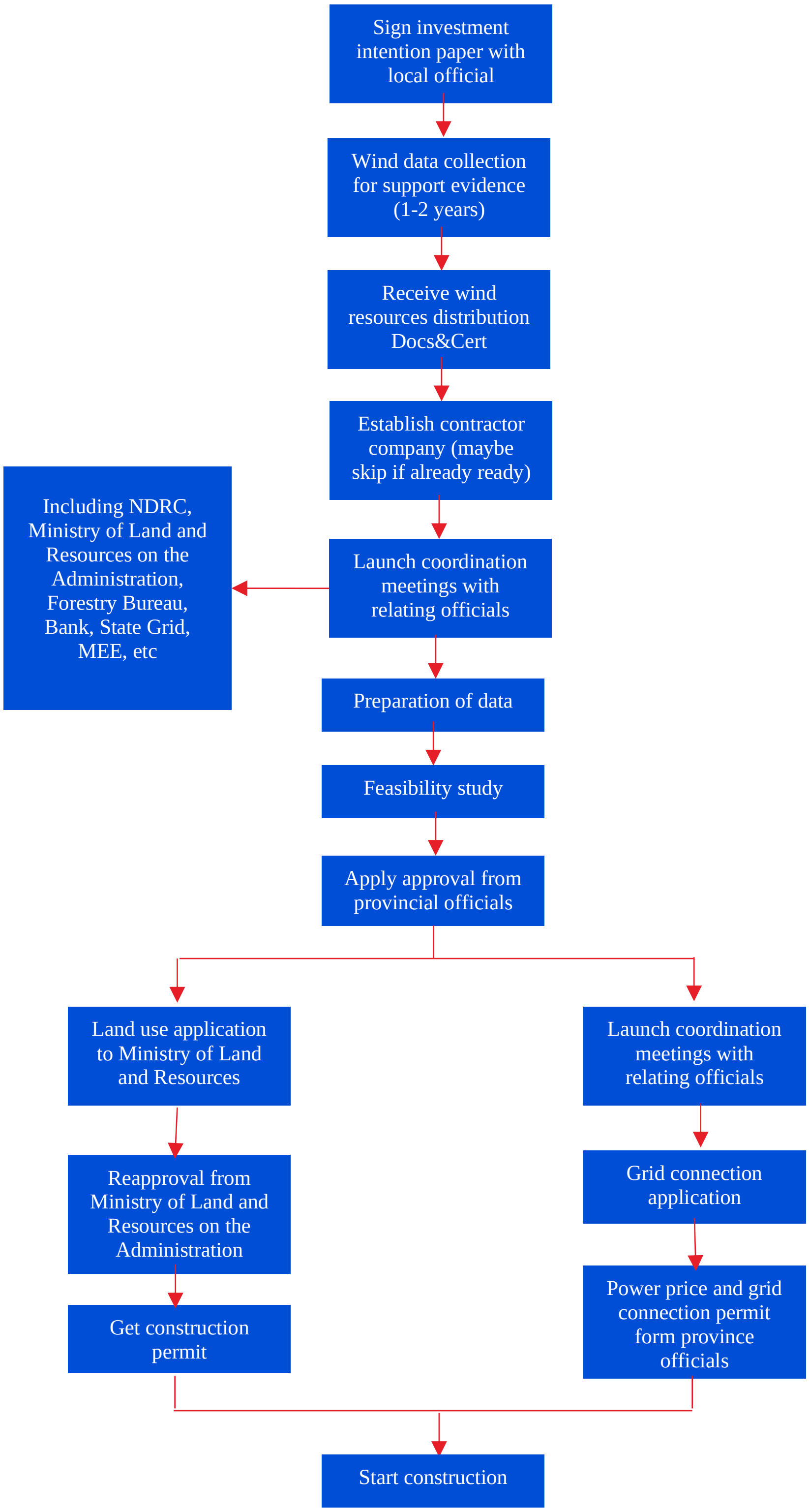


Figure 2-6 The OSW planning mechanism in China [31]

2.5 Offshore Wind Grid Connection

2.5.1 Electricity Utility Structure and Grid Connection Procedure

The domestic electricity network is run by three government-owned grid corporations: the State Grid Corporation of China (SGCC), the China Southern Power Grid Corporation (CSPGC) and the Inner Mongolia Electric Power Corporation (IMEPC). SGCC supplies power to over 1.1 billion people in 26 provinces, autonomous regions, and municipalities, covering 88% of China’s territory and making SGCC the largest power corporations in the world. CSPGC constructs and operates the grid in China’s five southern provinces, namely Guangdong, Guangxi, Yunnan, Guizhou, and Hainan, while IMEPC supplies over 720,000km^2 in China’s Inner Mongolia Autonomous Region. The map in Figure 2-7 highlights the footprint of the three companies.

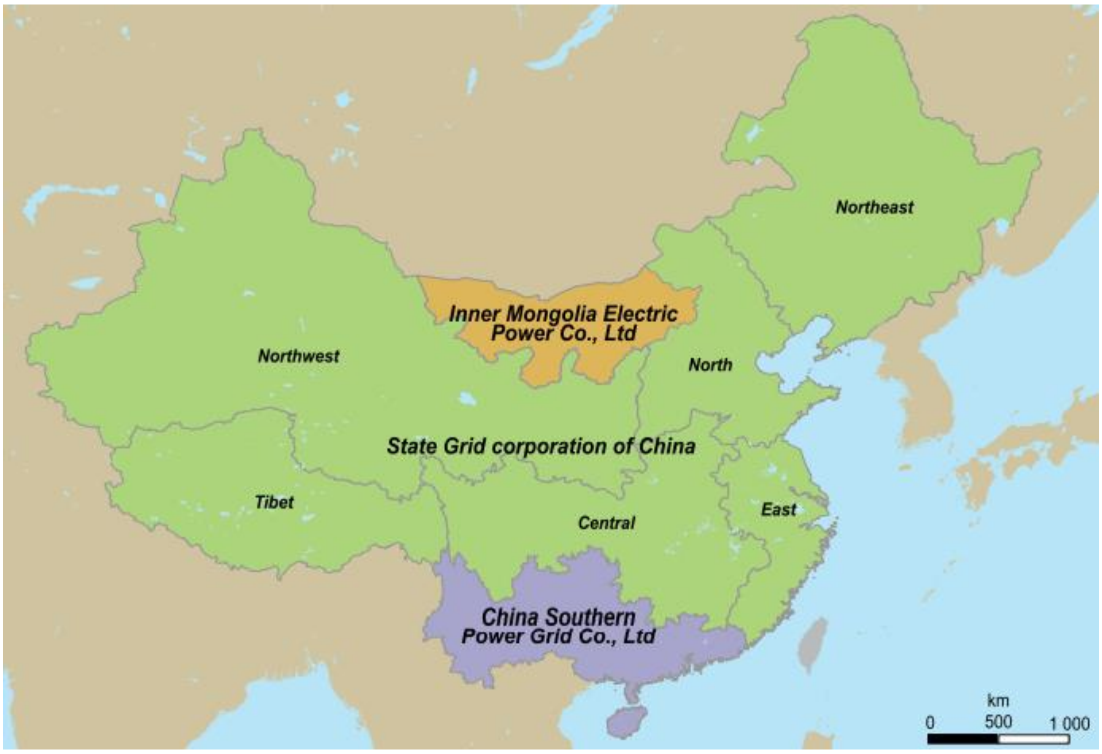


Figure 2-7 China grid service providers [12]

Most operational OSWs in China have alternative current (AC) transmission to the grid with voltages of either 110kV or 220kV. Currently, there are serval planned OSWs implementing flexible direct current (DC) transmission. The process for connecting an OSW farm to the grid is highly regulated by the NEA. Projects must be included in the NEA’s official development plan to apply for grid integration or construction. Projects are included in the plan through a competitive allocation process via local NEAs pursuant to the *Administrative Guidance for Competitive Allocation of Wind Power Projects (Trial)* [29].

The technical standards and requirements for connecting OSWs to the grid are published and regulated by the NEA. The earliest technical rule (GB/Z 19963-2005) for connecting wind farms to the grid was released in December 2005 and started to be implemented in February 2006. It was later replaced by technical standard (GB/T 19963-2011) for wind farm grid connection, which was implemented in June 2012. This standard is planning to be replaced by

GB/T 19963.1-2021 for onshore wind, and 20180777-T-624 for OSW. While the onshore wind standard was completed and was released in August 2021, the OSW standard is yet to be finalized. It is likely to assume that until the implementation of the OSW standard, procedures for grid connection should follow a similar approach to the latest GB/T 19963.1-2021 onshore wind guide. Table 2-5 provides a summary of the relevant documents.

Table 2-5 Relevant grid connection standards in OSW

Name	Standard code
Technical rule for connecting wind farm to power system	GB/T 19963-2011
Technical rule for connecting wind farm to power system, part two: offshore wind power	20180777-T-624
The grid operation code	DL/T 1040
Technical specification for voltage source converters of DC transmission systems integrating offshore wind farms	NB/T 10646-2021
Technical specification for DC circuit breaker of DC transmission systems integrating offshore wind farms	NB/T 10647-2021
Technical specification for control and protection equipment of DC transmission systems integrating offshore wind farms	NB/T 10648-2021

All OSW farms must satisfy the basic requirement of DL/T 1040 with frequency adjustment, peak shifting and backup capability and function. Table 2-6 presents the active power maximum value change under the normal operation condition.

Table 2-6 Technical requirement of maximum active power value change

Installed capacity (MW)	10 min active power maximum value change (MW)	1 min active power maximum value change (MW)
<30	10	3
30-150	Installed capacity / 3	Installed capacity / 3
>150	50	15

In case of an emergency, the wind farm should be able to automatically adjust its active power output or even shut down power output upon instruction from the grid operator. The OSW farm should also be equipped with power output prediction capability that can predict power output for periods of 0 – 72h and 15-min to 4-hour intervals. The wind farm should report its 15-min to 4-hour power output prediction curve to the grid operator every 15 minutes, as well as the power output prediction curve for 0 – 24h every day.

Regarding the reactive power requirement, the wind farm should be able to adjust its power with a power factor range of 0.95 leading to 0.95 lagging. The OSW must be equipped with reactive power frequency and voltage adjusting capability. The voltage should be maintained at 97% to 107% of the nominal voltage in the grid connection point. The requirements for action for the wind farm at different frequency ranges are presented in Table 2-7.

Testing, including active and reactive power control ability, power quality, low voltage ride through, frequency and voltage adaptability, is required for a wind farm with more than 40MW installed capacity. The wind farm should submit the testing proposal and the wind farm model as well as the system specifications and characteristic to the grid regulator. The testing report should be submitted within 6 months after the testing.

Table 2-7 Technical action in the different frequency range

Frequency range	Requirement
<48Hz	According to the lowest frequency allowed in the wind farm for operation
48-49.5Hz	Capable to operate for at least 30 minutes when lower than 49.5Hz
49.5 – 50.2Hz	Normal operation
> 50.2Hz	Capable to operate for at least 5 minutes and adjust the frequency according to the grid operator. The wind farm in shut-down status is not allowed to connect to the grid

2.5.2 Transmission Network and Expansion Plan

Existing and future Ultra-High Voltage (UHV) transmission lines owned by SGCC are shown in Figure 2-8. UHV AC refers to transmission of 1,000kV and above, while UHV DC refers to 800kV and above. The total 31 UHV projects, currently at different stages of development, cover 41,000km with a capacity over 450 gigavolt-ampere (GVA) [29].

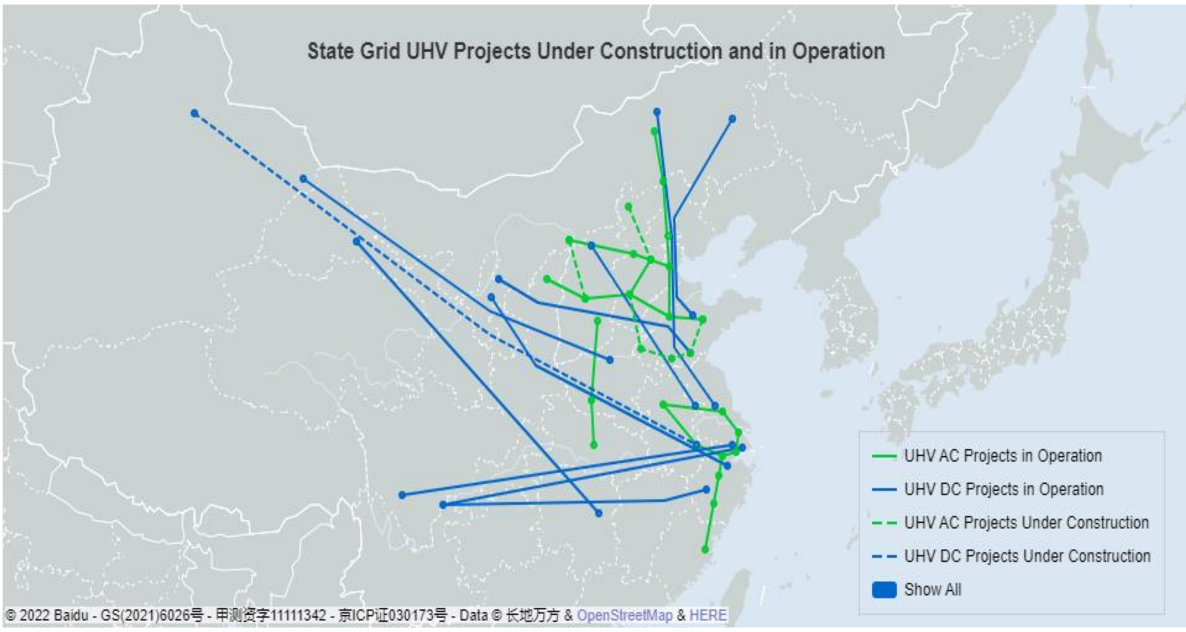


Figure 2-8 SGCC UHV projects under construction and in operation [24]

The other major grid owner, CSPGC manages a total of nineteen 500kV-networks (consisting of 8 AC and 11 DC), in the provinces of Guangdong, Guangxi, Yunnan, Guizhou and Hainan [32]. CSPGC operates 110kV high power cables running over 256,000km. To accommodate growing demand and a push for non-fossil generation, the company is looking to invest USD98 billion in the period 2020-2025 for grid expansion, digitization, and modern electrical system development [33].

According to the August 2022 statement of the NEA [34], the completed investment projects on the power grid are costing CNY23.64 billion (USD3.5 billion) from January to July 2022, and are expected to reach CNY100 billion by the end of the year. Four AC and four DC HV connection projects in Bauhetan-Jiangsu were completed in 2022, while the Fujin-Xiamen and Zhumadian-Wuhan UHV AC projects had started construction. The planned 1 AC and 5 DC HV projects for the connection of Xiaxi-Anhui, Xiaxi-Henan, Mengxi-Jinjinji, Gansu-Zhejiang and Tibet-Guangdong, valued at CNY11 billion, are in the pre-construction phase.

The expansion and investment plan of the grids has been focused on improving voltage regulation capability and better compatibility with renewable electricity generation. As mentioned by SGCC Chair Xin Baoan, they will invest USD350 billion between 2021 and 2025 to upgrade China's power grid and build new power systems to accommodate future OSW and other renewable development [35]. More than 20 provinces with nearly 300 grid expansion projects are recorded in 2021 [36]. Although these expansion plans do not specify detailed upgrades for OSW grid connection, the upgraded grid will be more flexible and can hence facilitate renewable development, such as OSW.

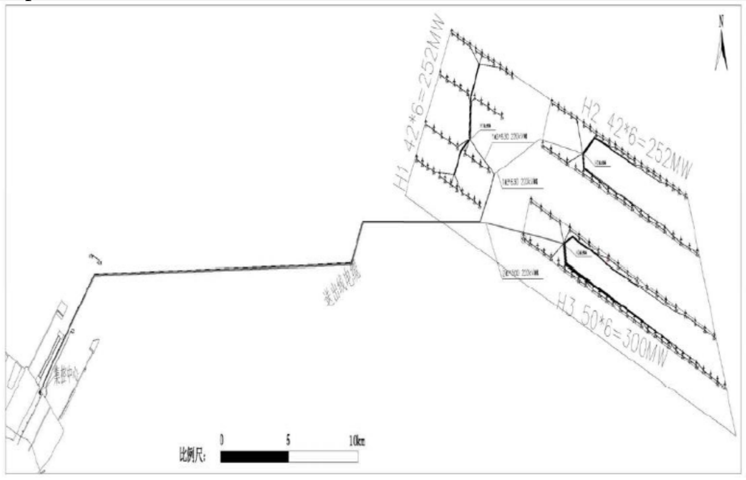
Moreover, the *14th FYP* highlighted the development of smart grids and smart micro-grids to accommodate more clean and renewable power and facilitate the development of renewables in China [37]. For example, Beijing is developing new generation of data and information technology and grid system integration for power distribution automation and intelligent grid self-diagnosis.

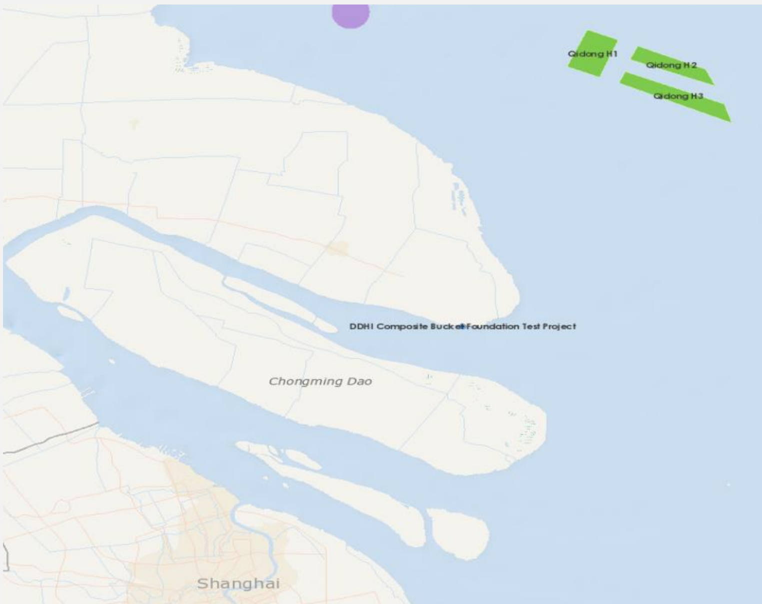
2.5.3 Offshore Wind Case Study

The fully operational OWFs in China include the largest ones when the report was prepared, namely, Jiangsu Oidong and Shanghai Donghai Bridge 1. Table 2-8 and Table 2-9 provide a summary for each project respectively [38].

Table 2-8 Jiangsu Qidong OSW Farm case study [39]

Jiangsu Qidong Offshore Wind Farm	
Location	35km from the city of Qidong. Around 40km from shore
Water Depth	Water Depth of 35-55 meters
Wind Turbines	134 turbines of 7 different types, developed by 4 different manufacturers
Foundation	Fixed, monopile
Capacity	802MW rolled out in 3 projects: H1, H2 and H3 Each of the wind farms has an independently operated 220kV offshore booster station but share 1 onshore centralized control center
Shareholder	• Developed and owned by: Jiangsu Huawei Wind Power and Qidong Hua Er Rui Wind Power Technology • Contractor: Huadong Engineering Corporation Limited • Render EPC: East China Survey and Design Institute • Turbine supplier: Shanghai Electric Wind Power Equipment
Status	• Construction commenced: 2020 • Commercial operation: December 2021 • Full capacity connection to grid: December 2021
Site condition	• Wind speed at 100m: 7.94m/s • Average wind power density: 497W/m^2
Choice of Technology	• 3 independent offshore substations with 1 centralized onshore power control and distribution center • Wind Turbine Generator (WTG) selection: 　o H1: 6MW x 42 WTG

<table>
<tr><th colspan="2">Jiangsu Qidong Offshore Wind Farm</th></tr>
<tr><td></td><td>
○ H2: 6MW x 42 WTG
○ H3: 6MW x 50 WTG
</td></tr>
<tr><td>Grid connection</td><td>
• Inter-array voltage: 35kV
• Export voltage: 220kV
WTGs are interconnected through 35kV XLPE-3×95 cables. The 220kV submarine export cable used is XLPE-3×500.


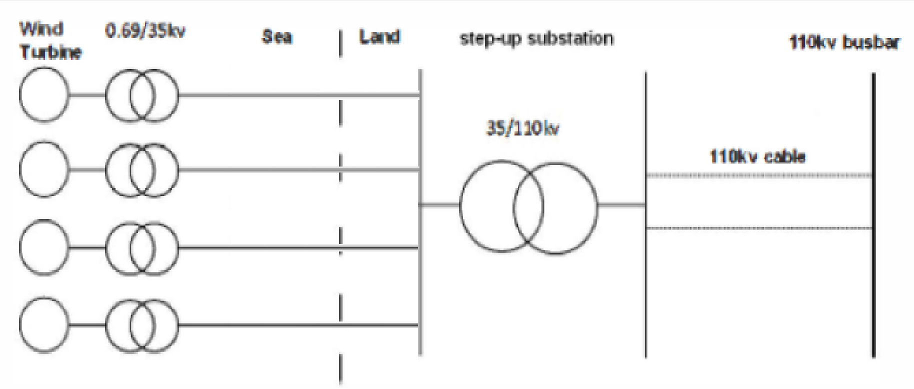
</td></tr>
<tr><td></td><td>


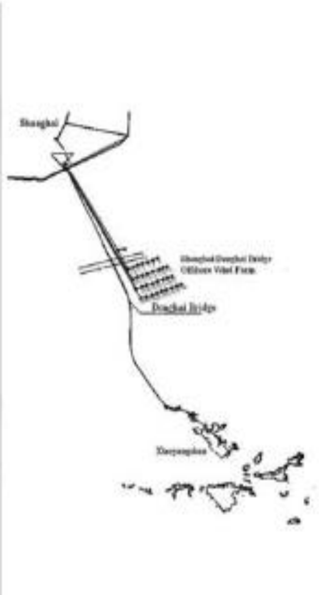
</td></tr>
</table>

Table 2-9 Shanghai Donghai Bridge 1 OSW Farm case study [40] [39]

Shanghai Donghai Bridge 1 Offshore Wind Farm	
Location	5.9 – 13km from shore of Shanghai
Water Depth	Water Depth of 10 meters
Wind Turbines	34 turbines made by Chinese manufacturer
Foundation	Fixed, High-Rise Pile Cap (HRPC)
Capacity	102MW

<table>
<tr><th colspan="2">Shanghai Donghai Bridge 1 Offshore Wind Farm</th></tr>
<tr><td>Shareholder</td><td>• Developed and operated by: Shanghai Dong Hai Wind Power Generation Company
• Owned by: Shanghai Eclectic Group
• Operator: Huadong Engineering Corporation Limited
• Turbine supplier: Sinovel</td></tr>
<tr><td>Status</td><td>• Construction commenced: 2008
• Commercial operation: December 2010
• Full capacity connection to grid: December 2010</td></tr>
<tr><td>Site condition</td><td>• Wind speed at 100m: 9.68m/s
• Average wind power density: 662W/m^2</td></tr>
<tr><td>Choice of technology</td><td>• 3-MW x 34 WTGs by Sinovel
• 1 onshore substation</td></tr>
<tr><td>Grid connection</td><td>• Inter-array voltage: 35kV
• Export voltage to onshore substation: 35kV
• Export voltage to grid: 110kV
The WTGs are connected in 4 strings of 8 or 9 WTGs each at 35kV, which then connect to the onshore substation. A 110kV cable line then connects the onshore substation to the transmission substation.




</td></tr>
</table>

Shanghai Donghai Bridge 1 Offshore Wind Farm

2.6 Offshore Wind Offtake Business Case

2.6.1 Participation in the Electricity Market

Prior to the reform in the power sector, the government controlled and owned all of the electricity generation and distribution systems, including electricity production, transmission, and distribution to the consumers. The only electricity retailers were the grid companies operated in each region. Following the reform in 2015, most power companies were still owned by the government, although the wholesale power price was deregulated, and consumers were able to sign contracts with chosen producers and retailers at an agreed price.

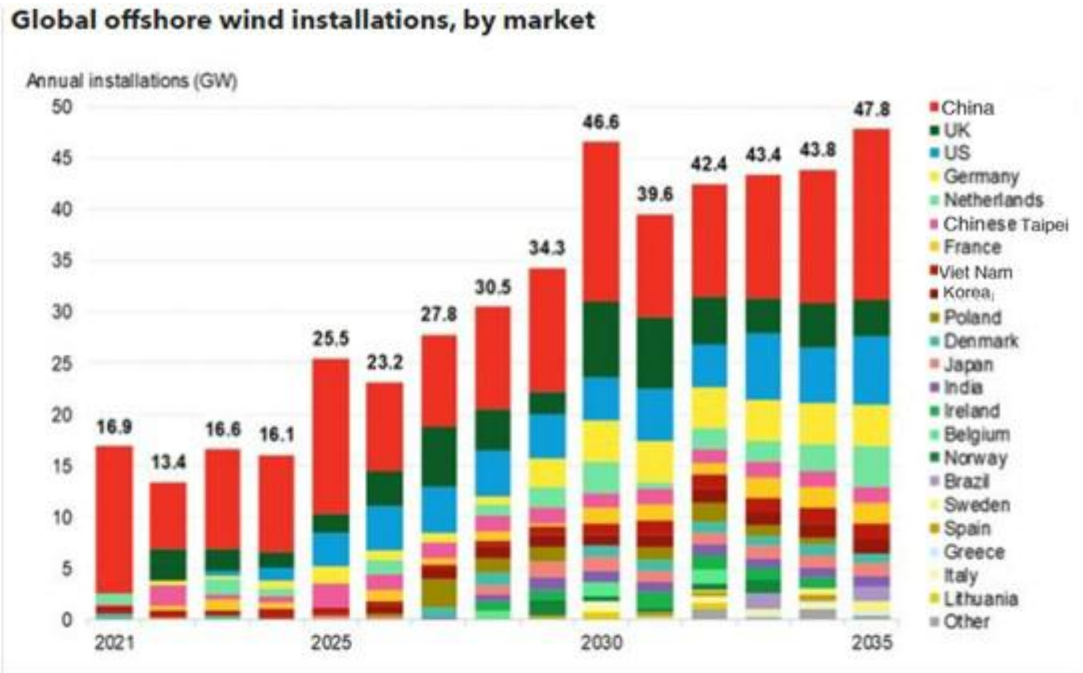
The 2015 Reform of Power System (Document No. 9) by the State Council established a free-market electricity pricing mechanism to encourage transmission between provinces in different grid networks [41] [11]. Overall, this reform document set guiding direction to liberalize the wholesale and retail electricity market allowing the government to have control only of the transmission grid. This was intended to help facilitate the development and installation of renewable energy capacity in the economy's transition, and to achieve its carbon neutrality by 2060 [11].

Apart from the liberalization, China also intends to standardize the whole electricity market, facilitating interconnection across provinces, cities, and districts. According to the announcement made the NDRC in January 2022, China plans to unify the electricity market economy-wide at a preliminary level by 2025 and complete the unification process by 2030 [42]. This is expected to provide the necessary efficiency to integrate more renewable power generation and allow large-scale green power trading. While this process will facilitate further development of OSW in China in the foreseeable future, it has been expected that the entire standardization process would be both complex and time-consuming.

2.6.2 Cost of Offshore Wind

The cost of OSW is expected to continue to decline thanks to the development in the local manufactures, policy support, the increasing installed capacity, and improving generation efficiency. The LCOE for OSW in China is predicted to drop from a range of USD54/MWh to USD96/MWh in 2022 to around USD27/MWh to USD44/MWh in 2050, which is approximately a 50% reduction [11]. A study conducted in 2021 found that out of the six provinces studied (Jiangsu, Zhejiang, Hebei, Liaoning, Fujian, Guangdong), Hebei Province has the highest LCOE value of USD125/MWh, while Fujian Province has the lowest LCOE value of USD100/MWh, representing a 20% difference between the two provinces [43]. The cost difference in this case is mainly due to the fact that the farm in Hebei Province has lower annual utilization hours hence higher unit cost, resulting in an 8.75% higher price than the NEA's policy guidance price.

The overall trend of reduction in the cost of China OSW can largely be contributed to the rocketing development and installation of OSW in China. According to BNEF, mainland China accounts for 80% of OSW installation in 2021 and the trend is expected to continue, as shown in Figure 2-9. As a result, it is not surprising to see the drop in China's OSW cost. This is an encouraging sign for the development of OSW in China. With the central government gradually removing subsidies for OSW projects, the cost of OSW must become more market competitive to overcome the financial barriers.



Source: [44] Jean-Michel, 10 August 2022.

Figure 2-9 Global offshore wind installations prediction by market

2.6.3 Participation in Provision of Ancillary Services

The NEA released *the Measures for Administration of Ancillary Services* in December 2021, which outlines the updates to ancillary services in China. Major changes were planned to be imposed, including the expansion of ancillary service products and types, the establishment of cost sharing mechanisms using the "who benefits, who pays" principle, and the addition of more eligible market participants. To incorporate more renewable electricity and follow the ongoing updates and reinforcement to the grid, the new measures will allow more ancillary services, totalling three categories, namely active power balancing services, reactive power balancing and emergency coping and recovery services, to enter the market.

For the first time since 2006, the ancillary service cost was passed to the end users, not just the generators. This implies that the consumers may end up paying more, thereby changing the level of the power tariffs. Renewable generators such as OSW can benefit from the downward ramping (peak shifting) ancillary products, but the allocation fees could increase as more renewable power entering the market [45].

2.6.4 Private Offtaker of Electricity

China has aimed to steadily establish an electricity market exchange to enable direct transactions between new and renewable energy projects and power users, as mentioned in the latest release from the NDRC and the NEA in May 2022 [46].To test and prepare for a possible future green power exchange market, the NDRC and the NEA have launched a trial scheme for trading green electricity. Currently, the two trading centers are the Beijing Power Exchange Center and the Guangzhou Power Exchange Center. Liaoning and Fujian provinces have launched their green electricity markets, with orders of more than 2.78 billion kWh [47] and transaction volume of 28.43GWh in 19 transactions respectively [48]. Although the establishment of a power exchange market is still at an early stage, it is an encouraging sign for possible cost reduction as well as demand boosts for renewable electricity and the OSW projects.

Although various approaches for trading green electricity have been explored at central government and local levels in China, there is currently no unified Power Purchase Agreement (PPA) with power producers available for off takers [49]. Green electricity transactions, in which power users directly participate, follow the basic frameworks of medium- and long-term electricity contracts (such as PPA), involving power generation enterprises, power grid enterprises and power users. However, due to the complexity and absence of the unified contractual solutions for electricity procurement, China has been regarded as one of the challenging markets for the private or foreign entities to reduce their GHG emissions related to electricity generation.

2.6.5 Curtailment

The rocketing growth of renewable generation capacity have created challenges for their integration with the power grid. The IEA mentioned in its report that a curtailment rate of 17.2% for wind generation and 10.3% for PVs was recorded in 2016. In some regions, the curtailment rates exceeded 40% [12]. The IEA summarized the following three reasons:

1. Poor coordination in the planning and investment processes leading to a large deviation between the plan and implementation;

2. Inefficient resource allocation due to the lack of sufficient market trading mechanisms;

3. No fully formed market-based pricing mechanism resulting in the power prices that are not commensurate with the costs.

Despite the challenges of integrating renewable power with the grid, Bloomberg analyst suggests that curtailment in China is lesser an issue in a mega-energy bases. This is because the generation added is much lower than the increase in demand, and even if the generation added is higher than local demand, other provinces would be able to absorb the excess generation [50]. The development of the UHV transmission lines has been the proactive response to the situation of unbalanced locations of load centres and renewable energy resources in China.

It is difficult to predict the exact curtailment rate in China as there is less available or up-to-dated data across different provinces. However, following the continual development and implementation of the market-based mechanisms and pricing systems in electricity sector, curtailment risk could be reduced in the future. Additionally, as more policies have been rolled out to address the carbon neutrality goal, it is expected that more policies and guidelines will be implemented to avoid the likely misalignment in the planning of the renewable energy projects.

2.7 Summary and Recommendations

While the rapid development of OSW energy in China is highly promising, several barriers remain. Some of the most significant barriers are associated with the member economy's current procedures and policies. The electricity market in China is regulated by the State Council, with the largest portion of electricity generation controlled by the SOEs. This monopoly situation leaves little room for private-owned companies to make their marks. Welcoming foreign investment would help to increase positive market competition, therefore drive the growth of the industry. Additionally, allowing more room for cooperation with the experienced foreign OSW companies and partnership with European economies, such as the UK or Germany, can promote OSW knowledge sharing to overcome the current barriers in OSW development procedures and policies.

Planning and application procedures for the development of OSW projects in China are complicated and vary across provinces. This is another barrier for the foreign investors as it makes the approval process challenging to navigate. Standardising the approval process and introducing great transparency would help to drive out the current monopoly. Policy-based strategies such as standard development and certification of key OSW equipment can further improve the transparency and strengthen the investor confidence.

Although the costs of OSW have dropped significantly over the past five years thanks to the many recent large-scale OSW farm installations, OSW in China is still among the most expensive renewable energy technologies in terms of LCOE. The ending of FiT for renewables poses more challenges for new OSW projects. The central and local governments can consider market-based strategies to aid the development of OSW projects. For example, issuing green bonds and green loans can help fill in the gap without FiT, and drive the development of the OSW-related industry.

While much work has been to upgrade and expand the grid network to accommodate the exponential growth in variable renewable power generation, in its current state, the gap stil exists for higher renewable penetration. Without appropriate network planning, the risk of curtailment for many investors is still a strong deterrent. The OSW grid connection is still in an early stage, with almost all OSW systems in AC transmission. To explore deeper water OSW development, such as floating wind farms, China should continue to examine and adapt the latest OSW transmission technology, such as DC transmission system. In-depth research on the key challenges of AC/DC transmission is of particular importance for future development and innovation. Demonstration platforms should be established for new technology trial applications.

As more green power enters the electricity market, its unification is increasingly important. With the reform in power sector, the government has planned to strengthen the network connection between provinces, cities, and districts. While still in its early stages, these changes would help to increase the number of participants in the green power market exchange. The establishment of medium- and long-term electricity contract mechanisms for the China market is needed for future OSW development.

3 Japan

3.1 Introduction

Japan has committed to the target of carbon neutrality by 2050. This announcement came in the first draft of the Green Growth Strategy released in December 2020. The strategy highlights the scale of the challenges and the magnitude of the transformation required among each of the 14 priority sectors across the economy.

Offshore wind plays an essential strategy in achieving Japan's Green Growth Strategy goals. The Japan Wind Power Association (JWPA) estimates that the economy has a total 552GW of potential offshore wind resource, although most of which are in deep waters (floating foundations required). Since Japan established its targeted promotional offshore wind areas in 2019, the value of entering the market has become much more favourable. Many Japanese utilities are attempting to partner with more experienced European utilities to tender for a spot in these promotional zones. Transmission infrastructure is now also being actively considered to support the offshore wind goals of the Green Growth Strategy. The DC power transmission networks are needed to connect the emerging OWFs to areas of demand.

3.2 Overview of Offshore Wind Resource

Figure 3- 1 shows the wind speed and water depth as heat maps for the offshore portions in Japan. The wind speeds at 100m hub height range from 2.8m/s to 11.4m/s along the coast, with the highest located in the north off the southern coast of Hokkaido. The water depth around Japan tends to drop much faster than some of the other APEC member economies, with the shallowest far coast waters being located off the southeast coast.

Water depths up to -70m are generally considered suitable for bottom-fixed foundations, while floating foundations are suitable for water depths between-70m and -1,000m. Sea depths greater than -1,000m are considered ultra-deep and are less economically favourable and more complex, and thus riskier in terms of development for floating foundation. Based on the wind resource, both fixed and floating foundation OSWs can be deployed desirably off Hokkaido and the north of Honshu (see Figure 3-2). It can also be seen from Figure 3-2, to capture most of the offshore wind potential in Japan, floating foundations will have to be deployed due to its unique bathymetry.

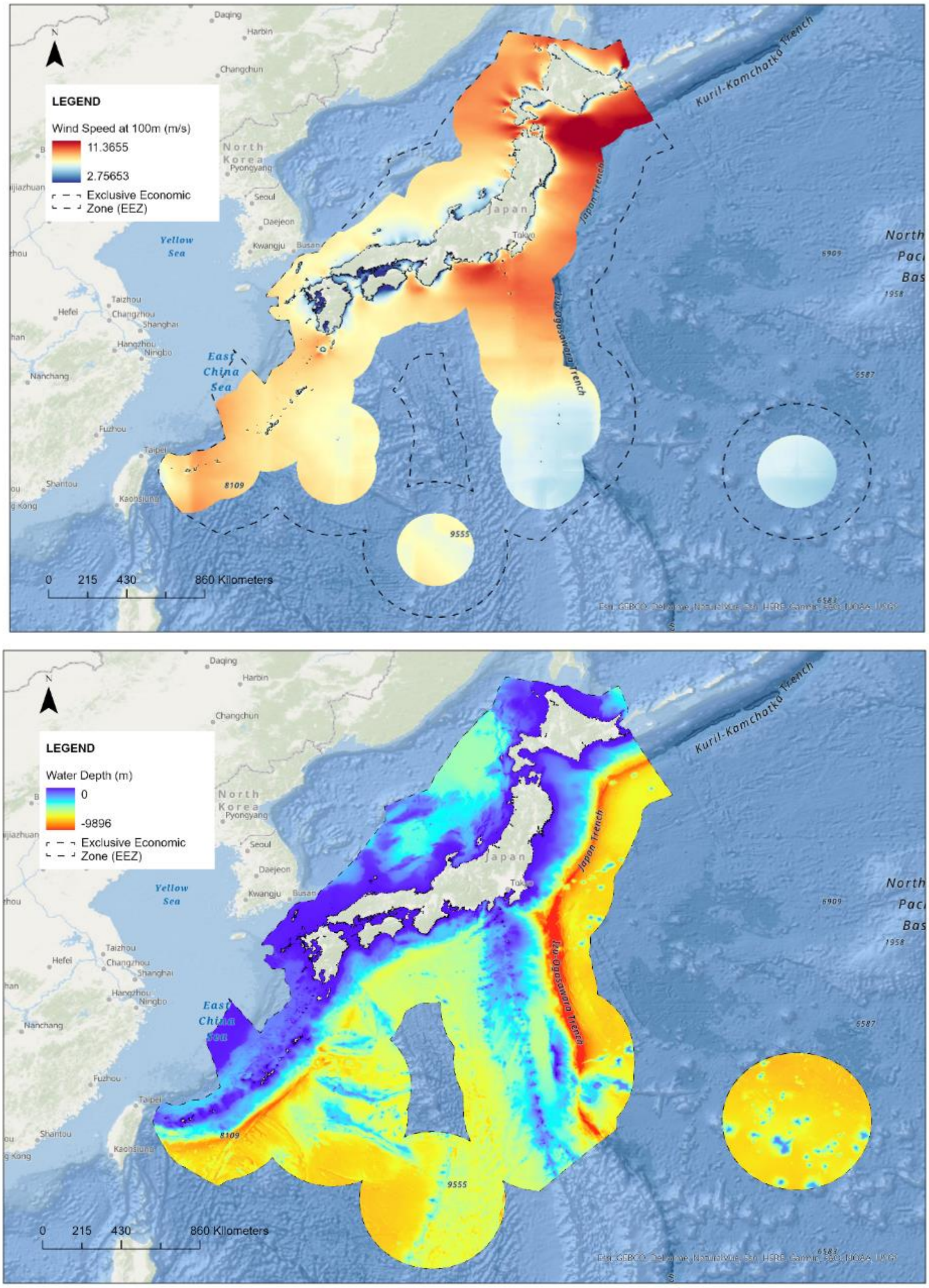


Figure 3-1 Wind speed (top) and water depth (bottom) of Japan's offshore areas

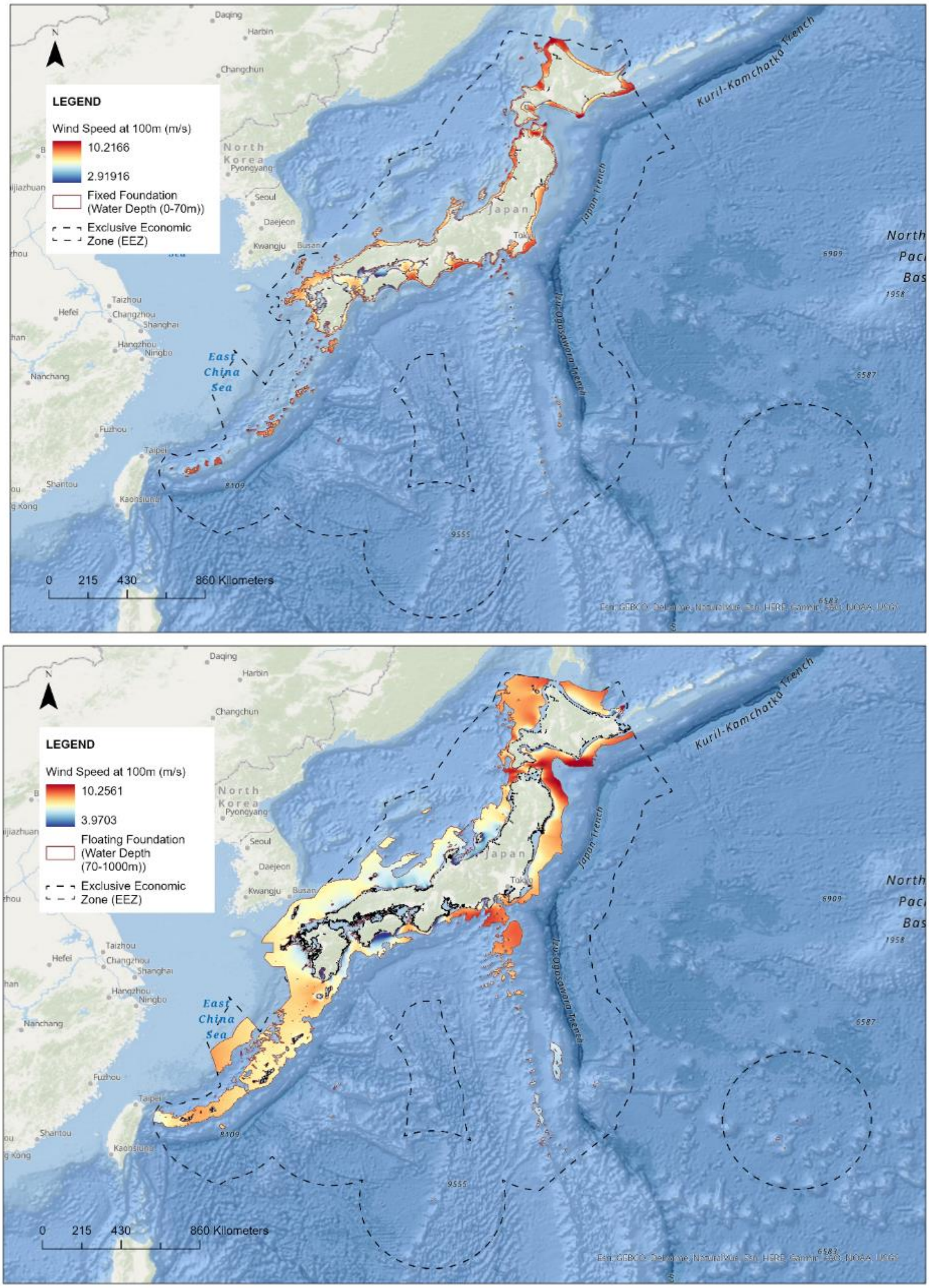


Figure 3-2 Wind speed for fixed foundation water depth 0 to -70m (top) and floating foundation -70 to -1000m (bottom) in Japan

3.3 Energy Sector and Regulatory Mechanism

3.3.1 Structure of Electricity Supply

Leading up to 2011, nuclear power generation was a large portion of Japan's electricity mix. Following the Fukushima incident, the share of nuclear electricity generation fell from 25% in 2010 to 0 in 2014, the gap of which was filled by the fossil fuels. Since the peak in 2012, the installed electrical capacity from the fossil fuels has been steadily declining. Between 2012 and 2021, renewable electricity generation grew by 70% and solar power accounted for almost 90% of this growth (due to the introduction of the solar FiT), while wind power made a modest contribution. The share of renewable energy in total power generation increased from 10% in 2012 to almost 21% in 2021 [51]. In 2021, natural gas accounted for 34%, coal 31%, solar 9%, hydro 8%, nuclear 6%, bioenergy and waste 4% as well as small shares of wind, geothermal and other fossil fuels and nuclear [52]. Historical electricity generation in Japan is shown in Figure 3-3 and the installed capacity in Figure 3-4.

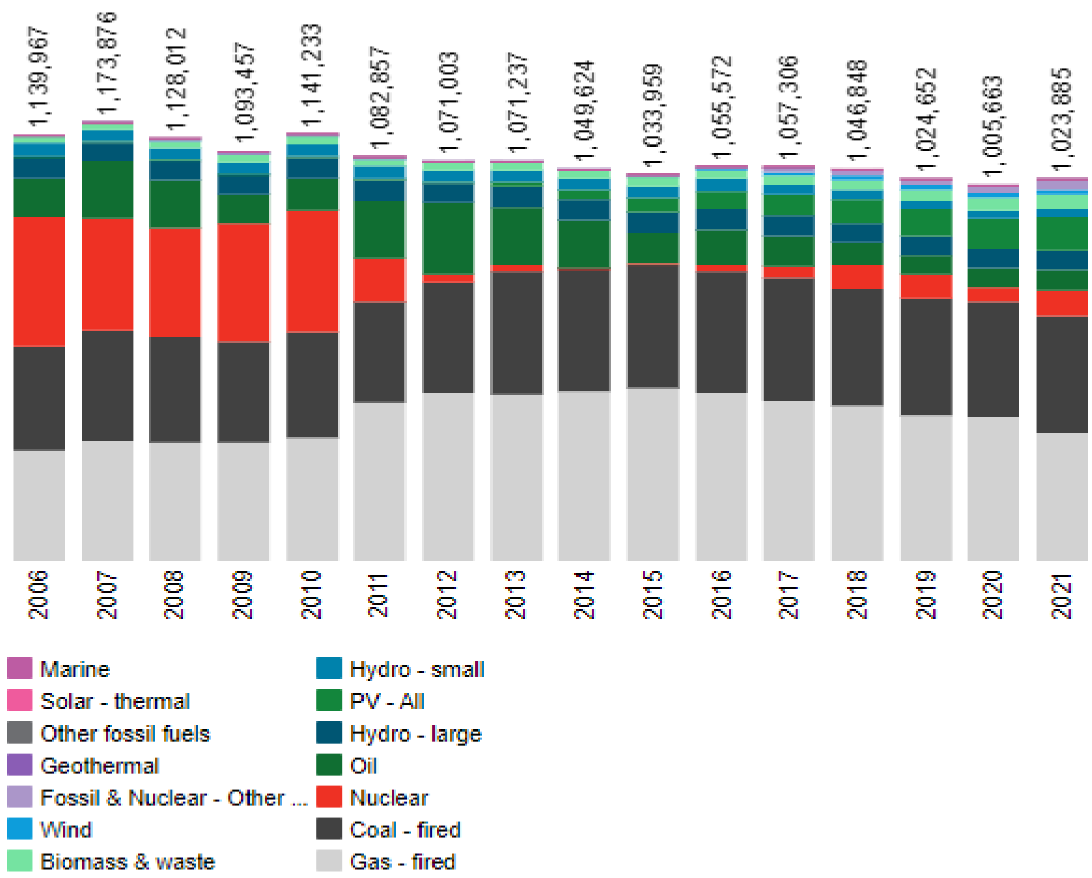


Figure 3-3 Historical electricity generation (GWh) by source in Japan 2006-2021 [51]

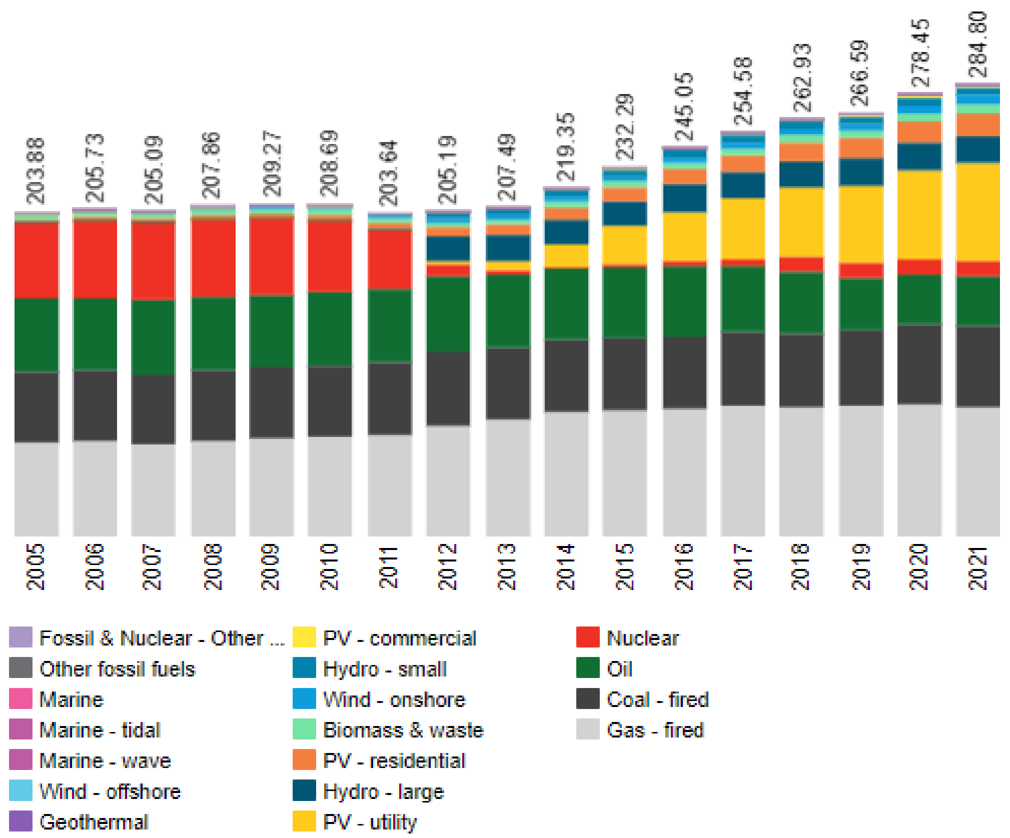


Figure 3-4 Historical installed capacity (GW) by source in Japan 2005-2021 [51]

3.3.2 Renewable Energy and Climate Change Policies and Targets

In the Japan's Nationally Determined Contribution (NDC) under the Paris Agreement, submitted on 22 October 2021, Japan updated its commitment to reduce its GHG emissions by 46% in 2030, compared to 2013 levels [53]. To achieve this goal, it has implemented *the Global Warming Countermeasure Plan* and had already reduced its GHG emissions by 11.8% in 2018 relative to 2013. The aim is to achieve carbon neutrality and a decarbonized society by 2050 [52].

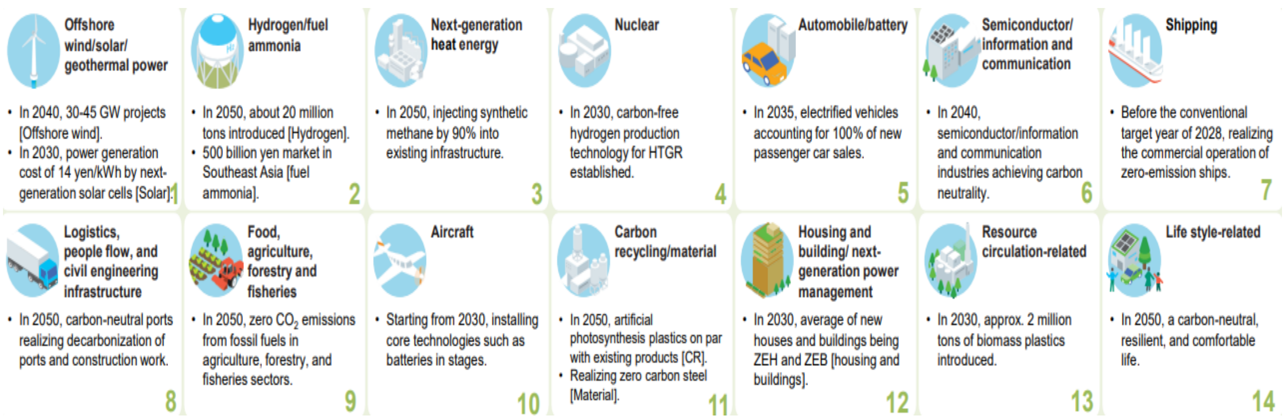


Figure 3-5 14 Sectors included in the Green Growth Strategy

In response to this ambitious target, the Ministry of Economy, Trade, and Industry (METI) in collaboration with other ministries and agencies formulated the *Japan's Green Growth*

Strategy Through Achieving Carbon Neutrality in 2050. The strategy presents a blueprint of energy policies and supply and demand mechanisms to achieving carbon neutrality. The plan specifies 14 promising fields and provides them with action plans from both the industrial and policy viewpoint [54]. A summary of the objectives for each of the promising fields can be seen in the following sub-section.

3.3.3 Offshore Wind Power Development Policies and Targets

The first sector of *the Green Growth Strategy* is concerned with next-generation renewable energy technologies, specifically offshore wind. The strategy emphasizes the importance of efforts to introduce offshore wind power in Japan from both an energy policy and industrial policy perspectives, while reducing the costs by cultivating Japan's offshore wind power industry and strengthening competitiveness. The government will set offshore wind power generation introduction targets, specifically to award capacity of 10GW by 2030 and 30-45GW (including offshore floating wind) by 2040. The recent legislation established 11 promotion zones in five prefectures, with the competitive auctions to support the offshore wind deployment [7]. The distribution of the targets by region is outlined in Figure 3-6 [53].

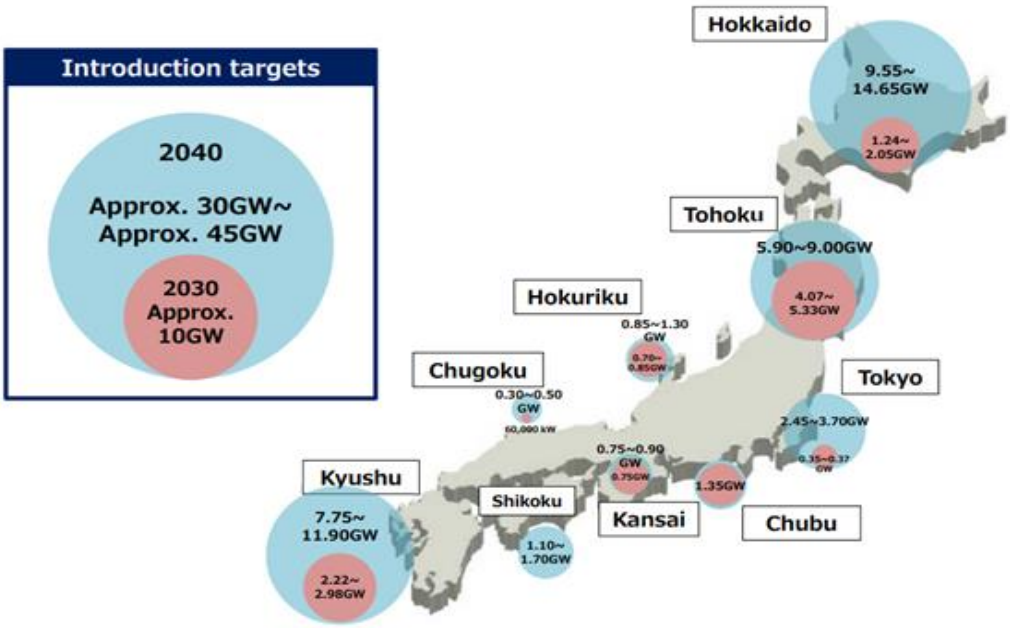


Figure 3-6 Offshore wind introduction targets by region [55]

The government is seeking to establish an attractive domestic offshore wind power market to attract domestic and foreign investment by reducing the costs of offshore wind in Japan, including growth of a competitive and resilient supply chain. To promote the establishment of local companies, the government aims to increase supply chain capability by 60% by 2040. By 2030, the LCOE of fixed-bottom offshore wind turbines must reach JPY8-9/kWh [56].

While most of Japan’s current project pipeline uses fixed-bottom type turbines, there are relatively few shallow areas available for offshore wind, which means that more ambitious deployment of offshore wind is likely to be tied to the successful development of floating turbines. Most of the technical potential of more than 9,000TWh per year is in deep water and would require floating platform technology. In 2013, Japan established the first offshore floating wind farm demonstration project (up to 14MW) in Fukushima; the wind farm is currently still in operation as an empirical research project with a view to further expanding offshore wind power capacity [52]. Japan's Demonstration Research Team is conducting research into the technologies aimed at reducing the cost of floating OSW generation to JPY20/kWh or less by 2030 [57].

Figure 3-7 shows the roadmap for the offshore wind development outlined in *Japan's Green Growth Strategy Through Achieving Carbon Neutrality in 2050*.

