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Resilience in Floating Offshore Wind Turbines: A Scoping Review

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Abstract

Background

With climate change a looming global threat, offshore wind energy is a vital resource, and floating offshore wind turbines (FOWT) are essential to capture its full potential. Unfortunately, high operations and maintenance expenses pose an obstacle to widespread implementation of FOWT. Reducing maintenance needs by limiting FOWT damage or failure in harsh environments will undoubtedly contribute to lowering costs and to improving on-site personnel safety. Resilience, an important concept in the field of risk management, may be instrumental in achieving these goals.

Objective

The objective of this thesis was to develop a thorough understanding of how resilience is understood and its applications to FOWT design and operation. The following issues were of greatest interest: the degree to which FOWT literature addresses resilience, the various interpretations and definitions of resilience that are employed in FOWT research, and how those definitions of resilience are applied to FOWT. These issues and objectives led to the question this thesis sought to answer, in order to map the knowledge and potential gaps in FOWT resilience research: *How is resilience understood and applied in the context of FOWT design and operation?*

Methodology

In order to answer this research question, a scoping review was conducted, in which two databases – ScienceDirect and GreenFILE – were searched for sources that discussed resilience with respect to FOWT. In accordance with the JBI scoping review methodology, a search and screening strategy, including search terms and inclusion criteria, was determined in advance. The multi-stage screening process ensured that all relevant sources were included, and the entire process is described in such a way as to be transparent and repeatable.

Results

Thirteen sources, consisting of twelve articles and one report, were found to meet the inclusion criteria, and these were thematically analyzed in order to investigate the definitions/interpretations and applications of resilience to FOWT technology. Several trends were discovered among the included sources, including a dominant engineering perspective and a glaring lack of explicit resilience definitions. Despite this lack of definitions, however, several interpretations of resilience were found to be used among the thirteen sources, and these are discussed in depth. Furthermore, the various applications of resilience to FOWT were mapped in order to identify popular topics, and these findings were compared to trends noted elsewhere in the literature.

Conclusions

The results of this review provide valuable insight into the main interpretations of resilience that are used in relation to FOWT. They also provide a solid foundation for future work and for improvements in FOWT resilience research. Among these are the need for a clear definition of resilience in FOWT studies and the potential benefits that could come from the development of a risk management approach to enhance the strong engineering perspective within the field of FOWT resilience research.

Acknowledgement

The submission of this thesis fulfills the requirements for the completion of my Master of Science degree in Risk Analysis and Governance at the University of Stavanger. It would not have been possible to do this alone, so it is fitting to take a moment to recognize and thank the people who have supported me.

I would like to give special thanks to my dad, Mike Lew, for sharing his wisdom whenever I was struggling, to my mom, Nicole Fath-Rincon, who always believed in me and encouraged me, and to my boyfriend Erlend Sørflaten, who has been endlessly caring and supportive. I am very lucky to have