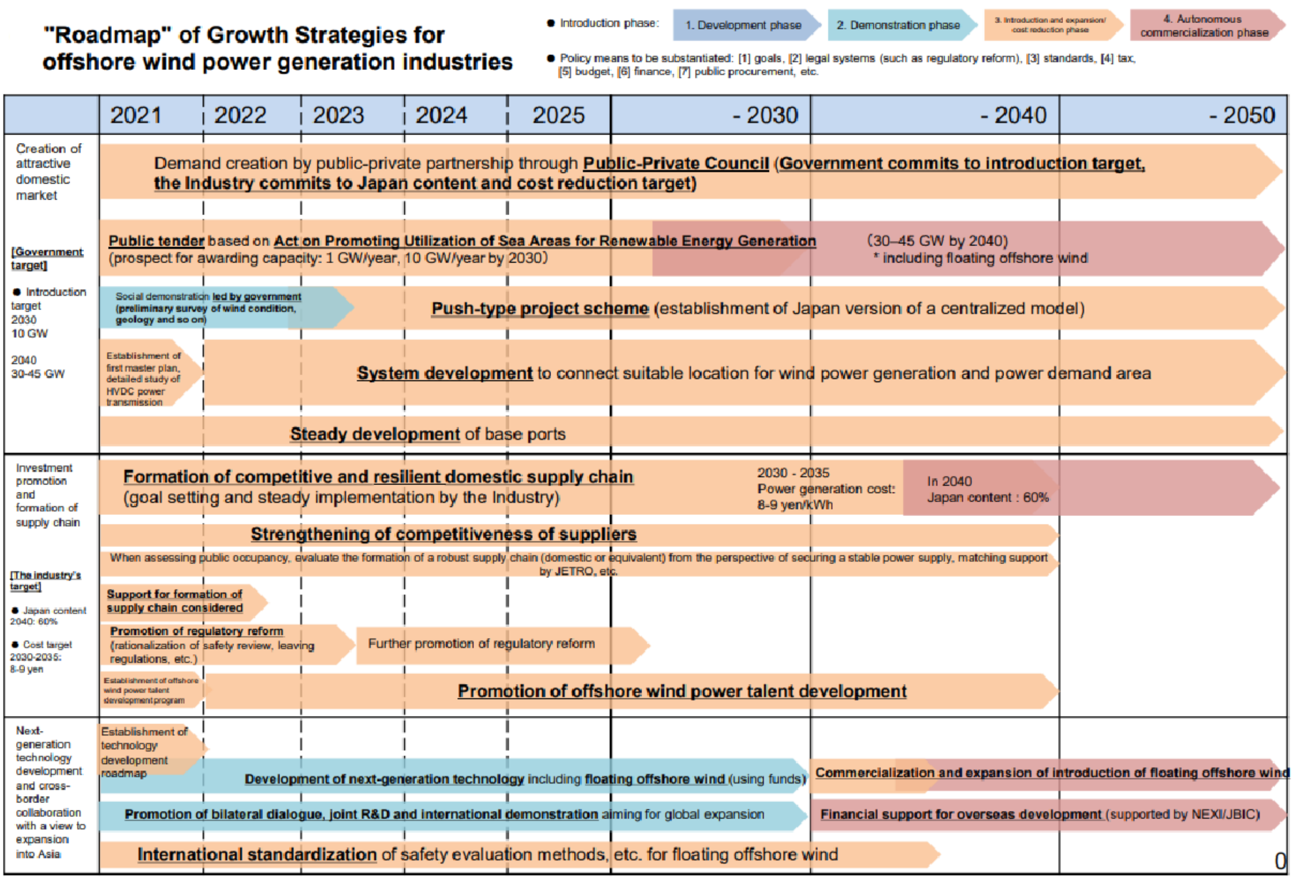


Figure 3-7 Roadmap of Growth Strategies for OSW power generation industries [58]

3.3.4 Renewable Energy and Offshore Wind Regulatory Support Mechanisms

A FiT scheme covering different renewable generators was introduced in July 2012. Under the FiT scheme, electricity utilities could pass on costs for the purchase of electricity generated by renewable energy resources to their customers. The Government revised the FiT scheme in 2016 for wind power and other generators, allowing purchase prices to be fixed for several years.

In 2020, the government decided to review the FiT system with the launch of a feed-in premium scheme to add premiums to the market price of renewables. The aim was to support the uptake of solar and wind electricity generation, thereby increasing their shares in the electricity mix. Table 3-1 shows the expected offshore wind FiT prices for the next a few years.

Table 3-1 Offshore wind FiT prices

Foundation type	FY2021 (JPY/kWh)	FY2022 (JPY/kWh)	FY2023 (JPY/kWh)	FY2024 (JPY/kWh)
Fixed	32	29	public tender	-
Floating	36	36	36	36

In April 2019, the *Act on Promoting Utilization of Sea Areas for Development of Power Generation Facilities Using Maritime Renewable Energy Resources* came into effect. This act introduced the rules for the lease agreement of maritime areas and the process for coordinating the interests of stakeholders, such as members of the fishing industry.

The government has been systematically promoting the establishment of power grids, ports and harbours, and other necessary infrastructure to achieve the offshore wind power capacity introduction targets. *The Power Grid Establishment Master plan* is scheduled to be completed by the end of FY2022. A study group was launched in March 2021 to form a detailed development plan for the introduction of long-distance submarine High Voltage Direct Current (HVDC) power transmission system from the offshore wind power generation sites (Hokkaido and Tohoku) to the large consumption areas [7].

Other incentives driven by the government include a regulatory review aimed at shortening the examination period of the METI and the Ministry of Land, Infrastructure, Transport and Tourism (MLIT), as well as the streamlining of their safety review procedures by increasing the percentage of equipment types that do not require detailed verification. Other policies include clarifying criteria for permission to leave the fixed bottom wind turbines in place and relaxing the criteria related to the installation of the aircraft warning lights on wind power generation facilities [53].

3.4 Offshore Wind Development Procedure and Stakeholder Engagement

3.4.1 Stakeholders and Their Responsibilities

The electricity market in Japan is divided into three main sectors: generation, transmission and distribution and retail. As of January 2020, there were 834 registered electricity providers in Japan. Most entrants to the generation business are autonomous distributed generators, including the firms from paper manufacturing, steel making, and the gas and petroleum industries. Some local governments have also entered, albeit on a small scale. The former Electric Power Companies (EPCOs) and the two largest former wholesale electric utilities (J-POWER and the Japan Atomic Power Company) still dominate the sector, jointly accounting for around 55% of capacity and approximately 80% of peak output (JEPIC, 2020). The retail market had 637 companies in January 2020 (including the retail arms of former EPCOs) [52].

The Japanese transmission and distribution network is organized into 10 regional grids, each operated by a utility company and its associated subsidiaries (see Table 3-2).

There are three primary ministries involved in the development of offshore wind:

- the Ministry of Land, Infrastructure, Transport and Tourism (MLIT);
- the Ministry of Economy, Trade and Industry (METI);

- the Ministry of the Environment (MoE).

Each ministry oversees certain regulations and acts. Those of relevance to offshore wind are included in Table 3-3.

Table 3-2 Electricity utilities and transmission and distribution subsidiaries in Japan

Electricity utilities	Transmission and distribution subsidiaries
Hokkaido EPCO	Hokkaido Electric Power Network, Inc.
Tohoku EPCO	Tohoku Electric Power Network, Co.
Tokyo EPCO	TEPCO Power Grid, Inc.
Hokuriku EPCO	Hokuriku Electric Power Transmission & Distribution Co.
Chubu EPCO	Chubu Electric Power Grid Co.
Kansai EPCO	Kansai Transmission and Distribution, Inc.
Chugoku EPCO	Chugoku Electric Power Transmission & Distribution Co.
Shikoku EPCO	Shikoku Electric Power Transmission & Distribution Co.
Kyushu EPCO	Kyushu Electric Power Transmission & Distribution Co.
Okinawa EPCO	Okinawa Electric Power Co.

Table 3-3 Involved Acts and the ministries in charge for OSW project development

Involved acts	Ministries in charge
Offshore Wind Promotion Act	METI, MLIT
Electricity Business Act	METI
Port and Harbour Act	METI, MLIT
Ship Safety Act	METI, MLIT
Civil Aeronautics Act	MLIT
Building Standards Act	MLIT
Coast Defence Act	MoE
Environmental Impact Assessment Act	MoE, METI
Ship Act	MLIT

Additional agencies that would be involved in the development of an offshore wind farm include:

- ANRE: *Agency for Natural Resources and Energy* is responsible for policies regarding energy;
- EGC: *Electricity and Gas Market Surveillance Commission* is responsible of monitoring energy markets and encouraging competition;
- NEDO: *New Energy and Industrial Technology Development Organization* is responsible of promoting the technological development necessary to achieve a sustainable society;

- JEPX: *Japan Electric Power Exchange* is responsible for the wholesale electricity market;
- OCCTO: *Organization for Cross-regional Coordination of Transmission Operators* is responsible to promote development of transmission and distribution networks.

3.4.2 Offshore Wind Approval Procedures

The current procedure for the development of an offshore wind farm is regulated by the *Act on Promoting Utilization of Sea Areas for Development of Power Generation Facilities Using Maritime Renewable Energy Resources*, which was enforced in April 2019. This Act designates sea areas for the construction and development of offshore wind and introduces a competitive auction scheme to provide 30-year seabed leases. Figure 3-8details the main steps included in the Act, which covers:

1. Preparation of Basic Policies;
2. Designation of the Promotional Zones;
3. Preparation of Guidelines for Occupancy;
4. Submission of Action Plans for Occupancy;
5. Certification of FIT;
6. Permission of Occupancy.

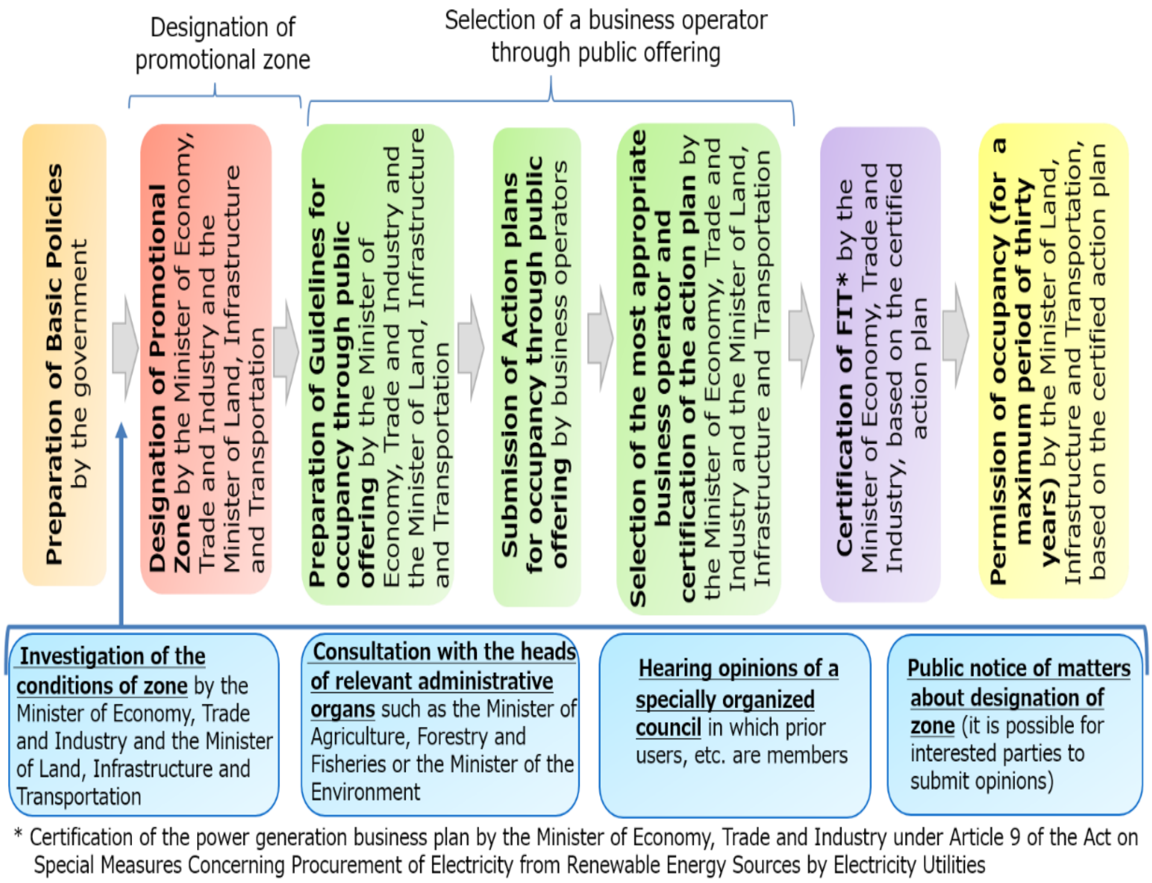


Figure 3-8 Procedures for the development of OSW projects [59]

The process used for the selection of the Potion Zones is outlined in Figure 3-9. This process takes about 10 months and is repeated each year to ensure fairness.

Due to the inefficiencies to carry out early-stage surveys by multiple operators, the Government of Japan decided to introduce the Japanese version of a Centralized Model with reference to instances in Europe. This Centralized Model is implemented during the promotion phase to increase the transparency of the selection process. The new policy including the Centralized Model for the selection of Promotion Zones is outlined in Figure 3-10.

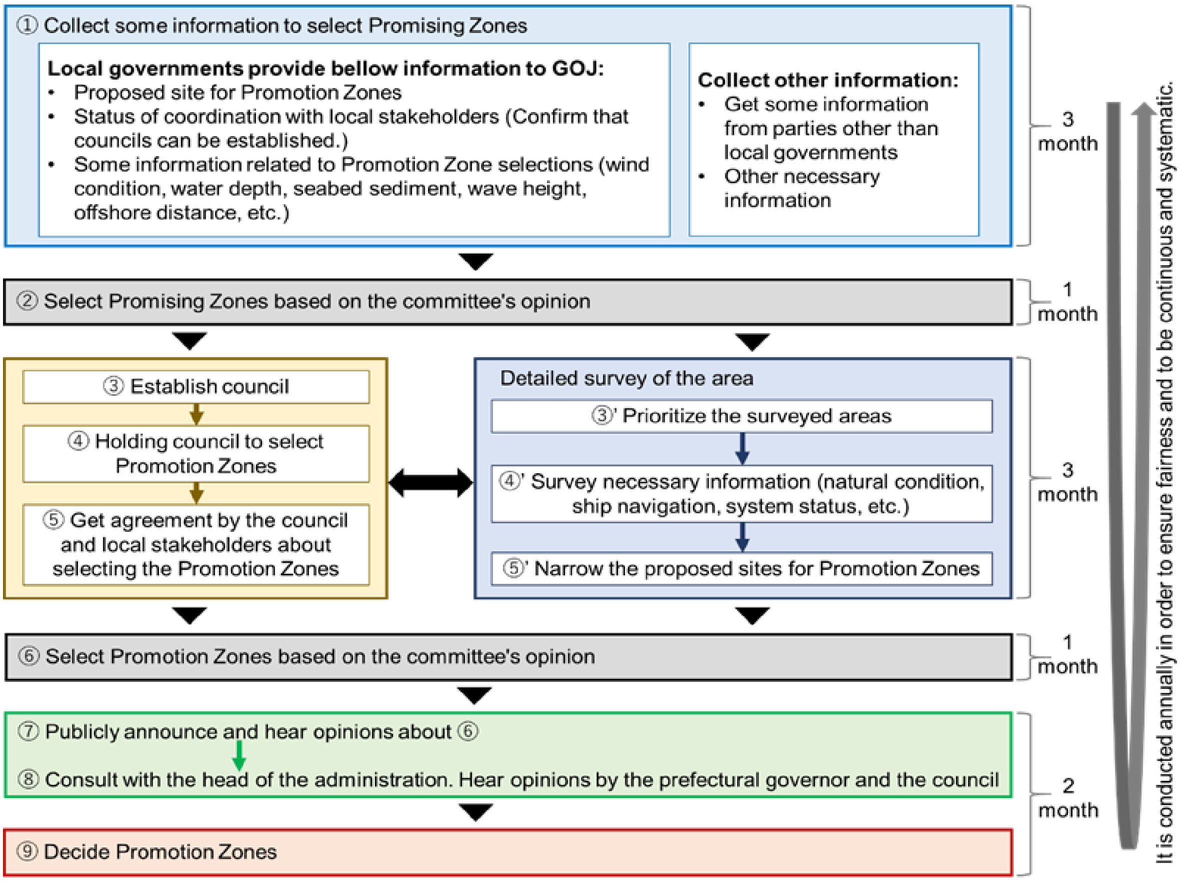


Figure 3-9 Promotion zone selection procedure

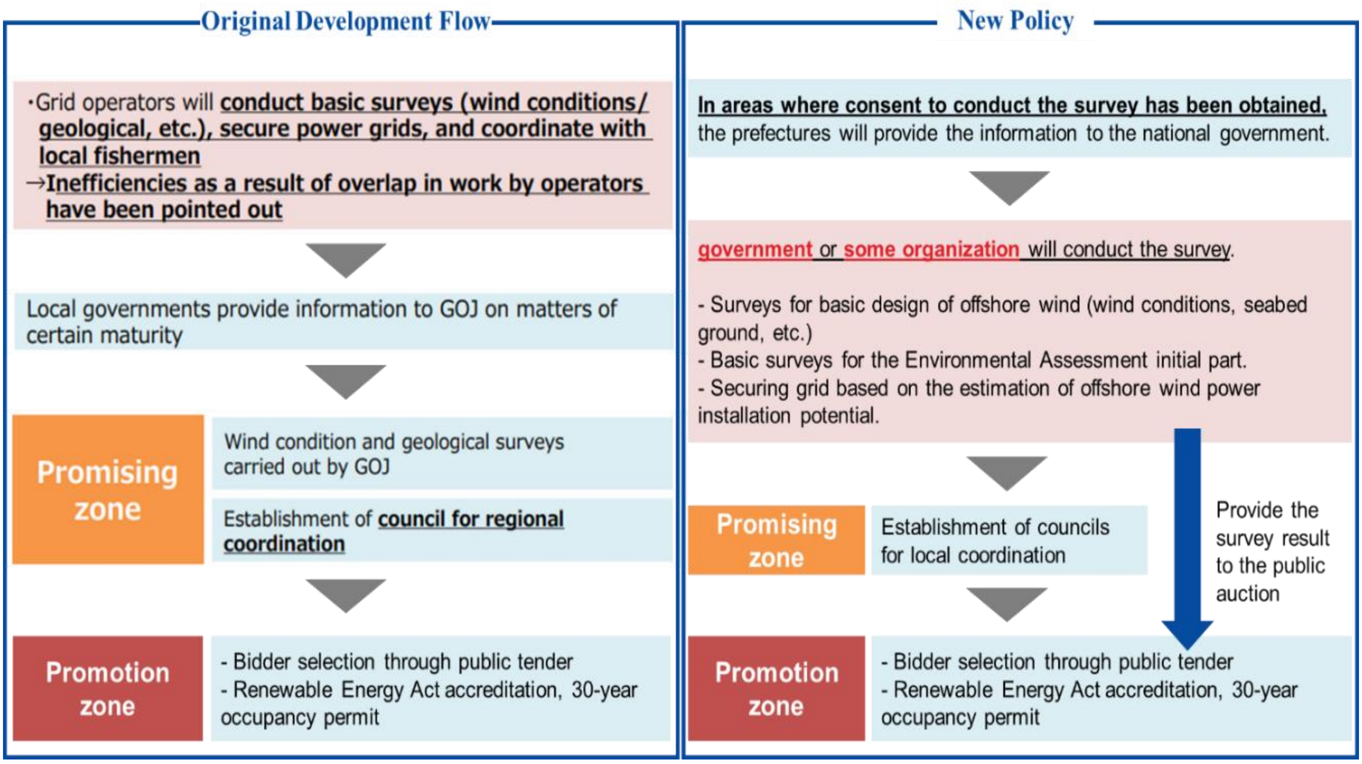


Figure 3-10 Centralized model for the selection of promotion zones

A wind power plant with an output of 10MW of more is considered a Class 1 project in which case an Environmental Impact Assessment (EIA) is required. One with an output between 7.5MW and 10MW is considered a Class 2 where the necessity of the EIA will be judged based on further consideration [60] [61]. The EIA permitting process is carried out in seven main stages with the engagement of four stakeholders. A flow diagram of the process is provided in Figure 3-11.

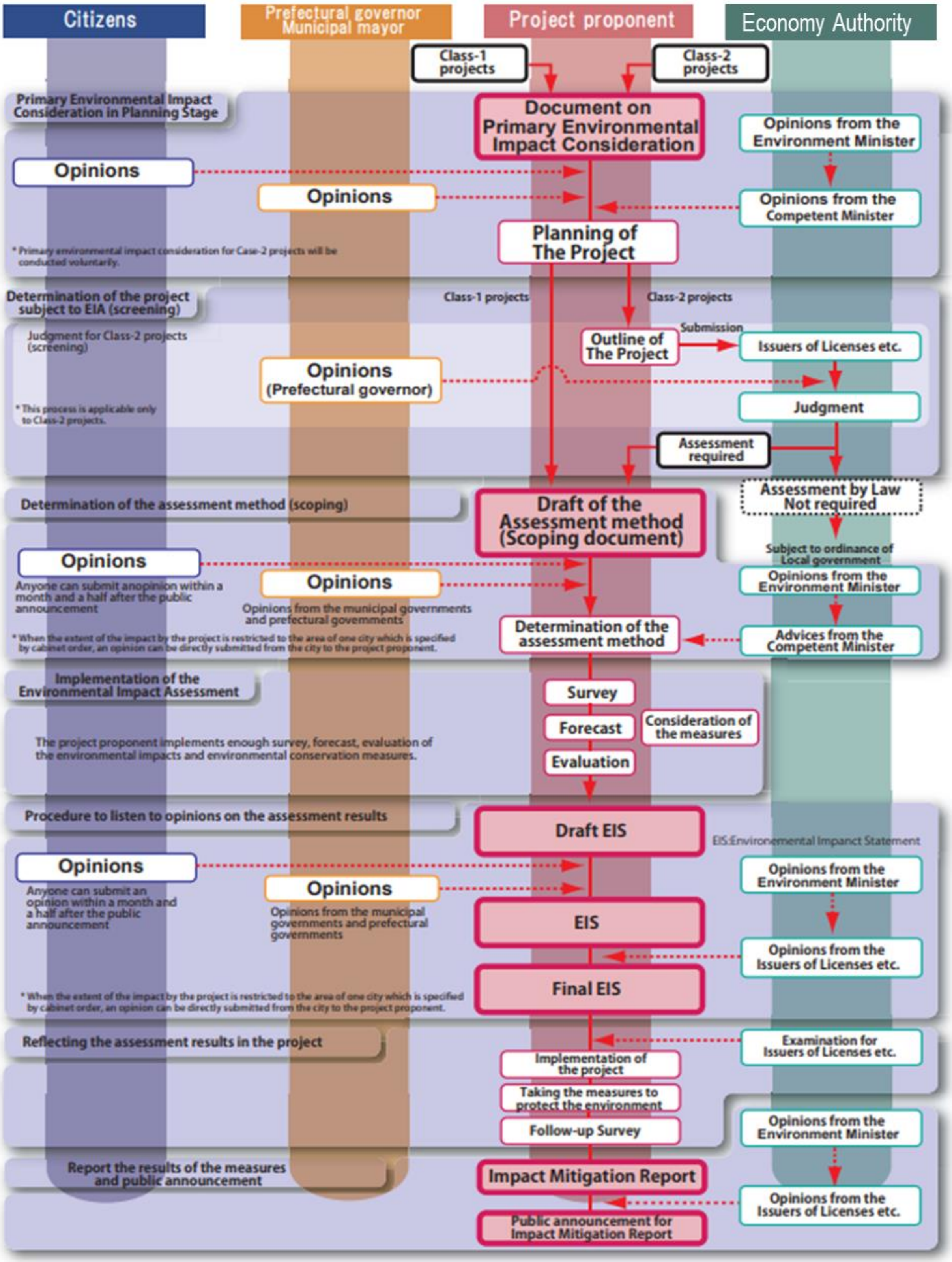


Figure 3-11 Procedure for EIA in Japan

Figure 3-12 outlines the occupation timeline for a granted site. The occupation plan validity period is 30 years after the bidder is decided. This assumes 5 years for the environmental assessment, 3 years for construction, 20 years for FIT and 2 years for decommissioning. The site occupation allowance period is from the construction to decommissioning, which is maximum of 30 years. However, the end of the occupation plan validity period comes 5 years earlier because of the 5 years needed for the environmental assessment before the construction starts, which leaves the actual time frame of 25 years. The extension of the occupation period is allowed with the MLIT permit, but it is currently unclear what procedures are required.

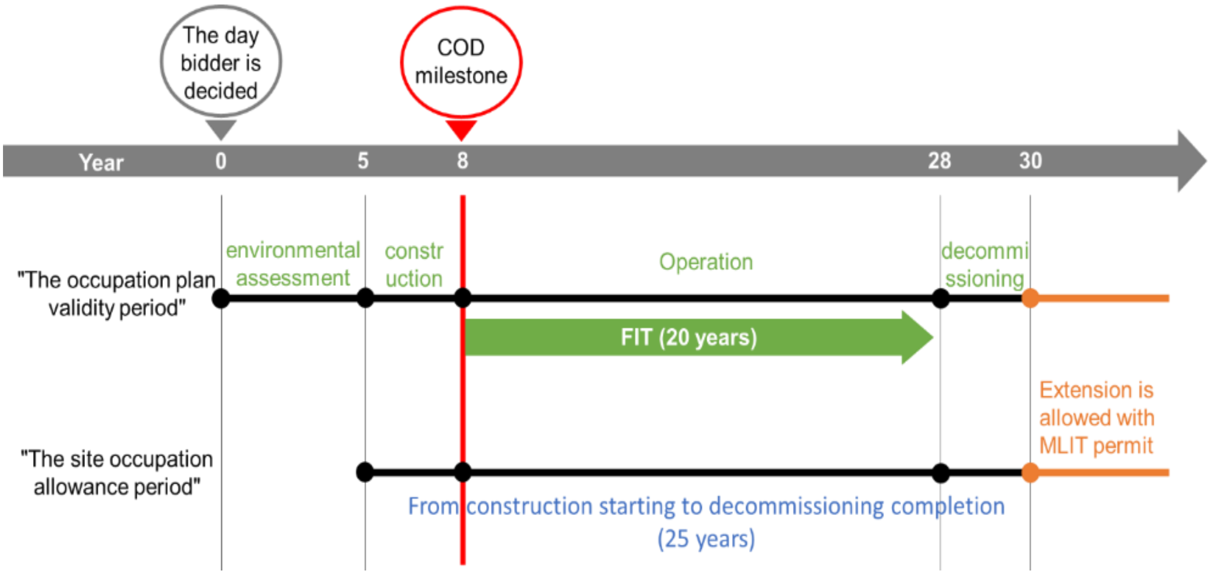


Figure 3-12 Occupation timeline

3.5 Offshore Wind Grid Connection

3.5.1 Electricity Utility Structure and Grid Connection Procedure

As an island with no cross-border interconnections, Japan needs to balance all of its electricity production and consumption itself. The transmission network is divided into ten regional grids arranged into two frequency levels. Since eastern Japan operates at 50Hz whereas western Japan operates at 60Hz, it is necessary to convert the frequency when transmitting electricity between eastern and western Japan [52].

Japan's bulk transmission system comprises of 500kV, 275kV, 220kV, 187kV, 154kV and 132kV transmission lines. All regional grids aside from Okinawa have maximum transmission voltage of 500kV. Japan's three largest metropolitan cities, Tokyo, Osaka and Nagoya are served by bulk transmission systems comprising of 500kV outer ring transmission lines surrounding the demand centers. TEPCO Power Grid serving Tokyo has constructed transmission lines designed to handle up to 1,000kV to accommodate future large-scale grid expansions. While most transmission lines are AC, DC transmission is used for interconnections between Hokkaido and Honshu and between Kansai and Shikoku.

As of March 2021, there were 7,137 substations with total installed capacity of approximately 869,000MVA throughout Japan. Due to heavy concentration of commercial and residential infrastructure, finding additional sites for substation development in urban areas is challenging. To overcome these challenges, utilities are using gas insulated switchgear (GIS) to reduce their footprints and are installing substations beneath the existing structures.

The grid connection process for offshore wind farms can take around 1.5 years to complete, with the local EPCO being the key stakeholder to apprise before project construction. The project company is required to have a preliminary consultation with the EPCO before submitting a System Impact Study (SIS) application. Any questions raised at this stage will be answered in around a month. For the high voltage cases, the SIS carried out by the EPCO following the application is expected to take around 3 months.

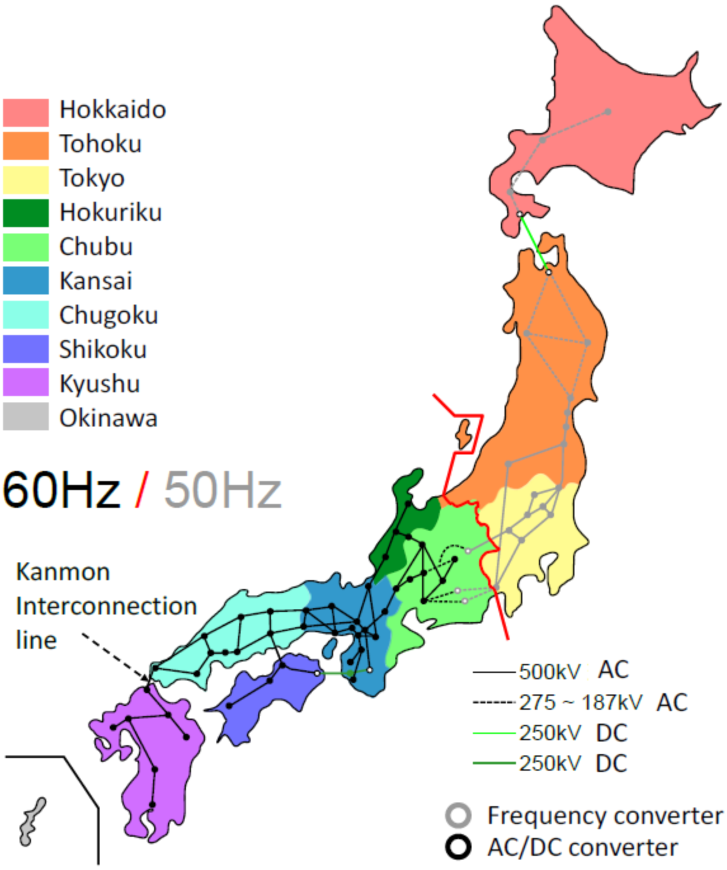


Figure 3-13 Electricity grid and utilities in Japan [62]

Once the results of SIS are provided, the project company may submit the grid connection application and power purchase contract application. For these to be accepted by the EPCO, an application for the sale of electricity and a detailed technical design is also required. The EPCO may refuse the grid connection on the following basis:

- The development company does not agree with the curtailment rules;
- Transmission capacity is exceeded;
- Supply exceeds demand.

The project company is required to pay the cost of construction related to grid connection within a certain timeframe after signing the grid connection agreement. Tohoku EPCO does not specify the exact days however, other EPCOs, e.g., TEPCO, request the payment within a month after the grid connection agreement is signed, prior to the expected construction. A guide for the grid connection process is provided in Figure 3-14.

Currently all near-shore wind farms in Japan are connected to on-shore substations. Wind turbines are typically grouped together into array which are connected at an onshore substation near the site. The voltage would typically be stepped up at the substation and onshore export cables installed taking the power to the grid substation for transmission.

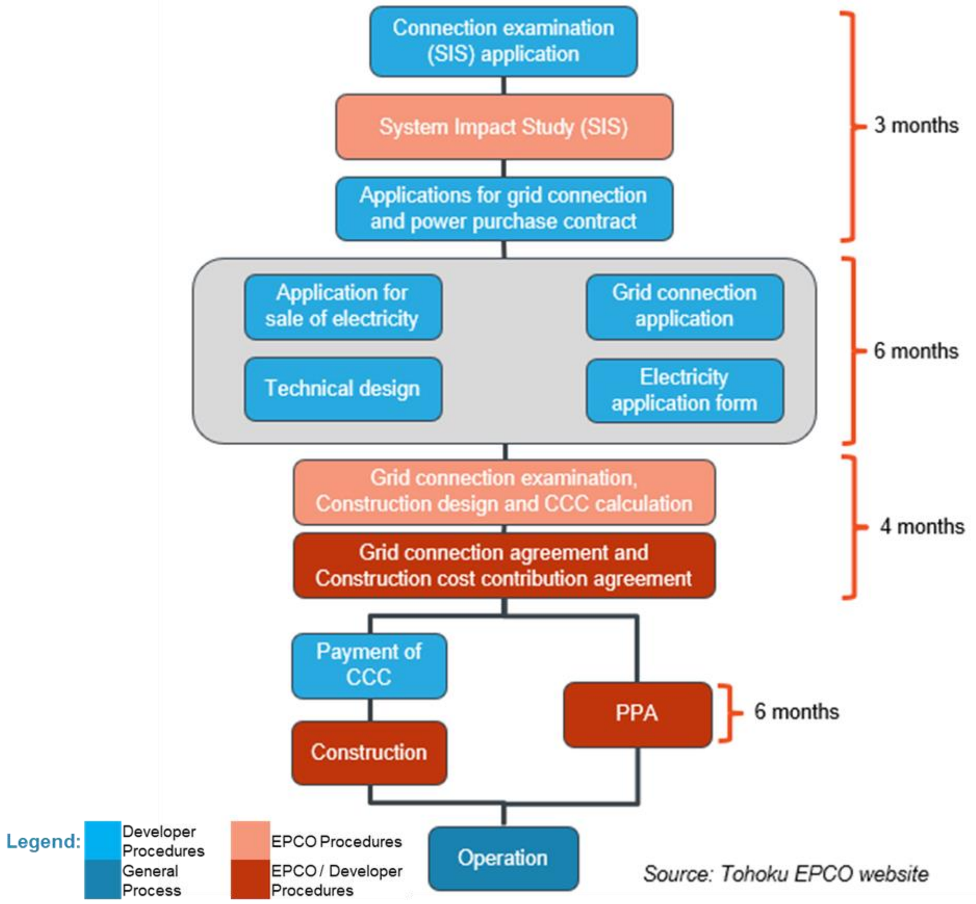


Figure 3-14 The grid connection process for OSW project

3.5.2 Transmission Network and Expansion Plan

Historically, access to high-voltage transmission in Japan has been based on first-come, first-served basis, under which power-generating facilities that are already connected to the grid are guaranteed transmission capacity equivalent to their maximum generating output. This rule triggered concerns that new renewable energy-generating facilities faced difficulties in connecting to the grid, as many grids lacked sufficient capacity and new facilities would need to bear part of the costs of reinforcing the grid [52].

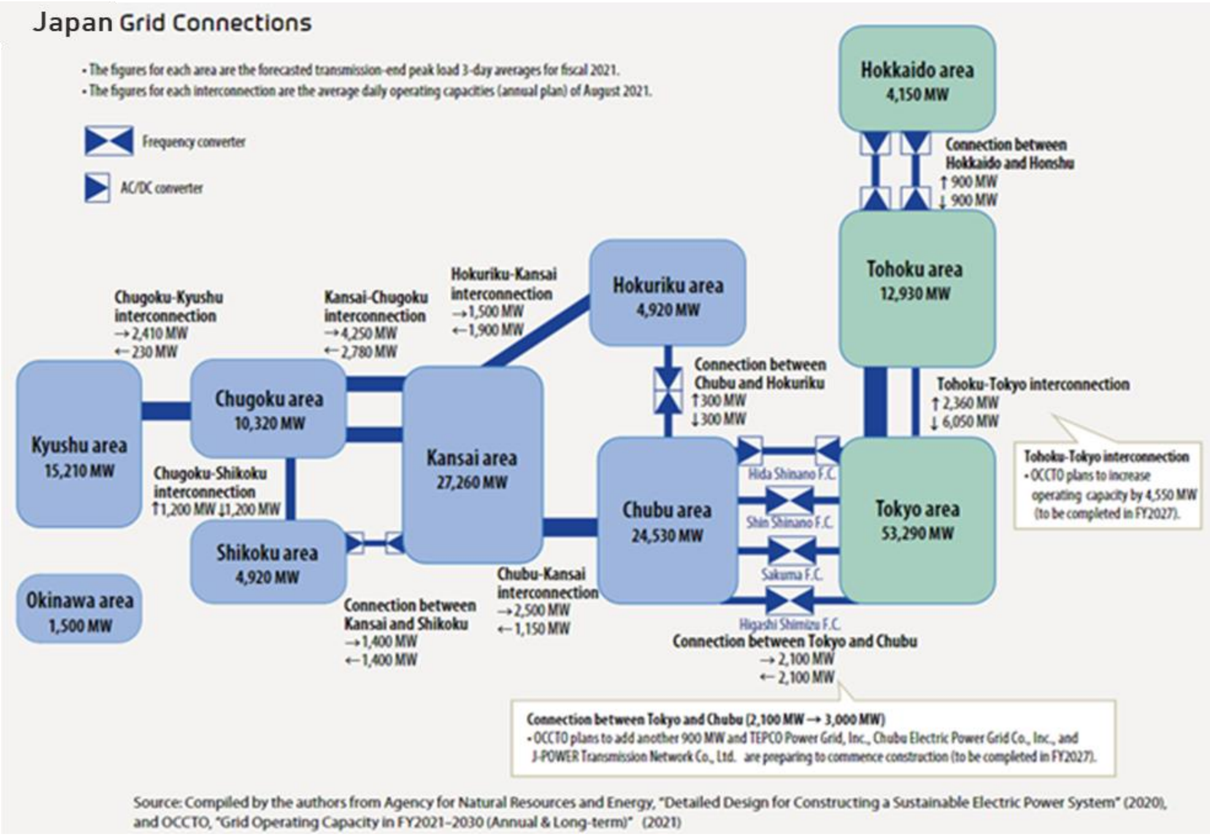
To address these issues, the government introduced the so-called "*Connect and Manage*" policy, under which new entrants can connect to a grid that is running short of available capacity before work to reinforce grid capacity is completed. In addition, the new policy changed the calculation of available grid capacity for variable renewables from maximum nameplate capacity to an estimated future power flow of electricity based on the previous performance. This will make more grid connection capacity available for variable renewables without additional grid enhancements under the condition that output is limited/curtailed in the case of grid contingency [52].

The Power Grid Establishment Master Plan was established by three committees: Next Generation Electric Power Networks Committee, Power Grid Master Plan Committee and

Power Grid Establishment Committee. Figure 3-15 outlines the planned upgrades and reinforcements to the electrical network in Japan. These upgrades were published by METI and include the integration of new interconnections between grids, and an increase in transmission line capacity. The Grid Master Plan includes the potential installations of long-distance high-voltage submarine transmission lines, which would support the transmission of power from northern locations with high wind resources to large demand centers like Tokyo. The Sakuma and Higashi-Shimizu frequency converters are planned to have expanded capacity to 900MW by 2027 to respond to the increase in new renewable generators in the grid.

In June 2020, the government passed legislation to strengthen the resilience of the electricity sector. The Act includes a requirement for transmission and distribution operators to develop partnership plans to facilitate a quick initial response to disasters, changes to the transmission charges to spur investments in transmission and distribution network, and promotion of distributed grids which are more resilient to natural disasters [52].

The government decided to introduce a wheeling charge to be paid by all power generators (a so-called G-charge) from 2023 onward (except for the residential solar PV less than 10kW), to finance investments in network facilities necessary for expanding renewable generation capacity. The G-charge would also promote the efficient utilization of network facilities, as generators will be offered a reduction in the charge if they are located in specifically designated areas (discounted areas). The G-charge under consideration will be non-discriminatory, technology-neutral and fairly distribute the network costs [52].



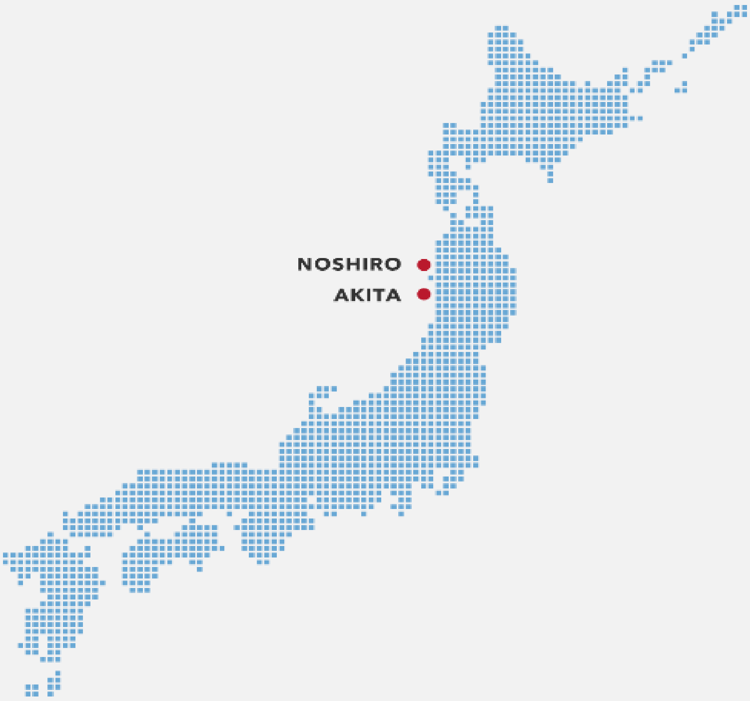
Source: [63] METI Ministry of Economy Trade and Industry.

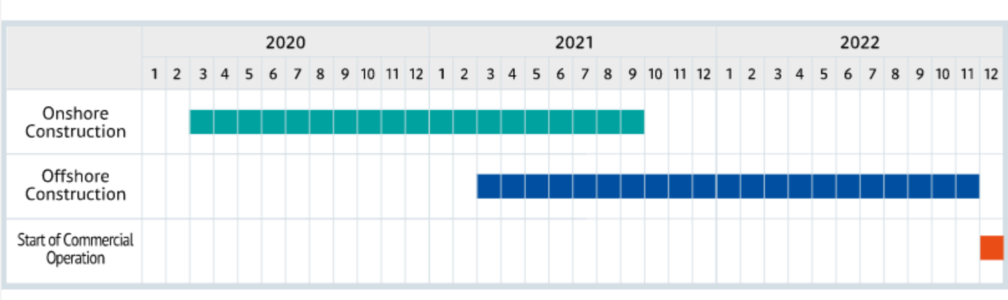
Figure 3-15 Power grid reinforcement plan

3.5.3 Offshore Wind Case Study

The only operational offshore wind projects in Japan are typically nearshore, small-scale (~20MW) demonstration projects. While there are no operational commercially sized OWFs, there are many in the pipeline. The Akita Noshiro Offshore Wind Project is the closest to achieving COD by the end of the financial year in 2022 [64]. The onshore substation and transmission line construction began in February 2020 near the Port of Akita and the Port of Noshiro. Around the same time, the design for the production and installation of subsea cables from the turbines to the onshore network began [64]. Details of the two OWFs under this project are provided in

Table 3-4 Akita Noshiro OSW Project case study

Akita Noshiro Offshore Wind Project [65]	
Location	 No more than 1.1km from the coastline [66]
Water Depth	Water depth of >10 meters.
Choice of technology	Akita Port (13 x 4.2MW wind turbine) Noshiro Port (20 x 4.2MW wind turbine) Turbines using fixed-bottom foundations 1 onshore substation per location
Capacity	Approximately 140MW
Shareholder	Marubeni Corporation OBAYASHI CORPORATION Tohoku Electric Power Co.,Inc. Cosmo Eco Power Co., Ltd. The Kansai Electric Power Co., Inc. Chubu Electric Power Co., Inc. The Akita Bank, Ltd. Ohmori Co., Ltd. Sawakigumi Corporation Kyowa Oil Co., Ltd. Katokensetsu.Co.Ltd. Kanpu Co., Ltd. Sankyo Co., Ltd.
Wind	Model: Vestas V117-4.2MW

<table>
<tr><th colspan="2">Akita Noshiro Offshore Wind Project [65]</th></tr>
<tr><td>Turbines</td><td>Rated power: 4.2MW
Rotor diameter: 117m
Gearbox: 2 planetary / 1 helical
Generator: PMSG
Wind speed range: 3-25m/s.
Wind class: IEC IB-T/IEC IIA-T/IEC S-T
Hub height: 84 / 91m</td></tr>
<tr><td>Grid connection</td><td>Inter-array voltage: 33kV
Export voltage to onshore substation: 33kV
Export voltage to grid: 161kV
The WTGs are connected forming strings at 33kV that connect with the onshore substation. From the onshore substation a line at 154kV connects to the transmission system substation.</td></tr>
<tr><td>Status</td><td>

The onshore construction work began in early 2020 and offshore work in early 2021. Both offshore and onshore work is expected to be completed by November 202.</td></tr>
<tr><td>Expected COD</td><td>End of 2022</td></tr>
</table>

As there is significant opportunity for floating offshore wind in Japan, demonstration floating projects have been conducted. One completed floating offshore wind demonstration project is the 14MW Fukushima FORWARD. This project was the world's first floating substation developed in 2013, with a rated voltage and capacity of 66/22kV and 25MVA. The demonstration project is located 23km from shore in water depth of approximately 110-125m and consists of three floating offshore wind turbines rated at 2MW, 5MW and 7MW respectively. The power cable arrangement is shown in Figure 3-16.

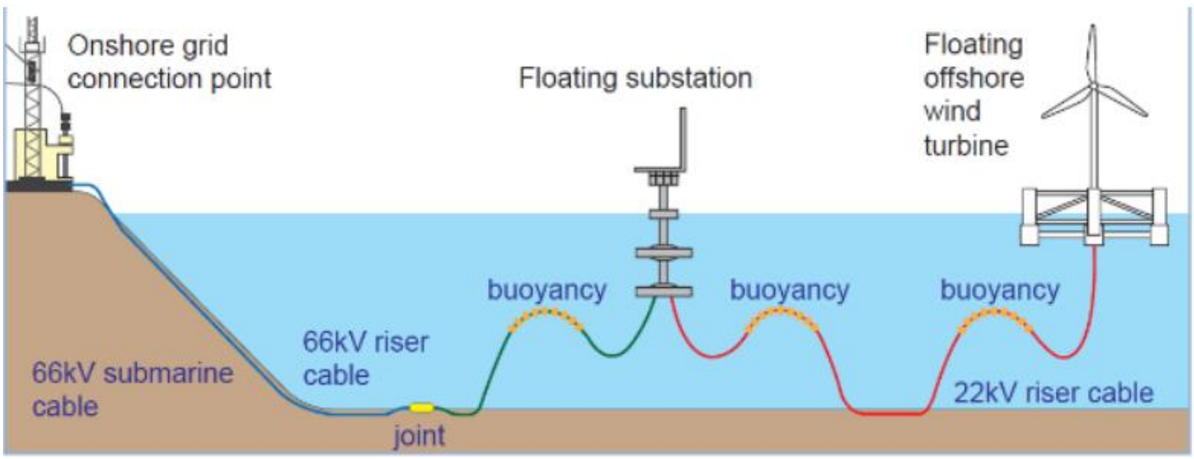


Figure 3-16 Fukushima FORWARD power cable arrangement

3.6 Offshore Wind Offtake Business Case

3.6.1 Participation in the Electricity Market

Prior to the electricity reform, regional monopolies produced and sold electricity directly to consumers with a single electric power company operating as the exclusive supplier in each region. In 1995 Japan began to follow the Western trend of deregulation of the electricity industry, liberalising entry into the electricity generation sector. The liberalization of retail supply for extra-high voltage customers was implemented in 2000 (20kV or more) and the rest in 2016.

The 2011 Great East Japan Earthquake that led to the power shortages and other issues prompted discussions about the ideal configuration and reform of the Japan's electric power system. Three phases of reform were since implemented:

- Phase 1: establishment of an Organization for Cross-regional Coordination of Transmission Operators (OCCTO) to manage supply and demand in different areas (completed in 2015);
- Phase 2: full liberalization of the retail electricity market (achieved 2016);
- Phase 3: separation of the transmission and distribution sector, and elimination of regulated retail rates (achieved 2020).

The METI emphasized the need to increase economic efficiency by promoting greater competition in the electric power sector. Based on these guidelines, new market types have been considered, including a baseload energy market, a capacity market, a balancing market, and a non-fossil value trading market, of which the baseload energy market and the capacity market are already in operation.

Following the liberalization of the retail market, new system licenses were introduced. These licenses were divided into three main categories for generation, transmission and distribution and retailing. As of March 2021, 986 companies had obtained a power generation license with a total installed capacity of 270GW.

Japan Electric Power Exchange (JPEX) was established for the first time in 2003 as a private and voluntary wholesale power exchange, and designated the wholesale electricity market in 2016. In December 2019, the volume of transactions at JPEX accounted more than 30% of all retail sales. The trades available in this market are the spot market, forward market, intra-day market, and over-the-counter trading. The spot market trades 30-minutes of electricity for the next-day, while the intra-day market allows for trading for the unbalances of the spot with at least one hour in advance [52].

In 2018, JPEX established a non-fossil fuel value market where the certificates for FIT electricity are traded to facilitate the purchase of electricity from renewable reources to new market entrants. Additionally, it was also expected that the cost of the environmental value of electricity generated by renewables through the FIT scheme would not be passed on to all customers, but only to those who want this value [52].

Figure 3-17 shows the status of the electricity market in Japan.

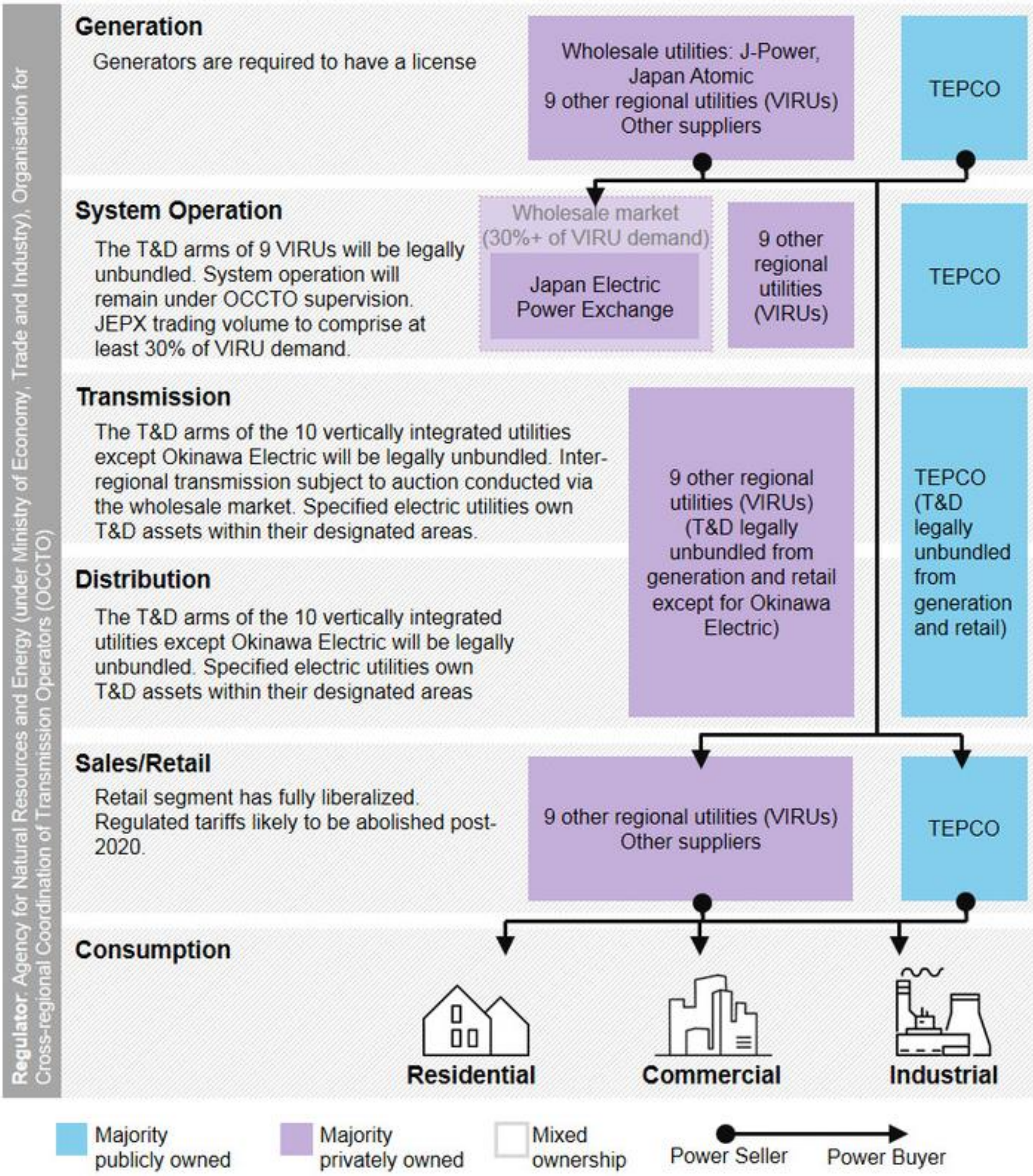
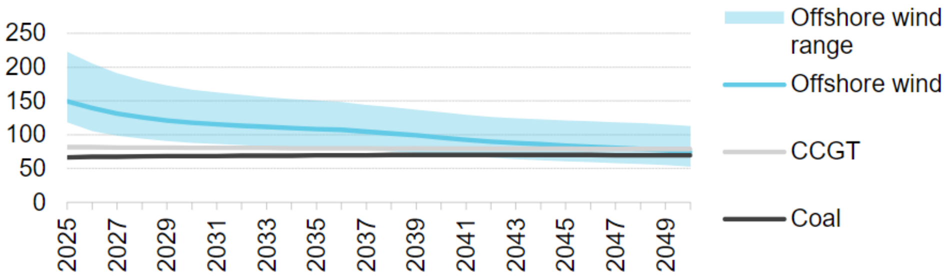


Figure 3-17 Japan electricity market structure [11]

3.6.2 Cost of Offshore Wind Electricity

The LCOE for offshore wind in Japan in 2018 was approximated at USD125/MWh [67]. While this is typically common in the Asia Pacific, it is much higher than the more developed markets in Europe and China. The price is due to a lack of government support for transmission infrastructure, a poor supply chain, administrative challenges related to permitting, and the technology risks. The FIT price for the offshore wind in Japan is currently JPY36,000/MWh (approximately USD250/MWh).

Recent research from BNEF has shown that the LCOE for offshore wind in Japan is expected to fall to 53 - USD113/MWh by 2050, making it competitive against the gas power plants. The forecast is shown in Figure 3-18.



Note: CCGT = combined cycle gas turbine
Source: BloombergNEF

Figure 3-18 Japan offshore wind LCOE forecast

3.6.3 Participation in Provision of Ancillary Services

The Japanese ancillary services are relatively immature compared to other developed economies, such as the US that allows power generators to provide the ancillary services to the Independent System Operators. Since 2014 Japan has been conducting the ancillary demonstration tests. Several electric power companies, such as TEPCO, started offering the services two years after testing, although currently the electric power companies are allowed to provide the services to power generators.

Japan's ancillary services are still undergoing investigations by the committees managed by the OCCTO, which consist of:

- The Coordinating Power and Supply-Demand Balance Evaluation Committee;
- Electricity Resilience Subcommittee;
- Supply-Demand Coordination Market Study Subcommittee;
- Subdivision of Coordinating Power and Wide-Area Procurement Technical Study Working Group;
- Sustainable Demand Fluctuation Study Group.

3.6.4 Private Off Taker of Electricity

In 2021, Japan established the onsite and offsite corporate PPAs for the procurements of renewable electricity. As renewable prices continue to drop, the corporate PPAs, particularly onsite ones, are becoming competitive with the regular tariffs. The Japanese government is implementing new policies to accelerate the corporate PPAs, such as the Feed-in Premium (FiPs), which allows the developers to receive premiums based on the wholesale market prices and retain the environmental attributes of renewables.

Historically, Japan's corporate PPA structure, unlike the direct third-party contracts in other markets, required the ower retailers to facilitate transactions between the developers and buyers. The new implementation of the virtual PPAs has provided more options to the private offshore wind developers. Clean energy buyers are now able to obtain the environmental attributes directly from new clean energy projects (not funded by FiTs) that started their operation after March 2022.

3.6.5 Curtailment

Limited interconnection capacity and difference in system frequencies have been exacerbating the grid congestion and curtailment issues, which appeared more as renewable electricity generating facilities have expanded. The power transmission capacity between the two frequencies network regions in Japan remains limited, and available wind (in the north-west) and solar resources (in the south-east) are far from major demand centers. Grid congestion already exists in the Kyushu and Hokkaido regions, which have experienced rapid deployment of solar PV. So far, only the Kyushu region has faced the issue of renewables curtailment. Curtailment rates of wind and solar PV plants are announced to generators one day ahead of delivery based on day-ahead weather forecasts, because curtailment requires physical presence at the plant site in many cases [52].

According to *the Act on Special Measures Concerning Procurement of Electricity from Renewable Energy Sources by Electricity Utilities*, the electric company can enforce curtailment on the generators. If the electric company provides a written document with the appropriate reasons, no compensation for damages will be provided to the generators. These cases may include:

- When electric supply is stopped due to natural disasters causing damage or to prevent the equipment in the system from breakdown;
- When electric power company stops electric supply due to contact with electrical equipment or the need to rescue someone in the vicinity of the equipment;
- When electric supply needs to be stopped for periodic inspections, temporary inspections, or repairs;
- When electric supply needs to be stopped due to necessary construction to connect third-party electrical equipment to the electrical equipment connected to the network.

3.7 Summary and Recommendations

Japan has significant potential for offshore wind power generation, which remains untapped. Limited development can be attributed to several policy and market challenges. The generation of substantial electricity in Japan's deep oceans necessitates the implementation of floating offshore wind technology. The floating turbine technology in Asia remains relatively under-developed, and it is considered with certain technological risk for some developers.

The permitting processes for the establishment of an offshore wind farm is still nascent in Japan, resulting in administrative challenges and delays in the development timelines. The supply chain for the offshore wind industry is relatively inexperienced, and the businesses are responsible for the entire project development cycle, including the offshore wind transmission lines. To overcome these challenges, it is crucial to grow the offshore wind supply chain, and leverage international experience through successful auctions and cost reduction measures. The Japanese government will require closer cooperation with the experienced international companies, increasing incentives for these companies to invest in the economy [52].

Japan has a strong transmission network expansion plan which is designed to keep pace with ambitious targets for the offshore wind development. The existing plans for new transmission lines connecting different regional distribution networks along with the addition of new substation facilities is promising. This development needs to be accompanied by a variety of smart network technologies to improve system stability, supply reliability and operating efficiency. The development plans include switches with sensors and static automatic voltage regulators, such as STATCOMs as well as smart meters to track the usage, and provide a means for limiting consumption when the balance is tight.

Upgrades to the transmission infrastructure, enhancement of the government support for local supply chain development as well as alleviation of the administrative permitting challenges will overall contribute to reducing to the current high LCOE (USD125/MWh) for the offshore wind projects. While the floating offshore wind technology is still under-developed, promising demonstration projects and increased government investment in this area may help reduce risks and costs for developers, and unleash Japan’s offshore wind potentials in the future.

4 Korea

4.1 Introduction

Korea is aiming to reach carbon neutrality by 2050. The economy's National Assembly passed the Carbon Neutrality and Green Growth Act, in addition to the 2050 goal, requires a reduction of at least 35% in the economy's GHG emissions from the 2018 levels by 2030 [68] .

Korea has a promising OSW resource due to its high latitude and long coastline. The western coast is dominated by shallow water as opposed to the deeper water found along the south and east coasts, including Jeju Island. The east coast also has the highest average wind speed of around 8.5m/s. A deep and steep sloping seabed in this area, however, creates a challenge for the installation of fixed-bottom OSW structures, and as such would be more suited to floating structures.

Taking environmental and technical considerations into account, the estimated OSW power potential in Korea is approximately 33.2GW. Currently, Korea has only 124.5MW of installed OSW capacity, while the government aims to achieve 12GW of OSW capacity by 2030.

4.2 Overview of Offshore Wind Resources

Figure 4-1 shows the heat maps of wind speed and water depth for the offshore portion of Korea. The wind speed at 100m hub height ranges from 3.6m/s and 9.8m/s along the coast, with the highest speed located along the south and southeast coast. In general, the water depths are reasonably shallow, especially over long distances along the southeast. However, very deep waters, such as below -1000m, can be found in further east.

Water depths of up to -70m are generally considered suitable for bottom-fixed foundations, while floating foundations are suited for water depths between -70m to -1,000m. Sea depths beyond -1,000m are considered ultra-deep, and are normally less economically favourable and more complex, thus making development riskier for floating foundation. Based on the wind resource, both fixed and floating foundation OWFs can desirably be deployed along the east coast of Korea (see Figure 4-2).

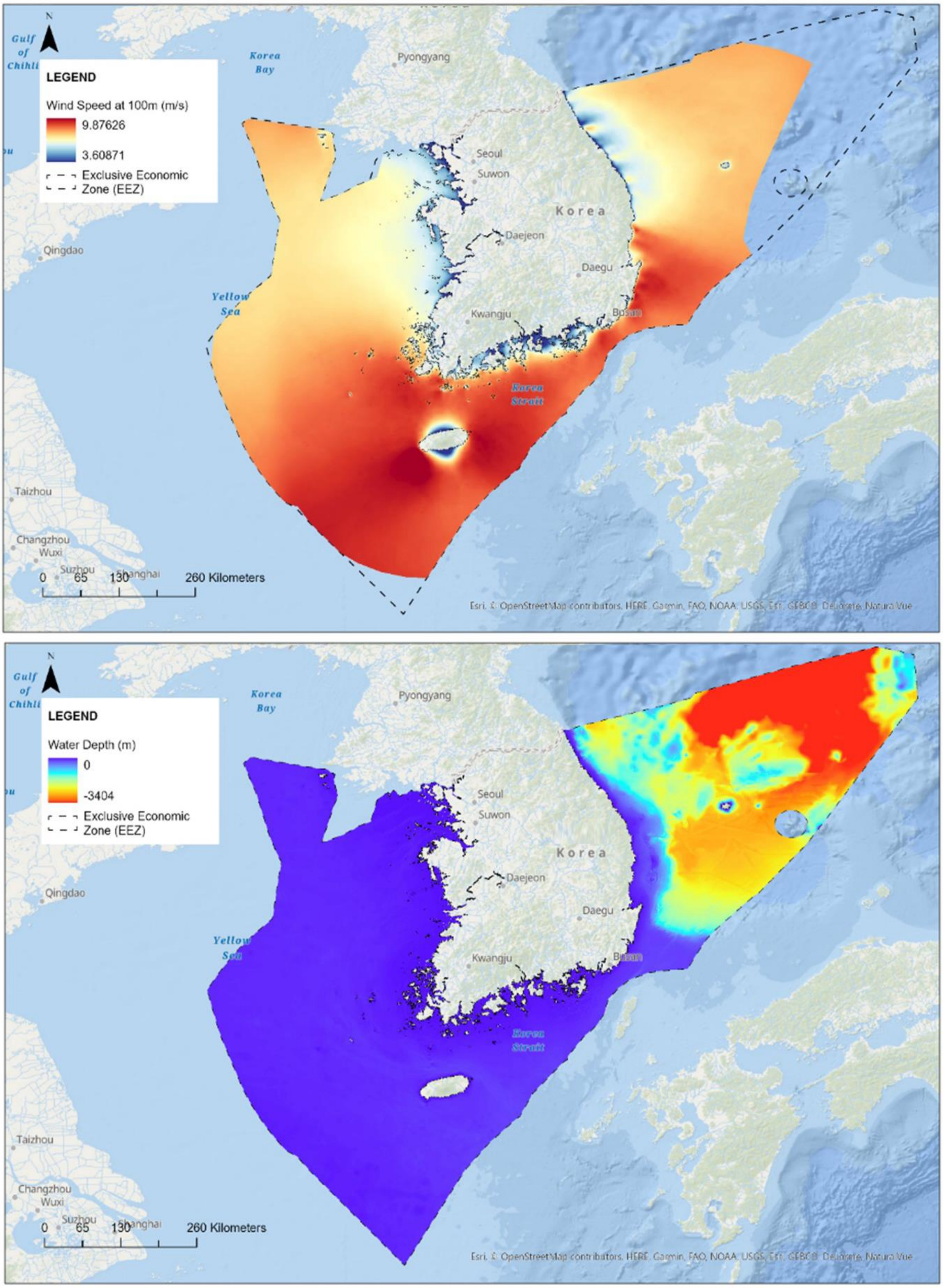


Figure 4-1 Wind speed (top) and water depth (bottom) in Korea's offshore areas

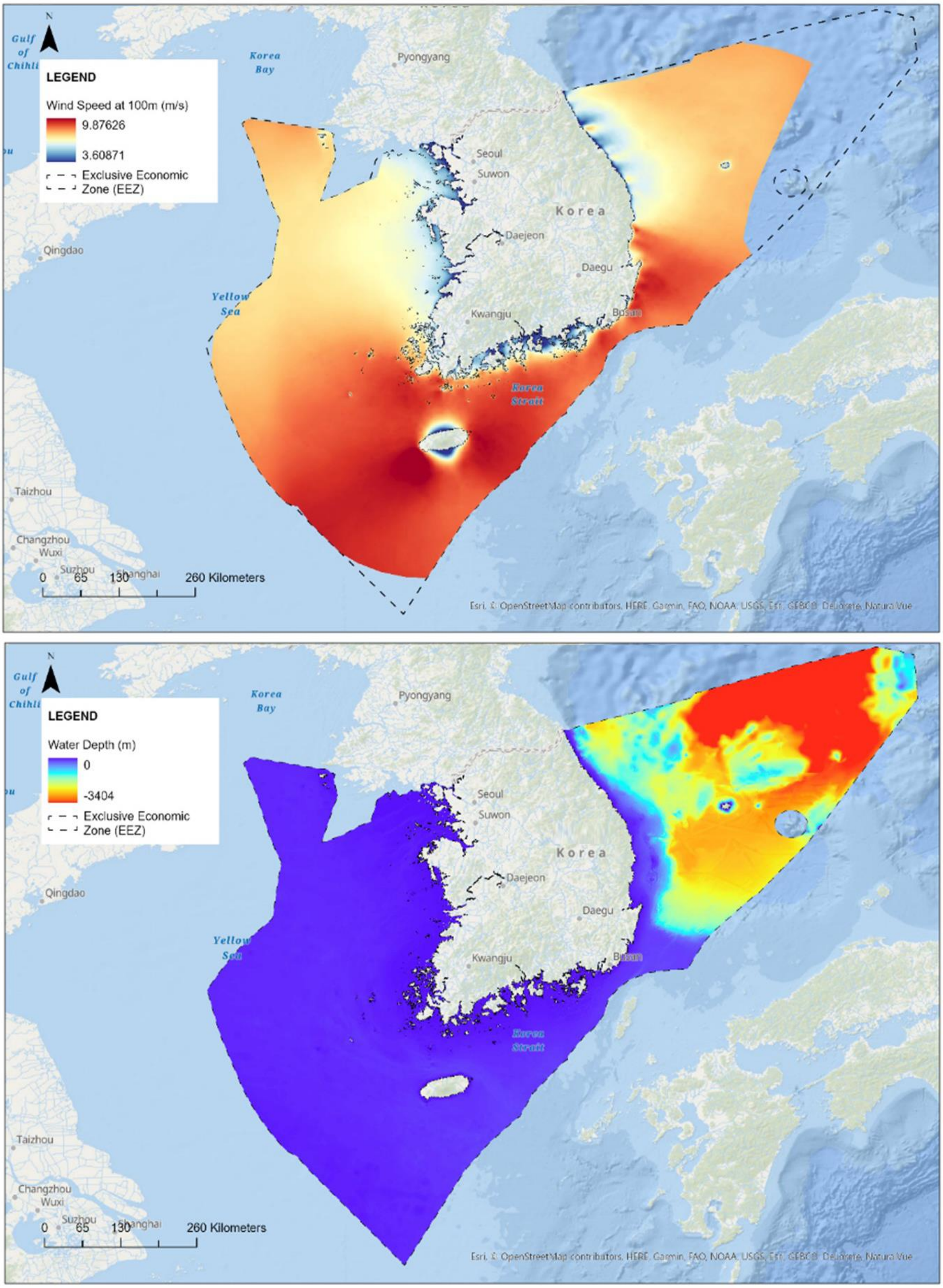


Figure 4-2 Wind speed for fixed foundation water depth 0 to -70m (top) and floating foundation -70 to -1000m (bottom) in Korea

4.3 Energy Sector and Regulatory Mechanism

4.3.1 Structure of Electricity Sector

Korea's installed capacity has practically doubled in recent years, growing from around 70GW in 2008 to almost 140GW in 2021. This growth has been mainly because of the installation of new capacity from coal and gas power plants. In recent years, there has also been a very notable growth in solar power. The installed capacity of wind technology represents a very small percentage compared to other technologies, as can be seen in Figure 4-3.

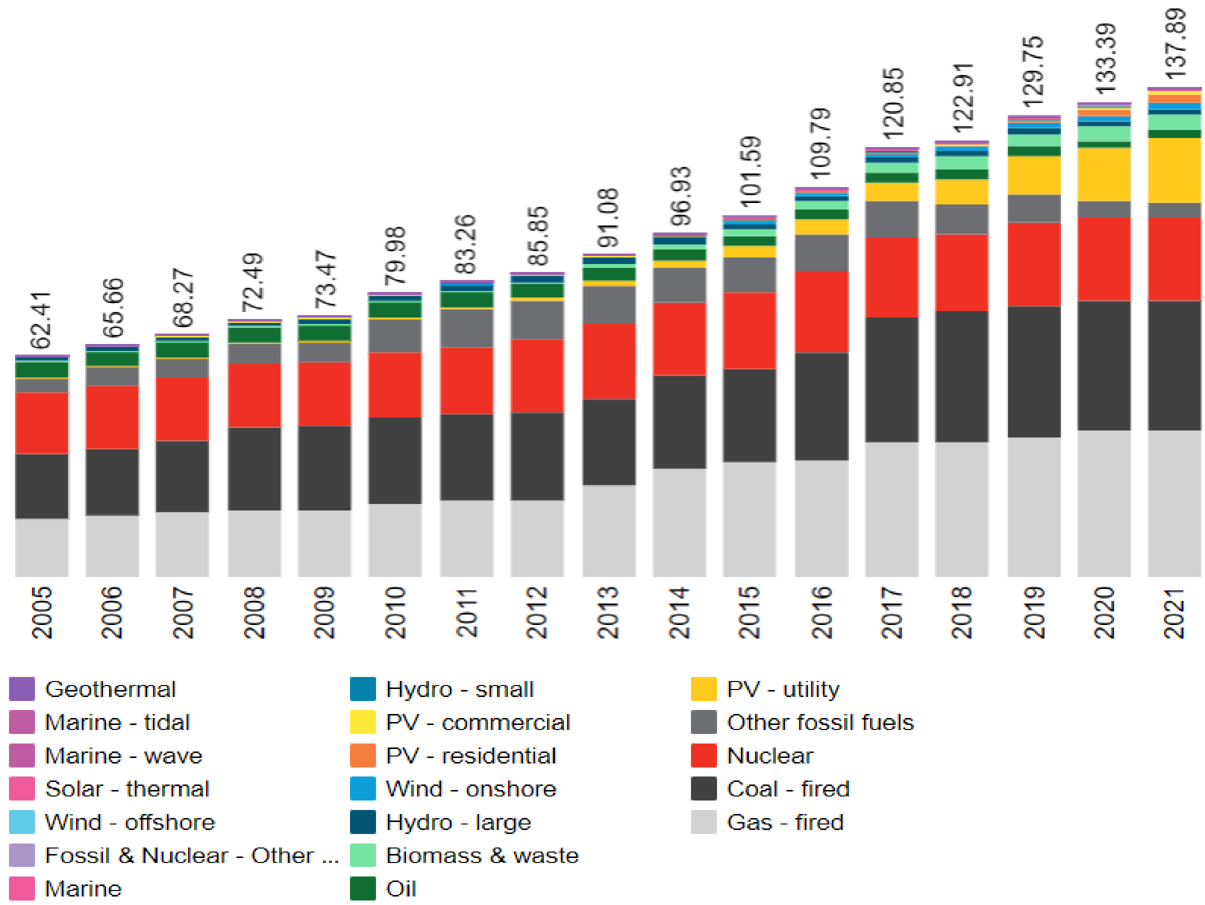


Figure 4-3 Korea's installed capacity (GW) by source 2005-2021 [69]

Electricity generation from fossil fuels rose by 1% from 350TWh in 2015 to 353TWh in 2020, supplying 66% of Korea's electricity in 2020. Over the period, wind and solar power's contribution to the economy's electricity supply increased, while it significantly fell short of the global average of approximately 9.4% renewables generation by 2020. Although the share of coal generation fell from 41% to 36%, gas generation increased to 27% to meet the demand gaps. All other non-fossil fuel generation sources remained unchanged in 2020, with approximately 27% electricity generated by nuclear power [70]. Figure 4-4 represents the evolution of electricity generation by source in Korea since 2006.

After *the Fukushima incident* in Japan, Korea decided to phase out nuclear power generation plants. According to the *8th Power Supply and Demand Plan,* the work started with Gori#1 in June 2017 and is expected to continue until February 2029.

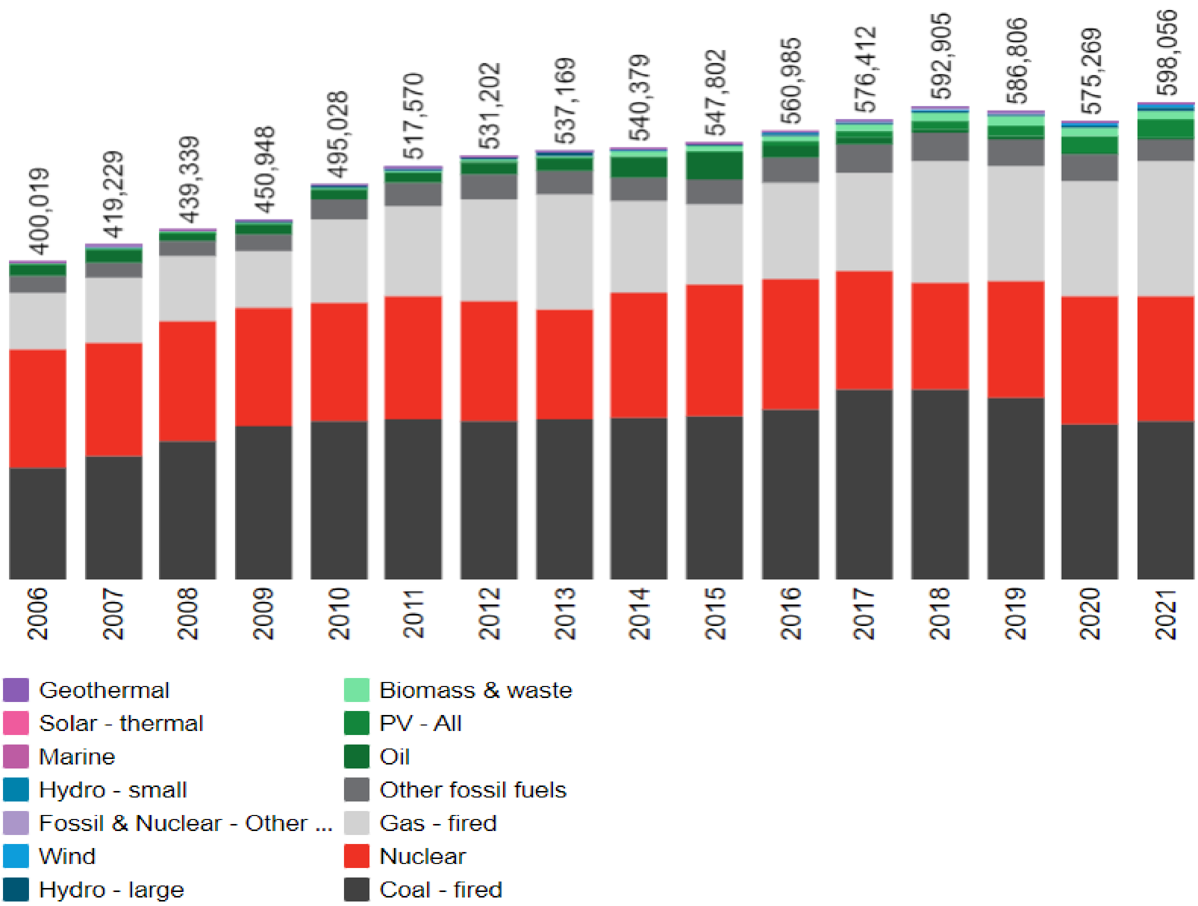


Figure 4-4 Korea’s electricity generation (GWh) by source 2006-2021 [71]

4.3.2 Renewable Energy and Climate Change Policies and Targets

In October 2020, Korea pledged its goal to achieve carbon neutrality emissions by 2050. In 2019, Korea’s emissions accounted for 2% of the global annual emissions, with its power and industrial sectors primarily contributing to the economy’s annual emissions at 37% and 36%, respectively [68].

Before the plans for achieving carbon neutrality, in December 2017, Korea announced the *Renewable Energy 3020 Implementation Plan*, which sets a target to increase the share of renewable energy in the economy’s energy mix from 7.6% to 20% by 2030 [72].

Korea’s energy deployment and supply strategies are based on the *South Korea Energy Masterplan* and *the Basic Plan for Long-term Electricity Supply and Demand (BPLE)*. The most recent, the *3rd Energy Master Plan* focused on a significant reduction in coal-fired power generation and an increase in electricity generation by renewable resources.

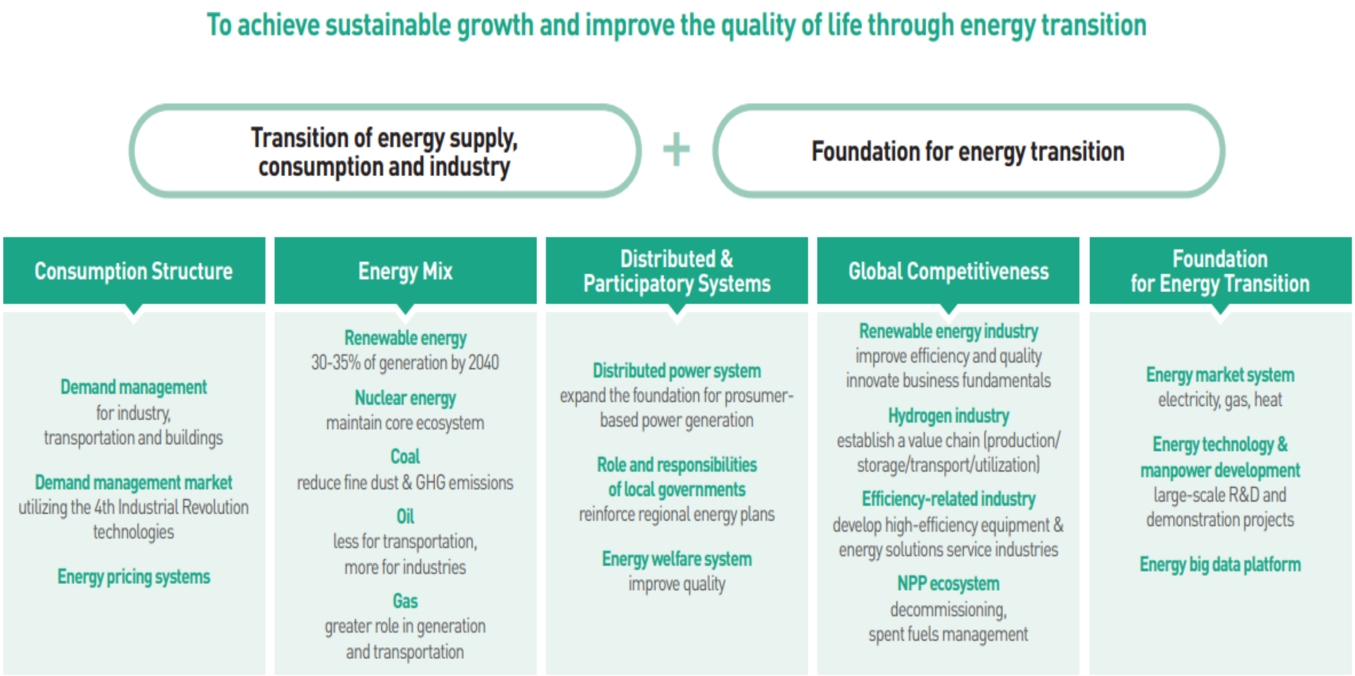


Figure 4-5 Snapshot of Korea's energy masterplan [73]

The 9th Basic Plan for Long-term Electricity Supply and Demand announced in 2020, set a similar renewable energy target of 20.8% in 2030 and to 30-35% by 2040 [74]. It is expected that solar and wind will account for 91% of the total renewable energy mix by 2034. The relevant policies mainly cover the long-term supply and demand forecasts, demand management goals, power generation and transmission development plans, expansion of the distributed power supply, and GHG and fine dust reduction plan.

In mid-2020, the Korean Government established a *Green New Deal*, which supports renewable energy and eco-friendly businesses with KRW73.4 trillion to create 659,000 jobs, build a renewable friendly energy infrastructure by 2025, and help the economy pursue carbon neutrality.

The strong governmental support for renewables is backed up by the policies implemented by the previous President Moon Jae-In. Mr Moon suggested four main topics for renewable energy innovation, including the RPS, development in agricultural areas and buildings, raising energy funds, and demonstrating energy-independent cities. However, Korea's new President Yoon Seok-yeol has expressed plans to revise the economy's decarbonization roadmap. Although there are currently no bills or laws that have been passed regarding this matter, there are speculations that the new president's pro-nuclear policy may affect Korea's renewable energy target.

4.3.3 Offshore Wind Power Development Policies and Targets

The development of OSW projects in Korea started in 2004, but the FiTs for both onshore and offshore wind projects, according to the IEA, were significantly lower (KRW107.6/kWh) than that for solar PV (KRW716.4/kWh). Duo to relative immaturity of the OSW technology in comparison to the PV technology, OSW was less attractive than other renewable energy technology, and the overall development was slow. In 2010, with the advancement in OSW technologies and the release of the Southwest Offshore Wind Project Development

Roadmap, the OSW market gained significant momentum in Korea. After the announcement of the roadmap, Korea launched an OSW development task force with multiple planned projects in the pipeline.

The Renewable Energy 3020 Implementation Plan (RE3020) sets out an ambitious plan to ramp up the OSW power capacity in Korea from 124.5MW to 12GW by 2030. In July 2020, the Ministry of Trade, Industry and Energy (MOTIE), the Ministry of Oceans and Fisheries (MOF), and the Ministry of Environment (MOE) issued the *Plan for Offshore Wind Power Generation in Collaboration with Local Residents and the Fishing Industry(the OSW Collaboration Plan)*. This plan aims to support the installation of 12GW of OSW power generation by 2030 to realize *the Green New Deal*, as well as support Korea in becoming one of the top five OSW power generation economies in the world. The plan includes government and local government-led siting and zoning, simplification of the licensing processes, and preparation and promotion of the OSW projects that are compatible with the livelihoods of the residents and fisheries groups. The plan is expected to create 87,000 new jobs annually, aiming to share the economic benefits of the OSW development with residents and the fishing industry.

There are currently six operational OWFs in Korea, which are summarized in Table 4-1 and located in Figure 4-6.

Table 4-1 Operational OWFs in Korea

Operational OWFs in Korea	Capacity (MW)	Turbine model
Tamra Offshore Wind	30	Doosan 10 x WinDS3000/91 (3MW)
Younggwang Wind	34.5	Unison 15 x U113 (2.3MW)
Southwest Sea Offshore Wind Demonstration Project	60	Doosan 20 x WinDS3000/134 (3MW)
Jeju Haengwon Test Site	3	Doosan 1 x WinDS3000/91 (3MW)
South Jeolla Demonstration Complex	9.6	Unison 1 x U113 (2.3MW) Doosan 1 x WinDS3000/91 (3MW) Unison 1 x U151 (4.3MW)
Doosan's Turbine Test Site in Gunsan	3	Doosan 1 x WinDS3000/91 (3MW)

Based on the *OSW Collaboration Plan*, Korea aims to prioritize the development of OWFs in the five regions highlighted in Figure 4-7. These areas include Incheon, South Jeolla, North Jeolla, Ulsan, and Jeju Islands. The regions highlighted in green are the ones that have the most attraction from both foreign and domestic developers.

On the provincial level, Jeju Island has an ambitious plan to be a carbon-free island by 2030 and to have several offshore windfarms planned for installation in the coming years with total capacity of 2GW. This is one of the reasons why several pilot projects have been developed in the area. Currently, in addition to the 30MW Tamra offshore wind project, five offshore wind projects have been planned around Jeju, with a total capacity of 525MW.

Currently, the key challenges for the local sector are lack of a track record in large-scale commercial offshore wind sites and the management of local communities. Despite these challenges, the market enjoys favourable conditions, with good topography, attractive wind resources along the coast, well established infrastructure, and the supports from the Korea government.

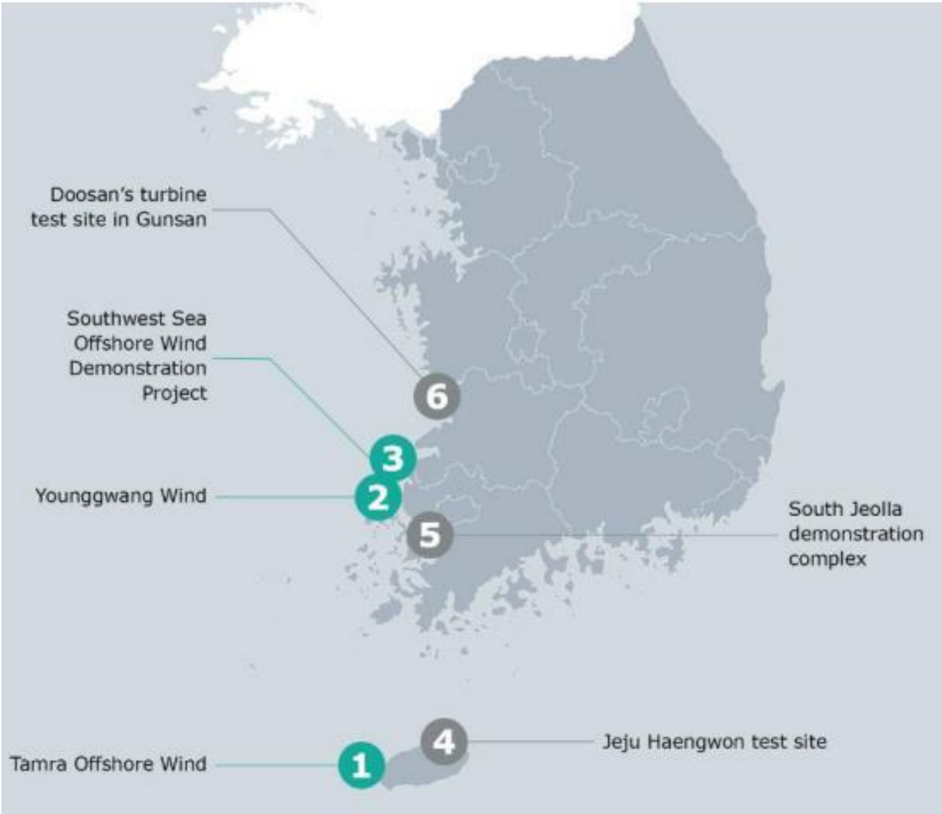


Figure 4-6 Location of operational OWFs in Korea [75]

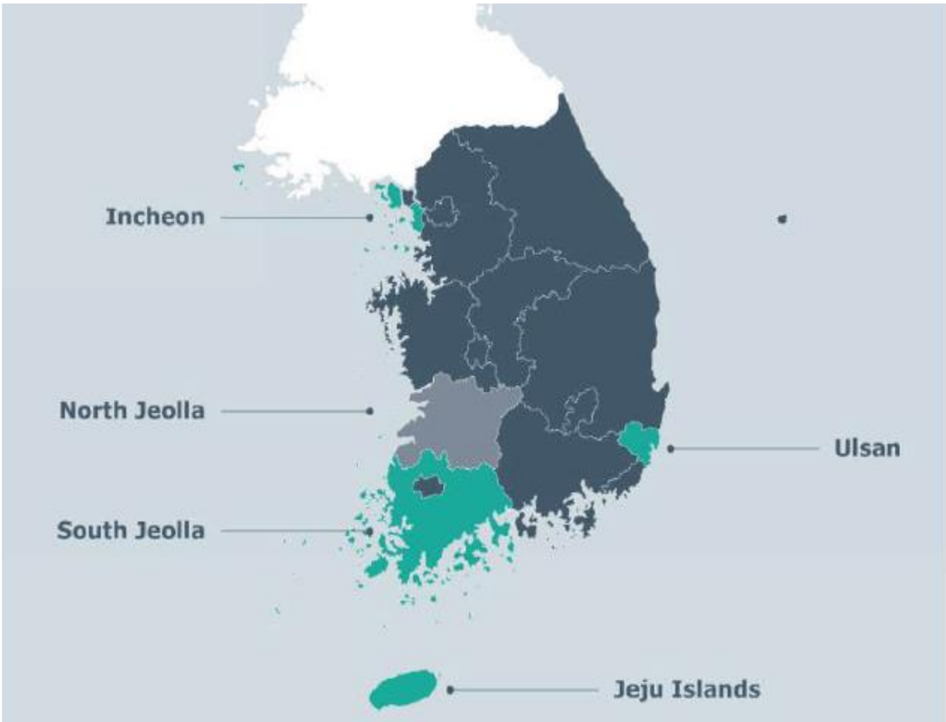


Figure 4-7 Promotion areas for OSW development [75]

4.3.4 Renewable Energy and Offshore Wind Regulatory Support Mechanism

To create a competitive market for the renewable energy sector and promote the uptake of renewable electricity in Korea, the member economy government replaced the FiT system with the RPS scheme in 2012. Under this scheme, large generators are obliged to produce a minimum amount of electricity generated from renewable energy resources or purchase the Renewable Energy Certificates (RECs) using a fixed-price contract regime administered by the New and Renewable Energy Center from the Korea Electric Power Exchange (KPX).

Specifically, the RPS requires 21 government-owned and private companies with installed capacity of 500MW or larger to produce a minimum portion of their power using new and renewable energy sources, with the yearly RPS target designed to rise annually from 2012 to 2023. Currently, the RPS mandatory supply ratio is 10%, and is targeted to be expanded to 25% in 2030.

In the current RPS scheme, power companies purchase electricity produced by offshore wind developers at a fixed price. The fixed price is derived from the sum of wholesale System Marginal Price (SMP) or wholesale electricity price and REC price. Thus, in return, under the RPS and REC schemes, the total income for power generation from offshore wind energy is a combination of SMP of electricity and the sale of REC.

REC uses a 1MWh as the reference unit. The REC weight value, which is assigned based on the technology used, location and installed capacity has been adjusted twice since the beginning of the RPS, to reflect the superiority of offshore wind compared to other renewable energy resources in Korea, including solar and onshore wind, in terms of economic efficiency and meeting policy goals. For offshore wind, the weight factors are estimated based on the straight distance between the closest coastline with a substation owned and operated by the Korea Electric Power Corporation (KEPCO) and the center point of wind turbine generator (WTG) closest to the coastline. The weight factors range between 2.0 and 2.5 or more. The weighting scheme is summarized in Figure 4-8.

Together with *the OSW Collaboration Plan* mentioned in section 4.3.3, Korea launched three initiatives as follow [76]:

- Government-led Siting and Streamlined Permitting: Under this government-led siting campaign, Korea aims to publish a marine cadastral map to propose potential offshore wind consideration zones and conduct feasibility studies therein. The government will also establish a one-stop-shop to grant all required permits and approvals for OWFs, to streamline the permitting processes for the development of OWFs.

- Encouraging Stakeholder Acceptance: Korea devised a profit-sharing model for implementation by the local governments for OWFs to encourage stakeholder acceptance. Furthermore, the MOTIE will develop demonstration projects to show the feasibility of coexistence for both OWFs and the fisheries industry. The MOTIE will also require site consulting by experts and public consultations prior to issuance of the Electric Business License (EBL) for OWFs. To minimize the impact of the OSW project to the environment, the Korea government has also introduced various measures covering all stages of the project life cycle, which include restoration performance security.

category	REC weighting	Energy source and criteria	
		Facility type	Criteria
Solar PV	1.2	Facility installed on general site	Less than 100kW
	1.0		More than 100kW
	0.7		More than 3,000kW
	1.5	Facility installed on existing buildings	Less than 3,000kW
	1.0		More than 3,000kW
	1.5	Facilities floating on the water	
Others	0.25	IGCCC, Byproduct gas	
	0.5	Waste, landfill gas	
	1.0	Hydro, onshore wind, bioenergy, RDF, waste gasification, tidal power (with embankment)	
	1.5	Wood biomass, offshore wind (grid connection less than 5km)	
	2.0	Fuel cell, tidal power	
	2.0	Offshore wind (grid connection longer than 5km), geothermal, tidal power (no embankment)	Fixed
	1.0~2.5		Variable
	5.5	ESS (connected to wind power)	'15
	5.0		'16
	4.5		'17

Figure 4-8 REC weighting scheme [42]

- Leveraging Large-Scale Projects to Enhance Industrial Competitiveness: The Korea government aims to expedite the construction of and prioritize the grid connection for large-scale OWFs. The MOTIE will also support the growth of secondary offshore wind infrastructure sectors, such as support docks, demonstration projects, domestic training, and domestic manufacturing facilities. Additionally, financial guarantees and low-interest loans would be given to developers and the Original Equipment Manufacturers (OEMs) that demonstrate low carbon emissions.

4.4 Offshore Wind Development Procedure and Stakeholder Engagement

4.4.1 Stakeholders and Their Responsibilities

The electricity market in Korea is primarily regulated by the *Electricity Business Act (EBA)* or *the Electric Utility Act*, including the subordinate presidential and ministerial decrees issued under them. The EBA covers the granting of licences to conduct prescribed electricity business, including generation, transmission, distribution, and retail businesses, consumer protection, prohibition of unfair trade practices, wholesale electricity market, the constitution and responsibilities of the electricity regulatory body, and the safety management of electricity equipment.

The main regulatory authority responsible for policy in the Korean electricity sector is the MOTIE. MOTIE's roles and responsibilities in its regulatory capacity include granting EBLs; registration of small-scale electricity brokerage businesses and electric vehicle charging businesses; approval of business transfers, mergers, split-offs and changes in the control of electricity business enterprises; cancellation and suspension of EBLs and imposition of sanctions or other disciplinary measures; approval of various tariffs relating to transmission lines, distribution networks and retail sales; regulating wholesale electricity prices; approval of the market rules; and approval of vesting contracts between generators and wholesalers.

The KPX operates the electricity market and the power system. It manages real-time dispatch as well as supply and demand monitoring to manage blackouts and brownouts. The KPX also supports Korea's green energy policies and plans, such as the basic plan for long term electricity supply and demand. KPX is responsible for matching demand and supply, and load balancing in the wholesale electricity market.

The Electricity Regulatory Commission (ERC) was established under the EBA and operated under the MOTIE. The REC's primary role includes licensing electricity companies, protecting the rights and interests of consumers, and monitoring anti-trust activities through the supervision of the operation of the electricity markets and the power system.

Other relevant regulatory bodies include the MOE, which is responsible for overall environmental protection, and the Ministry of Employment and Labour, which oversees overall labour issues, including occupational safety and health. The Electric Policy Council of MOTIE reviews the draft Basic Plans.

In general, the electricity market in Korea can be divided into electricity generation, transmission, distribution, and supply. Market stakeholders are summarized graphically in Figure 4-9.

In Korea, the six Generation Companies(GenCos), which are wholly owned subsidiaries of KEPCO, dominate the electricity generation. The GenCos accounted for over 70% of the total installed generation capacity in Korea. In addition to the GenCos, there are 17 independent power producers (IPPs), which do not include renewable energy producers and community electricity business companies.

KEPCO has a monopoly over transmission, distribution, and retail of electricity in Korea. Thus, the transmission and distribution facilities are constructed and operated by KEPCO, and the company oversees economy-wide grid connection. Since KEPCO is the sole retailer of electricity in Korea, it is also the sole wholesale purchaser of electricity in Korea. However, minor exceptions apply to the community electricity business companies that generate, distribute and supply electricity directly to the specific community or the customers in industrial complexes.

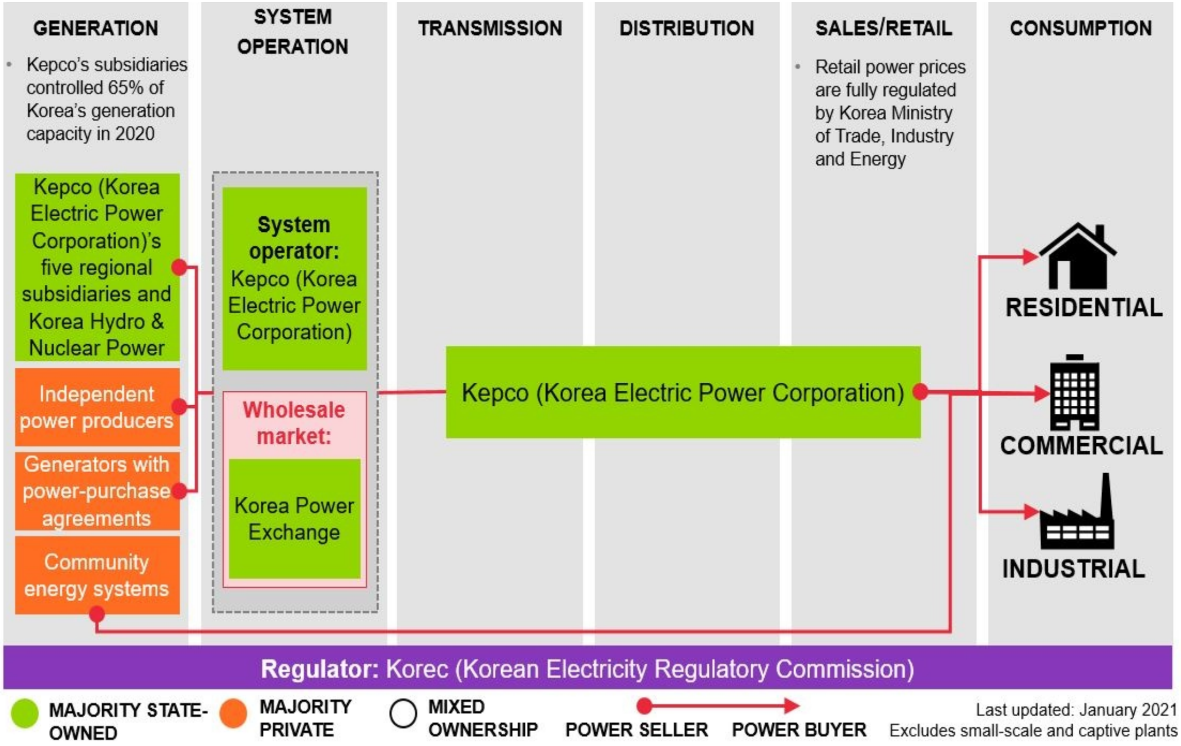


Figure 4-9 Electricity market in Korea [71]

4.4.2 Offshore Wind Approval Procedures

The primary legislative instruments for the renewable energy sector in Korea are the EBA and the Renewable Energy Act. The new Marine Spatial Planning and Management Act is another key legislative framework for the new OSW projects.

A wide range of other laws and regulations are relevant to OSW projects. These include:

- National Land Planning and Utilization Act;
- Public Waters Management and Reclamation Act;
- Electric Power Source Development Promotion Act;
- Environmental Impact Assessment Act;
- Act on Allocation and Trading of GHG Emission Permits;
- Rules on Operation of the Electricity Market, etc.

Despite Korea's attempt to streamline the site identification and permitting processes, the project developer has control over and is expected to conduct all project development activities, including site selection, site verification, and application for all approvals and permissions.

The permitting and regulatory processes is summarized in Figure 4-10.

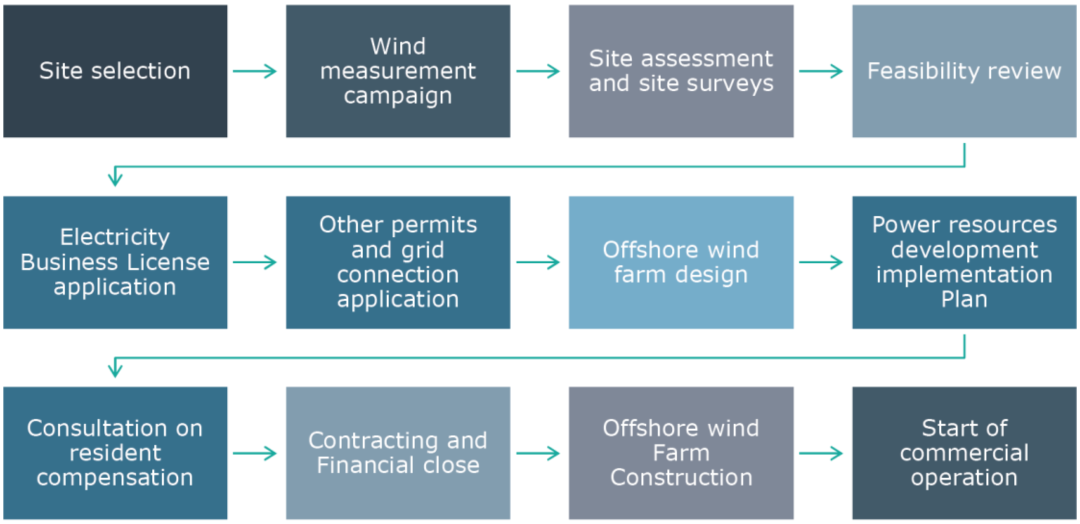


Figure 4-10 Government-led site identification and permitting processes

The permitting process for developing an offshore wind project in Korea involves several steps, which typically require:

- The issuance of an electricity generation business license;
- Conducting environmental-related assessments and issuance of an environmental impact approval;
- The issuance of a building permit / development permit;
- The approval / reporting of the electricity utilities construction plan;
- Approvals and permits during the construction phase;
- Pre-utilization / pre-operation inspection;
- Registration process with KPX;
- Facility certification / utilization approval;
- Filing of business commencement report.

The permitting process for the Jeju Island differs from the central government policy and its development procedures. The local government of the Jeju Island has created the Public Management System of Wind Resources clause. Through this clause, the island launched Jeju Energy Corporation, a local governmental agency involved in selecting and developing offshore wind farm projects.

To conduct a power generation business over 3MW in Korea, an EBL must be obtained from the MOTIE. To obtain the EBL, the business should provide the wind resource measurement data for at least one year, Wind Resource Assessment (WRA) reports, obtain residents consent, and submit a plan for grid connection to the power system. As of the end of April 2022, a total of 60 offshore wind farm projects totalling 18.13GW have obtained the EBL in Korea, with over 70% of these projects concentrated in the Jeonnam and Ulsan regions. Although the costs associated with gaining approvals and permits vary, the typical approximate costs and timeframe are summarized in Table 4-2 and are further broken down in Table 4-3.

Table 4-2 Typical costs and timeframe for each step in obtaining approval and permits [11]

Process	Responsible Bureau/ Department	Approx. costs (KRW)	Approx. timeframe
The issuance of an electricity generation business license	Ministry of Trade, Industry and Energy / Mayor and Governor	180,000,000	20 months
Conducting environmental-related assessments and issuance of an environmental impact approval	MOE	5,340,000,000	28 months
The issuance of a building permit / development permit	Municipal administrative agencies	240,000,000	14 months
The approval / reporting of the electricity utilities construction plan	MOTIE/ Mayor and Governor	Unknown	6 months
Approvals and permits during the construction phase	Multiple agencies and ministries	Unknown	Various
Pre-utilization inspection	Korea Electrical Safety Corporation	Unknown	6 months
Registration process with KPX	KPX	Unknown	1 month
Facility certification / utilization approval	Municipal administrative agencies	Unknown	1 month
Filing of business commencement report	MOTIE	Unknown	3 months

Table 4-3 Typical cost breakdown for each step in the pre-construction permitting process

Process	Outcome	Approx. costs (KRW)
Permission For Lidar	The issuance of an electricity generation business license	80,000,000
Electricity Business License		100,000,000
Military & Radar Interference Study	Conducting environmental-related assessments and issuance of an environmental impact approval	400,000,000
Cultural Property Investigation		300,000,000
Maritime Traffic Safety Study		300,000,000
Environmental Impact Assessment		1,500,000,000
Consultation On Utilization of Sea Area		200,000,000
Prior Examination of Factors Influencing Natural Hazards		90,000,000
Consultation On Sea Area Compatibility		150,000,000
Permission To Occupy Sea Space		100,000,000
Permission For Port Construction by Non-port Authority		100,000,000
Fishery Damage Influence Investigation		200,000,000
Fishery Damage Investigation		2,000,000,000
Development Permission	The issuance of a building permit / development permit	50,000,000
Substation Construction Permit		70,000,000
Road/Land Usage Permission		50,000,000
Electricity Facility Usage Application		70,000,000
Total Costs		**5,760,000,000**

Some projects have historically experienced time lag of between 8 to 11 years from gaining the EBL to commercial operation date (COD). The development timeline from EBL to COD of four projects in Korea is shown in Figure 4-11.

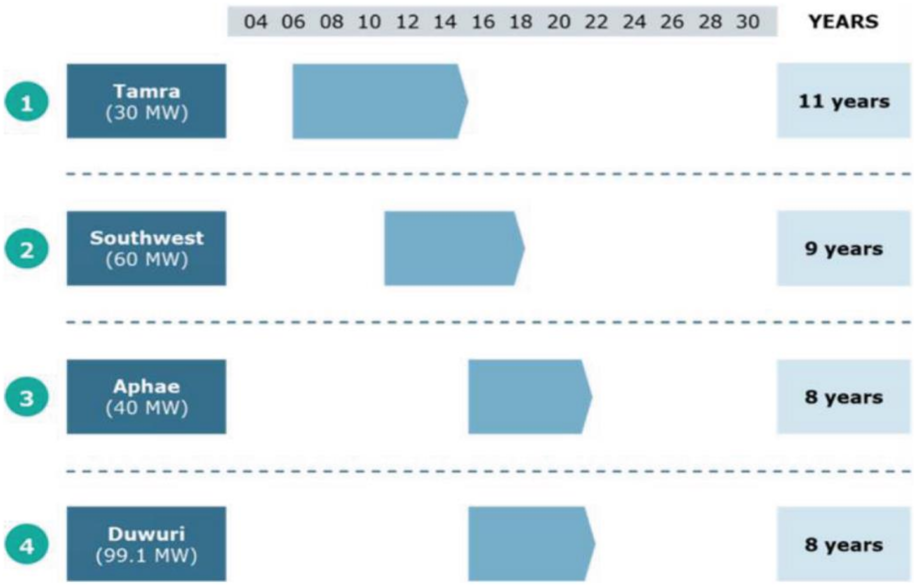


Figure 4-11 Sample development timeline from acquiring EBL to COD

4.5 Offshore Wind Grid Connection

4.5.1 Electricity Utility Structure and Grid Connection Procedure

Korea's electricity system is geopolitically isolated. The electricity produced by the six GenCos and the private generators are transmitted over high voltage lines to the central distribution station of each region, and from there to the substations. Korea's power system voltage levels are relatively high at 765kV, 345kV, 154kV, and 22.9kV. This contributes to higher reliability of the power system and reduces the transmission losses. In 2018, Korea's transmission loss was 1.59% [68].

The connection structure of OWFs in Korea is very similar to that of other economies, and only the connection voltage to the transmission system changes. The wind turbines are connected to each other forming arrays with a voltage that will depend on the manufacturer, some local manufacturers use 22.9kV while global manufacturers use 66kV as a standard. Depending on the distance to the shore, the arrays can be connected directly to an onshore substation at the inter array voltage or can be exported at a higher voltage through an offshore grid voltage, which in the case of Korea is 154kV, 345kV or 765kV. In addition, reactive power, and voltage compensation equipment such as reactors, capacitors, Static Synchronous Compensator(STATCOM), Static Var Compensator (SVC) or harmonic filters will be installed in any of the wind farm substations to comply with the requirements of the grid code.

To make the connection to one of the high voltage transmission networks, certain characteristics must be met [77]:

1) 154kV transmission lines:

   a. Generators over 500MW shall connect using 2 lines using ASCR410 mm2 x2B wires or equivalent.

2) Over 354kV transmission lines:

   a. Generators between 500MW and 1GW may connect using 2 lines with ASCR480 mm2 x2B wires or equivalent;
   b. Generators between 1GW and 2GW shall connect using 2 lines with ASCR480 mm2 x4B wires or equivalent;
   c. Generators between 2GW and 3GW shall connect using 2 lines with STACIR480 mm2 x4B wires or equivalent;
   d. Generators over 3GW must connect using 2 or more 765kV lines with ASCR480 mm2 x6B wires or equivalent.

The grid connection code for Korea is set and regularly updated by KEPCO. The code describes the technical requirements and specifications to connect to the KEPCO grid systems. The code also covers standards and requirements on renewable energy generators. For power transmission equipment, KEPCO specifies the following performance standards [78] [79]:

- Remain connected in the event of an instantaneous voltage drop (FRT capability);
- Supply or absorb reactive power according to the active power output. Power factor 0.95 lag-lead;
- Continuous operation within the range of 58.5-61.5Hz, being able to operate for at least 20 seconds within the range of 58.5-57.5Hz;
- Ability to reduce active power to 20% within 5 seconds and have an increase/decrease rate to within 10%/min;
- Continuous operation within up to 10% of the nominal voltage and be able to perform a reactive power control method;
- Being equipped with real-time communication and remote control to monitor status and power output.

When conducting offshore wind power development in Korea, the power producer should estimate the amount of power to be generated and consult with the relevant KEPCO Regional Headquarters in advance to determine whether the expected power generation can be accommodated in the related grid system. The power producer can have preliminary discussions verbally, but for an accurate review, the power producer must contact the KEPCO Regional Headquarters through an official letter [80]. For connecting new generators to the grid, the following chart needs to be considered:

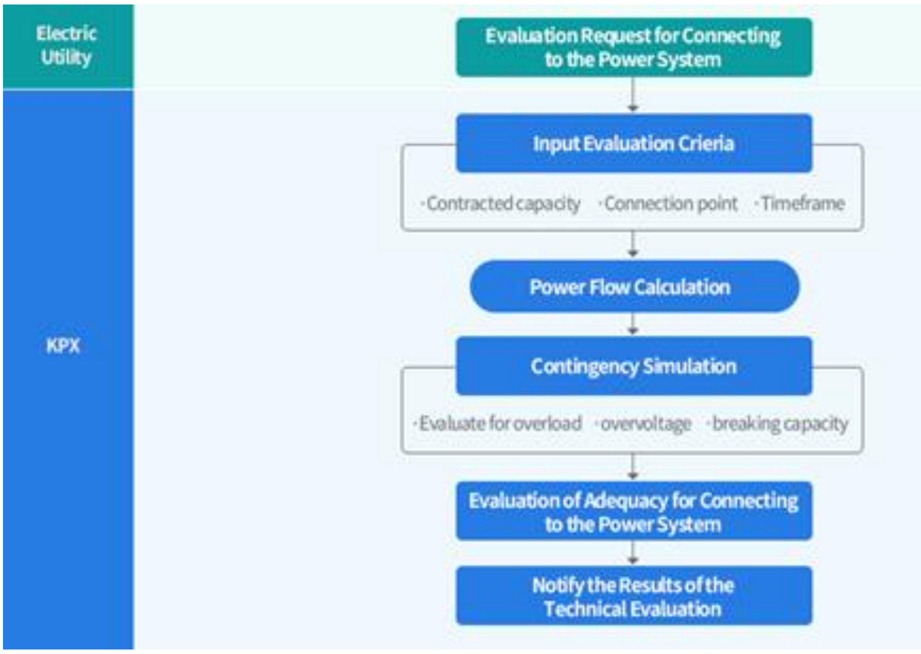


Figure 4-12 New equipment grid connection procedure [81]

Anyone wishing to start a generation business must obtain a generation business license from MOTIE. To obtain a license, an application form must be submitted to the MOTIE, and the Minister must submit to the ERC for review in order to authorize the license or a license change. The following figure shows the process to obtain the license.

The main documents for applying for a generation business are the following [82]:

- Business plan;
- Calculation of expected annual business profit and loss for 5 years after business start-up;
- 1/50000 topographic map specifying the boundaries of the project area.

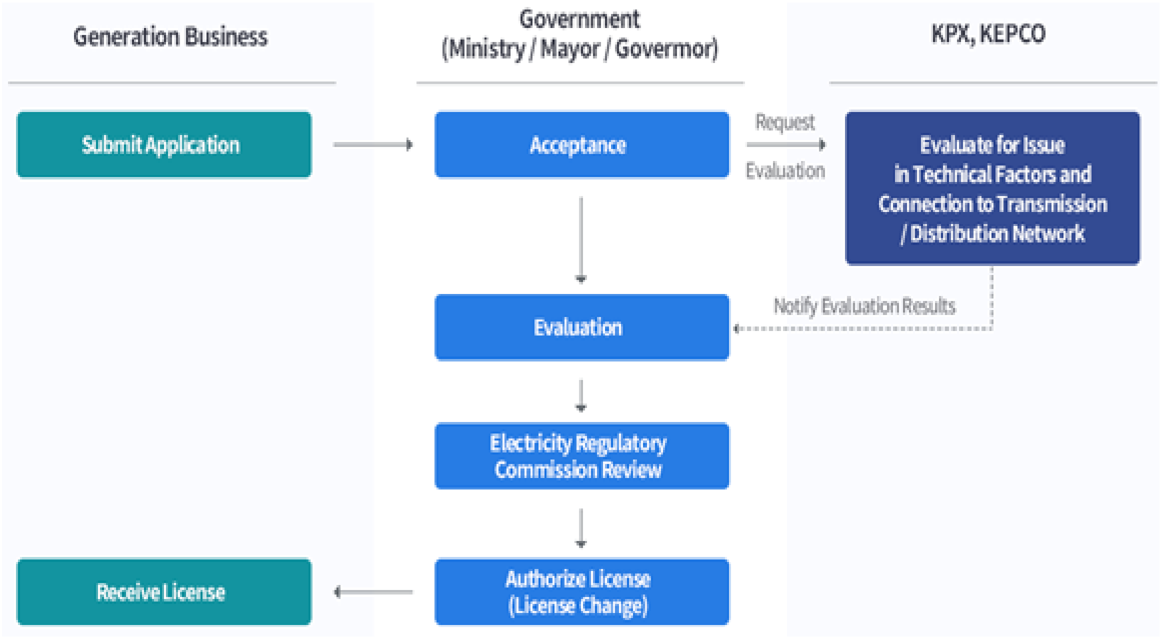


Figure 4-13 Generation business license application [82]

4.5.2 Transmission Network and Expansion Plan

Korea's transmission expansion plan is designed to span a 15-year period. The most recent plan is based on the goals outlined in *the 9th BPLE*, and includes projects aimed at reinforcing transmission infrastructure to accommodate the expected demand growth, and increased construction of decentralized new and renewable energy generation facilities. Currently, most of the renewable energy generation is in rural mountainous areas, requiring additional transmission lines to carry the electricity to the load centers [80].

Significant upgrades of the transmission system are expected to be necessary on Korea's west coast to manage future planned offshore wind facilities, particularly to prevent further grid congestion from the northward power flow. Figure 4-14 gives an indication of some of the planned upgrades.

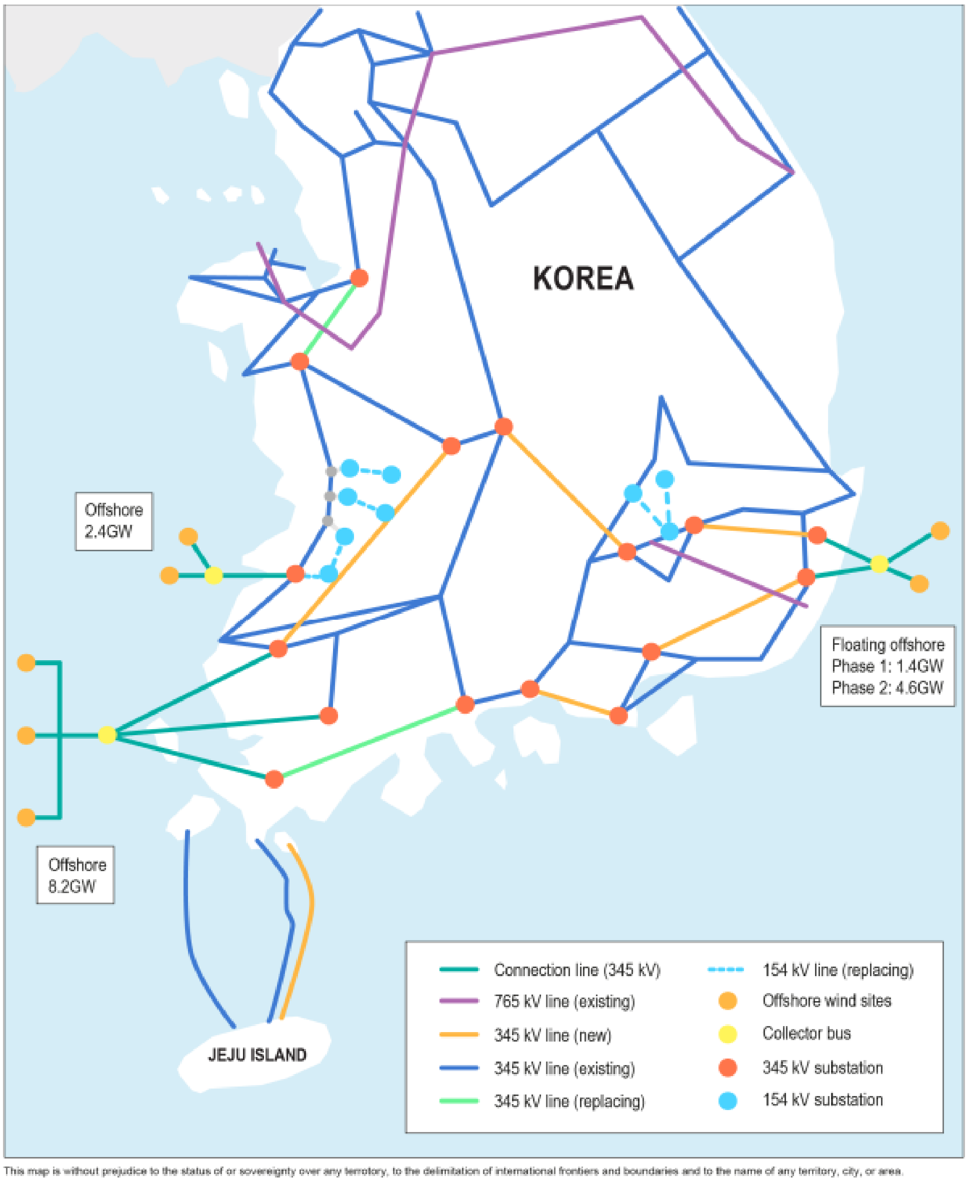


Figure 4-14 Planned sites for OSFs and expected grid reinforcement in Korea [80]

According to *the 9th BPLE*, main transmission lines are being established to improve the reliability of the system and provide a stable power supply. The upgrade of the electrical lines has foreseen the installation of new OSFs in Korea's coastal zones, including the island of Jeju. Table 4-4 shows the details of the projected transmission lines [83].

Since *the 8th BPLE* was launched, the capacity of the East Coast line has increased by 1.5GW through the introduction of a flexible transmission system when the new transmission lines are built. Additionally, the distribution infrastructure is also being reinforced to facilitate the integration of 8GW of renewable generation capacity through the installation of 1 substation, 59 transformers and 118 distribution lines. Table 4-5 shows the improvements being made to facilitate the connection of generators in the areas with renewable energy focus, which affect the installation of new OWFs in the coastal areas and the Jeju Island.

Table 4-4 Transmission line projects projected in the 9th BPLE [83]

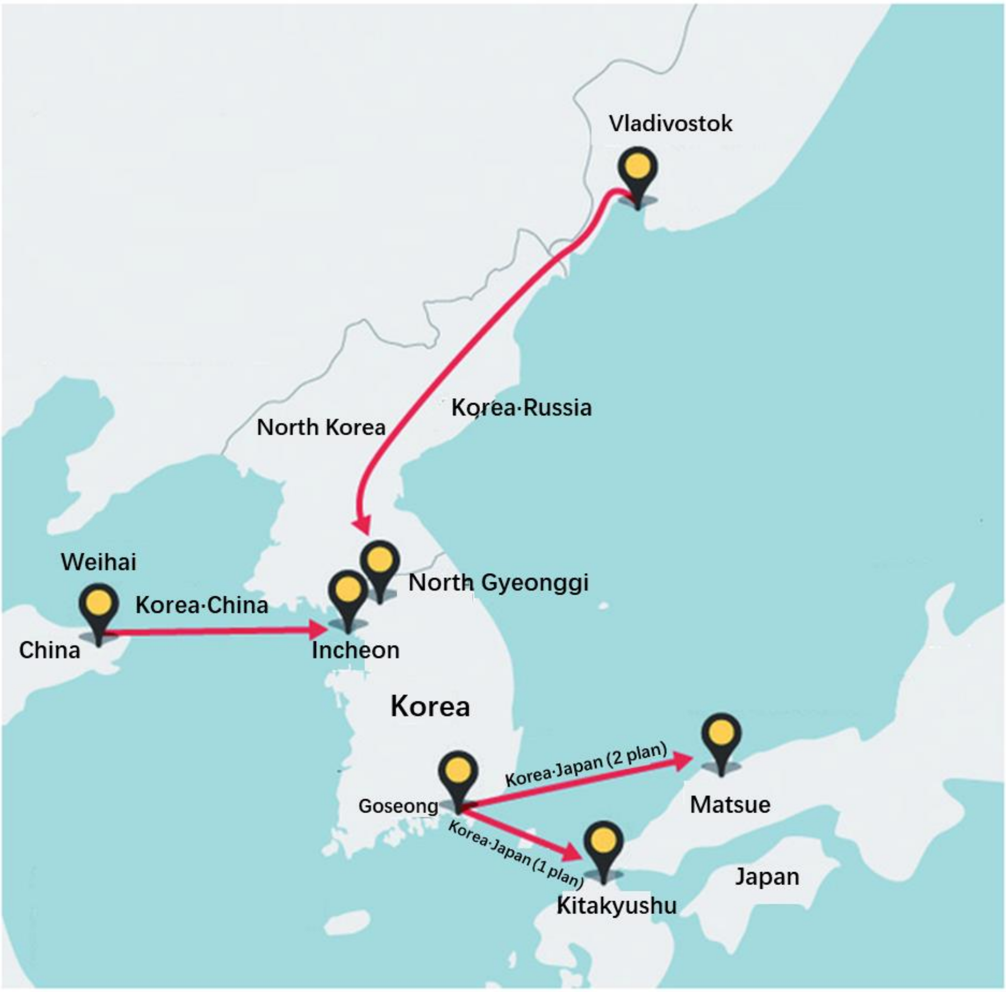
Section	Voltage	Expected date
Bukdangjin - Godeok #1	500kV (DC)	2020 (commissioned)
Bukdangjin - Godeok #2	500kV (DC)	2021 (delayed)
East Coast – Singapyeong	500kV (DC)	2025
East Coast – Metropolitan area	500kV (DC)	2026
Gwangyang C/C – Yeotsu T/P	345kV (AC)	2021 (commissioned)
Gwangju/Jeonnam	345kV (AC)	2022
Dongducheon C/C - Yangju	345kV (AC)	2022
Galsan - Shin Gwangmyeong	345kV (AC)	2022
Bukdangjin - Sintangjeong	345kV (AC)	2022
Godeok - Seoanseong	345kV (AC)	2023
Dangjin T/P - Sinsongsan	345kV (AC)	2023
Dongjeju - Wando	150kV (DC)	2022

Table 4-5 Grid reinforcement in renewable energy development zones [83]

Region	Current capacity (GW)	Expected capacity (GW)	Upgrade
Jeju	0.6	1.7	3rd HVDC transmission line (2022)
Gangwon	1.5	7.2	East Coast – Metropolitan HVDC (2026)
Jeonnam (Shinnan)	0.2	3.1	154kV Transmission line (2026)

Korea has an isolated power system, meaning that there are currently no interconnections with neighbouring economies. In 2016 Korea engaged with the Asia Super Grid initiative, a long-term project to build interconnections with China, Japan, and the Russian Federation. The proposed interconnection is expected to bolster the economies' decarbonization efforts and energy security [80].

Regarding the status of this project, China partnered with the government-owned power company, the National Outlook Corporation to sign *the Joint Development Agreement* (JDA) in 2019 to build a 2.4GW grid of about 330km. Japan's SoftBank Sawa completed a preliminary feasibility study for a 2.4GW, 340km network, and has received positive financial guarantees. The Russian Federation signed a Memorandum of Understanding with Rossetti to conduct a preliminary feasibility study on a 3GW, approximately 1,000km power line and is conducting joint research [83]. Table 4-6 shows the details of the planned connections.



Source: [84] Seoul Economy, 05 08 2021.

Figure 4-15 Korea's planned interconnections of the Asian Super Grid

Table 4-6 Projected connections of the Asian Super Grid [83]

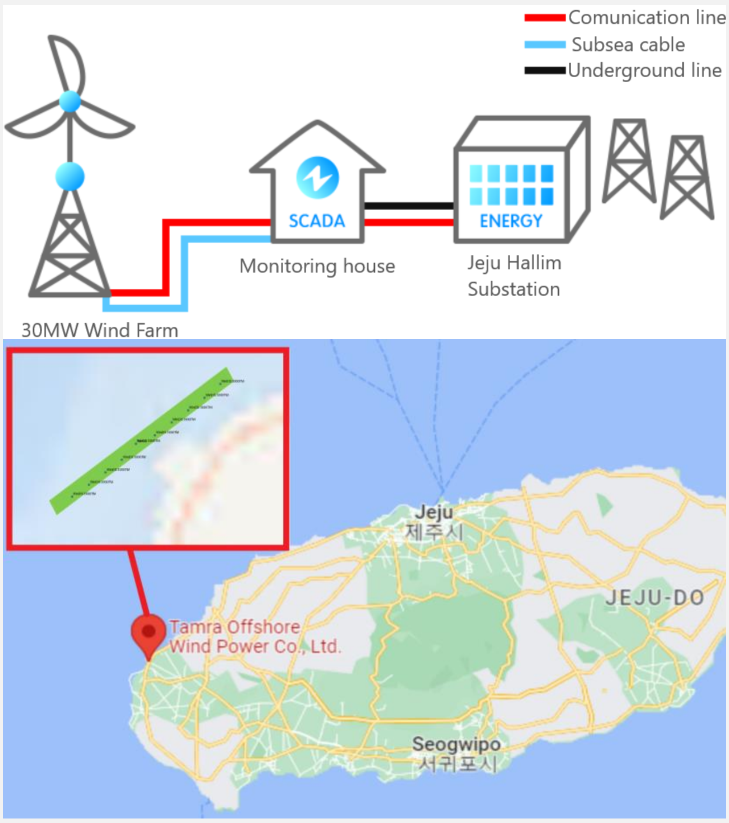
Classification	Korea – China	Korea – Japan	Korea - Russia
Characteristics	500kV HVDC, 2.4GW	500kV HVDC, 2.4GW	500kV HVDC, 3GW
Connection	Taean-Weihai	Gyeongsang Area - Matsue	Metropolitan Area - Vladivostok
Distance	330km	340km	1000km

4.5.3 Offshore Wind Case Study

Currently, more than 36 offshore wind projects are in various stages of development. However, by the end of 2018, except for the two units in the Jeju Woljeong test site with a capacity of 5MW (one 2MW unit and one 3MW), the only completed OWF was the 30MW Tamra offshore wind farm near the Jeju Island developed by the Korea Southeast Power (KOEN) and Doosan Heavy Industries & Construction. Details on the Tamra Offshore Wind Farm are summarized in Table 4-7.

Table 4-7 Tamra OWF case study [85] [86]

Tamra Offshore Wind Farm	
Location	East China Sea
Wind Turbines	10 WindDS3000 turbines Rated power: 3MW Rotor diameter: 91.59m Gearbox: 2 planetary/1parallel Generator: Permanent Magnet Synchronous Generator (PMSG) Wind speed range: 3-25m/s. Rated wind speed: 13m/s Hub height: 80m
Foundation	Fixed jacket foundations with a total height of 36m: - 16m over sea level - 20m under the sea
Capacity	30MW
Site conditions	7.6m/s average wind speed at 80m Depth 16-20m
Shareholder	Owned by KOEN and Doosan Heavy Industries and Construction
Status	Operational since November 2017. Generates 85,000MWh of electricity per year.
Grid connection	Inter-array voltage: 22.9kV Export voltage to onshore substation: 22.9kV Export voltage to grid: 154kV The WTGs are connected, forming a string at 22.9kV, which connects to the onshore substation (monitoring house). The subsea export cable is installed inside an iron pipe placed on the dredged seabed. From the onshore substation, a 10km underground line at 154kV connects to the transmission system at Hallim substation.



4.6 Offshore Wind Offtake Business Case

4.6.1 Participation in the Electricity Market

The privatization process in Korean's electric power sector started in 1999 with the establishment of the KPX to conduct the wholesale electricity trading. The government-owned KEPCO was then divested and divided into six wholly owned subsidiaries of KEPCO, known as GenCos, in the early 2000s. The GenCos are made up of five thermal, one hydro and one nuclear company. These companies include, Korea Western Power Co., Ltd. (KOWEPO), Korea Southern Power Co., Ltd. (KOSPO), Korea East-West Power Co., Ltd. (EWP), KOEN, Korea Midland Power Co., Ltd. (KOMIPO), and Korea Hydro & Nuclear Power Co., Ltd. (KHNP).

Figure 4-16 Structure of Korea's electric power industry [87]

Due to the political backlash against privatization in the mid-2000s, further liberalization initiatives were suspended. The Korean electricity industry came to be characterized by a mix of market and non-market forces. For instance, the installation of power plants is permitted only when the capacities resulting from the introduction of such power plants would be compatible with the economy's electricity supply and demand forecasted by MOTIE. Furthermore, wholesale electricity trading prices are not determined through supply and demand. The wholesale market price is instead determined by KPX according to a pricing mechanism under its *Electricity Market Operation Rules (Market Rules)*, over which the MOTIE exercises *de facto* control.

The status of the upstream, midstream, and downstream business of power industry is summarized as follows:

1) Upstream power generation is partially privatized, with most of the power generation dominated by GenCos, while allowing independent power producers(IPPs) to participate in the market in a smaller share;

2) Midstream power transmission and distribution (T&D) is non-privatized and dominated by KEPCO, acting as the integrated utility to regulate the T&D business;

3) Downstream power sales are also non-privatized, and KEPCO acts as the sole retailer of electricity, with KPX as the independent system operator. However, this is gradually changing due to the Electric Utility Act revision detailed below.

For a commercial offshore wind energy generator, the potential power sale mechanisms are summarized in Table 4-8.

Table 4-8 Typical power sales mechanisms for renewable energy generators

Power sale mechanism	Power sale channel	Eligibility	Descriptions	Case study
Cost-based pool system, with additional revenue from REC	Through the KPX spot market and the REC market	All power generators, including GenCos and IPPs	Under the cost-based pool system, power generating companies only bid for the amount of electricity that they supply based on their generation capacity. The price is determined by KEPCO's Generation Cost Evaluation Committee (GCEC) based on the cost of different production sources. This is the case for KEPCO's subsidiaries and large power generating companies. They are paid based on their production capacity and SMP weighted adjustment index. This SMP weighted adjustment index is equivalent to a capacity payment given to recover some amounts of fixed costs for large companies. Thus, the revenue by renewable generators is calculated as follow: Revenue = [REC Price x Multiplier] + Wholesale Electricity Price	The Tamra OWF went for this option for power sales, adjusting the REC price according to the SMP settlement price.
Fixed price contract system	Between KEPCO and renewable energy generators	All renewable energy generators (however, thus far it has only been applied to solar PV)	Since May 2017, under the New and Renewable Energy RPS, and the Fuel Mix Management and Operation Guidelines promulgated by MOTIE, the Korean Government has implemented a fixed price contract system combining the following: • The system marginal price (SMP) • The REC prices Successful bidders can enter into a long-term contract up to 20 years, with a fixed total price and REC price fluctuates depending on the SMP. Renewable generators required to fulfil	Utility-scale solar PV projects. It is uncertain if any existing onshore and OWFs have entered into a fixed price contract since their power sales mechanisms have mostly been confidential.

Power sale mechanism	Power sale channel	Eligibility	Descriptions	Case study
			RPS obligations can participate in the fixed price contract system through a bidding process, which is an attractive alternative to pool systems or PPAs, as it would reduce the volatility risks associated with the REC price and SMP spot price. However, the new system is currently only available for solar PV projects, and whether it would open for offshore wind projects is yet to be determined.	
Power Purchase Agreement (PPA)	Direct between KEPCO or IPPs, and end-users. Previously only between KEPCO and IPPs.	All power generators, including GenCos and IPPs. Previously only applicable for the generators in island areas that are not connected to the grid operated by KPX, and for electricity generated through renewable energy resources with a capacity of up to 1MW.	PPAs function differently from the spot market in the Korean electricity market. By having the PPA contracts with KEPCO or directly with the end-users, power generating companies lock in their prices in the PPAs in advance once the prices are determined and thus, do not need to go through the selling process in KPX market.	Previously, since the PPA structure is limited only to renewable generators in island areas or of up to 1MW capacity, offshore wind project developers are therefore unlikely to enter into the traditional form of PPAs. Thus, precedents include small generations, such as rooftop solar, although it is expected that future offshore wind farm projects can potentially pursue this scheme.

According to the RPS established by the Korean Government in 2012, energy suppliers with a power generation capacity greater than 500MW are required to produce a certain proportion of their total power from renewable resources. In 2015, the minimum proportion of the RPS obligations was 3% of the total power generation, with the intention of gradually increasing this proportion to 25% by 2026. Energy generators that are not able to meet their RPS obligations would then be required to pay penalties up to 150% of the REC price. Alternatively, they could purchase the RECs per 1MWh to fulfil their initial targets.

RECs are a market-based tool that energy suppliers can use to receive an economic incentive and avoid penalties, while using renewable energy resources for electricity generation. Under *the Act on the Development, Use and Diffusion of New and Renewable Energy*, a REC is defined as a certificate authenticating the fact of supply by using renewable energy facilities (one unit of REC = 1MWh of renewables generation). The REC market is regulated by:

1) KEPCO, which is responsible for managing general REC matters;
2) The New and Renewable Energy Center (KNRE), which is responsible for reviewing and issuing RECs to eligible companies;
3) Local governments, which are responsible for issuing licenses for the installations of renewable power plants located within their jurisdiction.

Unlike other markets, where RECs are often categorized as small-scale and large-scale renewable energy certificates, in Korea the RECs are categorized according to the energy resource (i.e., solar RECs and non-solar RECs). OWFs are eligible to issue RECs according to the REC weight value listed in Table 4-9.

Table 4-9 REC weight values for OSW projects

Interconnection distance	Weight value (up to 2018)	Weight value (2019)
5km of less	1.5	2.0
Above 5km but less or equal to 10km	2.0	2.5
Above 10km but less or equal to 15km		3.0
Above 15km		3.5

RECs are traded in two ways:

1) In the Over-The-Counter (OTC) market, where the seller and purchaser enter into a sale and purchase agreement, and report the contract to KNRE for the transfer of the RECs;
2) In the spot market on the KPX, where the sales are executed via auction or tendering. The spot market opens once a month, and every Thursday of the third week of the month for non-solar REC trading activities.

It is important to note that currently, there is no secondary market for the RECs in Korea since it is prohibited by law for the REC purchasers to resell their RECs.

The six GenCos are required to purchase a fixed number of RECs using the fixed price regime administered by the New and Renewable Energy Center at a 20-year fixed price. Different weight values have been assigned to different forms of renewable energy development, ranging from 0.5 to 5.0. The weight values are critical as they directly influence the revenue from the selling of the RECs, which is calculated using the following method:

Only eligible facilities are permitted to register and participate in the trading RECs. RECs may be issued to eligible facilities that commence commercial operation on or after 1 January 2012, although exceptions apply to the following:

1) Renewable power facilities that passed inception for completion on or after 17 September 2010;
2) Hydropower facilities exceeding 5MW;
3) Certain renewable energy facilities receiving FiT;
4) Off-gas power generators that obtained permits on or before 12 April 2010, and passed inception for completion on or before 31 December 2011;
5) Renewable energy facilities certified as green buildings.

Since the exceptions mentioned above do not apply to OWFs under development, new offshore wind projects should be eligible to issue and trade the RECs. REC weight values are attractive for offshore wind projects. In 2019, the highest weight value of 3.5 was assigned to offshore wind projects with interconnection distance greater than 15km, which is significantly more attractive than the previous weight value of 2.0 in 2018. Here, interconnection distance refers to the shortest straight line from the wind turbine closest to the coast to the machinery (substation and generator) connection to the land.

Since the RPS comes into place and the REC market became active in 2012, the price increased from KRW50,000/MWh to KRW240,000/MWh in early 2014, indicating the effectiveness of the RPS scheme. However, since then, the overall trend of REC price has been declining, indicating a possibility of diminishing wind farm revenue for renewable energy developers caused by the decreasing REC price.

The latest data entry shows that the REC price has been decreasing since the end of 2016. In March 2020, the REC price was around KRW30,000/MWh, which is lower than the price when REC was first set up in 2012. As of December 2021, the price was around KRW40,000 per REC. The downward trend is most likely because more renewable capacity came into the market while the increase of the RPS supply ratio remains slow. As a result, the supply of RECs has increased in the market, causing the market price to drop. Developers would be less incentivized if the price trend were to continue.

Thus, even though the REC weight values for the offshore wind projects is attractive, and the weight values might be further adjusted, the decreasing trend of the REC price will create a certain amount of risk for the developers as it may directly impact the revenue stability of upcoming OWFs, even though the Government has been adjusting the RPS supply ratio to regulate the REC price. The government is also continuously checking the supply and demand situation and price trend of the spot market to minimize the side effects caused by the price volatility such as the sharp price fall in the spot market.

Furthermore, there is an overall understanding in the Korean market that there are major flaws in the current REC system. The government has limited experience handling the REC systems and they are thus facing challenges in balancing the interests of GENCOs, renewable energy developers, and end-users who bear the increased costs of electricity because of the REC system. In addition, the current REC system provides only limited number of incentives for IPPs to invest and develop OSW projects, which makes it more difficult for the government to achieve the renewable energy goal on time.

4.6.2 Cost of Offshore Wind

The increase in capacity of the offshore WTGs installed has helped the offshore wind industry reduce the unit cost per MW, as well as the cost of electricity generation. From 2010 to 2014, the average size of the offshore WTGs increased from 4MW to 6MW, up to 50% over the period. BNEF estimates that the projects financed in 2021 had an average size of 9.7MW, and furthermore, 14MW and 15MW turbines are currently being projected [88].

In addition to the costs of the WTGs, to evaluate the LCOE, it is necessary to analyse other factors such as wind speed, depth, distance to ports and conditions of the electrical transmission network. In the case of Korea, due to the limited experience of local manufacturers on OSW equipment, although there may be an advantage in reducing transportation costs, it may still be more interesting to depend on foreign suppliers to reduce the LCOE [75].

Figure 4-17 and Figure 4-18 show the heat maps of the LCOE for fixed-bottom and floating foundation OSFs, respectively. These results were obtained from a recent study report published by the Denmark Embassy in Korea for the selected four promotion regions, and considering commercial-scale offshore wind projects of 500MW with COD in 2026 [75].

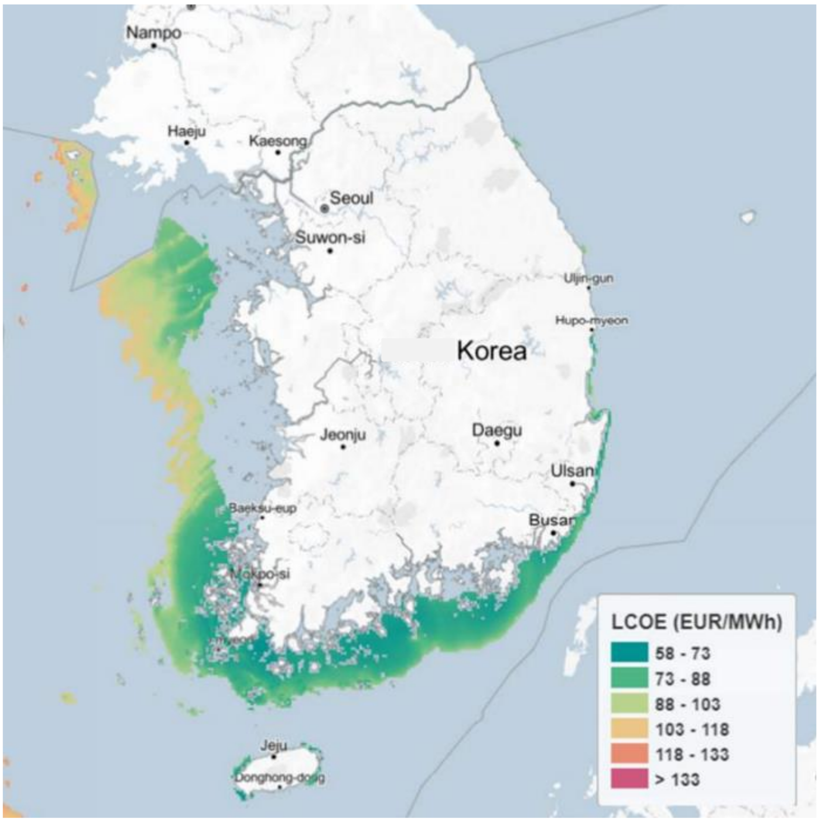


Figure 4-17 LCOE map for fixed-bottom wind project locations

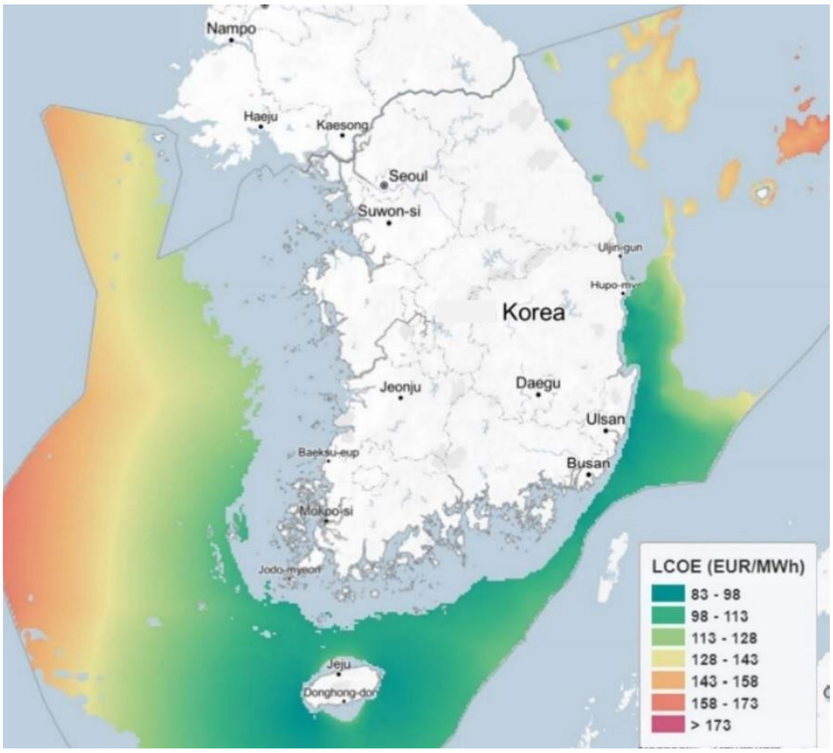


Figure 4-18 LCOE map for floating wind project locations

The results obtained for fixed-bottom foundations show an average levelized cost of EUR75/MWh in the case depending on global manufacturers, while the results for domestic manufacturers would be approximately 22% higher. This difference is mainly due to the costs of the turbines and the supply of the foundations. In the case of the floating foundations, an average levelized cost of EUR101/MWh is estimated when considering an association with the global manufacturers, while for the domestic manufacturers, it would be EUR116/MWh, which is approximately 19% higher [75].

Figure 4-19 shows the projection of the average LCOE for the fixed-bottom foundations in Korea in comparation with the costs in the European economies. This trajectory estimates a reduction from EUR82/MWh in 2023 to EUR52 in 2030, which is approximately 40% of the current costs. In the case of floating foundations, the estimation is a reduction of the levelized cost from current EUR110/MWh to EUR60/MWh in 2035 [75].

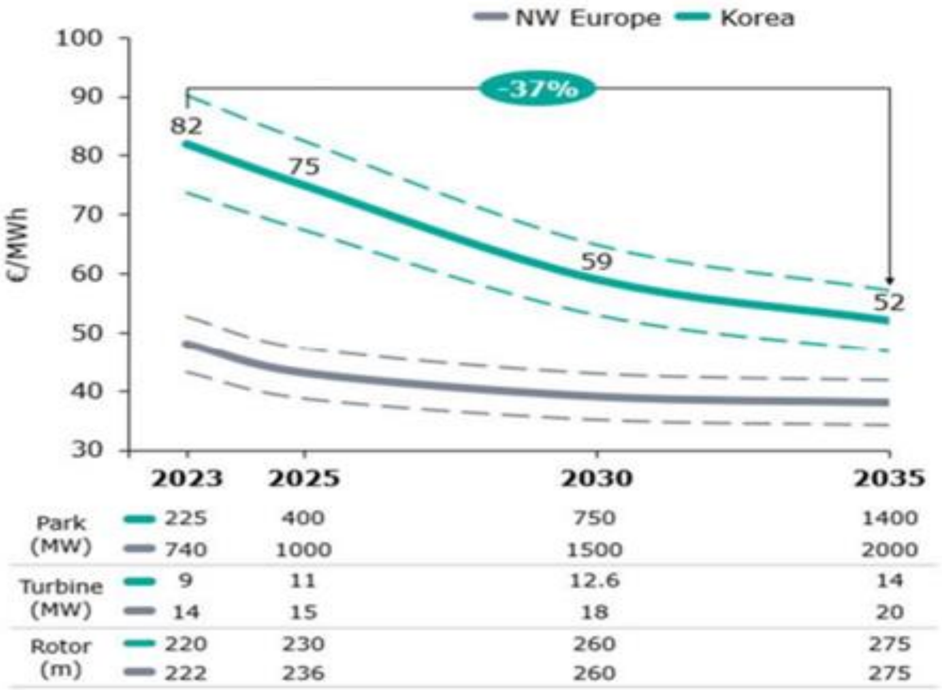


Figure 4-19 LCOE forecast towards 2035 for fixed-bottom projects

These expectations are based upon the increase of the rated capacity of the wind turbines, the maturity of the local supply chains, the improvement of the electrical network and the reduction of costs of turbines and foundations, as well as efficiency improvements in installation and technology and operation efficiency.

4.6.3 Participation in Provision of Ancillary Services

In Korea, the GenCos are mandated to provide the ancillary services in accordance with dispatch instructions from the KPX. The scheduled generators are required to provide the ancillary services such as automatic generation control, governor free, security of the optimal reserve, reactive power supply and demand, black starts and others which were not compensated for during the beginning period of the market. However, since the establishment of the ancillary-service system in May 2022, actual availability became the settlement standard for the compensation of the governor free and automatic generation control.

KPX uses 3 types of frequency control products: primary, secondary, and tertiary. However, the reserve mechanisms only reward the regulated costs avoided in each specific hour, instead of remunerating in respect to the needs of the electrical system. Additionally, the KPX currently has a fixed annual budget for the ancillary service costs. Figure 4-20 summarizes these services [80].

Frequency control type	Steady state	Contingency	Control	Response time	Duration	Resources
Primary	Primary reserve		Automatic provision from generators	10 sec	5 min	Generators (GF), primary ESS
Secondary	Frequency control reserve	Secondary reserve	KPX EMS automatically giving orders based on cost and response time	5–10 min	30 min	Generators (AGC), secondary ESS
Tertiary		Tertiary reserve, quick response resources	KPX operator manually giving orders (PSH is preferred)	30 min (tertiary reserve) 20 min (quick response)	4 hr	Generators

Figure 4-20 Structure of the ancillary services operated by KPX

In Korea the capacity charges are paid to centrally dispatched generators according to the registered available capacity in the day-ahead market, regardless of the actual amount of electricity traded or generated. These payments support renewables by imposing a penalty on coal-fired generation through a fuel switching factor. Costs for the capacity, ancillary services and re-dispatch are incorporated into the KEPCO's purchase prices, which are then passed on to the customers via electricity tariffs. Currently there is no penalty for causing imbalances in the market [80].

KPX needs to improve on the ancillary services, such as recognizing the value of fast actuators that can serve the steep system ramp requirements. The ancillary services will also have to be updated when the real-time market is included around the year 2025, for which they want to implement an imbalance system similar to the UK's flagging and tagging approach [80].

The Korean battery manufacturers, such as LG and Samsung, have been ranked among the world's best battery suppliers. However, the Korean electricity markets are still working towards improving the adoption of these new technology in their grid operations. Thus, as the ancillary services are developed in Korea, they should be harmonized with the energy market and embedded in the marginal cost of electricity, allowing for price increases during periods of stress, such as reserve shortages. This will reward the actions taken by the market participants to relieve stress in the power system.

4.6.4 Private Offtaker of Electricity

In early 2022, the Electric Utility Act was revised. The amendments allowed for the first time, renewable energy generators in Korea to sell electricity directly to end-users without having to go through the KPX [89]. Previously, the direct PPAs between generators and end-users were prohibited under the Electric Utility Act, and generators were required to sell electricity into the KPX's hourly auction pool with KEPCO as the sole offtaker, given that the KEPCO was the sole electricity sales business licensee under the Electric Utility Act.

Although it is still in the early stages of the reform, the amendments have effectively removed KEPCO's monopoly position on the downstream power sales to the end-users. It is important to note that the power sold under this new direct PPA scheme will not be eligible for the issuance of RECs, which were previously one of the main revenue streams for renewable generators in addition to selling electricity on the KPX. The direct PPA scheme will thus, allow both renewable generators and end-users to secure the prices in advance and minimize exposure to the potentially volatile spot market [90].

4.6.5 Curtailment

Renewable curtailment events in Korea generally are increasing, especially in the recent years due to the addition of intermittent small-sized PV farms. However, the current grid code does not include compensation for renewable generators curtailment. The highest curtailment events occurred on the Jeju Island as the thermal generators must run at a minimum power to maintain frequency and inertia levels and the small-scale solar generators are not controllable. The amount and frequency of wind curtailment increased to 9,223MWh on 46 occasions in 2019 (1.7% of total wind generation). This had been increasing every year, as it was 0.04% in 2016 and 3.35% in 2020 [91].

The increase in small non-controllable solar installations is taking place mainly in the southern part of Korea, where the weather conditions are better, making it more likely that curtailment will occur in the region. To avoid the curtailment, measures such as incentivising demand through electric vehicles, installing the battery systems in the most affected areas, or improving the capacity of transmission networks have been explored. Recently, the KPX has also announced that it will start including solar generators in the curtailment, as the amount of wind it can curtail if does not satisfy KPX requirements at critical hours [80].

4.7 Summary and Recommendations

While there is plenty of room for growth in the offshore wind market in Korea, there are still plenty of challenges. Korea's local supply chain has limited experience in the development, engineering, installation, and operation of large offshore wind projects. With current policies and a history of curtailments, the investment climate is not conducive to supporting the rapid growth of the supply chain required to meet the ambitious offshore wind development targets.

The LCOE for the offshore wind projects in Korea remains high compared to other economies with more experience. This cost is even higher when local agents are involved without relying on foreign suppliers. To reduce the LCOE, there is a need to improve the local supply chain and develop the capacity of the local manufacturers of turbines and foundations [80].

An increase in the current offshore wind REC weightings under the RPS scheme would provide greater incentives for the developers, but this would need to be supported by the accurate wind and Metocean data as well as a streamlined permitting process. Based on the existing completed projects in Korea, the development timeline for an offshore wind farm is expected to take 8 to 10 years, which is longer than that in many other economies. This duration is the result of a lack of supply chain experience and a complicated permitting and approval processes.

In addition, curtailment in Korea has been increasing due to the development of small intermittent PV farms, most significantly on Jeju Island. To increase the capacity of offshore wind, major upgrades are required in the transmission network to avoid the curtailment. Currently, major upgrades have been planned in the electrical network and international connections have been considered, which will allow the accommodation of more generators while reducing the level of the curtailments. It has been noted that some of the planned transmission lines are experiencing delays, and until they are completed, the level of curtailments for renewable generators will continue to increase.

Another aspect of the improvement is the incorporation of the fast regulation mechanisms that guarantee the security of the power system by incorporating more intermittent generators including offshore wind farms.

5 Chinese Taipei

5.1 Introduction

Chinese Taipei has limited domestic energy resources and has been relying heavily on oil and coal imports to support its energy demand. With a population of over 23 million people, the market's total electricity consumption per capita is around 10,750kWh which is three times higher than the regional average [92]. The electricity generation for Chinese Taipei is mainly from fossil fuel, including 45% from Coal, 35.7% from natural gas, 11.2% from nuclear and 5.4% from renewables [93].

In terms of the targets, Chinese Taipei plans to generate 20% power from renewable resources by 2025. Although the Chinese Taipei official has confirmed that the goal will be achieved by a year or two later, but it won't be missed. For the offshore wind roadmap, Chinese Taipei has allocated 5.7GW offshore wind to the grid between 2021 to 2025. Furthermore, an additional 15GW of offshore wind capacity will be deployed between 2026 to 2035. Based on the existing policies, offshore wind energy seems to be one of the main elements for the renewable goal of Chinese Taipei. The offshore wind roadmap consists of 3 Phases of the development. Currently, Chinese Taipei has just begun the Phase 2, where the demonstration site has just been completed and the concept of offshore wind in Chinese Taipei context has been proven. For the Phase 2, various projects have already been progressed positively toward obtaining all required permits. As such, the goal of Phase 2 has been progressing well.

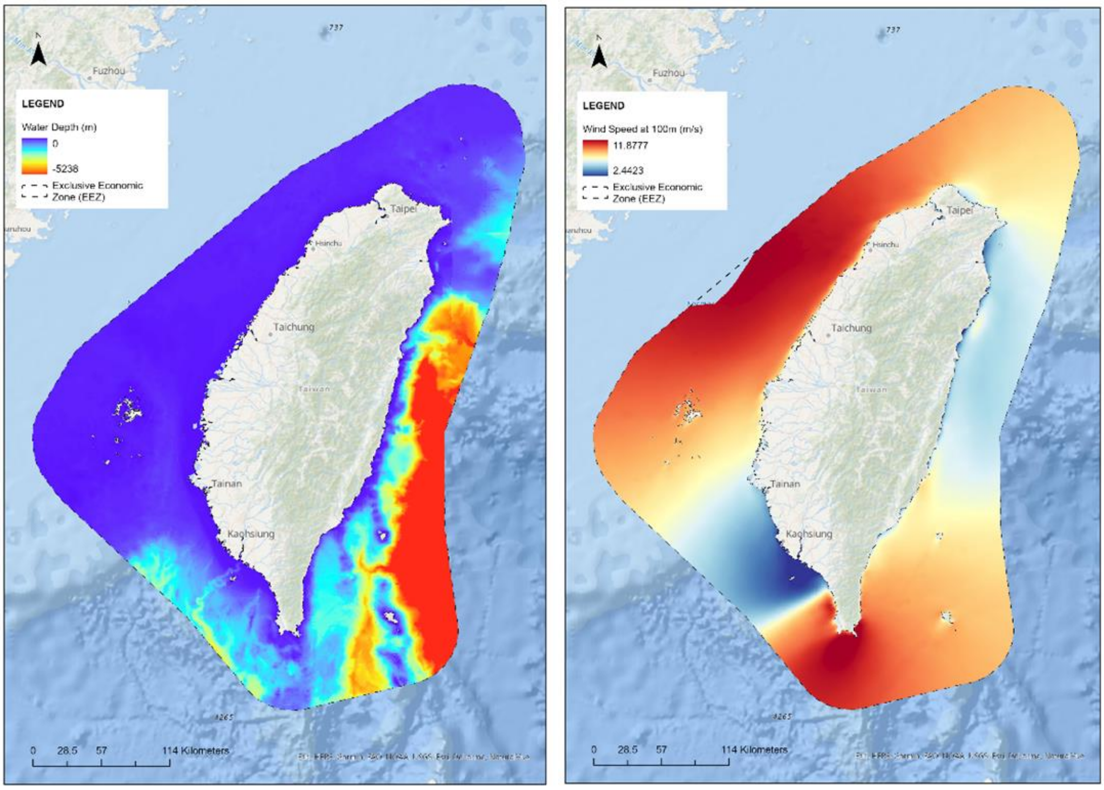


Figure 5-1 Wind speed (left) and water depth (right) of Chinese Taipei offshore areas

5.2 Overview of Offshore Wind Resource

Figure 5-1 shows the wind speed and water depth as heat maps for the offshore portion of Chinese Taipei. The wind speeds at 100m hub height range from 2.4m/s to 11.9m/s along the coast, with the highest concentrated along the Chinese Taipei Strait and the southern tip. In general, the west and north-west areas of Chinese Taipei are characterized by their far-shore shallow water depths, making them very suitable for fixed offshore wind projects. Alternatively, the east coast is characterized by very steep water depths and relatively low wind speeds which do not favour offshore wind project development.

Water depths up to -70m are generally considered suitable for bottom-fixed foundations, while floating foundations are suitable for the water depths between -70m to -1,000m. Sea depths greater than -1,000m are considered ultra-deep and are less economically favourable and more complex, and thus riskier in terms of development for floating foundation. Based on the wind resource, both fixed and floating foundation OWFs can desirably be deployed along the northwest coast and southern tip of Chinese Taipei (see Figure 5-2).

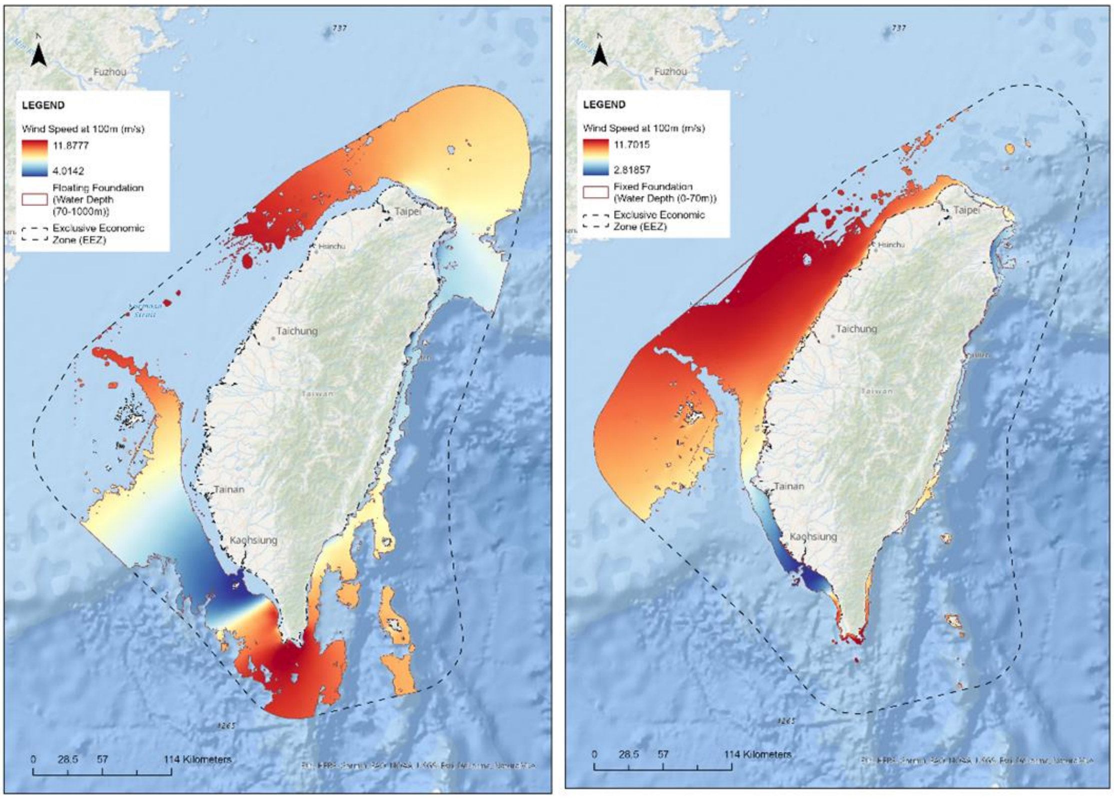


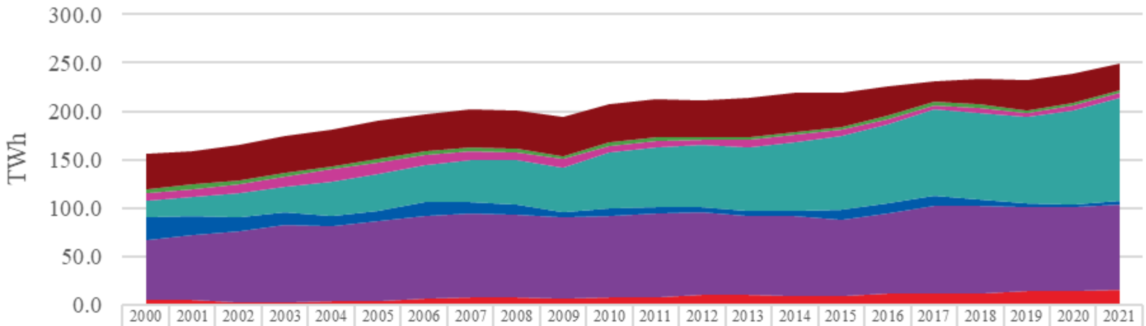
Figure 5-2 Wind speed for fixed foundation water depth 0 to -70m (left) and floating foundation -70 to -1000m (right)

5.3 Energy Sector and Regulatory Mechanism of the Target Economy

5.3.1 Structure of Electricity Sector

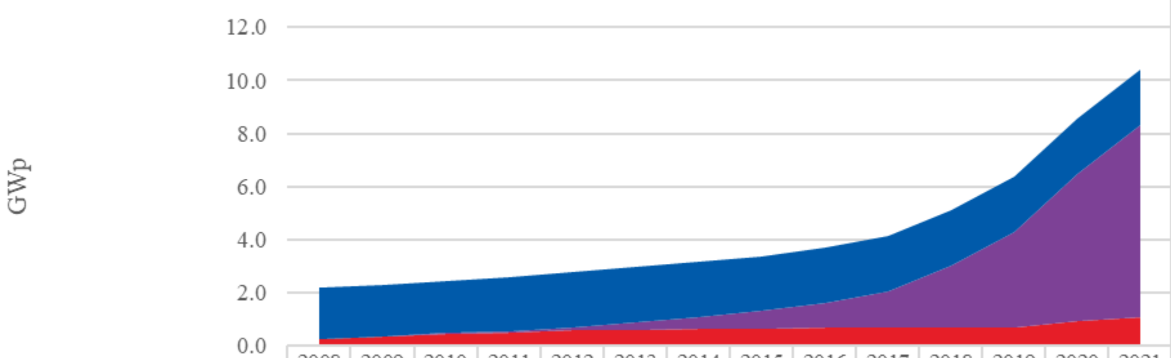
Energy generation from fossil fuels (coal, oil, natural gas, and cogeneration) rose by 12% from 181TWh in 2016 to 203TWh in 2021, supplying 82% of Chinese Taipei's electricity demand in 2021 [93]. The use of coal and oil in electricity generation has gradually been reduced and shifted to natural gas. While natural gas is also fossil fuel, its emissions are lower in comparison to coal and oil. One of the reasons for the increase in fossil fuel usage is the process of phase-out of nuclear power in Chinese Taipei. Nuclear power generation dropped by 12% from

30.5TWh in 2016 to 26.8TWh in 2021. By contrast, electricity generation from renewables also rose 36% from 11.6TWh in 2016 to 15.8TWh in 2021. This increase is attributed to the pro-renewables government policies in recent years. A historical summary of the electricity mix is available in Figure 5-3.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Nuclear	37.0	34.1	38.0	37.4	37.9	38.4	38.3	39.0	39.3	40.0	40.0	40.5	38.9	40.1	40.8	35.1	30.5	21.6	26.7	31.1	30.3	26.8
Pump hydro	4.3	4.1	3.6	3.9	3.3	3.8	3.9	3.9	3.5	3.3	3.0	2.9	2.9	3.2	3.1	3.0	3.3	3.3	3.4	3.2	3.1	3.2
Cogeneration	8.1	8.1	8.4	10.3	13.0	12.8	9.6	9.5	7.5	9.1	7.1	6.9	4.8	7.3	7.0	6.2	5.9	4.1	4.6	4.2	4.1	5.1
Natural gas	16.5	19.6	25.1	27.1	34.7	37.4	38.7	43.2	46.6	45.5	58.0	62.1	64.1	66.3	70.9	76.9	81.2	89.1	90.1	88.8	97.4	105.8
Oil	24.2	19.8	14.9	13.1	10.9	10.4	13.7	11.6	10.9	5.8	7.8	6.9	5.3	4.9	6.2	10.3	10.0	11.2	6.6	4.4	3.1	4.0
Coal	61.8	67.3	73.1	79.0	78.2	82.7	85.8	87.5	85.3	83.1	83.8	85.9	86.0	81.9	82.4	78.2	83.3	90.5	90.5	86.7	87.1	88.2
Renewables	4.5	5.1	2.8	3.0	3.2	4.1	6.6	7.1	7.2	6.8	7.6	7.9	9.6	9.7	8.8	9.3	11.6	11.2	11.4	14.0	13.8	15.8

Figure 5-3 Electricity mix by source in Chinese Taipei 2000-2021 [94]



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Others (includes hydro)	1.9	1.9	2.0	2.0	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Solar	0.0	0.0	0.0	0.0	0.1	0.3	0.4	0.7	0.9	1.4	2.3	3.6	5.6	7.2
Wind	0.2	0.3	0.5	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.9	1.1

Figure 5-4 Renewable generation mix by source in Chinese Taipei 2008-2021 [94]

The renewables industry in Chinese Taipei experienced significant growth starting in 2010, primarily due to the implementation of the FiT scheme. The scheme provided direct subsidies to incentivize the widespread adoption of renewable resources, allowing the developers to secure better prices for their electricity generation. Chinese Taipei has been proactive in encouraging the use of wind power, with a specific focus on offshore wind in recent years. As offshore wind technology continues to mature, it has been expected to see a large increase in its contribution to the generation mix. The historical growth of the renewable generation capacity in Chinese Taipei is shown graphically in Figure 5-4.

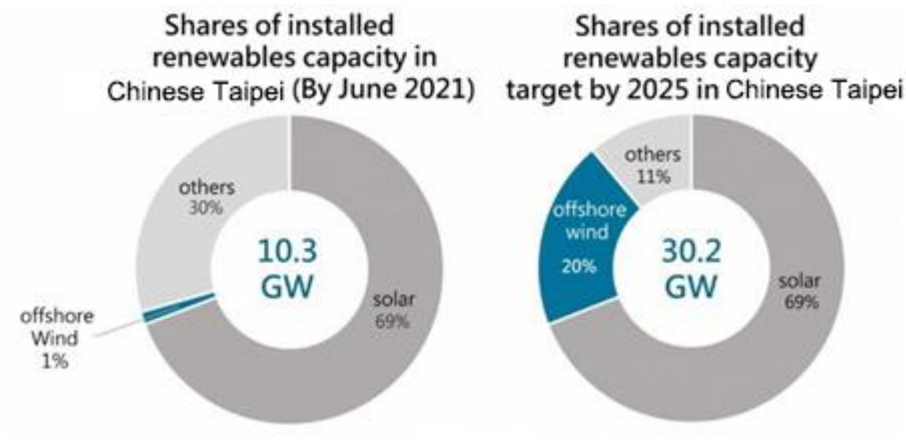
5.3.2 Renewable Energy and Climate Change Policies and Targets

In March 2022, the authority of Chinese Taipei published the Pathway to carbon neutrality Emissions in 2050, which provides the action pathway to achieve 2050 carbon neutrality Emissions [95]. Energy Transition is one of the four pillars for Chinese Taipei's NetZero roadmap. The predicted budget for renewables and hydrogen is around NTD210.7 billion (USD7.03 billion) by 2030. The Chinese Taipei authority intends to boost the total installed solar and wind capacity to 40GW by 2030, stop building new coal-fired power plants from 2025 [96]. Chinese Taipei is expected to continue its supportive policies for renewable energy development in the decade.

The main drivers for Chinese Taipei's renewable policies are to build a sustainable economy and achieving "nuclear-free homeland". Based on these drivers, the authority of Chinese Taipei has established clear and aggressive renewable targets. Chinese Taipei plans to increase its renewable generation to 20% by 2025, which was at 5.1% in 2021. Achieving this target will require the development of both offshore wind and solar power. Chinese Taipei has allocated the installation of an additional 5.7GW of offshore wind power to the grid between 2021 and 2025.

In January 2017, Chinese Taipei's electricity market was liberalized with the amended Electricity Business Act (EB Act). The primary objective of the amendment is to encourage renewable power generation. As per the revised Electricity Business Act, the monopoly electricity utility, Taipower, is required to unbundle its electricity generation business from distribution and transmission business by 2026, ensuring renewables can be sold directly to electricity customers [97].

Chinese Taipei's energy transition plan has four pillars: renewable development, less coal, more natural gas and nuclear-free. Chinese Taipei's initial renewable development goal translates to an installed generation capacity of around 27.4GW. However, due to the increased offshore wind potential, the goal was revised to 30.2GW (see Figure 5-5). While solar power will make up most of the share, accounting for 20GW by 2025, offshore wind will also play a significant role. The Government of Chinese Taipei also aims to allocate more than 1.5GW of offshore wind power annually from 2026 to 2035. It translates into 15GW in 10 years [4].



Source: [4] InfoLink Consulting, 30 August 2021.

Figure 5-5 Renewable target for Chinese Taipei by 2025

In May 2019, the authority passed a series of amendments to *the Renewable Energy Development Act* (REDA) which take a more aggressive step towards renewable targets. Heavy electricity users are now required to either develop their own renewable electricity generation facilities, purchase a certain proportion of renewable supply, or pay a dedicated amount to renewable energy developments [98]

According to the authority-led programme to promote wind power, named *Thousand Wind Turbine Pro*ject, the current installed capacity for wind power is 1,062MW which includes 825MW of onshore wind and 237MW of offshore wind [99]. Table 5-1 provides a summary of the installed wind power capacity.

Table 5-1 Statistics of wind power in Chinese Taipei

Onshore capacity (MW)	Offshore capacity (MW)	Annual electricity Production (TWh)	Annual CO_2 emission Reduction (million tons)
825	237	3.9	195

5.3.3 Offshore Wind Power Development Policies and Targets

Approved by the Executive Yuan in February 2012, *the Thousand Wind Turbines Project (TWTP)* was established to encourage offshore wind development through active authority support [99]. The Program is divided into three phases: Demonstration Incentive Program (DIP), Zones of Potential, and Zonal Development. The authority further announced the *Four-Year Wind Power Promotion Plan* on 16 August 2017 and published a draft *Regime Planning for Developer Selection* on 11 May 2021, refining the targets of wind energy capacity in each phase, specifically the plans for 2026 to 2035. The details of each phase of the TWTP are summarized in Table 5-2.

Phase 1 of the development program is aiming at showcasing the feasibility of the offshore wind technology in Chinese Taipei. At the end of Phase 1, two demonstration OWFs were completed. Under the Program, the authority provided subsidies for both the equipment and development processes [100].

Regarding Phase 2, in July 2015, Chinese Taipei Bureau of Energy (BOE) released 36 zones of potential (ZoP) for development of future commercial OWFs (see Figure 5-6). Wind farm developers were invited to submit an EIA to the BOE. According to the *Four-Year Wind Power Promotion Plan* the offshore wind energy target for this round was 5.5GW. The BOE proposed to allocate the capacity to competing developers through the selection criteria and competitive auction [101].

Table 5-2 Three phases of Chinese Taipei OSW development [101]

Phase 1: Demonstration Incentive Program (DIP)	Phase 2: Zones of potential	Phase 3: Zonal development
2019: Formosa 1 @Miaoli (128MW commissioned) 2021: Taipower 1 @Changhua (109.2MW commissioned)	2018: Completed capacity allocation • By Selection: 3.8GW • By Auction: 1.7GW 2025: 5.5GW will be in commercial operation.	2026 - 2035: 1.5GW to be developed annually • Directions of site planning was announced. • 2-stage selection: • Capability Review • Bidding Process

Phase 1: Demonstration Incentive Program (DIP)	Phase 2: Zones of potential	Phase 3: Zonal development
		• Industrial Relevance Plan will be included as well.
Total: 237.2MW	**Total: 5.5GW**	**Total 15GW**

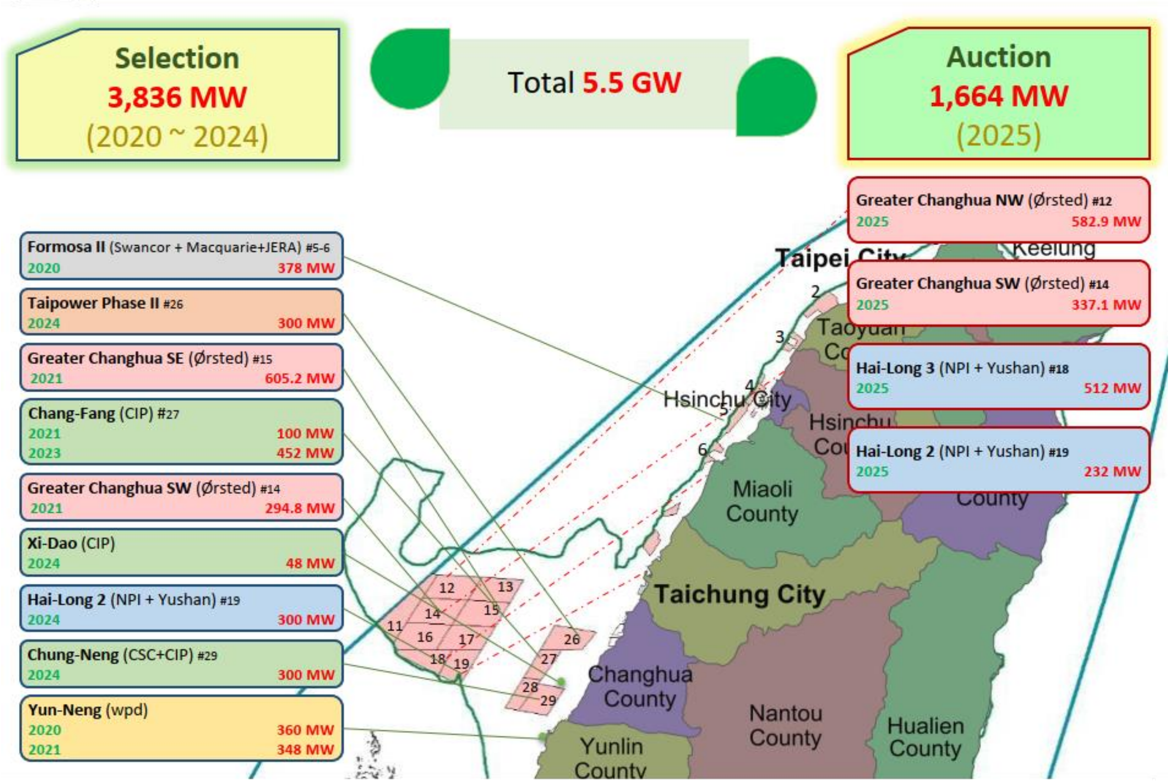


Figure 5-6 Phase 2 OSW zones [101]

A total of 3.836GW of capacity was assigned using the selection criteria process. The selection criteria comprised the following key considerations: construction capability, engineering design capability, operations and maintenance capability, and financial capability. The BOE made it clear that an emphasis would be placed on the promotion of local contents. Table 5-3 provides a summary of the local contents considerations that were taken into account for each element of the selection criteria.

Table 5-3 Selection criteria for DIP

Selection criteria item	Local contents considerations
Construction Capability (25%)	No applicable local content considerations.
Engineering Design Capability (20%)	Local cooperation in engineering design, construction, and installation.
Operations and Maintenance Capability (15%)	Local industry development plan. Local cooperation in operations and maintenance.
Financial Capability (40%)	10 points awarded if 20% of funding is allocated to local financial institutions.

There were 10 projects allocated in the selection criteria process. Five of the sponsors for these projects were international and two were local. Table 5-4 provides details of the allocated projects.

Table 5-4 Phase 2 allocated projects

#	Sponsors	Project	Capacity (MW)
i	WPD AG(wpd, German)	Yunneng	360 (2020) 348 (2021)
ii	Ørsted (Denmark)	Southwest Greater Changhua	294.8 (2021)
		Southwest Greater Changhua	605.2 (2021)
iii	Swancor (Chinese Taipei) and Macquarie (Australia)	Hai Neng	378 (2020)
iv	NPI Energía Renovable (NPI, Canada) and Yushan (Singapore)	Hai Long II	300 (2024)
v	Copenhagen Infrastructure Partners(CIP, Denmark)	Changfan	100 (2021) 452 (2023)
		Xidao	48 (2024)
vi	CSC (Chinese Taipei)	Power Generation	300 (2024)
vii	TPC (Chinese Taipei)	TPC II	300 (2024)

The remaining 1.663GW of capacity was assigned through competitive auction. There was no local content requirement as part of the competitive auction, only those project developers that applied as part of Phase 1 and scored a minimum of 60 points were eligible to participate in Phase 2. Table 5-5 details the results of the competitive auction.

Table 5-5 Phase 2 competitive auction results

Sponsors	Project	Capacity (MW)
Ørsted (Denmark)	Southwest Greater Changhua	337.1 (2021–2025)
	Northwest Greater Changhua	582.9 (2021–2025)
NPI (Canada) and Yushan (Singapore)	Hai Long II	232 (2021–2025)
	Hai Long III	512 (2021–2025)

Finally, for Phase 3 and in accordance with the draft *Regime Planning for Developer Selection* published by the BOE on 11 May 2021, the authority plans to allocate 1.5GW of offshore wind capacity each year, for a total of 15GW for 2026 to 2035, in this Zonal Development Round.

The whole round is divided into two stages, the first stage ranges from 2026 to 2031, with three rounds of offers of 3GW each. The selection process for the first round begins in June 2022. Following round selections will be announcement by the BOE. The second stage has not been fully defined but is expected to have an allocated capacity of 6GW assigned between 2032 and 2035. A summary of the development plan in Phase 3 is provided in Figure 5-7.

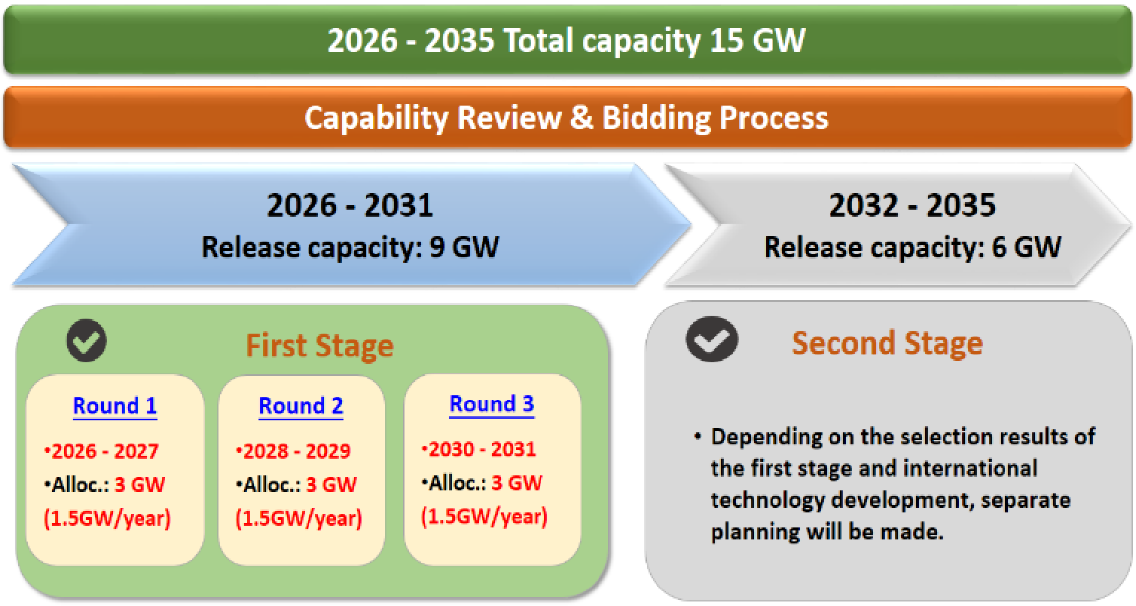


Figure 5-7 Phase 3 development of OSW in Chinese Taipei [101]

5.3.4 Renewable Energy and Offshore Wind Regulatory Support Mechanisms

The FiT scheme for renewable energy in Chinese Taipei was introduced in 2009. The structure of the scheme followed a typical price-based approach, where a fixed dollar payment was guaranteed for each kWh of electricity generated [102]. At the end of December 2021, the BOE of Chinese Taipei announced a draft of the *R.O.C. 2022 Renewable Energy Feed-in Tariffs (FIT) and Calculation Formulas*, which set forth the FiT rate for different renewable energy resources for the coming year [102].

The 2022 FiT rate for wind is summarized in Figure 5-8. Compared to onshore wind, offshore wind has a much higher FiT rate. It shows the Chinese Taipei authority's attitude towards promoting offshore wind energy for the coming decade which is in line with the new development policies. The FiT for the offshore wind projects ranges from NTD3.4001/kWh to NTD4.5024/kWh in 2022. The rates have slightly dropped when compared to the year of 2021 where the rates ranged from NTD3.5206/kWh to NTD5.3064/kWh. Developers have the option to go with a 20-year fixed rate or a 10 yearly phased tariff approach.

<table>
<tr><th>Renewable Energy Type</th><th>Category</th><th>Capacity Size</th><th colspan="3">Feed-In Tariffs (TWD/kWh)</th></tr>
<tr><td rowspan="6">Wind</td><td rowspan="3">Land</td><td>1 kW and above but under 30 kW</td><td colspan="3">7.4110</td></tr>
<tr><td rowspan="2">30 kW and above</td><td colspan="2">Installed LVRT</td><td>2.1223</td></tr>
<tr><td colspan="2">Non installed LVRT</td><td>2.0883</td></tr>
<tr><td rowspan="3">Offshore</td><td rowspan="3">1 kW and above</td><td colspan="2">Fixed 20-Year Tariff (upper limit on the tariff)</td><td>4.5024</td></tr>
<tr><td rowspan="2">Phased tariffs</td><td>The 1st 10 years</td><td>5.1356</td></tr>
<tr><td>The 2nd 10 years</td><td>3.4001</td></tr>
</table>

Figure 5-8 Chinese Taipei 2022 wind power FiTs

Two technical incentives for renewable energy development in Chinese Taipei have been provided:

- Direct Sales: Non-renewable energy generators are unable to sell electricity directly to end-users. Instead, they may sell electricity only to retailers or the power grid operator (TPC). However, renewable energy generators are allowed to sell power directly to end-users, either through their own transmission and distribution lines or through the TPC grid;

- Dispatch Priority: The TPC must prioritize the connection and distribution of renewable energy, subject to ensuring safety and stability of the power system.

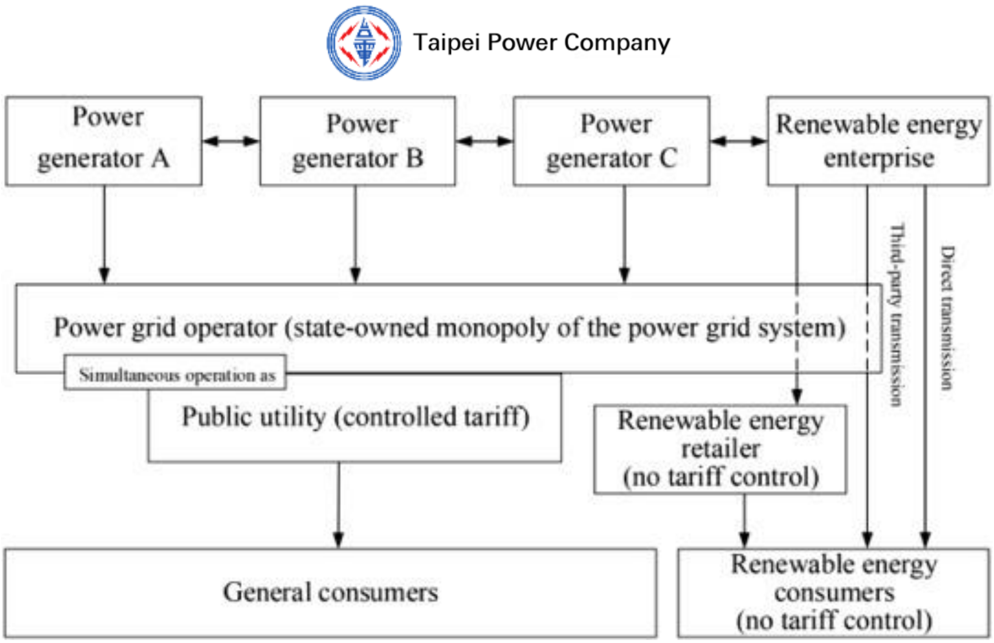
5.4 Offshore Wind Development Procedure and Stakeholder Engagement

5.4.1 Stakeholders and Their Responsibilities

Chinese Taipei has a long history of a monopoly authority-owned power supply. The Taiwan Power Company (Taipower) was first established in 1946 with the aim of maintaining relatively low electricity prices. While the electricity market mostly remains un-changed, the latest amendment to the Electricity Act (published 2017) set forth a major reform which focuses on opening the market to green energy [103]. A diagram of the structure of Chinese Taipei's current electricity market can be seen in Figure 5-9.

Chinese Taipei is hoping to reform the electricity market and at the same time create a more stable supply. To achieve this Taipower will need to be restructured into two subsidiary companies to oversee electricity generation and electricity transmission and distribution separately. The electricity transmission and distribution enterprise will be a authority-owned corporation and a single entity. It will be responsible for managing the dispatch of electric power by giving priority to the grid connections that allow access to the renewable energy on the condition that the power systems remain safe and stable.

The BOE, and the Ministry of Economic Affairs is Chinese Taipei are the major authorities for the energy issues. The BOE is responsible for managing Chinese Taipei's energy policy and relevant regulations. It also forecasts and plans the supply and demand of energy for the island. The BOE has the right to manage energy corporations, review energy rates, supervise renewable energy development and assess the new technologies. It is the main point of contact for renewable energy development in Chinese Taipei.



Source: [104] Tsay and Chen, Energy Reports, 2019.

Figure 5-9 Structure of Chinese Taipei's electric power industry

Chinese Taipei’s Environmental Protection Agency (EPA) is the official department responsible for assessing environmental related process related to the offshore wind development, such as environmental impact assessment.

In 2016, Chinese Taipei also set up the Office of Energy and Carbon. The goal of this office is to effectively coordinate the integration of relevant policies among different authority agencies. More importantly, it oversees and implements the measures for the low-carbon energy transition [105].

Due to the limitations of local technology and the supply chain, the offshore wind industry in Chinese Taipei is still largely dominated by the foreign developers and investors. In March 2021, the Taiwan Offshore Wind Industry Association (TOWIA) was established to promote and coordinate the development of offshore wind in Chinese Taipei. The association was a joint creation of eight local wind power companies, including CIP, the joint venture of TEPCO and Chubu Electric Power Company(JERA), Macquarie’s Green Investment Group, NPI, Orsted, Sempra Renewables (SRE), and Yushan Energy [106].

5.4.2 Offshore Wind Approval Procedures

Chinese Taipei has various regulations that require compliance for the development of renewable energy projects. Those that apply to offshore wind energy projects include but are not limited to:

- Energy Management Act;
- Petroleum Administration Act;

- Natural Gas Business Act;
- Electricity Act and Renewable Energy Development Act.

The framework of offshore wind development in Chinese Taipei is summarized in Figure 5-10. It consists of two main parts:

1) The permitting requirements under *the Electricity Act and the Renewable Energy Development Act*;
2) The Directions for Allocating Installed Capacity of Offshore Wind Potential Zones.

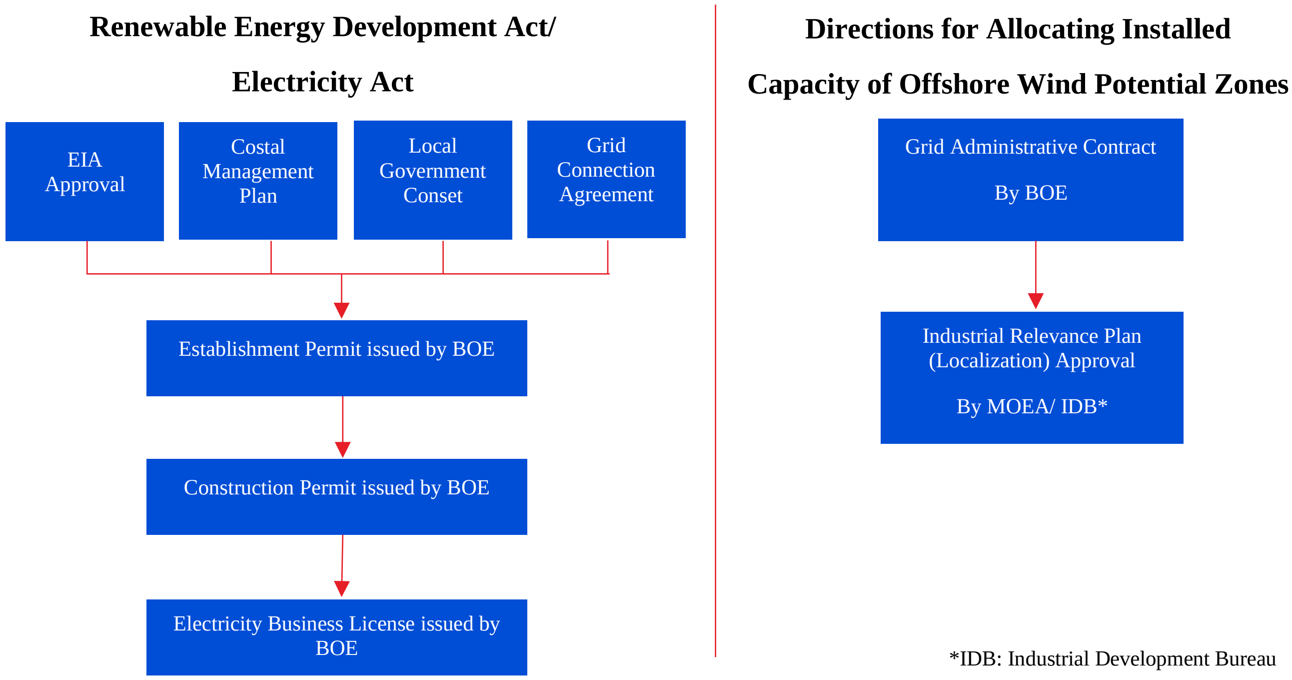


Figure 5-10 Regulatory approval framework for Chinese Taipei offshore wind development

According to the BOE, a milestone-based development approach is adopted for the offshore wind projects. The permitting process of the projects can be broken down into the stages outlined in Table 5-6.

Some OWFs are required to include a certain amount of local supply contents. This encourages the local development of an offshore wind supply chain and fosters the local economic growth. Table 5-7 outlines some local suppliers in Chinese Taipei who are capable for offshore wind project development.

Table 5-6 Chinese Taipei offshore wind development stages

Stage	Permitting requirements
Stage 1: Pre-development	The purpose of this phase is to conduct preliminary study to ensure the local environment protection and the security. Developer needs to undergo an EIA process which outlines all the ecological and social factors, undertakes detailed stakeholder consultation for both the statutory and non-statutory parties. Below is a list of required approvals and consent letters: • EIA Approval; • Site Recordation Agreement for Offshore Wind Facility; • Administration Contract for Grid Capacity Allocation, signed by the MOEA. This stage is a preparation stage where the developer explores suitable development areas with the authority and relevant stakeholders.
Stage 2: Development	After the approval of the required opinion letters and permits from pre-development stage, the project will secure grid capacity and officially enter the development stage. During the development stage, the project must apply for the Establishment Permit by submitting the prerequisite documentations including Opinion Letters for: Aviation Control, Radar Interference, Restricted Military Area, Prohibited or Restricted Area, Navigation Safety, Mining Rights, Fishing Rights, Aquatic Animal Reservation Area, Grid connection agreement as well as Opinion Letter issued by TPC of the System Impact Study report. The Establishment Permit is an official approval for developing an offshore wind farm. It shows the project has been endorsed by the BOE. There are certain conditions including a validity date specified in the permit. The permit usually is valid for three years upon the initial application. There is one chance to extend for a maximum of two additional years. After receiving the Establishment Permit, the project can proceed to activities such as signing the PPA.
Stage 3: Construction	Before actual construction work, a developer must apply for a Construction Permit. The prerequisite documentation for obtaining the Construction Permit includes the approval of Industrial Relevance Plan (IRP), approval of Coastal Zone Management Plan issued by the Ministry of the Interior (MOI), approval of subsea cable survey and laying, approval of Underwater Cultural Heritage Survey Results, offshore Area Zone Permit, registration of Renewable Energy Facility, Fishery Compensation Agreement signed and recognized by Fishery Administration. Generally, the construction working permit is valid for five years and the construction must be completed within this period. Also, the developer can justify extending one year with valid reason. The number of extension application is unlimited.
Stage 4: Operations	The Electricity Business License is the key operational permit for a wind farm. The license enables a wind farm to transmit generated electricity to the grid. When construction is completed, the project must apply for the electricity business license within 30 days. The MOEA will then inspect the project facility and authorize an Electricity Business License if no issues are raised. The validity period of the Electricity Business License is 20 years, and the developers can apply for an extension up to 10 years, at one year before the expiry date, for each application.

Table 5-7 Local OSW material suppliers

Scope	Contractor / Supplier
Siemens Gamesa Renewable Energy (SGRE) has already developed significant experience procuring components in Chinese Taipei and managing the logistics of importing components to Chinese Taipei.	SGRE
CDWE, which comprises of both the China Shipbuilding Corporation (CSBC) and Dredging, Environmental and Marine Engineering (DEME), is currently active on the CFXD and Greater Changhua projects and was previously active on the Formosa 1 project. CDWE has gained significant experience on the offshore wind industry and on offshore installation work in Chinee Taipei.	CDWE
TECO (Chinese Taipei listed company) has a focus on offshore wind power substations, energy storage systems and smart substations.	TECO
Century Wind Power Co Ltd (CWP) & Century Iron & Steel Industrial Co. Ltd(CISI) are the local supplier for foundation.	CWP & CISI

5.5 Offshore Wind Grid Connection

5.5.1 Electricity Utility Structure and Grid Connection Procedure

The grid network in Chinese Taipei, operated and maintained by Taipower, is comprised of 345kV and 161kV transmission lines connecting all load centers on the main island. Most of the demand is from highly populated cities along the western side. Figure 5-11 shows the network map including associated substations and power plants.

The grid connection process for the establishment of an offshore wind farm can be divided into two key milestones based on existing regulations and legislations by the MOEA:

- Signed Grid Administrative Contract (MOEA);
- Grid connection agreement (SIS approval, preliminary grid connection negotiation approval etc).

After signing a PPA, the developer will enter a process of negotiation regarding Administrative Contracts with the MOEA. The structure of administration contracts process is much like the other debt-financed infrastructure projects in Chinese Taipei. The contracts contain a series of key milestones which the project must meet, which include:

- Obtain establishment permit;
- Submit industrial relevance proposal;
- Obtain construction permit;
- All allocated grid capacity to be connected.

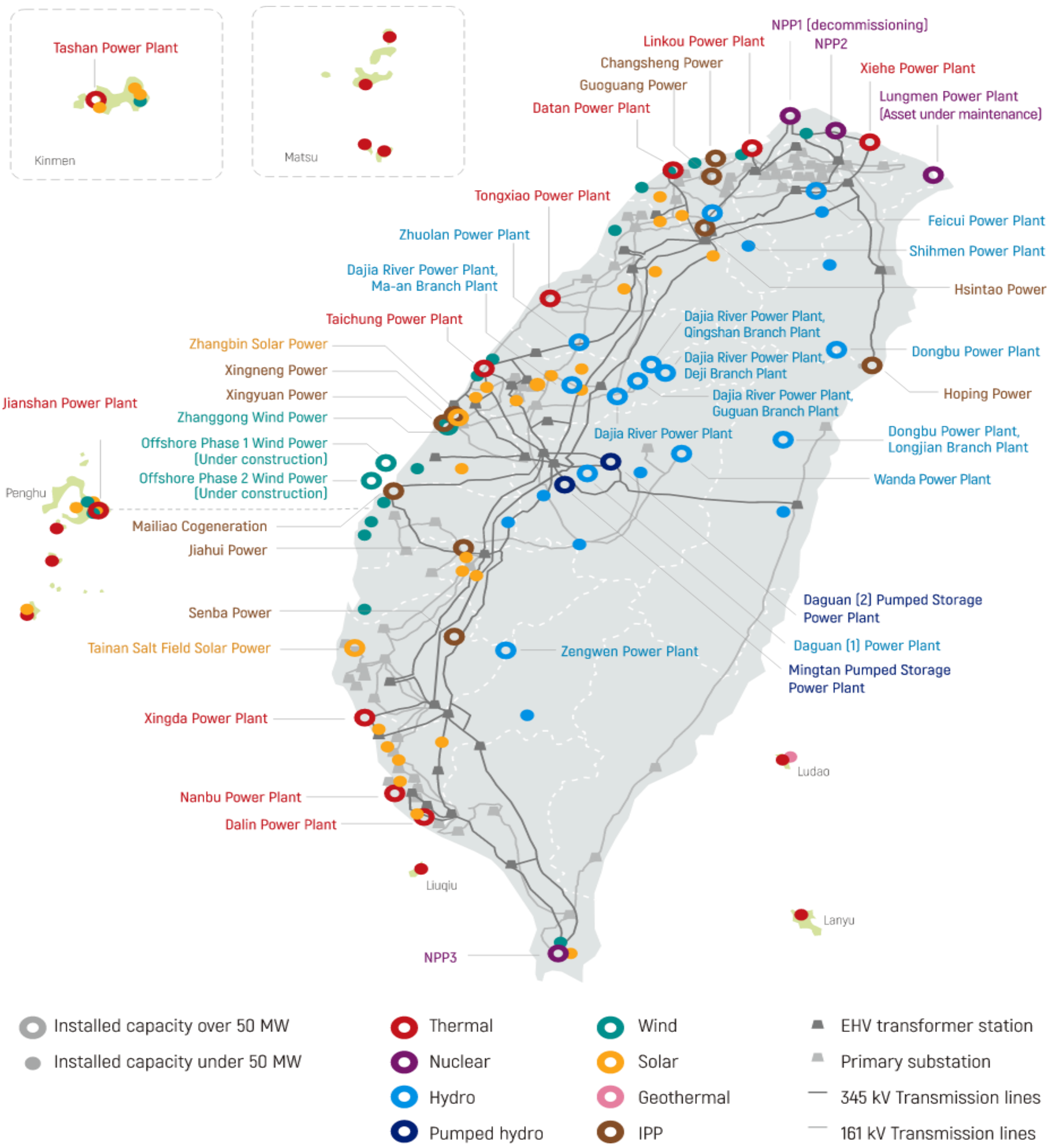


Figure 5-11 Chinese Taipei power grid configuration (Taipower) [107]

Under the administration contracts, the project is obliged to provide a performance bond deposit equal to the originally planned installed capacity. It is calculated on a per MW basis. If the developer cannot meet key milestones, they will need to pay a penalty of 3% to 5% of the bond deposit for each full month of delay. If the delay has continued for 12 months or more, the MOEA has the right to rescind the administration contracts.

In Chinese Taipei, the issuance of the final grid connection agreement includes a SIS approval letter issued by the TPC. This is followed by a Primary Grid Connection Negotiation (PGCN) from the TPC to state further technical aspects of the grid connection before a final detailed grid connection negotiation is achieved. This will include all technical aspects agreed upon with the TPC to complete the grid connection process.

The development company is required to submit an offshore wind farm grid connection prospectus and SIS to Taipower for technical evaluation. The SIS outlines the location, capacity, plan, point of common coupling (PCC), type of cable, estimated COD, schematic configuration diagram and the proposed WTG model. Following the submission of the SIS, the developer will receive a grid connection review opinion letter, providing the grid connection approval. The developer is then required to go through a series of negotiations with TPC, to finalize the grid connection review process.

According to *Taipower's Renewable Energy and Power Generation System Connection Technical Regulations* the SIS should cover the detailed grid system analysis, including:

- The load flow studies which show that the line capacity of the export cable is sufficient for the power export capacity at the PCC;
- The short circuit capacities for both proposed WTGs at the PCC are suitable and therefore confirm fault detection will be possible;
- The project's transient stability will be studied using the WTGs output power flow;
- Voltage flicker is in line with the standard of less than 0.83%, and voltage variation based on IEC 61400-21 is within the acceptable standards set by the TPC (±3%);
- Low voltage ride-through (LVRT) confirms the ability of the project to remain connected for at least 0.5 seconds when the voltage is temporarily depressed to 15% by a remote fault, meeting the TPC requirements;
- Power factor studies confirm that the project can meet the reactive power requirements at the PCC.

The overall grid connection procedure is summarized in Figure 5-12.

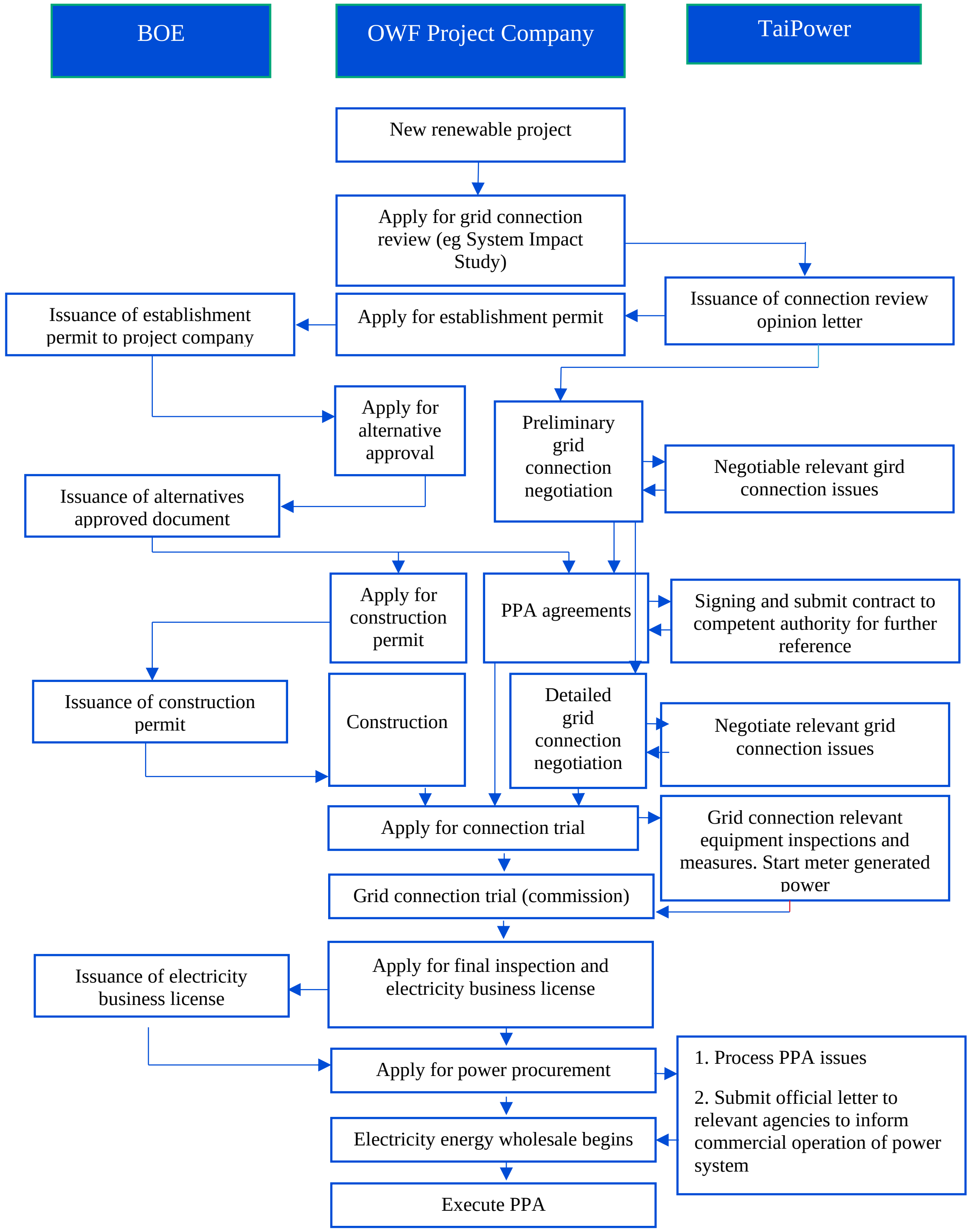


Figure 5-12 Overview of the grid connection process

5.5.2 Transmission Network and Expansion Plan

Taipower has three pillars for promoting renewable energy, including kind grid connection, leading demonstration, and system stability. Taipower has incorporated the authority renewable development goal into their grid expansion and enhancement plan. For kind grid connection, it emphasizes the grid enhancement to provide enough capacity for renewable electricity connecting to the grid [108].

Taipower is aware of the pressure being put on the grid due to increasing installation of renewable plants around the load centers. Taipower has therefore launched a project aimed at strengthening the power grid. This includes the expansion of Nanke UHV substation, construction of new Baoshan UHV substation, upgrades to integration capacity and the introduction of static synchronous compensation equipment. Taipower is committed to researching the grid connection dispatching systems and strategies and has built a power generation information integration platform to actively respond to future more network challenges [109].

According to Taipower, the grid reinforcement work for OWF is in good progress as of May 2022. The overall completion rate was 39.91%, exceeding 2.38% of the expected progress. Table 5-8 summarize the relevant grid expansion work [110].

Table 5-8 Grid expansion for OWF in Chinese Taipei

Expansion plan	Capacity (MW)	Expected completion
110 彰 - (甲) (110 Chang – (A))	1,000	2024
112 彰 - (乙) (112 Chang – (B))	500	2023
113 彰 - (乙) (113 Chang – (B))	1,000	2024
114 彰工升壓站 (114 Chang Gong step-up station)	2,000	2025
114 永興開閉所 (Wing Hing switching station)	2,000	2025
114 桃園地區 (Taoyuan region)	1,140	2025
114 主幹線加強電力網 (main grid reinforcement)	/	2025

5.5.3 Offshore Wind Case Study

The first demonstration project as part of Phase 1 of the Thousand Wind Turbines Project (TWTP*)* was Formosa 1 [111]. This offshore wind farm was built approximately 2 - 6km off the coast of Miaoli County and was carried out in two phases. The first phase was completed in April 2017 with the installation of 2 turbines with a total capacity of 8MW. The second phase, which was completed in December 2019, took the wind farm to a total capacity of 128MW with 22 turbines. Project investors include JERA, Ørsted A/S, Macquarie, Swancor. The location of the Formosa 1 Demonstration Project is provided in Figure 5-13.

The second demonstration project was Taipower 1 [101]. Taipower 1 OWF was built 5 - 8km off the coast of Changhua County in 15-25 meters water depth. It was completed in August 2021 with total installed capacity of 109.2MW and 21 turbines.

Another offshore wind farm under development is the Hai Long Offshore Wind Project. The project has a total capacity over 1GW which is jointly developed by Northland Power Inc., Yushan Energy Pte. Ltd. and Mitsui & Co., Ltd. Table 5-9 provides a summary of the Hai Long Offshore Wind Project.

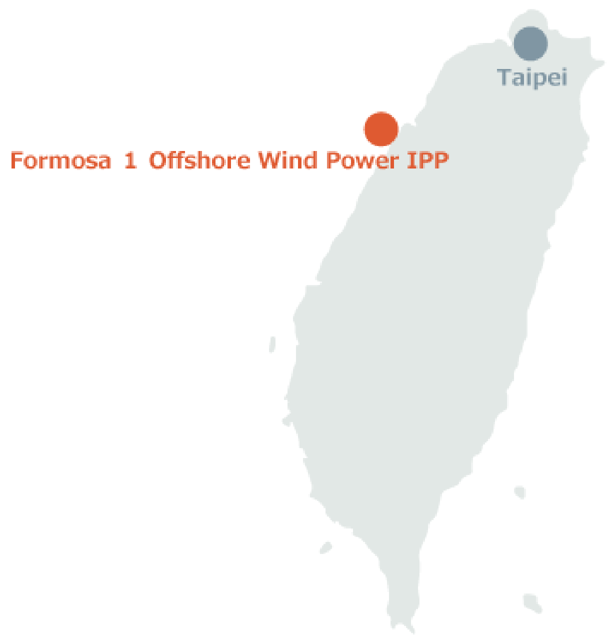
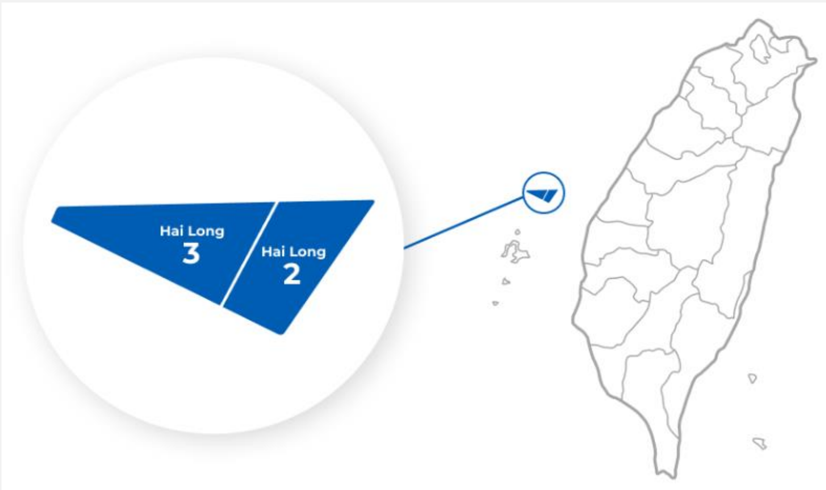


Figure 5-13 Location of Formosa 1 demonstration project

Table 5-9 Hai Long OSW Project case study [112]

Hai Long Offshore Wind Project	
Location	 40-50km off the Changhua coast
Water Depth	Water depth of 35-55m
Choice of technology	2 independent offshore substations 1 onshore substation HL2A: 21 x WTGs HL2B: 16 x WTGs HL3: 36 x WTGs
Capacity	A total of 1044MW approved
Shareholder	Northland Power (Canada) – main developer Yushan Energy (Singapore) Mitsui & Co. (Japan)

Hai Long Offshore Wind Project	
Status	Development Obtained the approval from the Environmental Protection Agency for the 2nd amendment to Environmental Impact Assessment report final version submission (July 2022) [113] Commercial Corporate PPA (CPPA) was signed which provides Hai Long 2B and 3 sites with a fixed price for delivering power for a period of 20 years, in addition to the RECs for the contract period (July, 2022) [114] Hai Long 2A is signed under Taipower PPA which guarantees a fixed revenue for Hal Long 2A project for 20 years at a price higher than CPPA.
Expected COD	Late 2026
Site conditions	Wind speed: 10-11m/s average Water depth: 35-55m
Wind turbines	Model: SGRE 14-222 Rated power: 14MW (14.7MW with power boost function) Rotor diameter: 222m Gearbox: direct drive Generator: PMSG Wind speed range: 3-28m/s. Rated wind speed: 13-15m/s Hub height: 143m One concern is that the process of getting local certification of the WTG model was still in progress in mid 2022, and expected to be completed in the middle of the development phase. It increases the uncertainty of the project.
Grid connection	Inter-array voltage: 66kV Export voltage to onshore substation: 245kV Export voltage to grid: 161kV The Hailong Project consists of three electrically separated project during normal operation, codenamed HL 2A (300MW), HL 2B (232MW) and HL 3 (512MW). The grid connection for all projects will be undertaken through Taipower at Zhanggong substation. Taipower is the sole grid operator in Chinese Taipei. Each of the individual projects will evacuate the generated energy in similar electrical configuration through the balance of plant (BoP) design into Taipower's asset. 

5.6 Offshore Wind Offtake Business Case

5.6.1 Participation in the Electricity Market

- Power Purchase Agreement

There are two approaches for offshore wind projects to receive revenue in Chinese Taipei. The first is to sign a PAA with Taipower selling electricity to the utility company. The second is to sign a corporate PPA selling electricity to a private company. Table 5-10 provides further details on each type of PPA.

Table 5-10 Key provisions for PPAs in Chinese Taipei

Key Provisions for PPA	
Taipower PPA	Taipower PPA is generally non-negotiable, and the template form of a Taipower PPA will specify, amongst other things, the installed capacity, tariff, purchased capacity and term of the PPA. Taipower is very similar to the template form of power purchase agreement. Taipower has used it in numerous renewable energy projects (principally onshore wind and solar), which have been the subject of external bank financing. The Taipower PPA was published by Taipower on its website on 1 December 2017, with the recent amendment made in March 2020. This revised form contained minor modifications compared to the previously published form of power purchase agreements applicable to the onshore wind and solar projects in Chinese Taipei.
Corporate PPA	Following the 2017 amendments to the EB Act and amendments to Article 9 of the REDA in May 2019, a renewable energy producer can choose to sell all or part of its power production directly to end-users via Corporate PPAs. This is a departure from the previous position whereby all sales were required to be sold to Taipower. While the REDA permits the power supply by a generator directly to an end customer via a privately owned transmission line, the more likely route for the OWFs in Chinese Taipei will be the supply to end-users through the power grid using the wheeling service provided by Taipower. This service is provided under Taipower's standard form power wheeling agreement (the "Wheeling Contract"). A positive feature of the Chinese Taipei electricity supply market is the ability for renewable energy generators who have signed corporate power purchase agreements to enter separate PPAs with Taipower, and who benefit from the FiT rate which would otherwise be applicable to the renewable energy generation project in the absence of a Corporate PPA. These take the forms of: (i) Surplus PPA: a surplus supply agreement with Taipower which runs concurrently with a Corporate PPA and provides for the supply to Taipower of generation which is in excess of that wheeled under a Corporate PPA. (ii) Backup PPA: a backup supply agreement with Taipower which may be entered into by the generator following the expiry or early termination of a Corporate PPA. These supply arrangements with Taipower provide a meaningful enhancement to the bankability of the offshore wind projects in Chiense Taipei that benefit from entering into them.

- REC Market

The Bureau of Standards, Metrology and Inspection (BSMI) of the MOEA established the National Taiwan Renewable Energy Certificate Center to issue the Tradable Renewable Energy Certificate(T-RECs) for all renewable electricity generators. Note that the T-RECs system excludes the electricity coming from the sources receiving support through FiT or issuing carbon credits through the GHG Offset Program [115].

The T-REC application process requires documentation review and site inspection following which the metering data will be transmitted to the T-REC Center for records. Once 1,000kWh (or 1MWh) renewable electricity is generated, a T-REC will be issued automatically in the T-REC database.

In support of the emerging REC market, different ownership transfer models have been considered. Figure 5-14 shows the mechanism of the current T-REC transfer model which includes:

1) Route 1 and Route 2 are for renewable electricity direct supply and wheeling;
2) Route 3 is the renewable electricity retail model;
3) Route 4A represents the on-site renewable electricity generation and consumption;
4) Route 4B is the transfer model for unbundled RECs of on-site renewable generation.

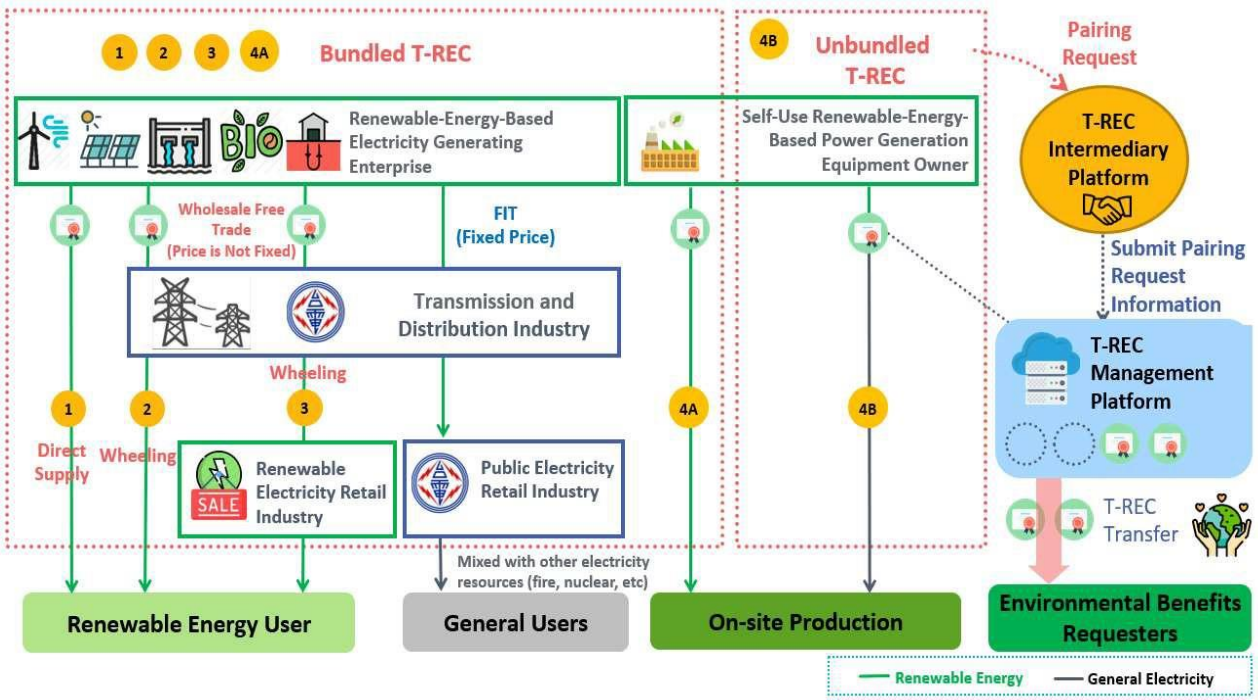


Figure 5-14 Current T-REC transfer models [115]

5.6.2 Cost of Offshore Wind

The development cost of a wind farm varies based on many factors, including geographical location, choice of technologies and international supply chain etc. We have investigated three commercial scaled offshore wind farms in Chinese Taipei from 2019 to 2022. The Capex ranges from USD4.9 million/MW to USD6.1 million/MW, which is around 30%-40% more than the cases in Europe. One of the reasons is because the local supply chain is in early stage in Chinese Taipei. Also, the LCOE can range from USD100-200/MWh according to the industrial experience. The Chinese Taipei offshore wind market still relies heavily on importing major equipment from oversea markets, such as importing offshore foundation and wind turbines from the Europe and Korea. To promote the local offshore wind development, the local authority has enforced local contents requirement among the selection criteria for certain projects (more details in 6.3.3).

5.6.3 Participation in Provision of Ancillary Services

With the aggressive renewable energy goals, the grid must be able to integrate significant portions of variable renewable energy while maintaining grid stability and reliability. To achieve this, Taipower has adopted four different types of auxiliary services, including Fast Response, Regulation, Spinning Reserve, and Supplemental Reserve. Drawing on these services, it plans to cope with the uncertainty and intermittence of the added renewable power generation.

Taipower plans to introduce nonconventional resources, including energy storage systems, demand response and other fast response power generation resources to provide robustness to system flexibility. By the end of 2019, three battery energy storage systems with 3MW had been installed in Chinese Taipei to help stabilize the system frequency [116]. Figure 5-15 summarizes Taipower's latest ancillary services measures.

Service type	**Fast Response Reserve**	**Regulation Reserve**	**Spinning Reserve**	**Supplemental Reserve**
Response time	**<sec**	**3 mins**	**10 mins (now 30 mins)**	**30 mins (now 60 mins)**
Duration	**3-15 mins**	**15 mins**	**1 hr**	**2 hrs**
2025 Procurement	1000~1200MW	±1300MW	1100MW	1100MW
Sources	**Energy Storage System (590MW)**			
	Demand Response with UF-Relay	**Demand Response** with Storage	**Demand Response** with Load Curtailment	
	Generators with Primary Frequency Response	**Generators** with Automatic Generation Control	Generators	Generators

Figure 5-15 Taipower ancillary services [116]

5.6.4 Private Offtaker of Electricity

According to the 2017 amendments to the EB Act in 2019, a renewable energy producer can choose to sell renewable electricity production directly to end-users via Corporate PPAs. This was a significant move where previously all electricity sales were required to be sold to Taipower. The more likely route for the OWFs in Chinese Taipei will be the supply to end-users through the power grid using the wheeling service provided by Taipower. This service is provided under the "Wheeling Contract" with Taipower.

In addition, a positive feature of the Chinese Taipei electricity supply market is the ability for renewable energy generators who have signed corporate power purchase agreements to enter separate PPAs with Taipower, and who benefit from the FiT rate which would otherwise be applicable to the renewable energy generation project in the absence of a Corporate PPA.

For instance, the Northland Power's Hai Long project has officially signed a 20-year cooperate PPA for its 744MW portion of the offshore wind plant whereas the remaining 300MW has secured a 20-year utility PPA with Taipower, the power utility. There is not much further public information available yet for the market since the private market electricity is still at is early stage. [117]

5.6.5 Curtailment

According to the latest Taipower PPA, if a Taipower substation or grid system fails, the offtaker is under no obligation to compensate the generator. Furthermore, the project company is required to operate by stopping operations or reducing its output in the event of grid failures, without any recourse for revenue loss. While the PPA does not specify the maximum number of the allowed grid outages per year, the generator should conduct a grid availability study with a grid specialist to quantify the risk of curtailment due to grid outages on a case-by-case basis. Nevertheless, it is understood that Taipower grid availability and reliability metrics have been relatively high when compared to industry standards. This mitigates the actual loss in the case of the curtailment. Now, no public figure for offshore wind curtailment is available.

5.7 Summary and Recommendations

Development of offshore wind energy is one of the main strategies for achieving Chinese Taipei’s climate goals. While the authority driven projects and relevant policies are supporting its growth, there are still some challenges that need to be addressed. Certain offshore wind projects are required to include the local contents into their development targets. This policy is to support the growth of the local supply chain, however it creates a risk for the developers who might struggle to find suitable local capabilities in a new market. Developing a mature local supply chain is a progressive process which needs significant efforts and time. Accelerating its development is possible through effective collaborations with the experienced international markets such as Europe and China. It is important that the local banks start financing the OSW supply chain in Chinese Taipei. For this to happen, banks need to be confident in the technology and its potential. The authority should support the investment in special equipment manufacturing, staff training, large specialised vessels making and new facilities development, such as large port side lay-down areas for turbines and foundations. As local banks gain more experience with lending to OSW projects and assessing their risk, they can start to take a more prominent role in this market [118].

Overall, Chinese Taipei has very strong incentives for offshore wind development. Although it has seen a drop in FiT rates over the years, the offshore wind FiTs have continued to be higher than alternative renewable energy technologies. Renewable energy generators are also provided technical privileges that allow them to have the priority and security over other generators by having revenue flexibility. While the approval process is entirely managed by the BOE, it has not yet streamlined for simplicity and speed. Based on previous experience, it can take up to 7 years from site allocation to project connection.

Chinese Taipei has many local fishery community groups and political parties that advocate for strict ocean protection regulation on any development in the sea, including OWFs [119]. Every wind farm development in Chinese Taipei must go through a strict environmental approval process that requires permits from local and central authorities. The standard and quality of these approvals is very high and can be quite costly for the developers. Streamlining the approval process might help reduce the time spent with the administrative tasks. More public engagement on the part of the authority might also be able to help balance the concerns of preserving ocean habitats with developing more clean energy.

6 The United States

6.1 Introduction

In April 2021, the US set an ambitious climate target of reaching carbon neutrality carbon emissions by 2050, a 100 percent carbon pollution-free power sector by 2035, and 50% reduction in GHG emission by 2030 [120]. Offshore wind will be one of the critical resources of power generation required to reach this target. The offshore wind is stronger and more consistent than onshore wind, making a significant contributor to the US clean energy mix. In fact, it is estimated that offshore wind could provide more than 2,000GW of energy in US [6].

To achieve these goals, the Federal leadership and State decision makers are required to provide plans and procedure to support the planning, production, and interconnection of offshore wind to the US electricity market. The Biden administration has taken laudable, early actions to advance offshore wind by setting an economy-wide offshore wind goal of 30GW by 2030 and has begun to address the bottlenecks in leasing and permitting projects that had been made worse during the Trump administration.

6.2 Overview of Offshore Wind Resource

Figure 6-1 shows the wind speed and water depth as heat maps for the offshore portion of the US The wind speeds at 100m hub height range from 1.1m/s to 11.7m/s along the coast, with the highest concentrated off California and southern Oregon. In general, near-shore water depths are shallower along the east and deeper along the west.

Water depths up to -70m are generally considered suitable for bottom-fixed foundations, while floating foundations are suitable for water depths between -70m to -1,000m. Sea depths beyond -1,000m are considered ultra-deep and are less economically favourable and more complex, and riskier in terms of development for floating foundation. Based on the wind resource, both fixed and floating foundation OWF can desirably be deployed along California and north-east coast (see Figure 6-2).

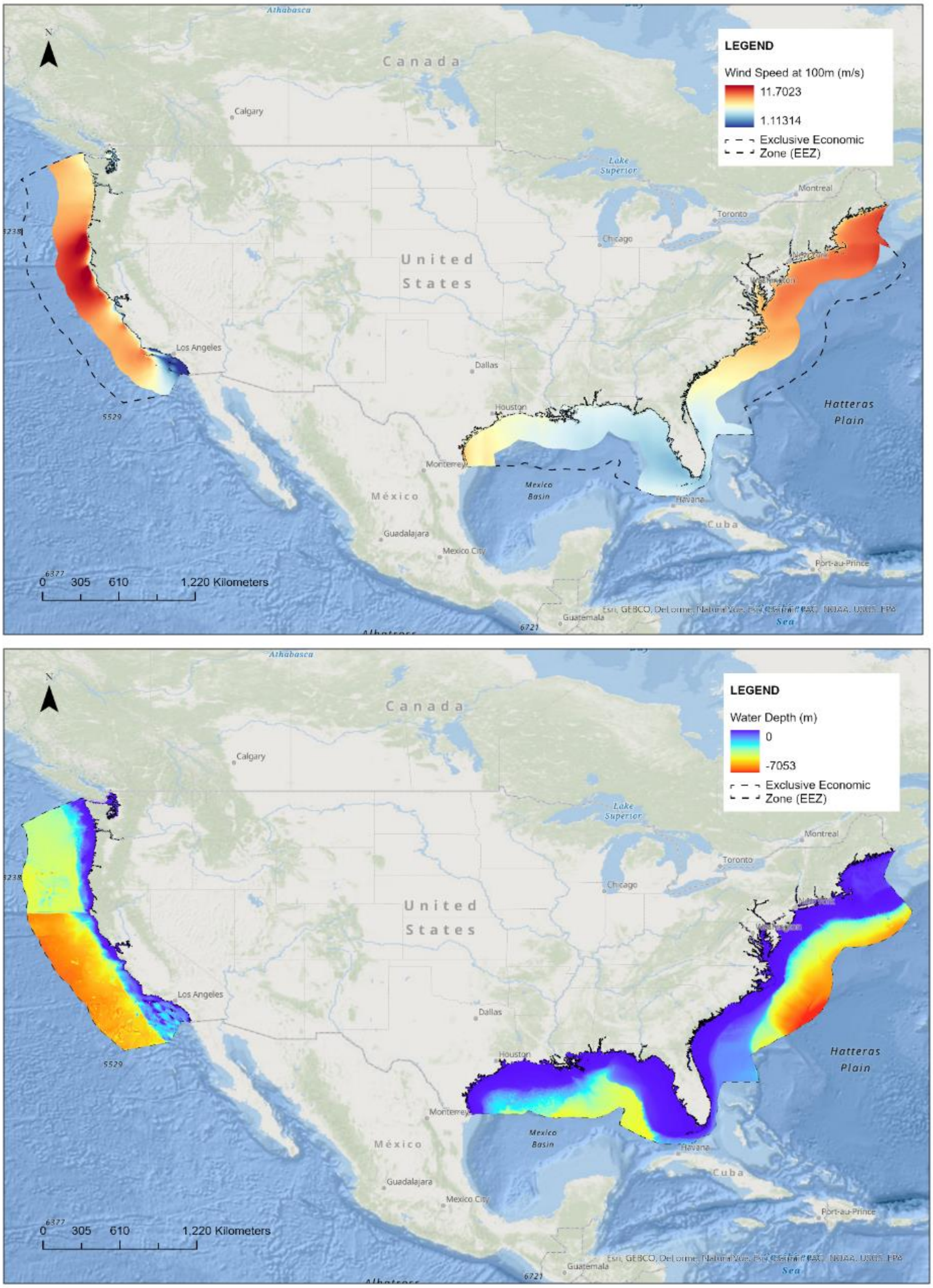


Figure 6-1 Wind speed (top) and water depth (bottom) of the US offshore areas

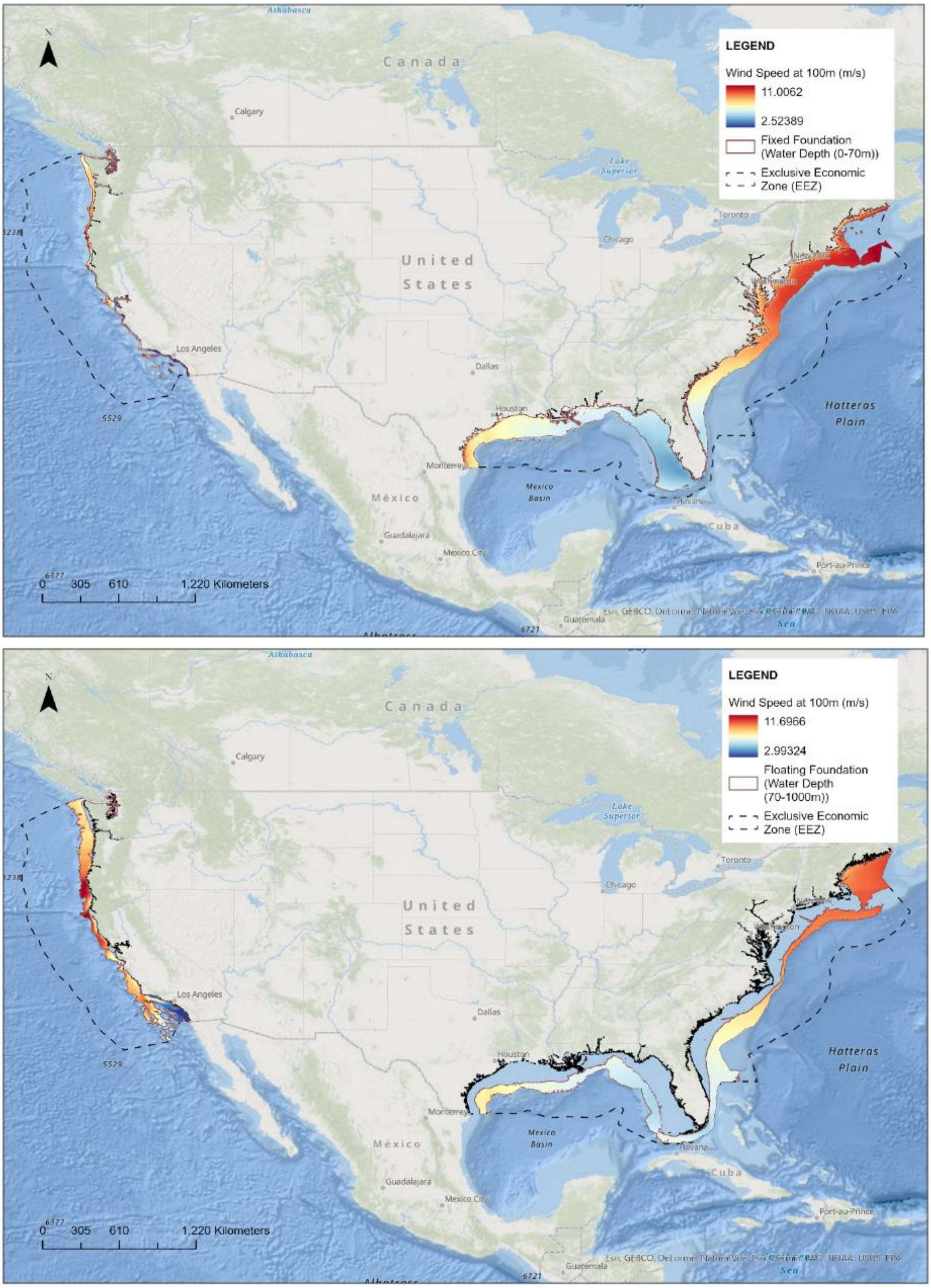


Figure 6-2 Wind speed for fixed foundation water depth 0 to -70m (top) and floating foundation -70 to -1000m (bottom) in the US

6.3 Energy Sector and Regulatory Mechanism

6.3.1 Structure of Electricity Supply

Electricity in the US is generated from both green and conventional power sources. Overall, the US power grid is created from over 7,300 power plants, nearly 160,000 miles of high voltage power transmission lines, and millions of miles of low voltage power lines. These infrastructure components connect 145 million customers across the territory , facilitated with distribution transformers.

The installed generation capacity in the US amounts to around 1,275GW of which approximately 62% corresponds to gas and coal plants. Regarding renewables, onshore wind has the largest installed capacity, adding around 11% of the total, followed by large-scale photovoltaic solar, which represents 6%. Figure 6-3 shows the evolution of installed capacity in the USA.

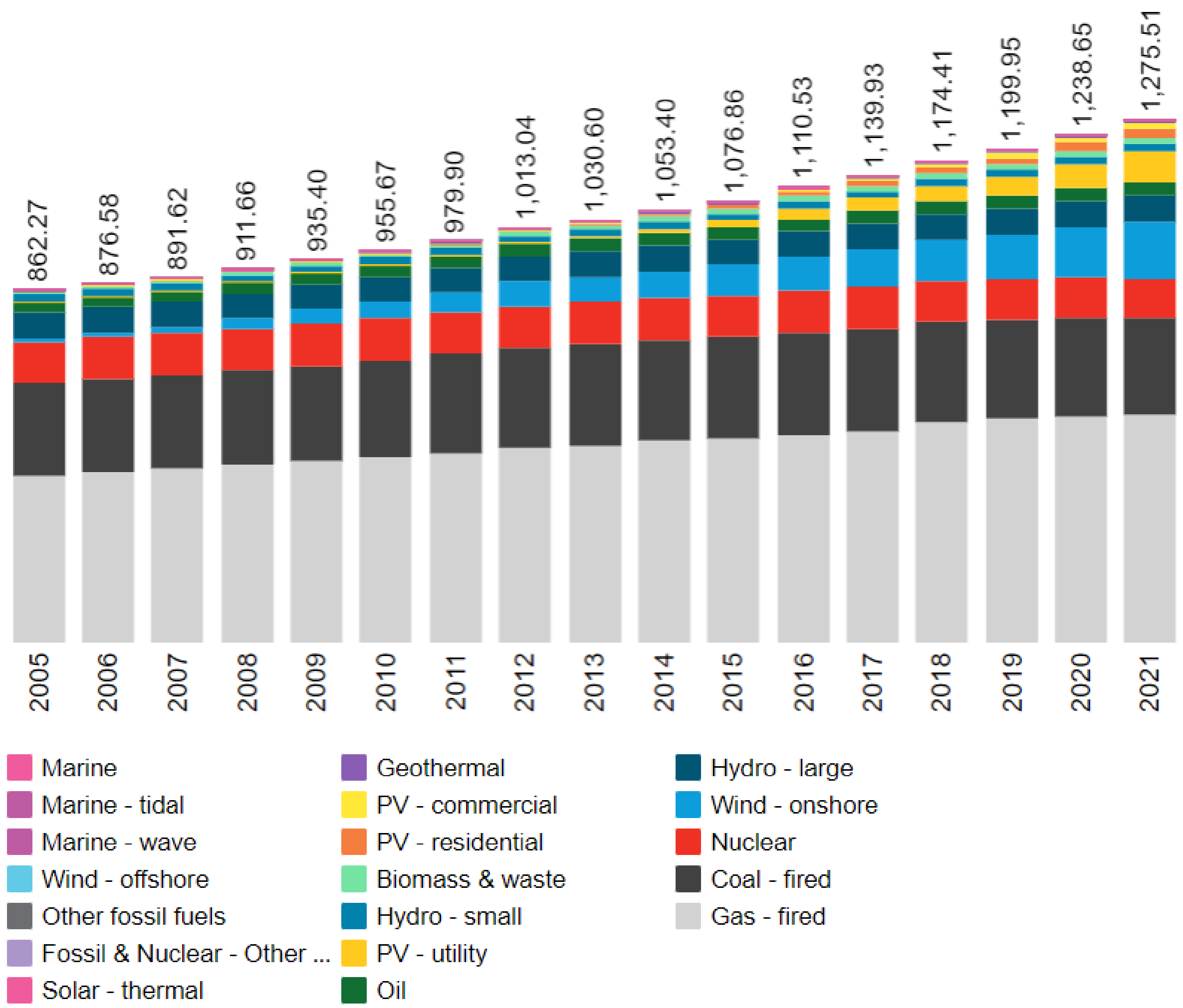


Figure 6-3 The US' installed capacity (GW) by source 2005-2021 [121]

The US electricity grid has been created from interconnection of the local grids. Overall, there are three major interconnections, functioning predominantly independently of one another, with limited exchanges of power between them. The eastern interconnection includes the area from the Great Plains states (excluding Texas) to the Atlantic coast. The Western interconnection includes the area west of Rocky Mountains and the Great Plains to the Pacific coast. The Electric Reliability Council of Texas (ERCOT) covers most of the state of Texas [122].

The regional operation of the electric system is managed by the entities called balancing authorities. These authorities are responsible for ensuring that the electricity supply constantly matches the power demand. Basically, the balancing authorities are the electric utilities that have taken on the balancing responsibilities for a specific part of the power system. The electric utilities are responsible for the planning for the future power needs of their customers. There are mandatory reliability standards for the planning and operating of the power system, which are developed and managed by the North American Electric Reliability Corporation (NERC). The Federal Energy Regulatory Commission (FERC) reviews and approve the standards.

According to BNEF [121], in 2021 about 60% of the generated electricity was from conventional supplies such as coal and gas. Also, about 19% was from nuclear energy, and more than 17% was from renewable energy sources. Figure 6-4 shows the electricity generation in the US in the last 15 years. The fossil fuels are the largest energy source in the US. Among the renewable energy sources, wind energy had the higher percentage (46%) in 2021, accounting for 9.2% of the total US electricity generation.

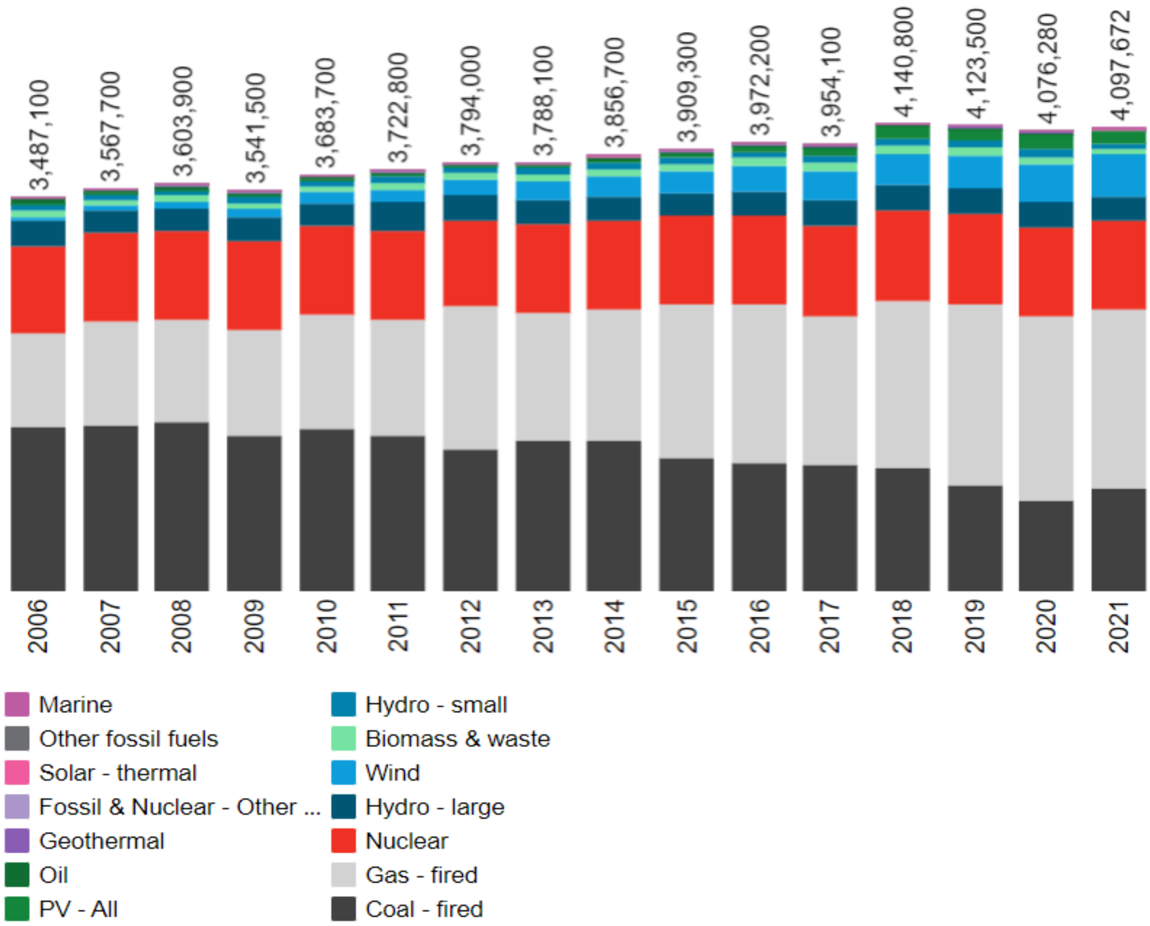


Figure 6-4 The US electricity generation (GWh) by source 2006-2021

6.3.2 Renewable Energy and Climate Change Policies and Targets

The US have been addressing climate change in the absence of stronger federal action. A wide range of policies have been adopted at the state and regional levels to reduce GHG emissions, develop clean energy resources, promote alternative fuel vehicles, and promote more energy-efficient buildings and appliances among other things. The Climate Action Plans generally include GHG emissions reduction targets and detailed actions that the state can take to help meet these goals.

Per the latest updated in August 2022 from US State Climate Action Plans [123], there are 33 states that either have released a climate action plan or are in the process of revising or developing one. This include 23 states that have released plans, eight states that are updating their plans, and one state that is developing a plan.

There is a wide range of state policies which aim to reduce the GHG emissions from the power sector. Some of these polices were enacted explicitly to address the climate change, while others have complementary objectives, for example, supporting in-state producers of preferred energy resources such as wind, solar, or nuclear. One of the most common state policies is a portfolio standard that requires electric utilities to deliver a certain amount of electricity from renewable or clean energy sources.

Renewable Portfolio Standard (RPS) has been adopted in 29 states and the District of Columbia that require a certain percentage of utility’s electricity to come from renewable energy resources. Also, Clean Energy Standard (CES) are adopted by seven states, which requires electric utilities to deliver a certain amount of electricity from renewable or clean energy resources. [124]

In general, the US uses 15 clean energy policies and programs to meet the energy, environmental, and economical objectives. Below Table 6-1 shows the summary of current active policies.

In April 2021, the US set an ambitious climate target to achieve: [125]

- 50% - 52% reduction in net GHG pollution from 2005 levels by 2030;
- 100% Carbon pollution-free electricity by 2030;
- Net-zero carbon emissions by 2050.

Specifically, for the power sector, the government plans to accelerate clean energy by (1) kick-off offshore wind industry in the US, (2) accelerate clean energy projects e.g., solar energy and distributed energy resources, (3) enhancing grid resilience, (4) USD20 billion Clean Energy Demonstration launched by the Department of Energy to encourage innovations to bring cost efficiencies to critical technologies, and (5) USD464 million investment for rural electric infrastructures. [126]

Table 6-1 Current active clean energy policies

Policy	Policy type	Start year	Status
US Renewable Electricity Production Tax Credit	Tax Incentives	Before 2010	In force
US Business Energy Investment Tax Credit	Tax Incentives	Before 2010	In Force
US Section 1703 Loan Guarantee Program	Debt/ Equity Finance incentives	Before 2010	In Force
US 1705 Loan Guarantee Program	Debt/ Equity Finance incentives	Before 2010	Ended
US – California Renewable Portfolio Standard	Target/ RECs*	Before 2010	In Force
US Department of Defence Requirement to Buy American Photovoltaics	Barriers	2012	In Force
US California 33% Renewable Portfolio Standard	Target/ RECs*	2011	Ended
US New Jersey RPS Carve-out for Offshore Wind	Target/ RECs*	2011	In Force
US Massachusetts RPS carve-out for photovoltaic generation	Target/ RECs*	2010	In Force
China Duties on Polysilicon from the US and Korea	Barriers	2013	In Force
India Anti-Dumping Duties on PV Products	Barriers	2012	Ended
US Duties on Chinese PV Cells	Barriers	2012	In Force
US Duties on Chinese PV modules consisting of cells produced beyond China	Barriers	2015	In Force
US California 50% Renewables Portfolio Standards	Targets /RECs*	2015	In Force
US Massachusetts Offshore Wind Request for Proposals	Auctions	2017	Announced

Source: Bloomberg NEF (WWW.BNEF.COM)

**Renewable Energy Certificate*

Table 6-2 US climate targets [127]

Item	Five goals to achieve the carbon neutrality economy	Stakeholders/Industry involved to meet this target
1.	At least half of power generated from locally supplied clean energy to meet 24/7 demand to reach 100% carbon pollution-free electricity	Utilities, developers, technology companies, Financing companies Target power procurement: solar, wind
2.	100% zero-emission vehicle acquisitions by 2035 and 100% zero-emission light-duty vehicle acquisitions by 2027	Electric vehicle, battery, and charging equipment manufacturers and installers
3.	Buy clean policy via promoting lower embodied emissions construction materials	Real estate
4.	50% reduction in building emission by 2032 and zero emission building by 2045	Real estate
5.	65% reduction in emissions generated from federal operations and carbon neutrality by 2050	Federal policy, federal infrastructure

6.3.3 Offshore Wind Power Development Policies and Targets

As part of the plan to achieve carbon neutrality economy, the Biden administration is on the track to deploy 30GW of offshore wind energy by 2030. If successful, it will unlock a pathway to 110GW of offshore wind capacity by 2050 [128]. The Department's Bureau of Ocean Energy Management (BOEM) is responsible for offshore renewable energy development in the Federal waters and has seen very strong interest in offshore renewable energy projects on the Outer Continental Shelf (OCS), and work closely with several states to develop the offshore wind energy. Also, the BOEM is in the process of coordinating federal-state task forces in certain coastal states.

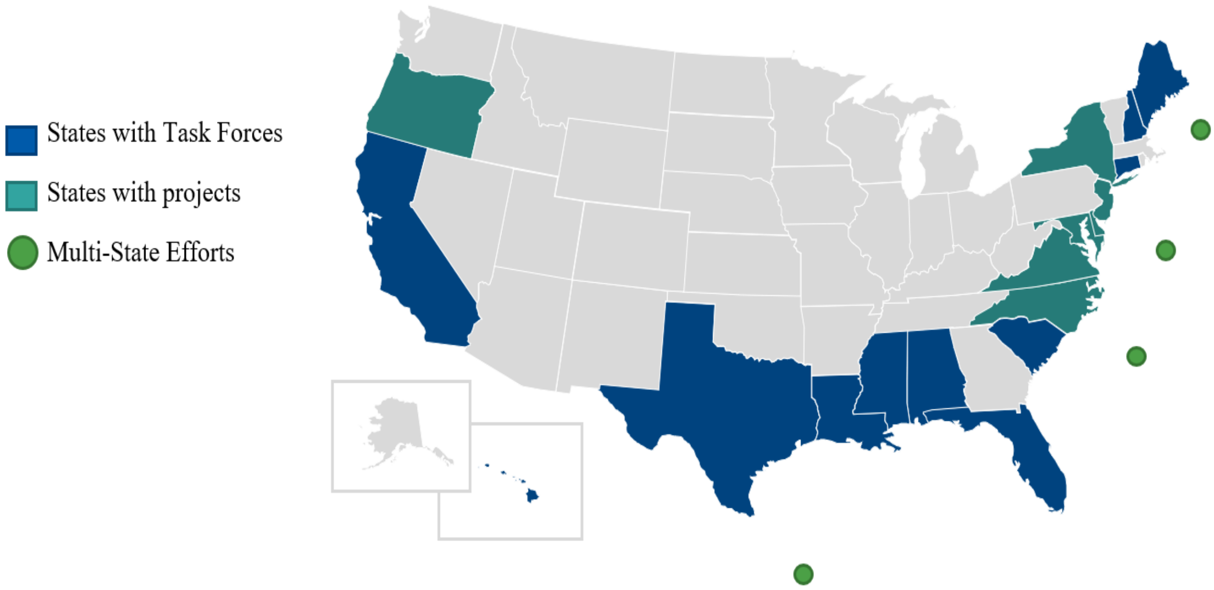


Figure 6-5 OSW development in the US [129]

The BOEM announced a new priority Wind Energy Area in the New York Bight and is progressing new lease sales. Additionally, they aim to complete the review of at least 16 *Construction and Operations Plans (COPs)* by 2025, indicating more than 19GW of capacity. As of 2021, the offshore wind pipeline has 35GW of projects in various stages of development, with majority being based on New York state. By February 2022, the sale of offshore wind development rights off the coasts of New Jersey and New York reached an astonishing USD3.3 billion. This sale consists of six leases across 488,201 acres and was the largest offshore wind auction [130].

By mid 2022, there was offshore wind activity on all the US coasts. The East Coast has seen the most commercial activity by far, with two operational projects and all lease sales to date taking place in that region. Several additional projects are nearing the construction phase. The Vineyard Wind project – an 800MW project consisting of up to 84 turbines located approximately 12 nautical miles offshore of Martha's Vineyard, Massachusetts, and 12 nautical miles offshore of Nantucket – received its COP approval in May 2021 and began construction in November 2021. [131]

Until 2021, the offshore wind industry in the US has largely been driven by state renewable energy goals and offshore wind targets. Eight East Coast states alone have set targets totalling 37GW. These targets, along with state policies and procurements, have played a significant role in shaping the industry's growth trajectory by providing a certain level of market predictability.

Table 6-3 State renewable energy goals and OSW targets [132]

State	Renewable Energy Goals	Offshore wind goals (megawatts)
Massachusetts	35% by 2030	5,600
Rhode Island	100% by 2030	Unspecified
Connecticut	44% by 2030	2,000
New York	70% by 2030	9,000 by 2035
New Jersey	50% by 2030	7,500 by 2035
Maryland	50% by 2030	5,200
Virginia	30% by 2030; 100% by 2050	5,200
North Carolina	70% reduction of GHG emission by 2030; carbon neutrality by 2050g	2,800 by 2030; 8,000 by 2040

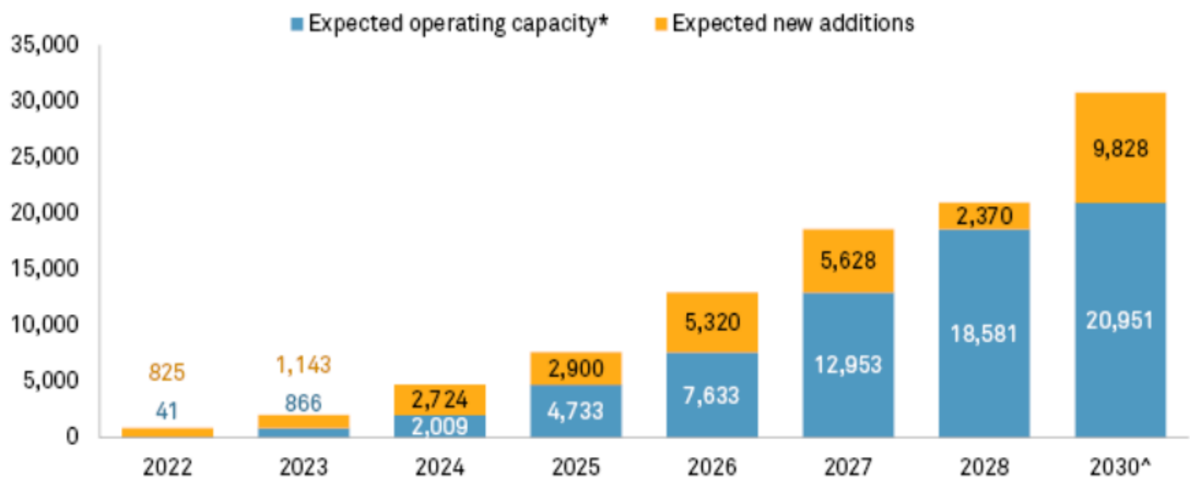


Figure 6-6 Planned OSW capacity (MW) in the US [133]

6.3.4 Renewable Energy and Offshore Wind Regulatory Support Mechanisms

To support the growth of offshore wind, the Department of Energy announced a USD3 billion loan program for the industry, funding through the XII Innovative Energy Loan Guarantee Program [134]. This program helps to support the offshore wind project developers who are based in the US with difficulties to accessing debt capital markets through extending loans to the projects or providing loan guarantees as a sole lender or as a co-lender. This loan program also has an in-house engineering group with specialized experience in innovative wind technologies.

Offshore wind investments also benefit two types of federal tax credits, Production tax credits (PTC) and Investment tax credits (ITC). PTC provides a tax credit of 1¢–2¢/kw for the first 10 years of electricity generation for utility-scale wind projects that commence construction after 31 December 2016 and before 31 December 2021. ITC is a one-time tax credits available for offshore wind projects that started construction after 2016 and before 2026. Projects meeting this criterion are eligible for a 30% ITC. To qualify for this tax credit, the projects must be in the US inland navigable waters or in the US coastal waters. Furthermore, in January 2021, the Internal Revenue Service (IRS) issued a rule providing a 10-year safe harbour period for offshore wind projects to receive the ITC – meaning that projects that start operations within ten years, after starting construction, will be eligible for federal tax credits [135].

6.4 Offshore Wind Development Procedure and Stakeholder Engagement

6.4.1 Stakeholders and Their Responsibilities

The US OSW is governed by multiple agencies at the Federal, State and Local government level.

At the Federal level, there are Secretary of the Interior, BOEM, the US Bureau of Safety and Environmental Enforcement (BSEE), and the FERC.

- Secretary of the Interior has the ultimate authority over offshore wind energy development and the statutory authority will be administered by BOEM;
- BOEM, an agency within Department of Interior, manages the responsibility of developing offshore energy and mineral resources in US, such as offshore wind development, lease sales, rights of way in federal waters and coordinating permitting activities;
- BSEE promotes safety, protects the environment, and conserve resources offshore through vigorous regulatory oversight and enforcement;
- FERC is an independent agency within the Department of Energy, who regulates the interstate transmission of natural gas, crude oil, refined petroleum products and electricity, and interstates wholesale electricity for electric transmission;
- The intrastate electricity industry is then overseen by the State Public Utility Commissions; managing generation, distribution, retail sales, public utility commission approvals, and energy solicitations. Additionally, the States have a regulatory responsibility under the Coastal Zone Management Act. For example, in California, the California Public Utilities Commission (CPUC) regulates all investors-owned utilities (IOUs) and approves all rates that each electric utility charges its customers.

The Regional Transmission Organizations (RTOs), also known as the independent system operators (ISOs), aims to foster competition for wholesale electricity generation participants by ensuring the safety and reliability of transportation of electricity on power grid. RTOs / ISOs are regulated by FERC. There are 10 RTOs/ISOs in the US:

- California Independent System Operator (CAISO) - operates a competitive wholesale electricity market and manages the reliability of its transmission grid. CAISO provides open access to the transmission and performs long-term planning;
- Midcontinent Independent System Operator (MISO) - MISO operates the transmission system and a centrally dispatched market in portions of 15 states in the Midwest and the South;
- New England Independent System Operator (ISO-NE) - ISO-NE serves six New England states: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island and Vermont;
- New York Independent System Operator (NYISO) – covering state of New York;

- Northwest Power Pool (NWPP) – covering states of Washington, Oregon, Idaho, Wyoming, Montana, Nevada and Utah, a small portion of Northern California and the Canadian provinces of British Columbia and Alberta;
- PJM Interconnection – covering Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia and West Virginia;
- Southeast electricity market - encompasses all or part of two NERC regions: the Florida Reliability Coordinating Council (FRCC) and the South-eastern Electric Reliability Council (SERC);
- Southwest electric market - covering Arizona, New Mexico, southern Nevada (AZ/NM/SNV) and the Rocky Mountain Power Area (RMPA) sub-regions of the Western Electric Coordinating Council (WECC);
- Southwest Power Pool (SPP) – covering 14 states; Arkansas, Iowa, Kansas, Louisiana, Minnesota, Missouri, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas and Wyoming;
- Electric Reliability Council of Texas (ERCOT) – operates a competitive wholesale electricity market in Texas.

6.4.2 Offshore Wind Approval Procedures

The US OSW projects require approvals from various agencies as they are built in the federal waters, under Federal jurisdiction (defined as more than three nautical miles from shore). *The Energy Policy Act of 2005 (EPAct)* authorized the BOEM to issue leases, easements, and rights of way to allow for renewable energy development on the OCS. The EPAct provided a general framework for the BOEM to follow when authorizing these renewable energy activities. For example, the EPAct requires that the BOEM coordinate with relevant Federal agencies and affected states and local governments, obtain fair return for leases and grants issued, and ensure that renewable energy development takes place in a safe and environmentally responsible manner. [136]

The BOEM's renewable energy program occurs in four distinct phases: planning, leasing, site assessment, and construction and operations. The BOEM engages key stakeholders throughout this process, as early communication with interested and potentially affected parties is critical to managing potential conflicts. The BOEM's renewable energy regulations were updated in October 2011 to reflect the Bureau reorganization, and will be updated in the future to incorporate the lessons learned and stakeholders’ feedbacks. [137]

Figure 6-7 Regulatory roadmap [138]

Below is an example of the approval process for an OSW project to be built in New York state, as shown in the following table.

Table 6-4 NYS permitting requirement for offshore wind generation and transmissions development [139]

Authorization	Permitting / Consultation requirement	Federal regulatory agency
Federal Authorizations and Consultations	1. Obtain a commercial lease of submerged lands for renewable energy development 2. Receive approval for a Site Assessment Plan (SAP) 3. Receive approval for a COP 4. Receive approval for a Facility and Design Report (FDR) 5. Receive approval for a Fabrication and Installation Report (FIR)	• Bureau of Ocean Energy Management (BOEM)
	6. Consultations pertaining to: • Magnuson-Stevens Fishery Conservation and Management Act, • Marine Mammal Protection Act, • National Historic Preservation Act, • Endangered Species Act	• National Oceanic and Atmospheric Administration (NOAA), • US Fish and Wildlife Service (USFWS), • Advisory Council on Historic Preservation
	7. Receive permit for subsea cables under the Clean Water Act	• US Army Corp of Engineers (USACE)
	8. Consultations pertaining to siting	• US Department of Defense (DoD) • Federal Aviation Administration (FAA)
	9. Receive permits for air quality and pollution prevention	• US Environmental Protection Agency (EPA)

Authorization	Permitting / Consultation requirement	Federal regulatory agency
		• USAC
	10. Receive authorization for incidental take or harassment under the Marine Mammal Protection Act, Endangered Species Act, Migratory Bird Treaty Act, the Bald and Golden Eagle Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act	• NOAA Fisheries • USFWS
State Authorizations and Consultations	11. Receive permit for the transmission system connecting the offshore wind farm to New York's electricity grid	• New York State Public Service Commission (NYC PSC)
	12. Receive permits for coastal environmental impacts	• NYC PSC • New York State Department of Environmental Conservation (NYS DEC)
	13. Receive an easement for underwater cables	• New York State Office of General Services (NYS OGS)
	14. Federal Consistency Review under the New York State Coastal Management Program	• New York State Department of State (NYS DOS)
	15. Receive permit for work on government -owned roads	• New York State Department of Transportation (NYS DOT)

6.5 Offshore Wind Grid Connection

6.5.1 Electricity Utility Structure and Grid Connection Procedure

The US's grid connects the 7,300 major power plants through 160,000 miles of high-voltage power lines with millions of miles of lower-voltage power cables and distribution transformers to provide power for 145 million customers [122]. The power grid in the US is divided into three regions: the Eastern Interconnection, the Western Interconnection and Texas Interconnected system. Figure 6-8 shows the distribution of high voltage transmission levels at 230kV, 345kV, 500kV, and 765kV.

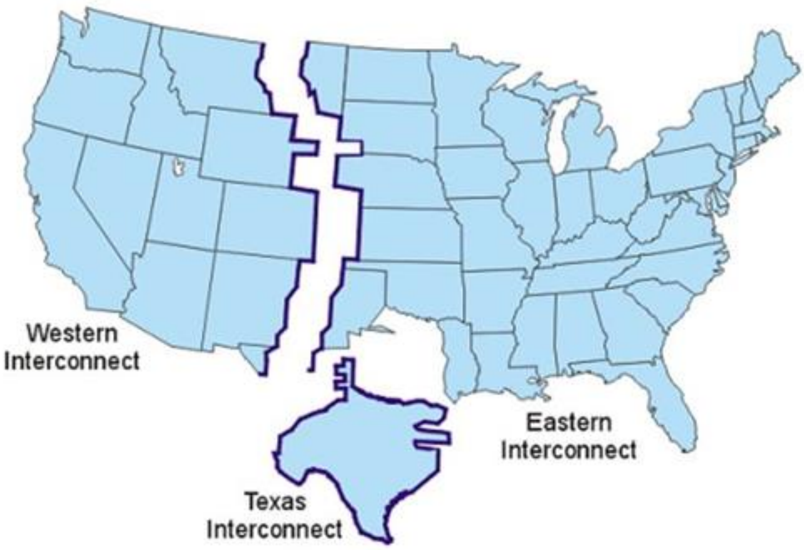


Figure 6-8 North America electric power grids [140]

The utilities in the US comprise of investor-owned, publicly owned, and cooperative. According to the US Energy information Administration (EIA), nearly three-quarters of the US power consumers acquire their energy from investor-owned utilities in 2017 [141].

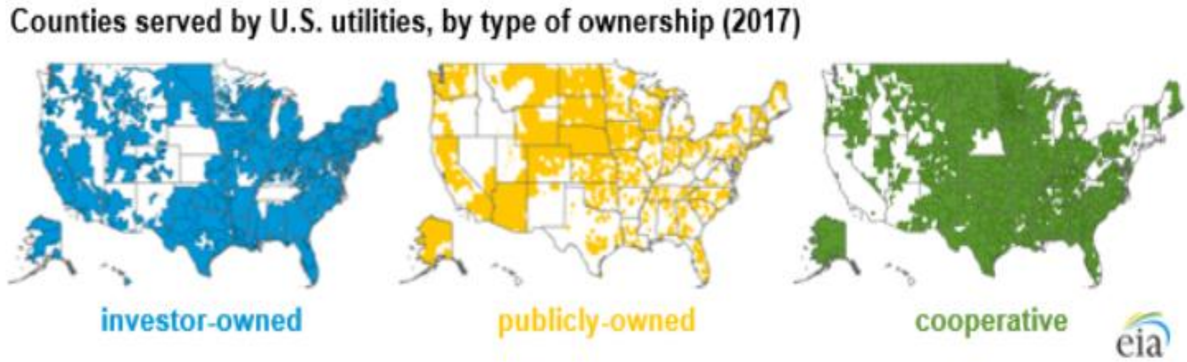


Figure 6-9 Type of ownership serving in the US utilities [141]

Due to the large mixture of parties and stakeholders in the grid network, OSW project integrating to the grid would require interconnection study. The process can be quite time-consuming, as shown in Figure 6-10, taking PJM Interconnection LLC, which is the grid operator for Delaware, Illinois, Indiana, Kentucky, Maryland, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia, and the District of Columbia, as an example for illustration. The total time per cycle is close to two years.

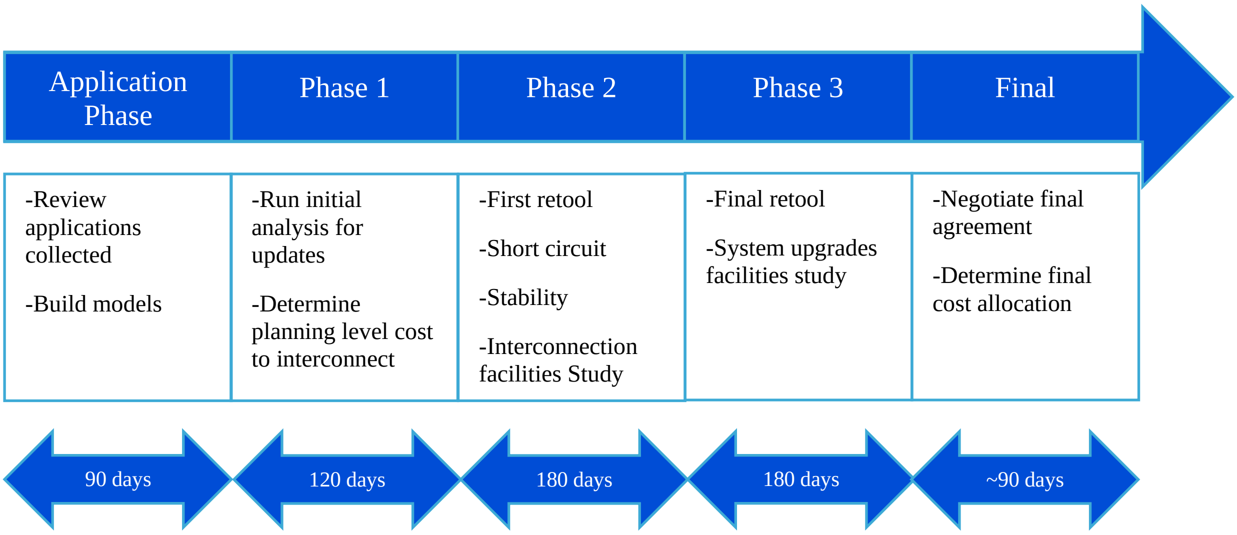


Figure 6-10 PJM interconnection study flow [142]

Moreover, there are significant integration costs associated with the OSW project. For OSW developments, there must be an onshore point of connection (POI) so generated energy can be integrated into the grid. So far, the regional developers have been responsible for creating these POIs. In 2020, only 55% of offshore wind energy was in the ISO-NE queue [143]. To support the new development of wind resources, POIs must be large enough to accommodate all planned OSW connections. In addition to developing the POI infrastructure, current onshore transmission infrastructure must be further developed. Adding OSW power to the existing infrastructure will increase congestion in transmission lines, so investments in these areas will be necessary to maximize the efficiency of the OSW developments.

6.5.2 Transmission Network and Expansion Plan

To achieve the goal of 30GW OSW electricity capacity by 2030, as stated by the Biden Administration, the US grid would require big upgrade to accommodate the addition of renewables [144]. The current grid in the US is designed for large power plant transmitting power to consumers in a one-way direction. To transit to more renewable energy, the grid system needs to be able to adjust for the weather-dependent nature of wind and solar energy. This includes managing consumer demand and smoothing out peak periods. Additionally, the grid system needs to become more distributed, allowing individuals to store, generate and sell electricity. According to Wood Mackenzie, an estimated amount of USD4.5 trillion of grid investment is needed over the next 10 to 20 years for a transition to 100% renewable [145].

In April 2021, the White House announced its upgrade and expansion plan, identifying more than 20 major transmission projects to unlock 60,000MW of green energy capacity [146]. The last major grid upgrade was back in 2009 where the Recovery Act allocated USD4.5 billion for grid modernization [147]. Over half of the budget went the installation of smart meters across the US. The new release highlights that new financing tools for building high-voltage transmission, as shown in Table 6-5, stated by the Department of Energy.

Table 6-5 The two critical financing tools facilitating high-voltage transmission lines

Programme	Amount (USD)	Purpose
Western Area Power Administration Transmission Infrastructure Program	3.25 billion	Supporting projects that unlock renewable energy in the West
DOE’s Loan Programs	5 billion	Supporting innovative transmission projects including HVDC systems, transmission to connect offshore wind, and facilities sited along rail and highway routes

With the mixture of different utilities, cooperation, systems and jurisdiction, the critical financing tools are vital trigger for the operators to opt for grid upgrade and expansion to incorporate more renewables. The new release is estimated to push for actual construction of 22 “ready to go” high-voltage transmission projects and attract USD33 billion investment to the renewable industry, as commented by independent analysts, Americans for a Clean Energy Grid [148].

The Atlantic Offshore Wind Transmission study was designed to evaluate planned and coordinated transmission solutions along the Atlantic coast from Maine to South Carolina. The study includes many scenarios for OSW generation and transmission configurations. New Jersey is at the forefront of transmission planning for offshore wind development. The state’s public policy has set a goal of 7.5GW of offshore wind energy by 2035 and is therefore investing in significant transmission network upgrades. Figure 6-11 outlines the potential transmission options in New Jersey 2021 State Agreement Approach.

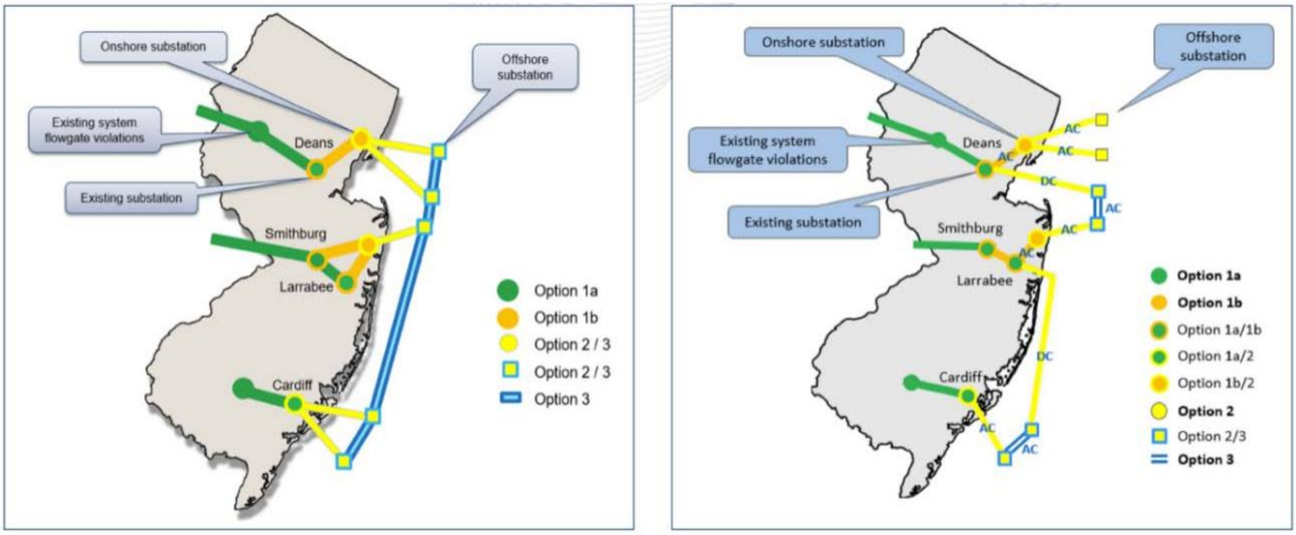


Figure 6-11 Potential transmission options in the New Jersey 2021 State Agreement Approach

Most of the projects in development in the US use high-voltage radial spurs (generator lead lines) to transmit electricity from the offshore wind farm to the onshore point of interconnection. Existing points of interconnection may not have sufficient available capacity to connect every planned project individually through generator lead lines. Instead, a system where multiple developers share the transmission to shore would be beneficial. This system of sharing would reduce the number of cables and beach landings, bringing improved reliability and fewer environmental marine ad coastal impacts [149].

6.5.3 Offshore Wind Case Study

Currently, there are two operating OSW facilities in the US, The Block Island Offshore Wind Farm and the first phase of the Coastal Virginia Offshore Wind Farm (CVOWF). A summary of each project is provided in Table 6-6 and Table 6-7. The full development of the CVOWF is expected to be completed in 2026, bringing its capacity to 2.6GW.

Table 6-6 Block Island OSW Farm case study [150] [38]

Block Island Offshore Wind Farm	
Location	6.1km from Block Island
Water Depth	Water Depth of 27m meters
Foundation	Fixed, Jacket Fabricated in Huma, Lousiana
Capacity	30MW
Shareholder	• Developed and owned by: Deepwater wind • Jackie fabrication: Gulf Island Fabricators • Structure design: Alstom Wind • Foundation design: Keystone Engineering Inc
Status	• Construction commenced: 2015 • Commercial operation: 2016
Wind turbines	Model: Alstom Haliade 150-6-MW Rated power: 6MW Rotor diameter: 151m Gearbox: direct drive Generator: PMSG Wind speed range: 3-25m/s. Rated wind speed: 13-15m/s Wind category: 3 Hub height: 600ft
Grid connection	Inter-array voltage: 34.5kV Export voltage to island switching station: 34.5kV Export voltage to grid: 34.5kV The WTGs are interconnected using a submarine inter-array cable of 34.5kV. From the last WTG, an export cable (offshore and onshore) at 34.5kV is used to connect to a switching station in Block Island. From the switching station an export cable at 34.5kV (onshore and offshore) is used to connect with the mainland substation.

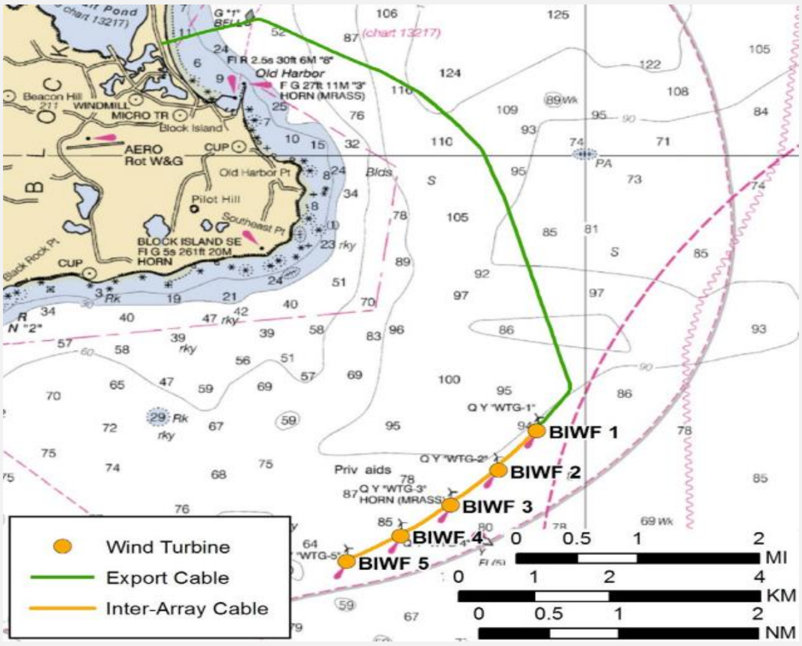
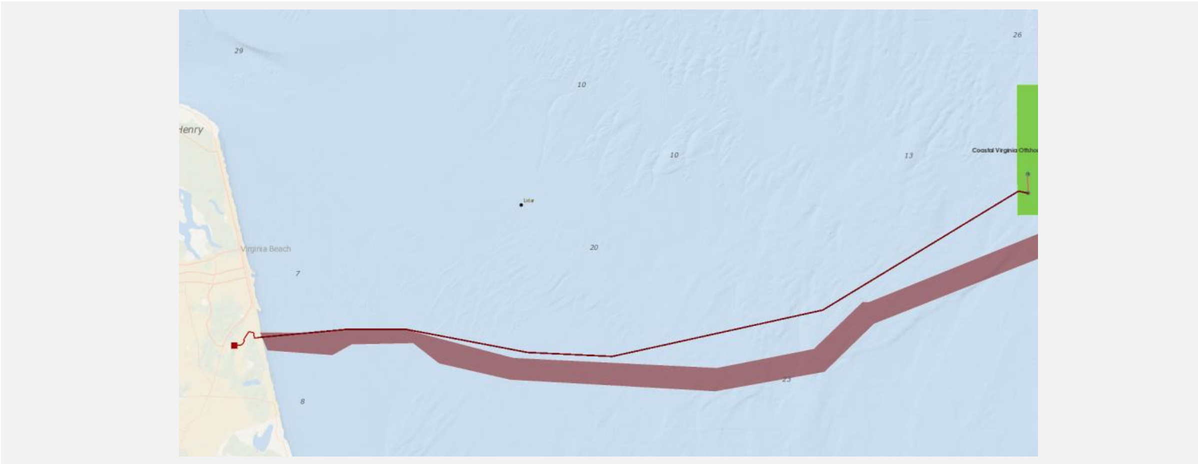
Block Island Offshore Wind Farm


Table 6-7 Coastal Virginia OSW Farm case study [38] [151]

Coastal Virginia Offshore Wind Farm Phase 1	
Location	43km from shore
Water Depth	Water Depth of 24m
Foundation	Fixed, Monopile with 7.8m diameter
Capacity	12MW
Shareholder	• Developed: Ørsted the US Offshore Wind • Owned by: Dominion Energy • Monopile fabrication: EEW Special Pipe Constructions (SPC)
Status	• Construction commenced: May 2020 • Commercial operation: October 2020
Wind turbines	Model: SGRE SWT-6.0-154 Rated power: 6MW Rotor diameter: 154m Gearbox: direct drive Generator: PMSG Wind speed range: 4-25m/s. Rated wind speed: 1m/s Hub height: 104-111m
Grid connection	Inter-array voltage: 34.5kV Export voltage to grid: 34.5kV The WTGs are interconnected using a submarine inter-array cable of 34.5kV. From the last WTG, an export cable (offshore and onshore) at 34.5kV is used to connect to the distribution network inland.



6.6 Offshore Wind Offtake Business Case

6.6.1 Participation in the Electricity Market

The US power markets have both wholesale and retail components. Wholesale markets involve the sales of electricity among electric utilities and electricity traders before it is eventually sold to consumers. Retail markets involve the sales of electricity to consumers. Both wholesale and retail markets can be traditionally regulated or competitive markets. There are some states that have the traditional regulated markets, meaning that vertically integrated utilities are responsible for the entire flow of electricity to consumers. They own the generation, transmission and distribution systems that are used to serve electricity consumers.

Other parts of the wholesale market (the Northeast, Midwest, Texas, and California) are restructured competitive markets. These markets are run by ISOs (ISOs includes both regional transmission organizations [RTOs] and ISOs). ISOs use competitive market mechanisms that allow independent power producers and non-utility generators to trade power. In restructured competitive markets, "utilities" are commonly responsible for retail electricity service to customers and are less likely to own generation and transmission infrastructure.

Below Figure 6-12 shows a view of US power market structure.

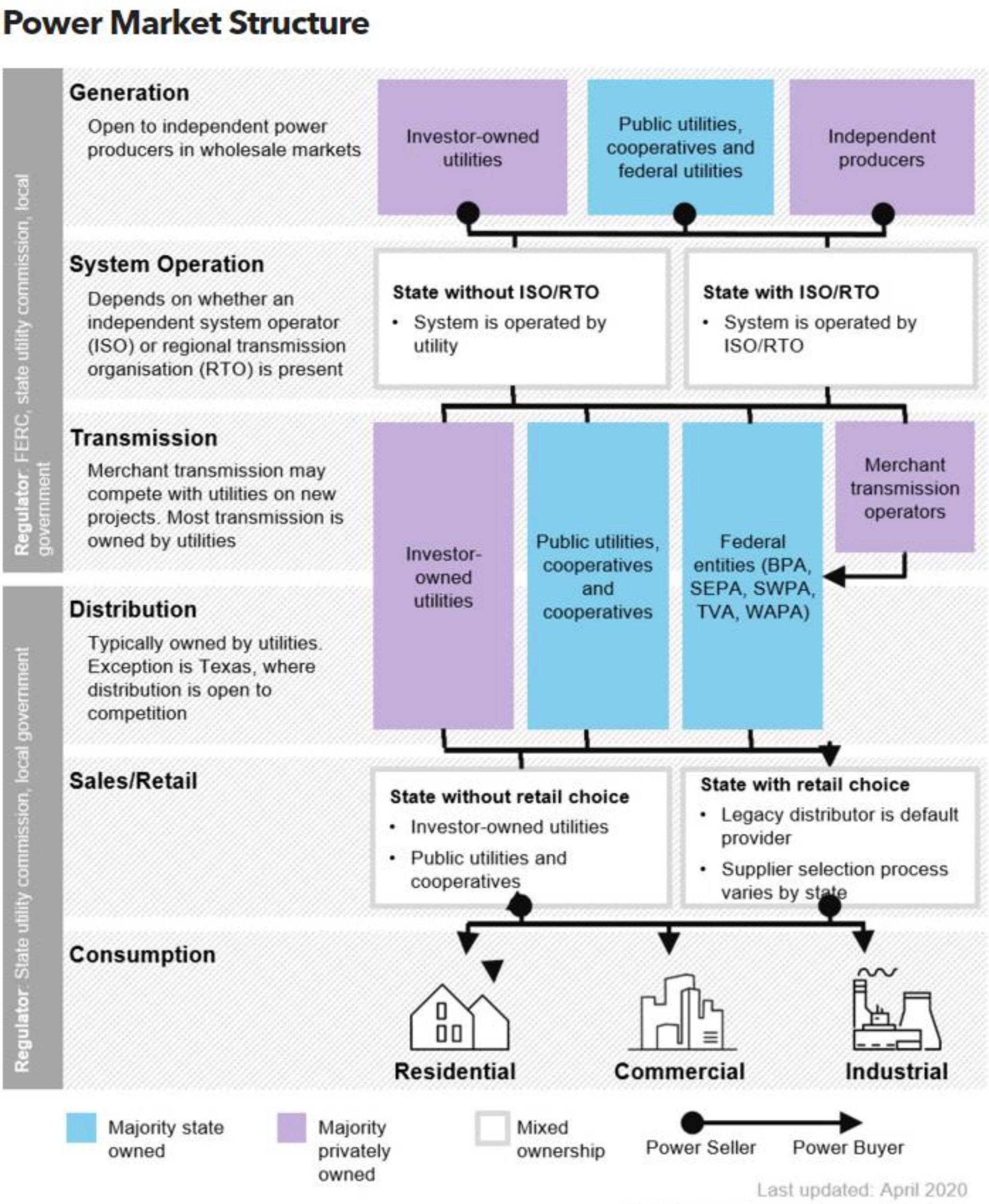


Figure 6-12 The US electricity market structure [11]

Entering the OSW electricity market comes with benefits of utilising a more sustainable energy resource and the reduction of fuel costs. The field is also growing quickly. In 2021, the US offshore wind pipeline grew 24% as compared to 2020, bringing a total capacity of 35.32GW in various stages of development around the economy [143]. A graph depicting active OSW projects in the US can be found below.

PPAs and offshore ORECs prices also offer insight into the current OSW industry. It is anticipated that the PPA and OREC prices in the US between 2022 and 2025 will range between USD96/MWh and USD71/MWh, yielding one of the lowest prices globally [143]. Procurement of PPAs has been increasing steadily in popularity and provides an opportunity to support the OSW development and make progress towards the sustainability goals.

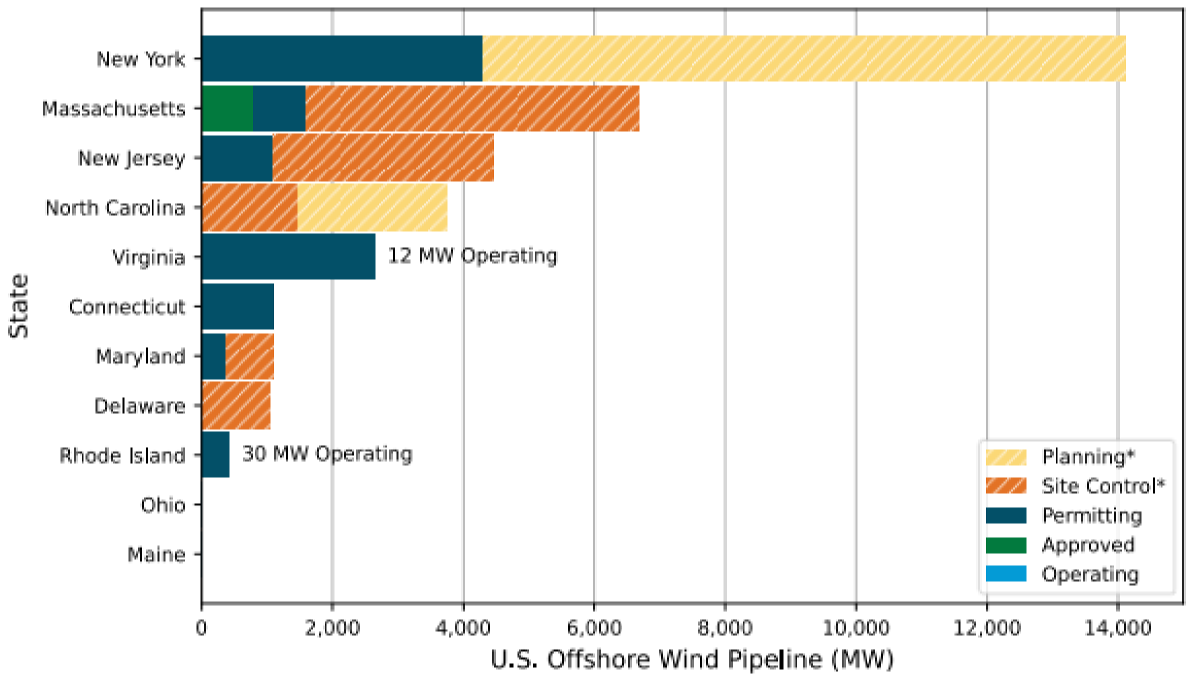


Figure 6-13 The US project pipeline by state 2021 [152]

6.6.2 Cost of Offshore Wind

The estimated LCOE for commercial-scale offshore wind projects in the US declined from approximately USD175/MWh in 2018 to an average of USD84/MWh in 2021. Currently, project LCOE may range between USD61/MWh and USD116/MWh. The changes to the LCOE are caused by differences in site characteristics such as wind speed and water depth, changes in regulatory and market environments, technology, and market maturity. Based on future projects, it is possible that the LCOE of offshore wind in the US by 2031 will reach approximately USD59/MWh [149].

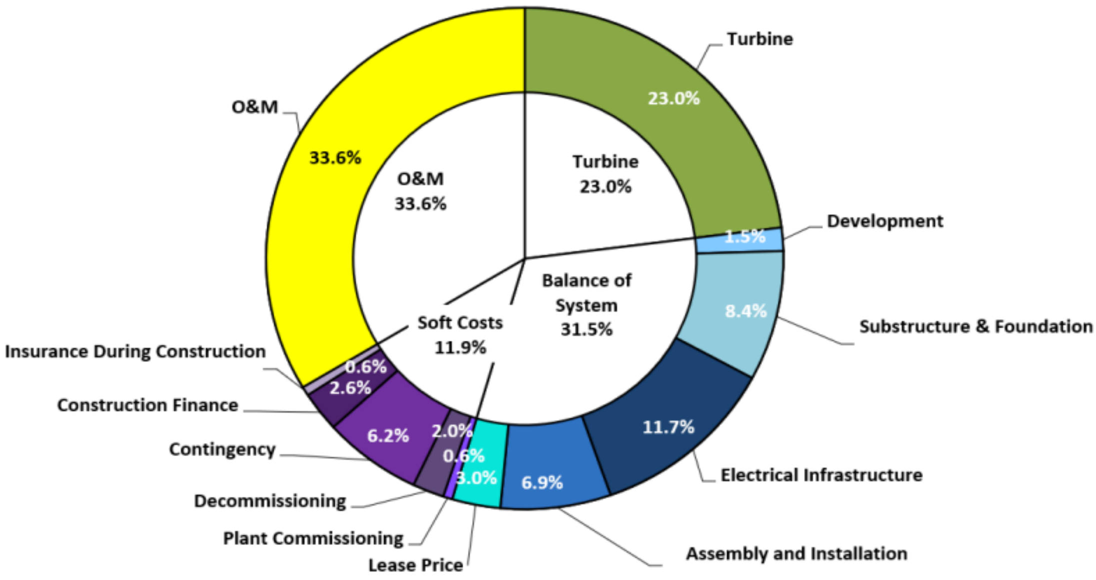


Figure 6-14 LCOE breakdown for 2020 fixed-bottom OWFs

According to the *2020 Cost of Wind Energy Report* published by the National Renewable Energy Laboratory, the largest contribution to LCOE for a fixed offshore wind farm, in addition to operation and maintenance cost, is balance of system. A breakdown is provided in Figure 6-14 [153].

6.6.3 Participation in Provision of Ancillary Services

Ancillary services comprise a large portion of the US electricity market. In 2019, ISOs' operations encompassed 60% of the overall US electricity demand [154]. And while the ISOs themselves do not claim the services to load-serving groups, their procurement of these resources comprises most of the demand. Wind power can be utilized to provide a variety of ancillary services, including regulating and contingency reserves, fast frequency response, and voltage control. But because electrical power systems need to provide reliable service, there are a few economic and practical considerations necessary prior to their implementation.

Because there are no fuel costs associated with renewables, utilising wind power in ancillary services is a very economical option. As there is a consistent demand, removing that cost would make a significant overall market impact. Subsidies for using wind energy could also be considered due to the reduction in emissions.

The nature of this consistent demand, however, makes for difficult implementation. As wind energy is dependent on the presence of the resource, and it cannot be reliably reproduced when supply is lower than demand, additional resources must be utilized to ensure that service can still be provided in a shortage. The system must then be set up to accommodate this need. Forecasting could assist this process by providing necessary notice for the periods of low renewable energy generation. Choosing the services that could handle the possibility of an outage is also beneficial, as this will reduce the risk if there is no sufficient supply [154].

The relatively fixed demand of ancillary services also provokes the issue of what is done with surplus supply. If more wind power is available than is needed, this extra wind power will not be utilized, resulting a lost opportunity cost. Providing a way for this excess supply to be used could mitigate this cost.

6.6.4 Private Offtaker of Electricity

Negotiating an offtake agreement to sell offshore wind electricity is another necessary step to developing a project in the US. Eight states (Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Maryland, Virginia, North Carolina) have unique procurements targets but use different mechanisms to procure electricity from a developer. Certain of these states also have aggressive procurement goals and contracted offtake mechanisms. These policies give developers the increased certainty regarding the demand for an offshore wind project's power and adequate compensation through PPA or offshore REC (OREC). As of 31 May 2022, 24 offshore wind offtake agreements were signed with 17,597MW of contracted capacity [149].

6.6.5 Curtailment

Historically, curtailment has impacted several renewable energy developments across the US. In 2013, as much as 3% of wind energy generation cited by MISO was lost to curtailment [155]. The curtailment for wind and solar recorded is 125.403GWh in 2021, a drop of 5.2% from 2020 [156].

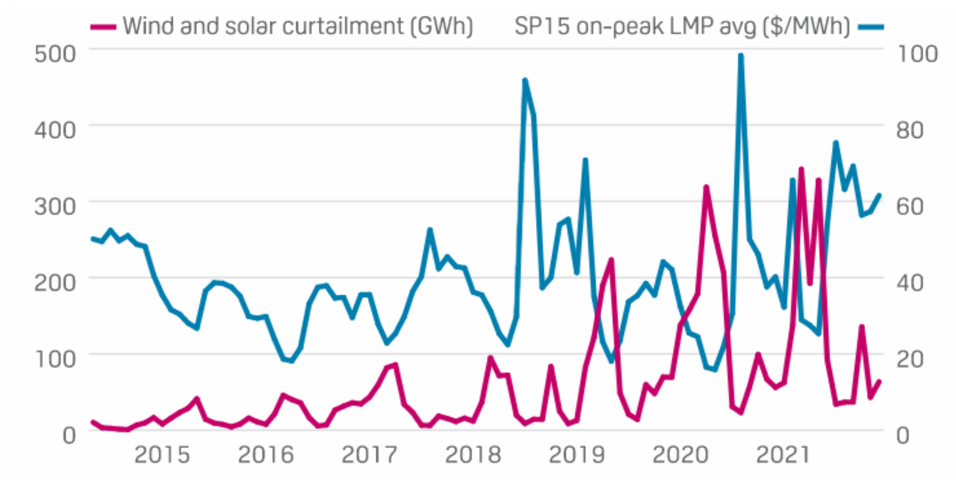


Figure 6-15 Curtailment of wind and solar 2005-2021 [156]

While the impact of this inefficiency has not been severe, reducing the occurrence of curtailment can reduce losses and provide a more efficient energy system. Common reasons for curtailment within an electrical power system include but are not limited to oversupply of electricity in low load periods, transmission constraints, high wind ramps, and local transmission outages.

In addition to these infrastructure and environmental-based causes, market-based activities can also affect the curtailment presence in a system. Downward dispatch is a common reason for energy inefficiencies, causing renewables to be underutilized. In the regions served by vertically integrated utilities, the wind project developer and utilities could have PPAs that include finances for future curtailment. Wind power capacity expansion outpacing transmission construction can also result in curtailment, as the increased wind power generation can cause congestion in existing lines [155].

Implementing measures to mitigate curtailment can offer increased efficiency and reduce overall losses. Introducing automated systems and increasing scheduling frequency can help to maximize the efficiency of energy dispatching. Other protocol changes like reducing minimum generation levels of generators can also provide some loss reduction.

6.7 Summary and Recommendations

There are several barriers to offshore wind development and grid connections in the US. The most significant is the lack of adequate transmission infrastructure. The existing transmission infrastructure, in general, is old and not adequate for the integration of new OSW projects. Grid architecture, transmission congestion, and additional power requirements affect the reliability of the existing grid. As upgrades are more often than not a requirement the connection process is extended and therefore becomes more costly for the developer. As of October 2020, more than 52GW of proposed offshore wind interconnection requests were in the queues for the PJM Interconnection, New York ISO, and ISO New England.

The existing onshore POIs to which generator lines from each plant connect, may not have sufficient capacity to connect every planned project individually. To reduce the environmental impact, improve reliability, and reduce cost, it would be preferred that multiple offshore wind projects share export cables to the POIs onshore. This would only be possible with clear planning and coordination at the state and federal level; otherwise, varying project timelines will start to cause challenges and early projects will default back to the generator-lead-line approach. Cable routing is also limited in certain harbours such as New York Harbour. For complex cable route, investigations may therefore create added cost for the developer.

Geopolitical and social challenges are very pertinent in the US Stakeholders' opposition to nearshore projects and the scarcity of nearshore sites are causing increased far-shore demand. Far-shore projects are often in deeper waters. Therefore, it would lead to increased cabling cost and technology risk. The domestic supply chain in the US is still very nascent, with the LCOE for the floating wind being much higher than the fixed. While the average LCOE is around USD84/MWh, and the fixed bottom offshore wind farm projects are typically closer to USD77/MWh and floating closer to USD129/MWh. Further reductions are possible by strengthening local supply chain, increasing state legislative support and adequate grid infrastructure.

7 Viet Nam

7.1 Introduction

Due to large population density, rapid economic growth and fast declining oil and gas reserves, Viet Nam is one of Asia's fastest growing energy markets [157]. Over the past decades electricity consumption has been growing by around 10% annually and the energy system is under pressure to keep the pace with the growing economy. The power sector is managed by the Government of Viet Nam that has been in a race to expand capacity [158]. According to the World Bank's survey, Viet Nam has the largest offshore wind potential in southeast Asia with an estimate total potential installed capacity of nearly 600GW [159] [5].

Viet Nam has been opening itself up to more offshore wind opportunities. The southern part of Viet Nam has the strongest mean wind power density, and the concentration of wind generation projects in the south are the greatest [160]. There are 124 offshore wind farm projects at different stages of development in Viet Nam. 22 of these are currently in operation and located in the south [161]. All 22 are bottom-fixed nearshore wind farms in the Mekong Delta provinces [162]. Figure 7-1 shows the location of the operating (green) OSWs and those under construction, application, planning and development.

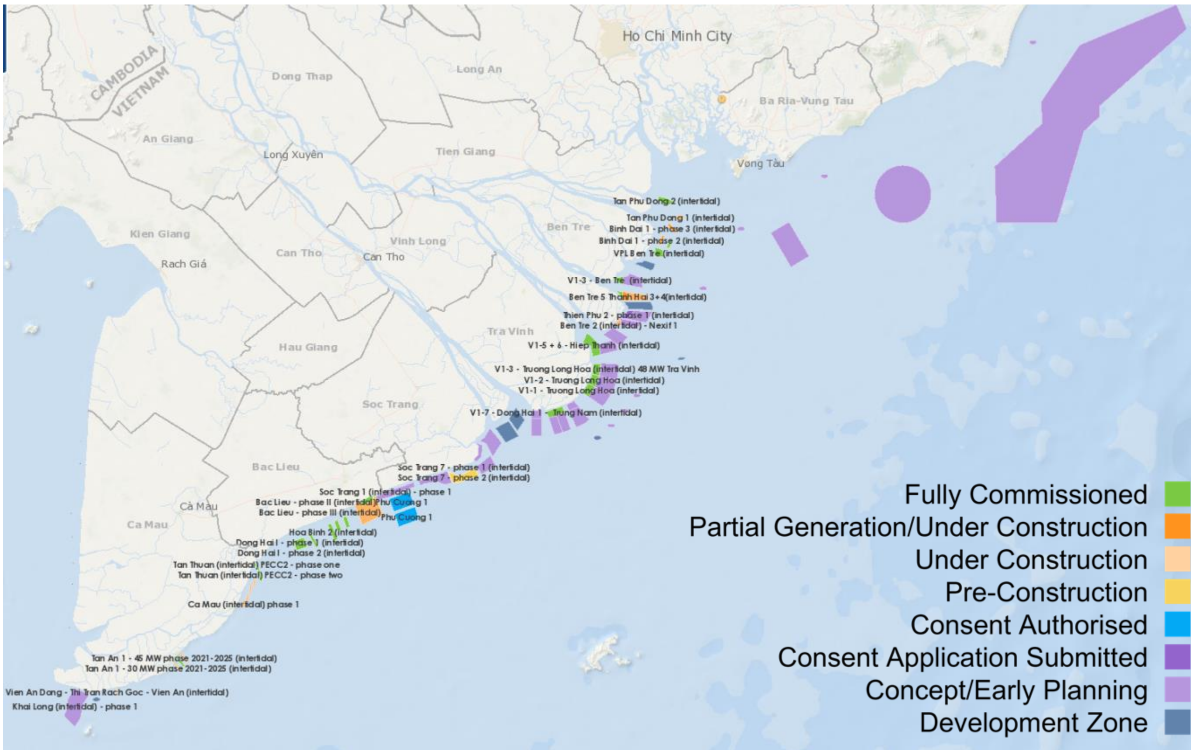


Figure 7-1 Location and stage of the OSWs in Southern Viet Nam [38]

7.2 Overview of Offshore Wind Resource

Figure 7-2 shows the wind speed and water depth as heat maps for the offshore portion of Viet Nam. The wind speeds at 100m hub height range from 1.9m/s to 11.4m/s along the coast, with the highest located off the coast of Ninh Thuan and Binh Thuan provinces. In general, the water depths are reasonably shallow, especially in the south-east, although there is a steep drop along the western bend of the offshore areas.

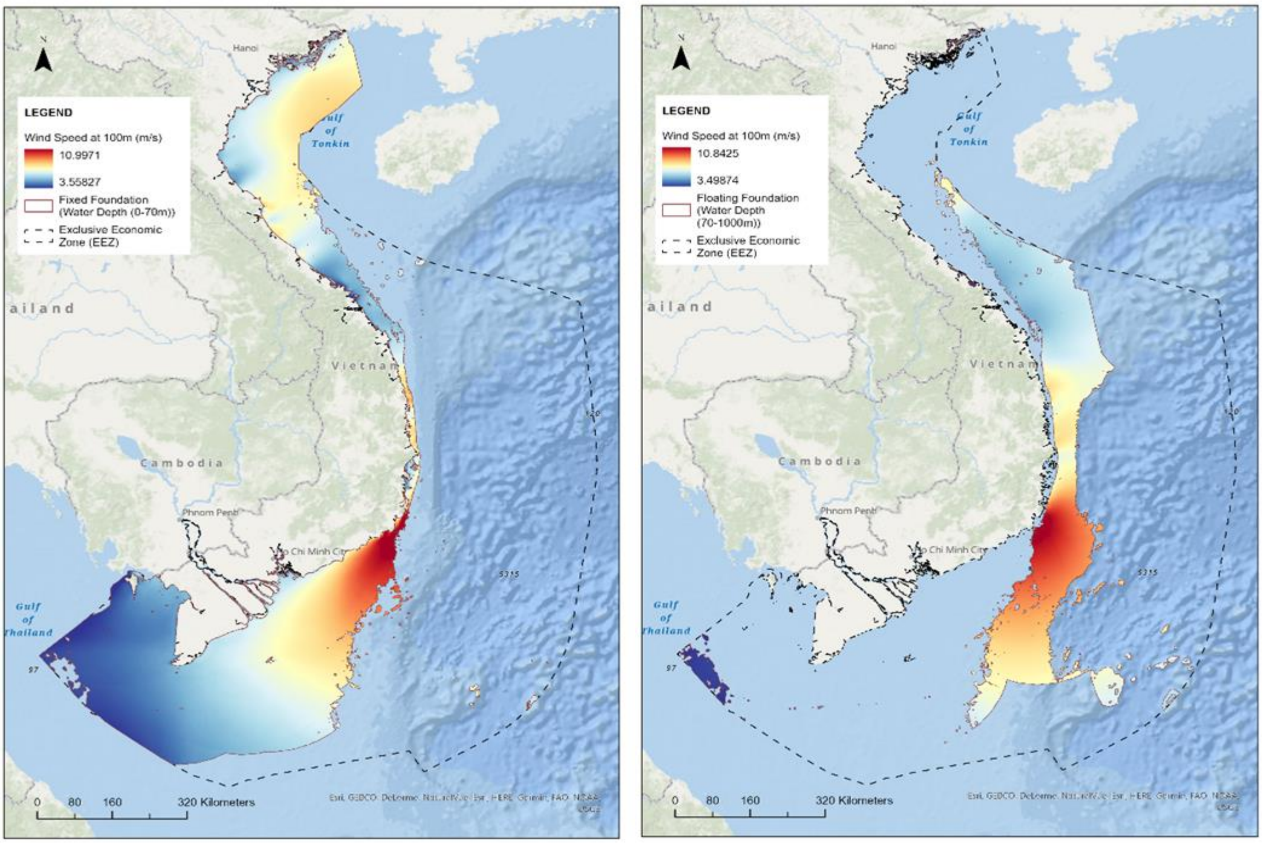


Figure 7-2 Wind speed for fixed foundation water depth 0 to -70m (left) and floating foundation -70 to -1000m (right) in Viet Nam

Water depths up to -70m are generally considered suitable for bottom-fixed foundations, while floating foundations are suitable for water depths between -70m to -1,000m. Sea depths beyond -1,000m are considered as ultra-deep and are less economically favourable and more complex, and thus riskier in terms of development for floating foundation. Based on the wind resource, both fixed and floating foundation OWF can desirably be deployed off the coast of Binh Thuan and Ninh Thian provinces (see Figure 7-3).

7.3 Energy Sector and Regulatory Mechanism

7.3.1 Structure of Electricity Supply

Viet Nam Energy's (EVN's) 2021 Annual Report recorded a total installed electrical power generation capacity of over 69GW by the end of 2020. By 2021 this was approximated to reach 78GW. While coal and hydropower remain as the largest portion of installed generation capacity, from 2019 to 2021 the most growth was in commercial rooftop solar, which grew from 0.58% to 13.4%. Historical installed capacity by fuel type and breakdown for 2021 are provided in Figure 7-3 and Table 7-1 [163].

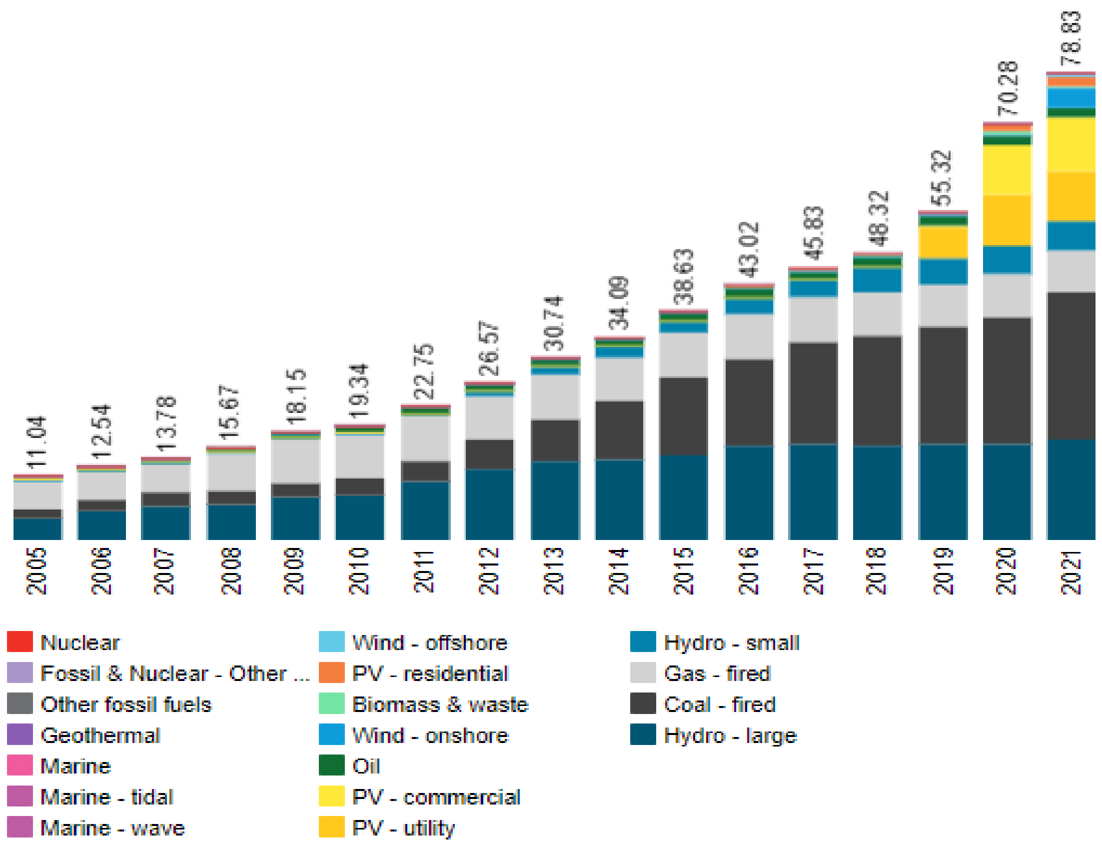


Figure 7-3 Historical installed electrical capacity (GW) in Viet Nam 2005-2021

Table 7-1 Viet Nam 2021 installed electrical capacity by fuel type

Power source	Capacity (GW)	Capacity (%)
Coal Fired	24.67	31.3
Hydropower	21.86	27.7
Rooftop Solar	10.57	13.4
Gas Fired & Oil Fired	8.77	11.1
Solar	8.51	10.8
Wind	4.07	5.2
Biomass	0.38	0.5
Total	**78.83**	**100**

In terms of energy consumption, it can be seen how Viet Nam's demand has been increasing in recent years and that part of this increase has been supplied by coal-fired power plants, which in 2020 supplied practically half of the energy consumed with around 115,000GWh. Regarding renewables, it can be seen how they have also been increasing their participation in the market, but it also continues to be a practically anecdotal contribution of around 12.2% of the economy's demand in the year 2021. Figure 7-4 shows the historical electrical generation by technology [163].

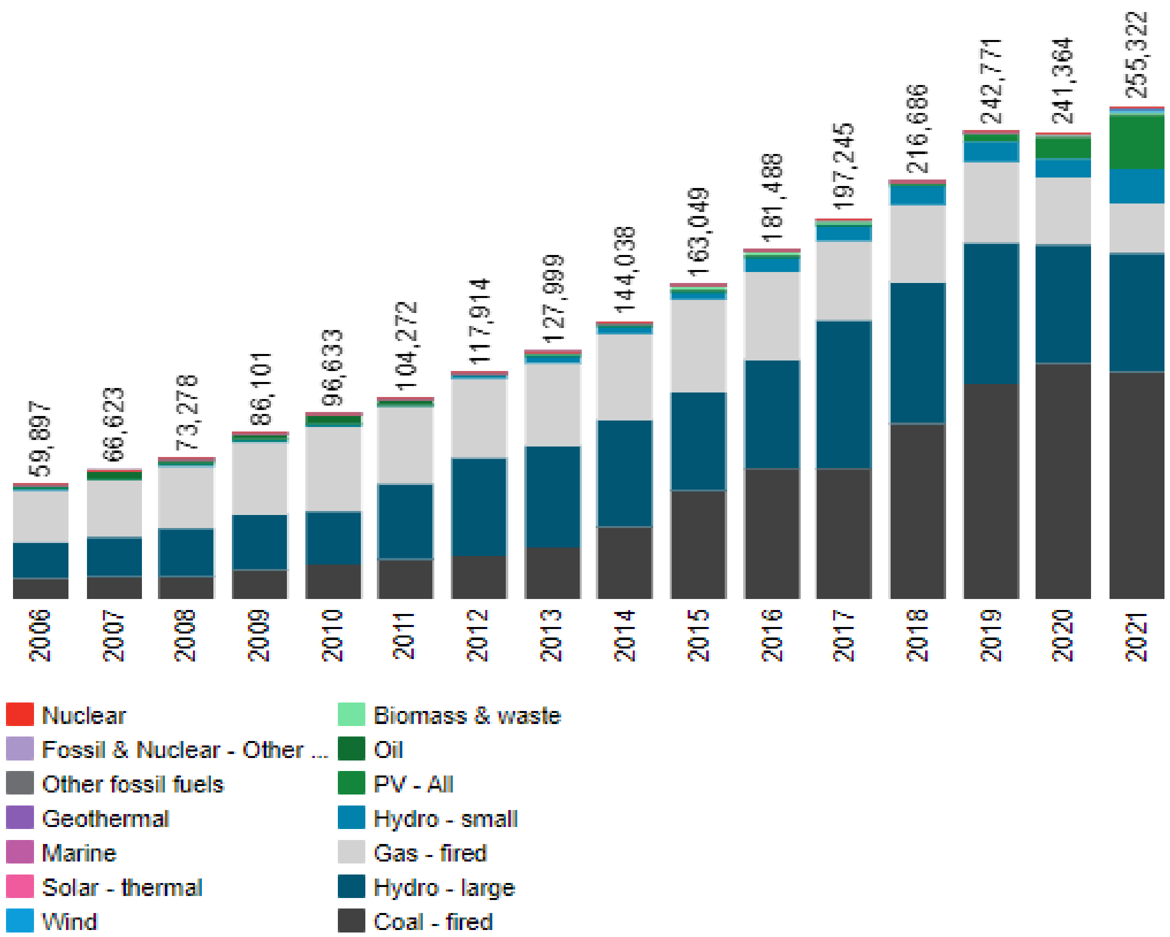


Figure 7-4 Electricity generation (GWh) in Viet Nam 2006-2021

7.3.2 Renewable Energy and Climate Change Policies and Targets

At COP26, Viet Nam announced its zero-emissions goal by 2050, and its new edition of *Power Plan Development (PDP)* is setting the trajectory for the power sector to reach that goal by 2045.

In October 2021, the Ministry of Industry and Trade (MOIT) released a draft proposal for the domestic power development plan (PDP8) for the period of 2021 - 2030 with a vision of 2045 [157]. The plan is set to more than double the installed power generation capacity by 2030 [158]. The expansion will be mostly driven by new large-scale solar and wind energy projects set to comprise 23% of the system capacity in 2030 and 38% in 2045 [164].

While the latest PDP has higher renewable targets than previous plans, it is likely still to leave a large gap to achieve Viet Nam's carbon neutrality by 2050 goal.

7.3.3 Offshore Wind Power Development Policies and Targets

On 9 June 2022, the Institute of Energy - the MOIT and the Global Wind Energy Council held a workshop called *Roadmap for the realization of offshore wind power in Viet Nam*. The workshop helped to clarify the development roadmap and offshore wind power planning process from the PDP8. The April 2022 draft of the PDP8 specifies the target capacity of offshore wind power of 7GW by 2030, 16GW by 2035 and 36GW by 2045 [159].

The PDP8 highlighted the prioritization of certain provinces in the south for offshore wind development. These provinces were Binh Thuan, Bac Lieu and Ca Mau. By the end of 2021, the Vietnamese government proposed several policies to boost the development of the wind energy sector, primarily including the extension of the increased offshore wind FiT price until the end of 2023 [157].

Specific policies and regulations that provide clear steps for OSW development and regulation are not yet developed and remain ambiguous, although a rough guide is available and described in Section 7.4.2. Table 7-2 outlines the policies and regulations currently relating to the offshore wind development in Viet Nam [162].

Table 7-2 List of OSW policies and regulations

Type	Year	Name	Issued by	Contents
Party documents	2018	Resolution 36/NQ-TU	Central Party's Executive Committee	Strategy for Sustainable Development of Sea-based Economy to 2030, vision by 2045
	2020	Resolution 55/NQ-TW	Political Bureau	Strategic orientation for economy energy development to 2030, vision to 2045
Laws	2015	Law on Marine and Island Resources and Environment	National Assembly	Regulating fundamental surveys on marine natural resources
	2018	Planning Law	National Assembly	Regulating economy and sectoral planning, including power development planning
	2022	Electricity Law	National Assembly	Regulating electricity sector, including power development planning, investment, markets, and transmission and distribution
	2022	Investment Law	National Assembly	Regulating investment in OWP
	2020	Law on Environmental Protection	National Assembly	Regulating OWP environmental impact assessment
	2020	Construction Law	National Assembly	Regulating construction of OWP projects
Government decrees and Prime Minister decisions	2018	Decision 39/2018/QĐ-TTg	Prime Minister	The mechanism supporting the development of wind power projects in Viet Nam
	2015	Decree 75/2015/NDCP	Government	Management of activities of people and transport means in maritime boundary areas of the Socialist Republic of Viet Nam
	2015	Decision 2068/ND-CP	Prime Minister	Issuing National Strategy on Renewable Energy by 2030, with a vision to 2050

Type	Year	Name	Issued by	Contents
	2020	Resolution 26/2020/NQ-CP	Government	An overall plan and five-year plan to implement Resolution 36/NQ-TU
	2021	Decree 11/2021/ND-CP	Government	Assignment of rights over seabed leasing
	2021	Decree 15/2021/ND-CP	Government	Management of construction projects
	2021	Decree 31/2021/ND-CP	Government	Guidance on implementation of Investment Law
	2022	Decree 08/2022/ND-CP	Government	Guidance on implementation of Law on Environmental Protection
Ministerial circulars	2020	Circular 07/VBHN-BCT	MOIT	Regulation on wind power project development and power purchase agreements
	2012	Circular 96/2012/TT-BTC	MOIT	Guidelines for the financial mechanism to support the electric price for wind power projects
	2020	Merged Document 10/VBHN-BCT	MOIT	Guidance on implementation of Electricity Law
	2021	Circular 18/TT-BTNMT	The Ministry of Natural Resources and Environment(MONRE)	Regulation on fees for using marine areas under the jurisdictions of Prime Minister and MONRE

7.3.4 Renewable Energy and Offshore Wind Regulatory Support Mechanisms

The Vietnamese Government offers various incentives to promote the development of renewable energies. Decision 2068 provides incentives which include [165]:

- Zero import duty for assets to form the fixed assets of a renewable energy project, and for materials and semi-products that are unavailable in the domestic market;
- Corporate income tax exemption or reduction;
- Land rental exemption or reduction;
- Government funding for research and technology of pilot projects.

In 2011 the Vietnamese Government established the first FiT scheme for wind power. While this FiT was intended to support deployment, it was much too low and fell behind the Government's expectations. In 2018 the decision was made to issue a higher FiT and to differentiate between onshore and offshore wind projects. While this spurred more development, the original application deadline of November 2021 had to be extended to December 2023 due to the difficulties associated with COVID-19 [166]. The current FiT for offshore wind projects is set at USD98/MWh. Following December 2023, the Government of Viet Nam is intending to introduce a competitive auction system for renewable energy projects, although no details have yet been made publicly [167].

Another supporting mechanism established for all renewable projects was the mechanism of exemption and reduction of corporate income tax. The income tax will be 0% for the first four years, 5% for the next nine, 10% for the next two and 20% for the next five. In addition, there are exemptions and reductions on import taxes and land allocation and rental for the offshore wind developments connected to the power grid [166].

7.4 Offshore Wind Development Procedure and Stakeholder Engagement

7.4.1 Stakeholders and Their Responsibilities

EVN is the government-owned enterprise established by the Government of Viet Nam. EVN ensures sufficient power supply, improves power system services, and secures power investment and development. EVN has three power production subsidiary companies [163]:

- Power Generation Corporation 1 (GENCO 1);
- Power Generation Corporation 2 (GENCO 2);
- Power Generation Corporation 3 (GENCO 3).

In 2020, 42.6% of the installed electricity generation capacity in Viet Nam belonged to EVN and its subsidiary power companies [163]. The economy-wide power utility company and its subsidiaries have monopoly position in the power sector over the transmission and distribution of electricity in Viet Nam [157].

The National Power Transmission Corporation (EVNNPT) is another subsidiary company of EVN which regulates the domestic power transmission network. Its network is arranged into four power transmission companies (PTC1, 2, 3 and 4) each operating a designated region. EVN also has five subsidiary distribution companies [163]:

- Northern Power Corporation (EVNNPC);
- Central Power Corporation (EVNCPC);
- Southern Power Corporation (EVNSPC);
- Hanoi Power Corporation (EVNHANOI);
- The Ho Chi Minh City Power Corporation (EVNHCMC).

The electric power sector is under the jurisdiction of the MOIT [157]. The Directorate General of Energy under the MOIT is responsible for overall energy planning and policy in power sector [157]. The Electricity Regulatory Authority of Viet Nam (ERAV) advises and assists the MOIT in establishing and supervising the power market, power planning, tariff regulation and licensing [157].

Table 7-3 provides a summary of key authorities and partners and their responsibilities in the development and connection of the offshore wind projects in Viet Nam. This summary is the result of a study done by Allens Linklaters in May 2020 published in a report named “Viet Nam Offshore Wind: Where to from here?” [160].

Table 7-3 Key authorities and their responsibilities in the development of OSW [160]

Authority	Responsibilities
Central Governmental level	
Prime Minister (PM)	Approving power development plans
Ministry of Industry and Trade (MOIT)	Developing the power system plan
Ministry of Planning and Investment (MPI)	Appraising provincial master plan, including the power plan component
Ministry of Natural Resources and Environment (MONRE)	Assigning sea area in certain cases
State Bank of Viet Nam (SBV)	Approving foreign loan registration
Viet Nam Energy (EVN)	Signing PPA and buying electricity
Electricity Regulatory Authority of Viet Nam (ERAV)	Issuing electricity generation licence
Local level	
Provincial People's Committee (PPC)	Giving investment approval Assigning sea area in certain cases Approving environmental impact assessment report
Department of Planning and Investment (DPI)	Issuing investment registration certificate Issuing enterprise registration certificate
Department of National Resources and Environment (DONRE)	Assessing environmental impact assessment report
Department of Industry and Trade (DOIT)	Assessing basic design in feasibility study and technical design
Department of Construction(DOC)	Issuing construction permit

7.4.2 Offshore Wind Approval Procedures

The following procedure is an overview in relation to the approval process for establishing an offshore wind farm in Viet Nam [168], [160], [169]:

1) Preparation stage

All project sites are required to be included in the PDP. Most sites included in the PDP are priority areas with existing site analysis and wind speed measurements. If the site for project development is in the PDP, then the developer may proceed with the investment. If the site is not in the PDP, the developer must apply for a temporary land lease to survey the location and complete the necessary pre-feasibility work before applying for a written approval for the supplementation and adjustment of the Prime Minister's PDP through the General Department of Energy.

2) Investment and Enterprise Registration

Once the project site is in the PDP, to carry out an investment project in Viet Nam, the investors need to obtain an investment policy decision from the PPC. Investment registration certificate (for foreign investment) will be issued by the DPI within five working days after the policy approval decision. To establish the project company in Viet Nam, it is necessary to apply for an enterprise registration certificate through the Viet Nam Business Registration Office.

3) Obtain relevant agreements and licences

Following the Investment Decision, the developer must obtain certain agreements and licences which will require outputs from the completion of a detailed feasibility study. Some of the agreements and licences include:

- Power Purchase Agreement from EVN;
- Grid connection agreement from EVN or relevant grid owner (if <200kV the agreement is under the responsibility of the Regional Power Corporation; if >=200kv the responsibility is with the National Power Transmission Corporation);
- Metering agreement from EVN or relevant grid owner;
- Supervisory Control and Data Acquisition (SCADA) agreement from EVN or relevant grid owner;
- Protective relay agreement from EVN or relevant grid owner;
- Seabed lease through the PPC (if <6nm to shore) or MONRE (if >6nm);
- Land lease agreement (the lease term cannot exceed the project term and is likely to be around 20 years);
- Land use right certificate from MONRE;
- Fire prevention and firefighting approval;
- Environmental impact assessment and issue through DONRE and the PPC;
- Construction permit from DOC;
- Electricity generation licence (for power plant) from ERAV.

The span of the entire project development process is estimated to be five years, with an additional two years for installation [162].

7.5 Offshore Wind Grid Connection

7.5.1 Electricity Utility Structure and Grid Connection Procedure

The Vietnamese government maintains its monopoly of electricity transmission network to ensure the energy security. In general, the existing grid infrastructure is inadequate with weak grid capacity, which will obstruct the integration of new generation capacity, particularly from renewable energy projects. In Viet Nam, the power is transmitted at 50Hz. As of June 2022, EVNNPT has been managing and operating 28,612km of transmission lines (including 10,053km of 500kV and 18,559km of 220kV), with a total capacity of 115,650MVA [170]. To facilitate the flow of electricity from south to north, the network uses two parallel 1,500km 500kV transmission lines. This connection is highly loaded, especially in the rainy season when the wind resources are abundant [167].

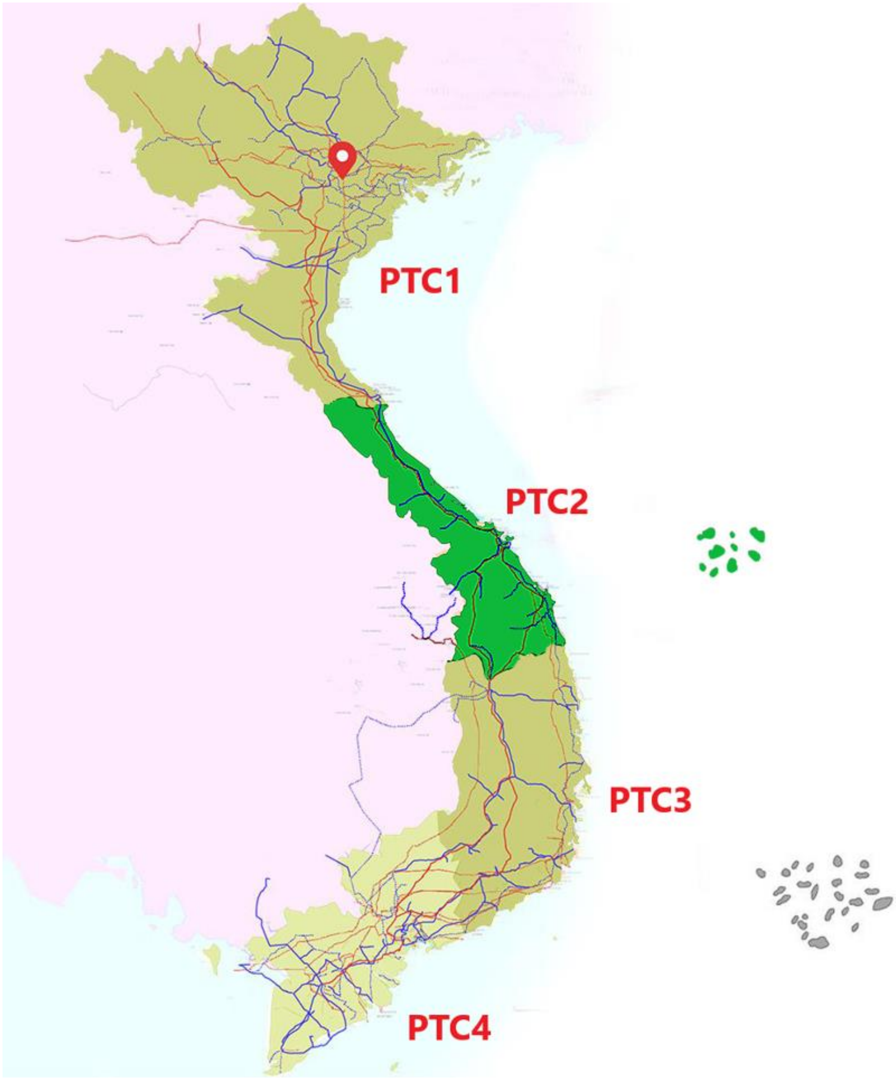


Figure 7-5 Regions in which each transmission company operates [170]

The four transmission companies are divided throughout the different areas of Viet Nam. As can be seen in Figure 7-5, PTC1 operates in the northern zone that includes the Ha Noi population center; PTC2 in the central zone; PTC3 between the south and central zones and PTC4 supplying the Ho Chi Minh and Mekong River areas. According to EVNNPT, PTC1 and PTC4 have the largest number of transmission lines, totalling 10,000km and 7,600km, respectively. Moreover, they transmit twice as much energy as PTC3, and more than four times as much as PTC2, which has the least number of lines [170].

For connecting new power plants to the transmission network, it is necessary to satisfy all the technical and safety requirements established in the Electricity Laws, as well as signing an agreement with the EVNNPT. As part of the application process, EVN will review the request, considering factors such as system inertia, harmonic levels, protection settings, and reactive power.

Additionally, to be able to include the wind farm in the PDP8 [171], it is necessary to provide a report with clear information about the current state of power sources and grid, calculation of the impacts on the source and the grid during the implementation of the project, and evaluation of the absorbance potential of the power grid when the project is brought into operation. It is also necessary to receive the opinions of the regional power corporations or transmission power corporations, depending if connecting to the power distribution system or transmission system, and the opinions of EVN on the absorption potential of the power grid within the area.

Connection of a OSF to the power grid comprises of two parts. The first is the interconnection line which connects the offshore wind farm to the connection point. The second is the grid connection line which transmits power from the connection point to the power grid. The location of the connection point is agreed in a connection agreement between the offshore wind project developer and EVN. As most of EVNs existing substations and transmission lines are situated onshore, it is likely that EVN will require an onshore connection point. The responsibility of construction and maintenance of the subsea power cable from the wind farm to the connection point belongs to the developer [172].

As of March 2022, due to amendments to the Electricity Law, the offshore wind project developer is entitled to invest, construct, operate and maintain its own Grid Connection line. Although EVN holds the monopoly in the transmission and distribution grid, the amendment allows a private investor to operate the transmission lines invested and construction by themselves. The offshore wind project developer is now also able to use its transmission line to transmit electricity generated from other nearby offshore wind projects to the power grid. Additional risks arising from this joint transmission activity are required to be handled by the transmission line owner [172].

The main steps for the procedure to sign the connection agreement include [170]:

Step 1: Connection Agreement

- Submit a formal Connection Application. EVNNPT will review the connection application and prepare and deliver the draft of Connection Agreement in 30 working days;
- Negotiate and sign the Connection Agreement.

Step 2: Technical Agreement

- Agreement of the technical details for the connection (relays, communication connection, etc).

Step 3: Inspection, Testing and Commissioning

- Preparation before energizing;
- Connection point inspection;
- Connection point energizing;
- Commissioning.

Technical requirements that the wind generators must meet in order to connect to the power grid are as the following [173]:

- Have active power control with a change rate of at least 10% of nominal power per minute;
- Continuous operation when the system frequency is in the range of 49-51Hz;
- Reduce active power when the frequency is over 51Hz (droop control);

- Supply or absorb reactive power according to the active power output, the power factor range of 0.95-0.85 (lag-lead);
- Have voltage control in the range of +/-10% of the rated voltage;
- Remain connected in an event of an instantaneous voltage drop (FRT capability);
- Total harmonic distortion below 3%.

All power plants that want to connect to the grid shall be operated in accordance with the regulations on the electricity system operation, standards and technical regulations of the electric power industry and other related regulations [174]. Some of the requirements for the operation can be seen below:

- Operation plan: Prior the starting day of the agreement it shall be provided charts of capability for annual average electrical power generation of the power plant monthly, and every year it is needed to provide the production plan for the next year. It is also needed to provide information about maintenance and repairing plans in compliance with the regulation on the operation of the power electricity system;
- Operation of power grids: The organization is responsible for the management, operation and maintenance of the electrical equipment and power grids under the management scope for properties prescribed in the agreement of connection with power grid maintenance units;
- Power coefficient: The power plant shall be synchronized with the power grid, with the capacity coefficient determined in accordance with the current regulations on the electricity distribution and transmission systems. This coefficient is determined for the Point of Connection.

7.5.2 Transmission Network and Expansion Plan

Domestic transmission infrastructure in Viet Nam has been struggling to keep pace with rapidly growing electricity requirements and the rapid increase in renewable generation. The National Load Dispatch Center has been lowering hydropower plants outputs to prioritize the solar integration and prevent the grid overload. Since 2019 EVN has also been in a process of upgrading the transmission lines. Under the PDP8 draft, the MOIT is estimating USD32.9 billion will be required to re-develop its power grids between 2021 and 2030, with a focus on reducing grid overload and addressing power curtailment issues.

While no detailed system analysis has been completed, the PDP7 and more recently the PDP8 draft provide an outline of transmission network upgrades required to increase the reliability of electricity supply in Viet Nam. The PDP7 set a goal of 25 substation extension and line projects to be completed by 2025. In addition to the North-Central 750km 500kV line upgrade, one of the major planned projects includes a transmission line in the North-South corridor [167]. The proposal is to develop a 500kV transmission network that can connect power systems among regions as well as with neighbouring economies. Since the concentration of the demand in Viet Nam is in the two extremities (north and south), it is critical that such transmission upgrades between regions take place. The PDP8 include 86GVA of additional capacity for 500kV substations and nearly 13,000km of transmission lines by 2030. By 2045, a further 103GVA with a capacity of 500kV and nearly 6,000km of transmission lines are planned. The 220kV grid plans to reach a capacity of 95GVA with nearly 21,000km of transmission lines by 2030, and an additional 108GVA with 4,000km of transmission by 2045.

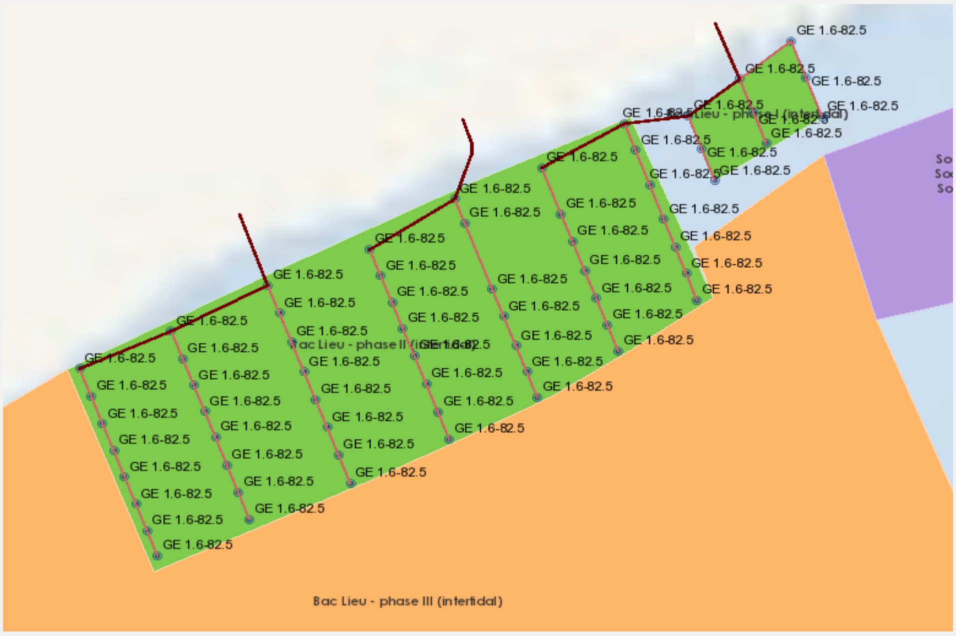
The PDP7 and PDP8 propose the application of smart grid technologies to help mitigate some of these challenges associated with the offshore wind power generation [167]. The MOIT is currently trialling the applications of smart grids and 4.0 technology into the transmission network. The EVNNPT has been granted funding from the US Trade and Development Agency to upgrade its information technology, communications, and power transmission systems to enable future smart grid investments [157].

7.5.3 Offshore Wind Case Study

Bac Lieu is a combined 99.2MW intertidal wind farm located in the East Dam region of Bac Lieu province. The first two phases of the project are fully commissioned and currently selling power to EVN. The electricity generated from the wind farm is supplied to EVN under a power purchase agreement. Digital and bi-directional type electricity meter systems at the connection point measure the export and import of electricity from the wind farm [175].

Each turbine is made of stainless-steel, weighs more than 210 tons and is fixed to a tabular steel tower with a height between 80 and 100m. The OSW farm uses a doubly fed asynchronous generator with partial power converter system. The turbines are equipped with an electric-drive pitch control system and battery backup for efficient speed regulation [175]. Table 7-4 provides a summary of the Bac Lieu OSW Farm. Bac Lieu OSW Farm case study [38] [176].

Table 7-4 Bac Lieu OSW Farm case study [38] [176]

Bac Lieu Wind Farm	
Location	Bac Lieu province
Water Depth	Intertidal
Choice of technology	62 turbines GE1.6-82.5
Foundation	Fixed, Jacket
Capacity	99.2MW
Shareholder	Developed: Cong Ly Operator: Cong Ly
Status	Construction commenced: 2015 Commercial operation: 2016
Wind turbines	Model: GE 1.6-82.5 Rated power: 1.6MW Rotor diameter: 82.5m Gearbox: spur/planetary Generator: DFIG Wind speed range: 3.5-25m/s. Rated wind speed: 10m/s Wind class: IIa Hub height: 80/100m
Grid connection	Inter-Array voltage: 22kV Export voltage to onshore substation: 22kV Export voltage to grid: 110kV The WTGs are interconnected in a branch configuration, collecting the power from the OWF, in the last three WTG using an inter-array voltage of 22kV. From the last WTGs, three export cables (underground and overhead lines) at 22kV are used to connect to the onshore substation. From the onshore substation an overhead line at 110kV is used to connect with the power grid.
	

Dong Hai 1 is a 100MW intertidal wind farm located off the coast of the Duyen Hai district of Tra Vinh province. VND5,000 billion was invested into the project and has an average generation of 330GWh/year connected to the power grid [177].

Table 7-5 Tra Vinh Dong Hai 1 OSW Farm case study [38] [178]

Tra Vinh Dong Hai 1 Offshore Wind Farm	
Location	Duyen Hai district
Water Depth	Intertidal
Choice of technology	25 turbines SG5.0-145
Foundation	Fixed, Jacket
Capacity	100MW
Shareholder	Developed: Mainstream Renewable Power Operator: Trung Nam Group Owner: Trung Nam Group
Status	Commercial operation: 2022
Wind turbines	Model: SG 5.0-145 Rated power: 5.0MW Rotor diameter: 145m Gearbox: spur/planetary Generator: DFIG Wind speed range: 3-25m/s. Wind class: IIb Hub height: 90-127.5m
Grid connection	Inter-Array voltage: 33kV Export voltage to onshore substation: 33kV Export voltage to grid: 220kV The WTGs are interconnected in a branch configuration, using an inter-array voltage of 33kV. Export cables at 33kV are used to connect to the onshore substation. From the onshore substation an export line at 220kV is used to connect with the power grid at the Tung Nam substation.
	

7.6 Offshore Wind Offtake Business Case

7.6.1 Participation in the Electricity Market

The government-owned EVN still has a monopoly on regulation, wholesale, transmission, distribution and retail of electricity. Generation segment is the only part which is open to cooperate with other participants and having a competitive market structure [165].

In Decision No.26/2006/QD-TTg the Prime Minister approves the roadmap for development of different levels of electricity market in Viet Nam [179]. Therefore, the electricity market shall be formed and developed through different levels.

- Level 1 (2005-2014): The competitive electricity production market;
- Level 2 (2015-2022): The competitive electricity wholesale market;
- Level 3 (after 2022): The competitive electricity retail market.

This decision aims to develop a competitive market and to attract investment outside the economy into electricity-related activities while reduce the government investment in the power industry.

Before the wholesale market operated for the first time, EVN was the only wholesale purchaser of electricity in Viet Nam, and the price offered to renewable power plants was low in comparation with the costs of production, and also is reported that they are selling generated electricity to consumers at a loss [165].

In this scenario investors will need to sign PPAs with EVN to sell electricity, and according to Circular 07/VBHN-BCT the energy generated by a wind farm shall sign a PPA with EVN or authorized organizations [171].

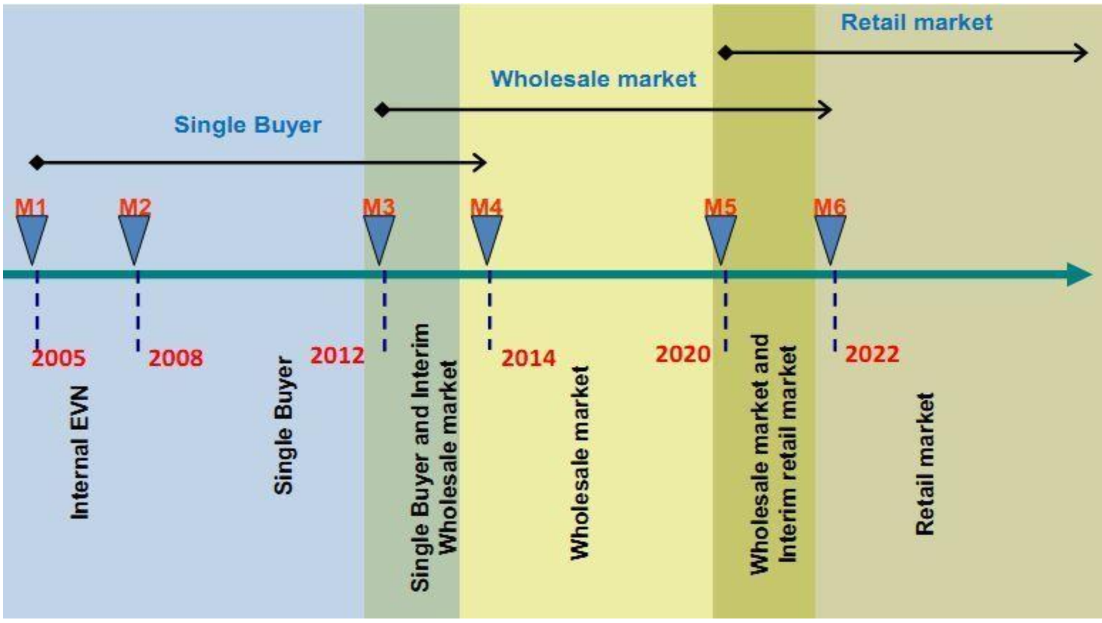


Figure 7-6 Roadmap for the formation and development of different levels of the electricity market [17]

Since early 2019 the wholesale market VWEM has operated, and by the end of 2020 about 40% of the power system participated directly in the power market [163]. It is expected that in the next few years all the generators will participate in the wholesale market as indicated in the roadmap, opening new possibilities for remuneration than those that existed before. Below Figure 7-7 shows a view of the Viet Nam power market structure.

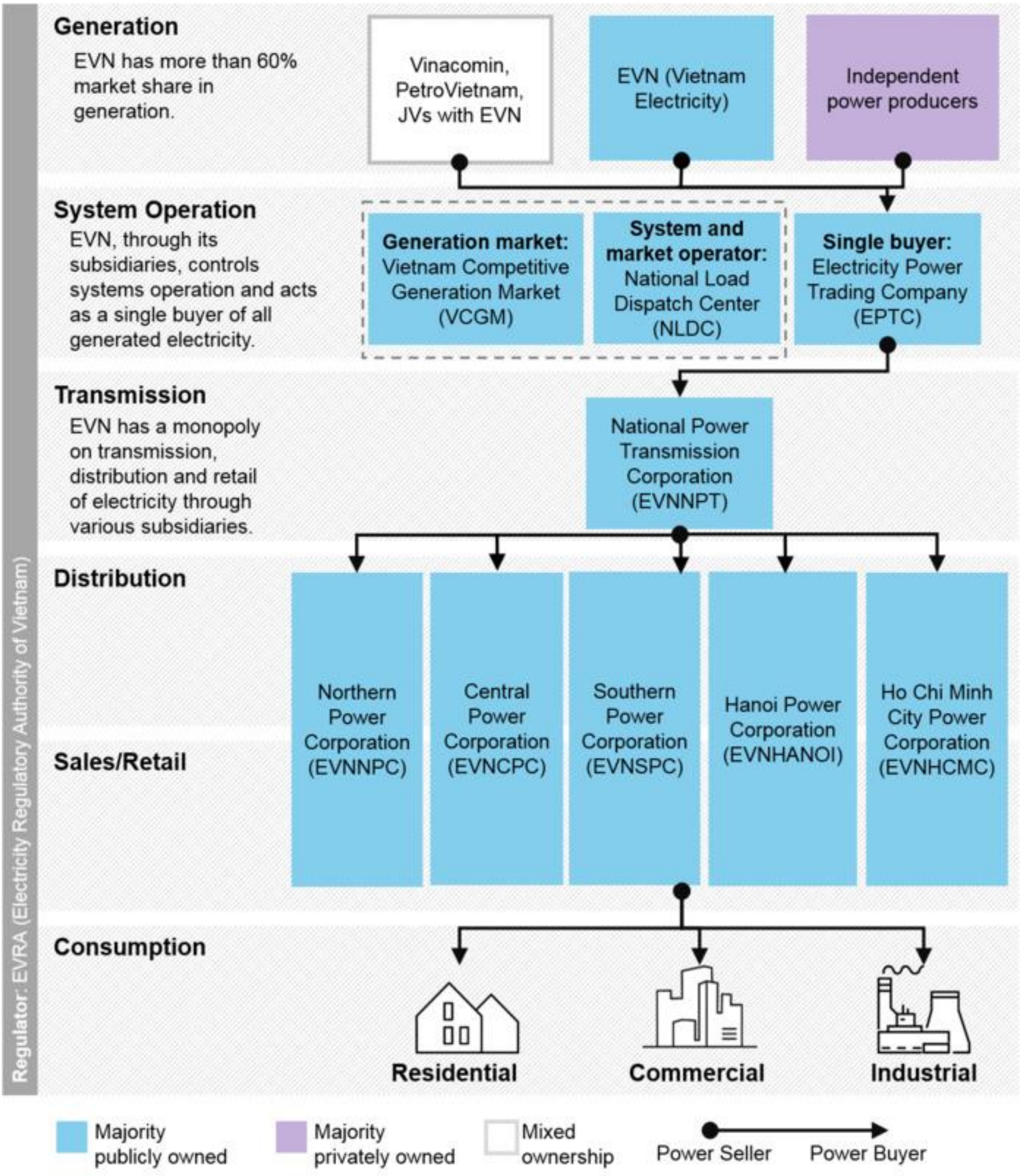


Figure 7-7 Power market structure [180]

Viet Nam currently has no limit for foreign ownership of renewable energy infrastructure. While there are foreign-invested thermal power projects in cooperation with the Government under the Build-Operate-Transfer (BOT) partnership, it is not applicable for most renewable energy projects. Renewable energy projects are therefore carried out as independent power projects [160].

To be able to operate a power plant in Viet Nam, it is necessary to obtain an electricity generation license and the following conditions must be satisfied [165]:

- Have a feasible project or scheme for electricity activities;
- Have an investment project for the construction of a power plant that conforms to the approved plan on the development of electricity in the economy (PDP8);
- Have valid application files for the grant, amendment, or supplementation of electricity activity licences;
- Have administrators or managers with managerial capability and professional qualifications that are suitable in the fields of electricity activities;
- Fulfil the conditions and requirements to operate electricity generation plants;
- Have paid the license fee.

7.6.2 Cost of Offshore Wind

According to the scenarios in the World Bank Report, the predicted LCOE for the earliest projects is expected to exceed USD150/MWh. This cost is expected to reduce to around USD70-90/MWh by 2030 and USD50-70/MWh by 2035, depending on the growth rate of the scenario. The key drivers anticipated to contribute to the growth of the wind energy sector include the use of larger turbines with rotors designed for lower wind sites, a reduction in capital cost facilitated by the availability of finance, and the growth of local and regional supply chain driven by market confidence [167].

Figure 7-8 shows the relative LCOE according to a 500MW reference project in Viet Nam waters. This serves as a guide to indicate the areas that are expected to have the lowest cost of electricity. The most affordable sites tend to have the highest wind speeds, shallowest waters and closest proximity to shore and ports. Of particular interest is the northern region and the southeast region for low LCOE in both fixed and floating OSW projects [167].

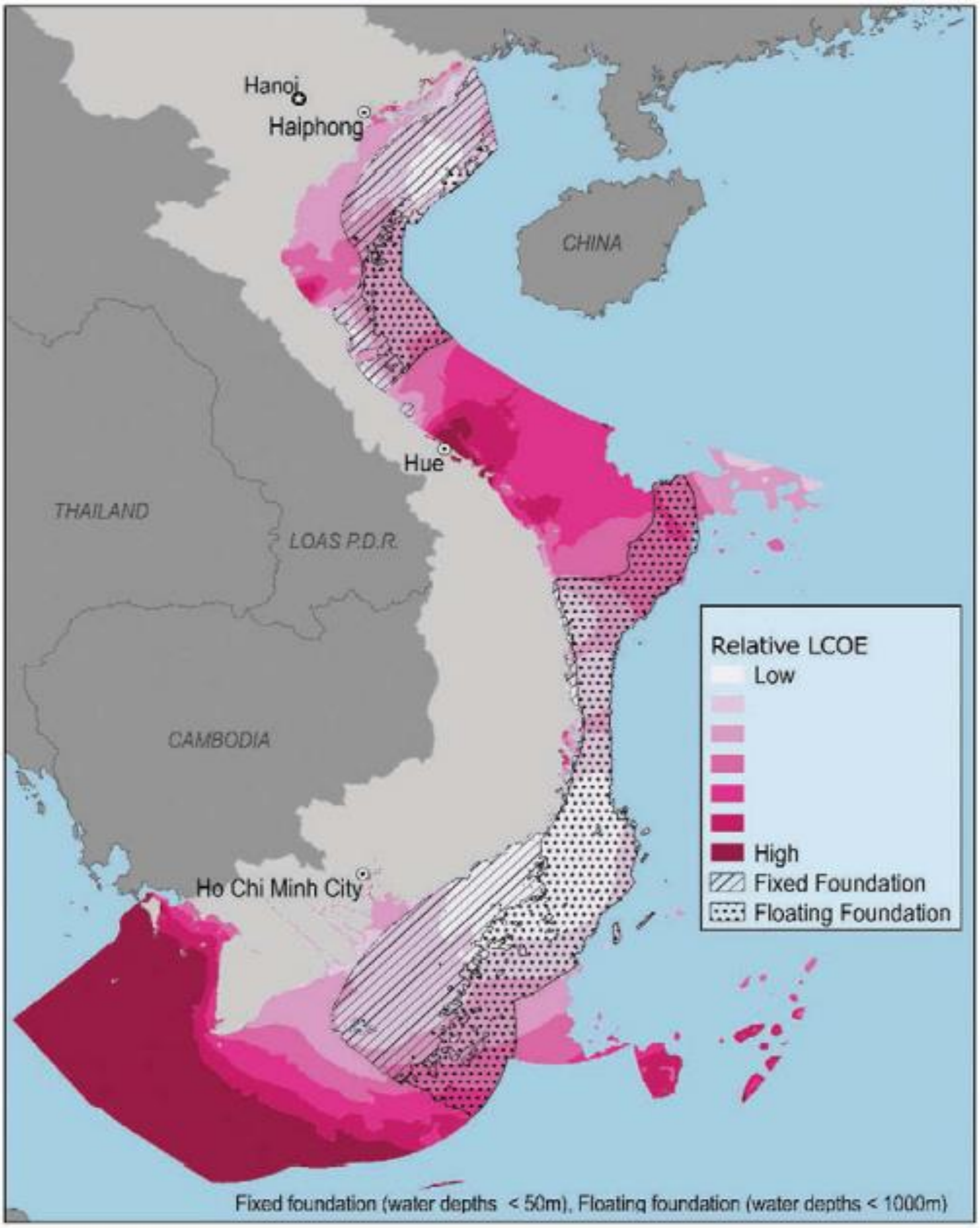


Figure 7-8 Relative LCOE in Viet Nam

7.6.3 Participation in Provision of Ancillary Services

Once the wholesale market is established, according to Decision 8266/QD-BTC, it is planned to have a mechanism for auxiliary services [11]:

- Frequency control service: These services may be purchased in the spot market. Upon application of the ex-ante pricing, the mechanism for co-optimization of energy and frequency control service shall be implemented;

- Other ancillary services: The electricity system and market operator shall contract service providers by implementing the competitive bidding or bid appointment procedures.

In addition to the Minister Decision, EVN is co-operating with international organizations, such as the United States Trade and Development Agency and General Electric, to examine the feasibility of deploying advanced energy storage technologies to determine how much battery storage or how many transmission devices (FACTS) would be needed and where to deploy them to strengthen the grid performance [181]. To date, no specific regulations have been issued to facilitate investment in this area [165].

7.6.4 Private Offtaker of Electricity

Direct Power Purchase Agreement (DPPA) Pilot Program is a scheme developed by the MOIT and the United States Agency for International Development (USAID) to support renewable energy generators to participate directly in Viet Nam's wholesale electricity market at agreed long-term prices and allow the generators to directly sell energy to private offtakers [160]. Currently, EVN is the sole offtaker in the market.

The pilot DPPA scheme is proposed to run from 2022 to 2024, supporting the opening of the electricity market. The pilot scheme currently has a maximum capacity of 1,000MW and requires generators and offtakers to submit applications to participate. The DPPA includes three types of contracts which are described below and represented in Figure 7-9 [160] [182]:

- **Generator PPA:** A PPA between the renewable energy generator and Electricity Company (one of 5 EVN subsidiaries). Under this contract, the Electricity Company guarantees to purchase 100% of generated electricity. The generator is prioritized except in the cases of overload. The spot price is set periodically on the wholesale market;

- **Offtaker PPA:** A PPA between a private offtaker and Electricity Company. The generators cannot directly sell physical electricity to private off takers, instead the offtakers will be required to enter into a separate PPA with EVN. The price is comprised of an amount that the Electricity Company periodically pays in the wholesale market and a DPPA service fee calculated per electricity unit which covers transmission, distribution, system operation and transaction fees;

- **CfD/Virtual PPA**: A PPA directly between the renewable energy generator and private offtaker. This is a requirement of each offtaker for the purpose of documenting a pre-agreed electricity purchase price. The renewable energy generator receives the spot price from the Electricity Company and difference between spot price and agreed price from the private offtaker. This contract must be at least 10 years long but not exceeding 20 years from the plant's commercial operation date.

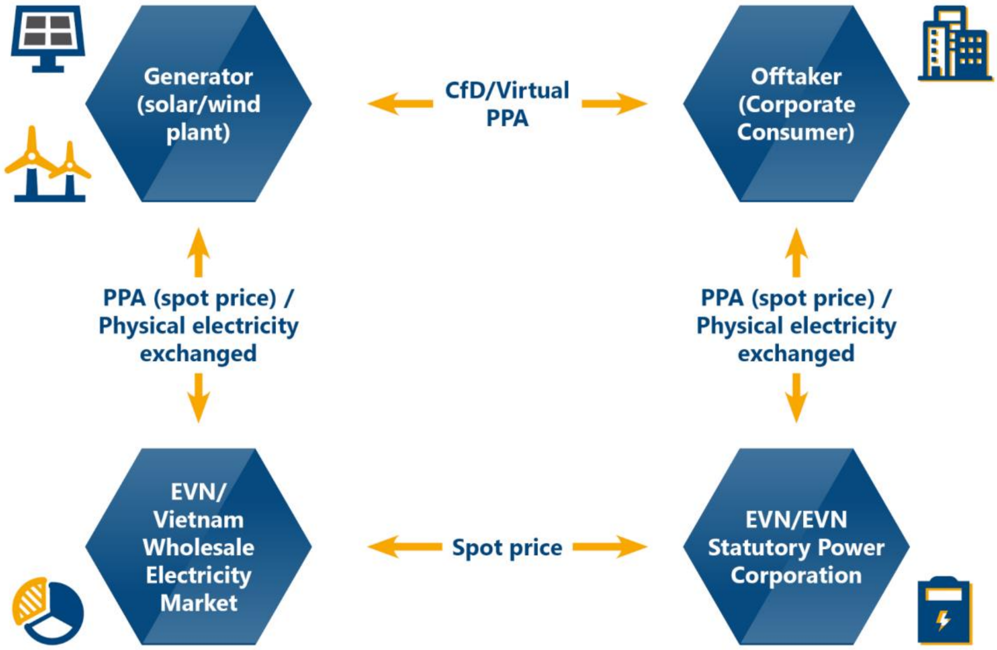


Figure 7-9 Proposed DPPA contractual mechanism

7.6.5 Curtailment

There was a large amount of solar power connected to the grid in 2019 under the approval of the Government. This created an unforeseen surge of added capacity in the concentrated provinces which created enormous pressure on the power system. As a result, EVN requested curtailment without compensation to a number of solar and wind projects. Curtailment risk in Viet Nam is the highest in the central regions where most of the renewable projects have been registered [160].

When there are technical issues on the grid, EVN may not be obligated to purchase power based on the terms of the PPA. While the PPA might require that EVN provide 10 days' notice to minimize the reduction or suspension in its receipt of power, it is unlikely this will sufficiently reduce the risk of uncapped curtailment [167].

7.7 Summary and Recommendations

The challenges/barriers for the development of offshore wind energy in Viet Nam are of institutional, technical, and economic nature. They tend to impact foreign investment more than local investment. The current approval process for the development of a wind farm in Viet Nam is very complicated and unclear [169]. There are six laws, over 20 regulations and nine agencies that need to be involved [162]. As a result, those looking to invest in offshore wind project in Viet Nam, particularly the foreign investors may find the administrative process too challenging. An enabling policy framework with transparent and detailed regulations on environmental and administrative issues would help to mitigate loss of investment due to these challenges.

Another barrier is that there is limited data regarding wind, seabed, and maritime conditions in Viet Nam, which has been impeding the decision of investors [162]. A reliable wind map would be a good start to helping provide confidence to the investors looking to enter the offshore wind market in Viet Nam [169]. Additionally, a lack of grid capacity and a large concentration of offshore wind power generation in the south, has caused an increasing risk of curtailment [162]. Upgrading the grid may take years to complete due to a lack of capital and complex negotiation processes [162]. Solutions to the grid problem must incorporate cross-collaboration with the government and private investors.

The electricity market is in a process of modernization. Up until now, the government-owned company, EVN was the sole buyer of electricity, ensuring a single set price [165]. By allowing the market to become competitive more investors will receive appropriate renumeration. It is likely that overall price for developers will decrease. Viet Nam has a current approximate LCOE for offshore wind of USD150/MWh. This is particularly high compared to the most advanced markets in Europe and China which have LCOE of around USD75-100/MWh. This is not surprising, given the lack of local OSW supply chain in Viet Nam compared to Europe and China [167].

Reducing the cost of capital for offshore wind projects in Viet Nam is a key driver to reducing the LCOE and encouraging inward investment. While the current tax and policy incentives are stimulating, the World Bank Offshore Wind Roadmap for Viet Nam provides further financial recommendations. These actions include encouraging participation in offshore wind projects by multilateral lenders, deployment of credit enhancement mechanisms and the adoption of green standards. The next step proposed to the government would be to undertake consultation with international investors to gather their perspectives to help identify solutions. Overall greater competition can help reduce the cost of offshore wind financing [167].

8 Recommendations on OSW Deployment and Grid Connection in the APEC Region

Over the last decade, the development of offshore wind within the APEC member economies has been impressive and is continuing to grow. It is evident that not all economies are at the same stage of development with varying development models in different economies. China, for example, is a global leader in the offshore wind development, having developed a rather mature market with a significant portion of investment and supply chain available. . Effective development of the offshore wind sector could maximize the economic value for the local industry, but the requirement for local supply chain is high. The markets in economies such as Korea and Chinese Taipei are more reliant on foreign investments and overseas suppliers. The growth of local supply chains is reinforced through the collaboration with experienced oversea companies. These economies are putting in place local content requirement to foster the growth of the local offshore wind industry.

One common key element for building a successful offshore wind industry is stable grid infrastructure, which minimizes the risks of energy curtailment. A stable grid reinforces developers' and investors' confidences. A transparent and consistent framework for gird reinforcement considering offshore wind integration is essential for long-term development. The local government officials shall set forth solid frameworks to shape the grid development roadmaps. The grid operators should work with the local governments so that they can plan for the relevant reinforcement work. The grid operator is usually the one who implement the plan, so their involvement is at the core of the grid reinforcement. An appropriate regulatory framework and incentive mechanism must be in place so that the grid operator is properly engaged. For instance, the mechanism of wheeling charges, grid ownership and operation management, etc. On the technical side, system impact studies must be carried out to assess the integration and sensitivity. The reinforcement plan must align with the government targets, and consider the plan realistically if the plan involves local community engagement and approvals. Local parties such as environmental groups and fishery associations would have to be highly engaged along with the project development. The stakeholder management can be very complicated that could go beyond the expectation and significantly delay the project development. For larger the economies such as China, a unified technical procedure and specification for the grid connection could help remove the barriers for foreign developers who want to participate in the market.

The local governments shall set an ambitious goal which indicates its determination in developing offshore wind projects. This will attract private sector's attention and hence they would put in resources to do investigation into the market. The government usually finds it easier to set policy by absorbing private sector experience and technical know-how integrated with internal policy considerations. The development target must reconcile with the gird reinforcement plan which acts as an indicator for offshore wind development investments. Also, a consistent and transparent permitting procedure is important because it helps developers to draft and visualize development timeline. Sometimes potential projects could be cancelled before construction due to permitting and approval issues. Therefore, permitting process is among the key aspects to offshore wind project development.

From the commercial side, a solid revenue model shall be demonstrated. A utility PPA is usually available for the early-stage market where the government is subsidising and incentivizing early projects. It can demonstrate a workable model to the world for offshore wind projects and enhance the confidence of early investors into the market. Utility PPAs for early-stage markets usually have a higher premium tariff that is adequately attractive economically. The rate for later projects is expected to gradually decrease because the development risk is relatively smaller compared to early projects. In addition, corporate PPAs must be available which often comes later than utility PPA. It indicates the actual commercial needs and confidence for the green electricity in the local private sector. The rate is usually lower than utility PPA because corporate PPA are supposed to be competitive in the local market.

The government shall engage local industry as early as possible for preparing the local supply chain. Offshore wind projects are complex engineering works involving various aspects of highly sophisticated engineering streams. The related suppliers sometimes are only available to certain regions due to global supply chain allocation. Therefore, early markets often rely heavily on foreign suppliers which could bring more uncertainty due to the global logistic conditions nowadays. To maintain a stable development environment, a solid local supply chain shall be developed for a long-term development of offshore wind market.

References

[1] LI Junfeng, et al. "CHINA WIND ENERGY OUTLOOK," GLOBAL WIND ENERGY COUNCIL, 2012.

[2] Korean Energy Agency, "2016 New & Renewable Energy White Paper," 2016.

[3] Asia Wind Energy Association, "Overview: Japan," 2022.

[4] InfoLink Consulting, "Analysis of Asia Pacific Offshore Wind Market - Taiwan," 30 August 2021. [Online]. Available: https://www.infolink-group.com/energy-article/Analysis-of-Asia-Pacific-Offshore-Wind-Market-Taiwan.

[5] The World Bank, "Offshore Wind Technical Potential in Vietnam," January 2021. [Online]. Available: https://documents1.worldbank.org/curated/en/340451572465613444/pdf/Technical-Potential-for-Offshore-Wind-in-Vietnam-Map.pdf.

[6] Office of Energy Efficiency and Renewable Energy, "Offshore Wind Research and Development," Wind Energy Technologies Office, 2021. [Online]. Available: https://www.energy.gov/eere/wind/offshore-wind-research-and-development.

[7] IEA, "Offshore Wind Outlook 2019," IEA, Paris, 2019.

[8] IEA, "Electricity Market Report," IEA, Paris, 2020.

[9] Global Wind Atlas, Technical University of Denmark, 2022. [Online]. Available: https://www.gebco.net/data_and_products/gridded_bathymetry_data/.

[10] General Bathymetric Chart of the Oceans (GEBCO), "Gridded BAthymetry Data," 2020. [Online]. Available: https://www.gebco.net/data_and_products/gridded_bathymetry_data/.

[11] NEF, Bloomberg, "China," NEF, Bloomberg, [Online]. Available: https://www.bnef.com/.

[12] C. A. H. Alva and X. Li, "Power Sector Reform in China an international perspective," International Energy Agency, 2018.

[13] China Academy of Management Science Institute of Industry Development, "2021 China Top 500 Energy Group," China Academy of Management Science Institute of Industry Development, 16 December 2021. [Online]. Available: http://www.zgyhys.org/bencandy.php?fid=75&id=4989#_bdtz_.

[14] CEC, "China Power Industry Annual Development Report 2016," CEC, 2016.

[15] The Government of the People's Republic of China, "China's Mid-Century Long-Term Low Greendhouse Gas Emission Development Strategy," UNFCC, 2021.

[16] CarbonBrief, "What does China's 14th 'five year plan' mean for climate change?," CarbonBrief, 12 03 2021. [Online]. Available: https://www.carbonbrief.org/qa-what-does-chinas-14th-five-year-plan-mean-for-climate-change/. [Accessed 16 08 2022].

[17] J. Luan, "Renewables in China's 14th Five-Year Plan: Subdued Hopes," BloomberNEF, 28 01 2021. [Online]. Available: https://www.bnef.com/insights/25399. [Accessed 16 08 2022].

[18] Y. C. Q. Liping Jiang, "Wind Energy in China," *IEEE Power and Energy Magazine,* pp. 36-46, 2011.

[19] Z. Z. e. al, "Grid Connection and Transmission Scheme of Large-Scale Offshore Wind Power," *Engineering,* vol. 23, no. 4, p. 10, 2021.

[20] Netherlands Enterprise Agency, "China Offshore Wind," Netherlands Enterprise Agency, 2022.

[21] N. Kou, "Renewables to Serve Bulk of China's Energy Demand by 2025," BloomberNEF, 03 06 2022. [Online]. Available: https://www.bnef.com/insights/29093?query=eyJxdWVyeSI6IiIsInBhZ2UiOjEsIm9yZGVyIjoiZGF0ZSIsImZpbHRlcnMiOnsiY29udGVudFR5cGUiOiJpbnNpZ2h0IiwicmVnaW9uIjpbXSwic2VjdG9yIjpbXSwiYXV0aG9yIjpbIjQwMTQ4Il0sImluc2lnaHQtdHlwZSI6W119fQ%3D%3D. [Accessed 16 08 2022].

[22] GWEC, “Global Offshore Wind Report 2020,” GWEC, Brussels, 2020.

[23] State Council, State Council, May 2022. [Online]. Available: http://www.gov.cn/zhengce/content/2022-05/30/content_5693013.htm.

[24] JingJiRiBao, ““十四五”可再生能源发展提速,” JingJiRiBao, 8 June 2022. [Online]. Available: http://www.gov.cn/zhengce/2022-06/08/content_5694539.htm.

[25] International Energy Agnecy and Tsinghua University, “Enhancing China's ETS for Carbon Neutrality: Focus on Power Sector, Coordinating climate and renewable eneryg policy,” 2022.

[26] X. Yine, “Guangdong leads China’s offshore wind drive with ambitious pricing-parity plan,” Upstream, 17 June 2021. [Online]. Available: https://www.upstreamonline.com/energy-transition/guangdong-leads-china-s-offshore-wind-drive-with-ambitious-pricing-parity-plan/2-1-1026623.

[27] IEA, “Enhancing China's ETS for Carbon Neutrality: Focus on Power Sector,” IEA, France, 2022.

[28] S. Saeed, “Demystifying China's Power Grid,” Power Technology Research, 06 11 2020. [Online]. Available: https://powertechresearch.com/demystifying-chinas-power-grid/. [Accessed 16 08 2022].

[29] State Oceanic Administration, “Administrative Measures for the Development and Construction of Offshore Wind Power,” 05 01 2017. [Online]. Available: http://www.gov.cn/xinwen/2017-01/05/content_5156800.htm. [Accessed 16 08 2022].

[30] W. B. Li Hongtao, “Rules and Standards for Offshore Wind Power Farm Facilities in China,” China Classification Society, 26 10 2021. [Online]. Available: https://www.ccs.org.cn/ccswzen/articleDetail?id=202110260995994844&columnId=202101040581503047. [Accessed 16 08 2022].

[31] Comprehensive Energy Knowledge, “Approval, development, construction, operation, and required procedures for wind power projects,” 12 09 2019. [Online]. Available: https://m.in-en.com/article/html/energy-2281917.shtml#cd-nav. [Accessed 16 08 2022].

[32] Southern Power Grid Corporation , “company overlook,” Southern Power Grid Corporation , 2021. [Online]. Available: https://www.csg.cn/gywm/gsjs/.

[33] ZHESHANG SECURITIES CO.LTD, “CSPGC gird upgrade during 14th FYP,” ZHESHANG SECURITIES CO.LTD, 14 Novermber 2021. [Online]. Available: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://pdf.dfcfw.com/pdf/H3_AP202111151529244027_1.pdf?1637010781000.pdf.

[34] National Energy Administration, “The State Grid Corporation of China has made every effort to promote the construction of major projects,” 05 08 2022. [Online]. Available: http://www.nea.gov.cn/2022-08/05/c_1310650399.htm. [Accessed 16 08 2022].

[35] IRENA, “IRENA and China State Grid Pave Way Towards Smart Electrification,” IRENA, 21 Februray 2021. [Online]. Available: https://www.irena.org/newsroom/articles/2022/Feb/IRENA-and-China-State-Grid-Pave-Way-Towards-Smart-Electrification.

[36] IN-EN, “Investment in China grid expansion,” IN-EN, 19 March 2022. [Online]. Available: https://m.in-en.com/article/html/energy-2313945.shtml.

[37] EPTC, “14th Five-Year Plan power grid construction and development plan,” 25 04 2022. [Online]. Available: https://new.qq.com/rain/a/20220425A07QLH00. [Accessed 16 08 2022].

[38] 4C Offshore, “4C Offshore Map,” [Online]. Available: https://map.4coffshore.com/offshorewind/. [Accessed 16 08 2022].

[39] Renewable Energy World, “Project Profile: Shanghai Donghai Bridge,” Renewable Energy World, 2011. [Online]. Available: https://www.renewableenergyworld.com/wind-power/project-profile-shanghai-donghai-bridge/. [Accessed 28 09 2022].

[40] Shanghai Investigation, Desing & Research Institute, “Donhai Bridge Offshore Wind Farm Engineering Feasibility Study,” Shanghai Investigation, Desing & Research Institute, 2009. [Online]. Available: https://jz.docin.com/p-212669133.html. [Accessed 28 09 2022].

[41] State Council, “Opinions of the CPC Central Committee and the State Council on further deepening the reform of the electric power system (ZhongFa [2015] No. 9),” 2015.

[42] NDRC, “National Energy Administration's guiding opinions on accelerating the construction of a unified national electricity market system,” 18 01 2022. [Online]. Available: http://www.gov.cn/zhengce/zhengceku/2022-01/30/content_5671296.htm. [Accessed 16 08 2022].

[43] K. Y. &. J. Y. Yan Xu, “Levelized cost of offshore wind power in China,” *Environmental Science and Pollution Research,* 2021.

[44] C. Jean-Michel, “China, UK and US Will Lead Offshore Wind Boom to 2035,” BloomberyNEF, 10 August 2022. [Online]. Available: https://www.bnef.com/shorts/14585.

[45] National Energy Administration, “Measures for the Administration of Electric Power Auxiliary Services,” 21 12 2021. [Online]. Available: http://zfxxgk.nea.gov.cn/2021-12/21/c_1310391161.htm. [Accessed 16 08 2022].

[46] General Office of the State Council, “Notice of high-quality development implementation plan,” 30 05 2022. [Online]. Available: http://www.gov.cn/zhengce/content/2022-05/30/content_5693013.htm. [Accessed 16 08 2022].

[47] International Trade Administration, “CHINA LIAONING GREEN POWER MARKET,” 08 03 2022. [Online]. Available: https://www.trade.gov/market-intelligence/china-liaoning-green-power-market. [Accessed 16 08 2022].

[48] Fujian Energy Regulatory Office, “The first green electricity trading in Fujian Province was successfully carried out,” 03 08 2022. [Online]. Available: http://www.nea.gov.cn/2022-08/03/c_1310649327.htm. [Accessed 16 08 2022].

[49] Dentons, “The aspects of green electricity trading contracts are based on the perspective of direct participation of electricity users in transactions,” 16 06 2022. [Online]. Available: https://www.dentons.com/zh/insights/articles/2022/june/16/key-terms-and-major-legal-risks-for-direct-trading-of-green-electricity.

[50] T. Zhao, “Curtailment Issues Unlikely in China’s Mega-Energy Bases,” BloombergNEF, 13 07 2022. [Online]. Available: https://www.bnef.com/insights/29337/view. [Accessed 16 08 2022].

[51] NEF Bloomberg, Japan, “Japan,” NEF Bloomberg, 2022. [Online]. Available: https://www.bnef.com/core/country-profiles/jpn.

[52] IEA, “Japan 2021 Energy Policy Review,” [Online]. Available: https://iea.blob.core.windows.net/assets/3470b395-cfdd-44a9-9184-0537cf069c3d/Japan2021_EnergyPolicyReview.pdf.

[53] The Government of Japan, “Japan's Nationally Determined Contribution (NDC),” UNFCCC, 2021.

[54] METI, “Green Growth Strategy (Overview),” [Online]. Available: https://www.meti.go.jp/english/policy/energy_environment/global_warming/ggs2050/pdf/ggs_overview_all.pdf.

[55] METI, “Overview of the Vision for Offshore Wind Power Industry (1st),” 15 12 2020. [Online]. Available: https://www.mlit.go.jp/kowan/content/001390488.pdf. [Accessed 24 08 2022].

[56] Public-Private Council on Enhancement of Industrial Competitiveness for Offshore Wind Power Generation, “Overview of the Vision for Offshore Wind Power Industry (1st),” 15 12 2020. [Online]. Available: https://www.mlit.go.jp/kowan/content/001390488.pdf. [Accessed 19 08 2022].

[57] NEDO, “Demonstration Project of Next-Generation Floating Offshore Wind Turbine,” [Online]. Available: https://www.nedo.go.jp/floating/project.html. [Accessed 19 08 2022].

[58] METI, “Green Growth Strategy Through Achieving Carbon Neutrality in 2050,” 25 12 2020. [Online]. Available: https://www.meti.go.jp/english/press/2020/pdf/1225_001b.pdf. [Accessed 24 08 2022].

[59] ANRE, "“Offshore wind power generation” Progress since enforcement of the new law," METI, 25 12 2019. [Online]. Available: https://www.enecho.meti.go.jp/en/category/special/article/detail_152.html. [Accessed 22 08 2022].

[60] Environmental Policy Bureau - Ministry of the Environment - Government of JApan, "Environmental Impact Assessment in Japan," May 2012. [Online]. Available: https://www.env.go.jp/en/focus/docs/files/20120501-04.pdf.

[61] METI, "Japanese Central System. Issues for consideration," 14 01 2022. [Online]. Available: https://www.meti.go.jp/shingikai/enecho/denryoku_gas/saisei_kano/yojo_furyoku/pdf/010_02_00.pdf. [Accessed 24 08 2022].

[62] H. S. L. Alex Bunodiere, " "Renewable Energy Curtailment: Prediction Using a Logic-Based Forecasting Method and Mitigation Measures in Kyushu, Japan", MDPI," 2020.

[63] METI Ministry of Economy Trade and Industry, "LArge-Scale Introduction of Renewable Energy and Next-Generation Electri Power Networks," [Online]. Available: https://www.meti.go.jp/shingikai/enecho/denryoku_gas/saisei_kano/index.html.

[64] "Offshore Construction Starts at Japan's First Large-Scale Offshore Wind Farm," [Online]. Available: https://www.offshorewind.biz/2021/04/27/offshore-construction-starts-at-japans-first-large-scale-offshore-wind-farm/.

[65] Akita Offshore Wind Corporation, "Company Guide," [Online]. Available: https://aow.co.jp/en/company/.

[66] "Overview of the Offshore Wind Farm Project off the coast of Happo Town and Noshiro City, Akita Prefecture," [Online]. Available: https://www.tepco.co.jp/en/rp/about/newsroom/press/archives/2021/pdf/210924e0201.pdf.

[67] International Energy Agency, "Levellised cost of electricity in Japan," 18 November 2019. [Online]. Available: https://www.iea.org/data-and-statistics/charts/levelised-cost-of-electricity-in-japan-2040.

[68] IEA, "Korea 2020 Energy Policy Review," IEA, 2020.

[69] BloombergNEF, "Korea (Republic)," BloombergNEF, [Online]. Available: https://www.bnef.com/core/country-profiles/kor. [Accessed 27 09 2022].

[70] IEA, "Korea," [Online]. Available: https://www.iea.org/countries/korea. [Accessed 15 08 2022].

[71] BloombergNEF, "Korea (Republic)," BloombergNEF, [Online]. Available: https://www.bnef.com/core/country-profiles/kor. [Accessed 24 08 2022].

[72] Ministry of Trade, Industry and Energy, "Korea's Renewable Energy 3020 Plan," December 2017. [Online]. Available: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://gggi.org/wp-content/uploads/2018/10/Presentation-by-Mr.-Kyung-ho-Lee-Director-of-the-New-and-Renewable-Energy-Policy-Division-MOTIE.pdf.

[73] Ministry of Trade, Industry and Energy, "A new energy paradigm for the future, Third Energy Master Plan," Ministry of Trade, Industry and Energy, 2019.

[74] Ministry of industry , "9th Basic Plan for Electricity, Expansion of Renewable and LNG Power Generation," Ministry of industry , 2022.

[75] Embassy of Denmark in Korea, "Accerlerating South Korean offshore wind through partnerships," 2021.

[76] Ministry of Trade, Industry and Energy, "Offshore Wind Power Generation Plan," Ministry of Trade, Industry and Energy, 19 July 2020. [Online]. Available: http://www.motie.go.kr/motie/gov3.0/gov_openinfo/sajun/bbs/bbsView.do?bbs_seq_n=163153&bbs_cd_n=81.

[77] KEPCO, "Renewable Generator Transmission System Connection Technology Standard," KEPCO, 29 03 2021. [Online]. Available: https://cyber.kepco.co.kr/ckepco/front/jsp/CY/H/C/CYHCHP01001.jsp. [Accessed 15 09 2022].

[78] Korea Electric Power Corporation (KEPCO), "Regulations on the use of electrical equipment for transmission and distribution," Korea Electric Power Corporation (KEPCO), 2022. [Online]. Available: https://cyber.kepco.co.kr/ckepco/front/jsp/CY/H/C/CYHCHP00601.jsp.

[79] KEPCO, "Renewable Generator Transmission System Connection Technology Standard. Technology Standards," KEPCO, 29 03 2021. [Online]. Available: https://cyber.kepco.co.kr/ckepco/front/jsp/CY/H/C/CYHCHP01002.jsp. [Accessed 15 09 2022].

[80] International Energy Agency, "Korea Electricity Security Review," International Energy Agency, 2021.

[81] KPX, "New equipments connection procedure," KPX, [Online]. Available: https://new.kpx.or.kr/menu.es?mid=a20405020000. [Accessed 20 09 2022].

[82] KPX, "Generation Business licensing," [Online]. Available: https://new.kpx.or.kr/menu.es?mid=a20406000000. [Accessed 20 09 2022].

[83] MOTIE, "9th Basic Plan for Electricity Supply and Demand (2020-2034)," MOTIE, Seoul, 2020.

[84] Seoul Economy, "Hand over key security resources to non-allies... North Korea may take the power grid "hostage"," Seoul Economy, 05 08 2021. [Online]. Available: https://www.sedaily.com/NewsView/22Q2LFEGY0. [Accessed 27 09 2022].

[85] Tamra Offshore Wind Power, "Bussiness Development," Tamra Offshore Wind Power, 2019. [Online]. Available: http://tamra-owp.co.kr/2019/sub0204.php. [Accessed 28 09 2022].

[86] H. Kim, "Tamra Offshore wind power generation leading the renewale energy industry 'without sound'," Seoul Finance, 24 07 2019. [Online]. Available: https://www.seoulfn.com/news/articleView.html?idxno=350217. [Accessed 28 09 2022].

[87] "Overview of Korea's Electric Power Industry," Korea Electric Power Corporation (KEPCO), 2013. [Online]. Available: https://home.kepco.co.kr/kepco/EN/B/htmlView/ENBAHP001.do?menuCd=EN020101.

[88] A. V. Tifenn Brandily, "1H 2022 LCOE Update," BloombergNEF, 30 06 2022. [Online]. Available: https://www.bnef.com/insights/29271/view. [Accessed 14 09 2022].

[89] Shin&Kim, "Implementation of Direct PPA System Between Renewable Electricity Generators and Electricity Consumers," Shin&Kim, 5 November 2021. [Online]. Available: https://www.lexology.com/library/detail.aspx?g=82370280-698b-4933-8b3a-4e5bf963cd90.

[90] E. BELLINI, "South Korea's first renewables-linked PPA," PV magazine, 23 March 2022. [Online]. Available: https://www.pv-magazine.com/2022/03/23/south-koreas-first-renewables-linked-ppa/.

[91] Seung-JinKANG, "Curtailment Issue of Renewable Electricity in JejuIsland," 14 August 2020. [Online]. Available: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.aperforum.org/files/2020-01-korea.pdf.

[92] Enerdata Intelligence and Consulting, "Taiwan Energy Information".

[93] S. Wenlin, "Electricity consumption hit a record high in 2020 poor water conditions affected renewable energy performance," Environmental Information Center Taiwan, 2021.

[94] Taiwan Power, "Infographics," [Online]. Available: https://www.taipower.com.tw/tc/Chart.aspx?mid=194. [Accessed 24 08 2022].

[95] National Development Council, "Taiwans Pathway to Net-Zero Emissions in 2050," March 2022. [Online]. Available: https://www.ndc.gov.tw/en/Content_List.aspx?n=B927D0EDB57A7A3A.

[96] C. Wang, "Taiwan Vows $32 Billion Clean Energy Spree as It Lags on Targets," Bloomberg, 30 03 2022. [Online]. Available: https://www.bloomberg.com/news/articles/2022-03-30/taiwan-vows-32-billion-clean-energy-spree-as-it-lags-on-targets#:~:text=The%20government%20plans%20to%20stop,2040%2C%20the%20government%20report%20said.. [Accessed 24 08 2022].

[97] M. Hassan, A. Wong and S. Polito, "Renewable Energy Law and Regulation in Taiwan," CMS Legal, 18 December 2020. [Online]. Available: https://cms.law/en/int/expert-guides/cms-expert-guide-to-renewable-energy/taiwan.

[98] CMS, "Taiwan," 18 12 2020. [Online]. Available: https://cms.law/en/int/expert-guides/cms-expert-guide-to-renewable-energy/taiwan. [Accessed 24 08 2022].

[99] Bureau of Energy, Ministry of Economic Affairs, "Thousand Wind Turbines Project - Statistics of Wind Power Promotion STatus in Taiwan," 2022. [Online]. Available: https://www.twtpo.org.tw/eng/Home/.

[100] J. Day, "Taiwan Offshore Wind Farm Projects: Updates to Guide Investors and Financiers through the Legal and Regulatory Framework," 2021.

[101] Bureau of Energy, Ministry of Economic Affairs, "The Development and Prospect of Offshore Wind Energy in Taiwan," 2021.

[102] K. M. Wang and Y. J. Cheng, "The evolution of feed-in tariff policy in Taiwan.," Energy Strategy Reviews, 2012.

[103] Tak Associes - ECOVIS, "Major Amendments to the Taiwan Electricity Act (2017)," 16 January 2017. [Online]. Available: https://www.takassocies.com/single-post/2017/01/16/Major-Amendments-to-the-Taiwan-Electricity-Act-2017.

[104] S. Tsay and P. H. Chen, "A dual market structure design for the reform of an independent power grid system - The case of Taiwan," Energy Reports, 2019.

[105] Executive Yuan, "Executive Yuan to set up energy and carbon office," Department of Information Services, 16 June 2016. [Online]. Available: https://english.ey.gov.tw/Page/61BF20C3E89B856/f5e3677e-a7df-4b99-b850-319482c49b8f.

[106] Liberty Times Net, "Taiwan Wind Power Industry Event Offshore Wind Power Industry Association TOWIA announced its establishment today," 10 March 2021. [Online]. Available: https://ec.ltn.com.tw/article/breakingnews/3462759.

[107] Taipower, "Taipower Profile," [Online]. Available: https://csr.taipower.com.tw/en/sustainability/intro.

[108] Taiwan Power Company, "Sustainability Report," Taiwan Power Company, Taipei, 2021.

[109] Taipower, "Taipower Sustainable Development Plan," 2021.

[110] T. Power, "OWF Grid Expansion Work Progress," 2022. [Online]. Available: https://www.taipower.com.tw/tc/page.aspx?mid=1467&cid=2690&cchk=4b125c4f-992c-4d50-bb42-f577d65a83ee.

[111] Jera, "formosa 1 Offshore Wind Poer IPP," [Online]. Available: https://www.jera.co.jp/english/business/projects/formosa1.

[112] Hai Long Offshore Wind, "Hai Long Offshore Wind Project," Hai Long Offshore Wind, [Online]. Available: https://hailongoffshorewind.com/en/. [Accessed 28 09 2022].

[113] "Hai Long Offshore Wind Official Website," [Online]. Available: https://hailongoffshorewind.com/en/overview.

[114] "Northland Power signs 20-year CPPA for 744MW of Taiwanese offshore wind project," [Online]. Available: https://www.nsenergybusiness.com/news/northland-signs-ppa-for-744mw-hai-long/.

[115] C. Yen-Haw, H. Te-Hui, Y. Hsi-Hsun, C. Yen-Ling, T. Ying-Fan, C. Yen-Lin and J. Zih-Yi, "Introduction of the Linkage between Taiwan Renewable Energy Certificate Tracking System and National Greenhouse Gas Registry Platform".

[116] Taiwan Power Company, "Smart Grid - Ancillary Services in Taipower," [Online]. Available: http://smartpowernet2020.db-coder.com/en/page.aspx?mid=43.

[117] N. E. S. Writer, "Northland Power signs 20-year CPPA for 744MW of Taiwanese offshore wind project," NS Energy, 12 7 2022. [Online]. Available: https://www.nsenergybusiness.com/news/northland-signs-ppa-for-744mw-hai-long/#.

[118] C. Yates and M. Leybourne, "Financing Offshore Wind in Tiwan," Research Gate, 2019.

[119] [Online]. Available: https://tw.news.yahoo.com/2050%E5%B9%B4%E5%8F%AF%E8%83%BD%E5%B0%87%E7%84%A1%E9%AD%9A%E5%8F%AF%E5%90%83-%E6%B0%91%E7%9C%BE%E9%BB%A8%E6%8E%A8-%E6%B5%B7%E6%B4%8B%E4%BF%9D%E8%82%B2%E6%B3%95-%E4%BF%83%E6%B5%B7%E6%B4%8B%E4%BF%9D%E8%82%B2-040900097.html.

[120] White House, “FACT SHEET: President Biden Signs Executive Order Catalyzing America’s Clean Energy Economy Through Federal Sustainability,” White House, 8 December 2021. [Online]. Available: https://www.whitehouse.gov/briefing-room/statements-releases/2021/12/08/fact-sheet-president-biden-signs-executive-order-catalyzing-americas-clean-energy-economy-through-federal-sustainability/.

[121] Bloomberg NEF, “United States,” Bloomberf NEF, [Online]. Available: https://www.bnef.com/core/country-profiles/usa. [Accessed 27 09 2022].

[122] US Energy Information Administration, “US Energy Information Adminstration,” US Energy Information Administration, 2021. [Online]. Available: https://www.eia.gov/todayinenergy/detail.php?id=27152.

[123] Centre for climate and energy solutions, “US State Climate Action Plans,” Centre for climate and energy solutions, August 2022. [Online]. Available: https://www.c2es.org/document/climate-action-plans/.

[124] “Center for Climate and Energy Solutions,” C2ES, [Online]. Available: https://www.c2es.org/content/state-climate-policy/.

[125] “The White House - Fact Sheet,” 22 April 2021. [Online]. Available: https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/.

[126] G. M. N. C. A. JOHN KERRY - SPECIAL PRESIDENTIAL ENVOY FOR CLIMATE, “The long Term Strategy of the United States - Pathways to Net-Zero Greenhouse Gas Emission by 2050,” United States Department of State and the United States Executive Office of the President, Washington DC, November 2021.

[127] “Fact Sheet - The Federal Sustainability Plan,” The White House, 08 December 2021. [Online]. Available: https://www.whitehouse.gov/briefing-room/statements-releases/2021/12/08/fact-sheet-president-biden-signs-executive-order-catalyzing-americas-clean-energy-economy-through-federal-sustainability/.

[128] “The White House - Fact Sheet,” White House, 29 March 2021. [Online]. Available: https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/29/fact-sheet-biden-administration-jumpstarts-offshore-wind-energy-projects-to-create-jobs/.

[129] Bureau of Ocean Energy Management (BOEM), “State Activities,” [Online]. Available: https://www.boem.gov/renewable-energy/state-activities.

[130] N. R. E. L. (. Walter Musial, “Offshore Wind Market Report,” U.S. Department of Energy, 2021.

[131] G. M. Raimondo, “U.S. Department of Commerce,” 11 May 2021. [Online]. Available: https://www.commerce.gov/news/press-releases/2021/05/biden-harris-administration-approves-first-major-offshore-wind-project.

[132] “The Road to 30GW: Key Actions to Scale an Offshore Wind Industry in the United States,” 14 March 2022. [Online]. Available: https://www.americanprogress.org/article/the-road-to-30-gigawatts-key-actions-to-scale-an-offshore-wind-industry-in-the-united-states/.

[133] J. Horwath, “US offshore wind pipeline reaches 30.7 GW,” S&P Global Market Intelligence, 2022.

[134] US Department of Energy, “Wind Energy Projects - Loan Programs Office,” [Online]. Available: https://www.energy.gov/lpo/wind-energy-projects.

[135] U. D. o. Energy, “Advancing the Growth of the U.S. Wind Industry: Federal Incentives, Funding, and Partnership Opportunities,” The office of Energy Efficiency & Renewbale Energy, 2021.

[136] A. Vann, “Wind Energy: Offshore Permitting,” Congressional Research Service, 2021.

[137] B. o. O. E. Management, “Regulatory Framework and Guidelines,” U.S. Department of the Interrio, [Online]. Available: https://www.boem.gov/renewable-energy/regulatory-framework-and-guidelines.

[138] BOEM, “Overview of BOEM's Regulatory Framework,” [Online]. Available: https://www.boem.gov/renewable-energy/regulatory-framework-and-guidelines.

[139] New York State Energy Research and Development, “Permitting and Approvals - Understanding federal and state requirements,” [Online]. Available: https://www.nyserda.ny.gov/All-Programs/Offshore-Wind/Focus-Areas/Permitting.

[140] US Enviromental Protection Department, “U.S. Electricity Grid & Markets,” US Enviromental Protection Department, May 2022. [Online]. Available: https://www.epa.gov/green-power-markets/us-electricity-grid-markets.

[141] US Energy Information Adminstration, “US Energy Information Adminstration,” US Energy Information Adminstration, 15 August 2019. [Online]. Available: https://www.eia.gov/todayinenergy/detail.php?id=40913.

[142] Office of Electricity, US Department of Energy, “June 28 Offshore Wind Transmission Stakeholder Workshop,” in *Atlantic Offshore Wind Transmission Stakeholder Workshop* , Online, 2022.

[143] O. o. E. E. &. R. E. U.S. Department of Energy, “Offshore Wind Market Report,” 2021.

[144] Y. R. Justin Horwath, “US offshore wind boom entangled in transmission debate,” S&P Global Market Intelligence, 2021.

[145] Wook Mackenzie, “Decarbonising US power grid 'may cost US$4.5 trillion',” Wook Mackenzie, 27 June 2019. [Online]. Available: https://www.woodmac.com/press-releases/decarbonising-us-power-grid-may-cost-us$4.5-trillion/.

[146] White House, “FACT SHEET: Biden Administration Advances Expansion & Modernization of the Electric Grid,” White House, 27 April 2021. [Online]. Available: https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/27/fact-sheet-biden-administration-advances-expansion-modernization-of-the-electric-grid/.

[147] Office of Electricity , “Recovery Act Reports and Other Materials: Smart Grid Investment Grant (SGIG),” Office of Electricity , 2016. [Online]. Available: https://www.energy.gov/oe/recovery-act-reports-and-other-materials-smart-grid-investment-grant-sgig.

[148] R. G. a. M. S. Michael Goggin, “Transmission Projects Ready To Go: Plugging Into America’s Untapped Renewable Resources,” Americans for a Clean Energy Grid, April 2021. [Online]. Available: https://cleanenergygrid.org/portfolio/transmission-projects-ready-to-go/.

[149] P. Spitsen, P. Duffy, P. Beiter, M. Marquis, R. Hammond, M. Shields and W. Musial, “Offshore Wind Market Report: 2022 Edition,” US Department of Energy, Office of Energy Efficiency and Renewable Energy, 2022.

[150] TETRA TECH, “Environmental Report / Construction and Operations Plan,” DEEPWATER WIND, Boston, 2012.

[151] Dominion Energy, “Amendment to the Coastal Virginia Offshore Wind Project,” Dominion Energy, 21 05 2018. [Online]. Available: https://www.boem.gov/sites/default/files/renewable-energy-program/State-Activities/VA/CVOW_RAP_Amendment_Memo.pdf. [Accessed 28 09 2022].

[152] Energy.Gov. [Online]. Available: www.energy.gov .

[153] T. Stehly and P. Dufft, “2020 Cost of Wind Energy Review,” Naitonal Renewable Energy Laboratory, 2020.

[154] Electric Power Research Institute, “Ancillary Services in the United States: Technical Requirements, Market Designs and Price Trends,” 2019.

[155] N. R. E. Laboratory, “Wind and Solar Energy Curtailment: Experience and Practices in the United States,” 2014.

[156] SP Global, "CURTAILMENT TRACKER: CAISO wind, solar curtailments rise with more capacity," SP Global, 21 January 2021. [Online]. Available: https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/electric-power/012122-curtailment-tracker-caiso-wind-solar-curtailments-rise-with-more-capacity#article0.

[157] International Trade Administration, "Vietnam - Country Commercial Guide," United States of America Department of Commerce, 15 September 2021. [Online]. Available: https://www.trade.gov/country-commercial-guides/vietnam-power-generation-transmission-and-distribution.

[158] M. Brown and T. Vu, "Vietnam's EVN Faces the Future: Time to Get Renewables Right," *Institute for Energy Economics and Financial Analysis,* 2020.

[159] D. Nga, "Roadmap for the realisation of offshore wind power in Vietnam," Institute of Energy, 10 June 2022. [Online]. Available: http://www.ievn.com.vn/tin-tuc/Lo-trinh-hien-thuc-hoa-dien-gio-ngoai-khoi-tai-Viet-Nam-1-1440.aspx.

[160] Linklaters, "Vietnam Offshore Wind: Where to from here?," May 2020. [Online]. Available: https://lpscdn.linklaters.com/-/media/files/insights/thought-leadership/asia-renewables/vietnam-osw/linklaters_vietnam_offshore_wind_report_may_2020.ashx?rev=38a89974-a102-4053-8adf-081fccdf968c&extension=pdf.

[161] 4C Offshore, "Offshore Wind Farms in Vietnam," 2022. [Online]. Available: https://www.4coffshore.com/windfarms/vietnam/.

[162] T. Nam Do, P. J. Burke, L. Hughes and T. Dinh Thi, "Policy options for offshore wind power in Vietnam," *Australian National University,* 2022.

[163] Vietnam Electricity (EVN), "Annual Report 2021".

[164] Baker McKenzie, "Vietnam: October 2021 updates ot the Draft PDP8," 2021.

[165] Tilleke & Gibbins, "Electricity regulation in Vietnam: overview," Tilleke & Gibbins, 2020.

[166] Danish Energy Agency, "Input to Roadmap for Offshore Wind Development in Vietnam," COWI, 2020.

[167] The World Bank, "Offshore Wind Roadmap for Vietnam," The World Bank, Washington, 2021.

[168] Linktakers, M. Keane, H. Tran and H. Nguyen, "Renewables in Vietnam, Opportunities for Investment," 28 January 2021. [Online]. Available: https://www.allens.com.au/insights-news/insights/2021/01/renewables-in-vietnam/.

[169] A. Agut, T. Truong Han, V. Chi Mai and P. Cattelaens, "Guide to Wind Power Investment in Vietnam," Ministry of Industry and Trade, GIZ Energy Support Program, Hanoi, 2016.

[170] EVNNPT, "National Power Transmission Corporation," 06 2022. [Online]. Available: https://www.npt.com.vn/en-US. [Accessed 18 08 2022].

[171] Thu Vien Phap Luat, "Circular 07/VBHN-BCT," 06 03 2020. [Online]. Available: https://thuvienphapluat.vn/van-ban/Thuong-mai/Van-ban-hop-nhat-07-VBHN-BCT-2020-Thong-tu-thuc-hien-phat-trien-du-an-dien-gio-Hop-dong-mua-ban-mau-447493.aspx. [Accessed 12 08 2022].

[172] Vietnam Business Law, "Transmission Line for Offshore Wind Power Projects in Vietnam," 2022.

[173] M. Pöller, N. T. Nam and T. A. Tuan, "Revision of Grid Code and Distribution Code for facilitating Variable Renewable Energy Integration," Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Hanoi, 2019.

[174] Thu Vien Phap Luat, "Circular 02/2019-TT-BTC," 15 01 2019. [Online]. Available: https://thuvienphapluat.vn/van-ban/EN/Thuong-mai/Circular-02-2019-TT-BCT-wind-power-project-development-and-power-purchase-agreement/406600/tieng-anh.aspx. [Accessed 12 08 2022].

[175] Power Technology, "Bac Lieu Offshore Wind Farm," 29 January 2016. [Online]. Available: https://www.power-technology.com/projects/bac-lieu-offshore-wind-farm/.

[176] Power Technology, "Bac Lieu Offshore Wind Farm," Power Technology, 29 01 2016. [Online]. Available: https://www.power-technology.com/projects/bac-lieu-offshore-wind-farm/#:~:text=The%20Bac%20Lieu%20wind%20power%20project%20also%20included,Vietnam%20Development%20Bank.%20Credit%3A%20The%20Vietnam%20Development%20Bank.. [Accessed 28 09 2022].

[177] Vietnam Energy, "Inaugurating Dong Hai 1 Wind Power Project," 2022.

[178] Trung Nam 18, "NHÀ MÁY ĐIỆN GIÓ ĐÔNG HẢI 1 (V7-1)," Trung Nam 18, [Online]. Available: https://trungnam18.vn/du-an/nha-may-dien-gio-dong-hai-1-v71/305.html. [Accessed 28 09 2022].

[179] Thu Vien Phap Luat, "Decision 26/2006/QD-TTg," 26 1 2006. [Online]. Available: https://thuvienphapluat.vn/van-ban/Linh-vuc-khac/Quyet-dinh-26-2006-QD-TTg-lo-trinh-dieu-kien-hinh-thanh-phat-trien-cac-cap-do-thi-truong-dien-luc-Viet-Nam-10848.aspx. [Accessed 12 08 2022].

[180] BloombergNEF, "Vietnam," BloombergNEF, [Online]. Available: https://www.bnef.com/core/country-profiles/VNM. [Accessed 18 08 2022].

[181] G. Electric, "Vietnam Electricity awards GE battery energy storage feasibility study funded by U.S. Trade and Development Agency," General Electric, 12 April 2019. [Online]. Available: https://www.ge.com/news/press-releases/vietnam-electricity-awards-ge-battery-energy-storage-feasibility-study-funded-us. [Accessed 10 08 2022].

[182] B. Thompson, D. Harrison, M. B. Chow and D. Haberfield, "Vietnam's Direct PPA Pilot Scheme - Energy Market Update - February 2022," Mayer Brown, 01 March 2022. [Online]. Available: https://www.mayerbrown.com/en/perspectives-events/publications/2022/03/vietnams-direct-ppa-pilot-scheme-energy-market-update-february-2022.

[183] SGCC, "Power Grid," [Online]. Available: http://www.sgcc.com.cn/html/sgcc_main_en.

[184] METI, "Designated areas to promote development of marine renewable power facilities," 07 2021. [Online]. Available: https://www.enecho.meti.go.jp/category/saving_and_new/saiene/yojo_furyoku/dl/legal/guideline.pdf. [Accessed 19 08 2022].

[185] "U.S. Energy Information Administration," [Online]. Available: https://www.eia.gov/tools/faqs/faq.php?id=427&t=3.

[186] N. R. E. Laboratory. [Online]. Available: https://www.nrel.gov/.

[187] IEA, "Japan 2021," IEA, Paris, 2021.

[188] EIA, "Electric Power Annual," 10 03 2022. [Online]. Available: https://www.eia.gov/electricity/annual/. [Accessed 24 08 2022].

[189] M. I. Intelligence, "The Supply Chain Study of Offshore Wind Industry in Taiwan," [Online]. Available: https://www.bcctaipei.com/sites/default/files/2022-03/Taiwan%20Offshore%20Wind%20Supply%20Chain%20Report%200322.pdf.

[190] State Council, "Opinions of the CPC Central Committee and the State Council on further deepening the reform of the electric power system (ZhongFa [2015] No. 9)," State Council, 2015.

[Insert APEC Publication number] [Insert ISBN/ISSN]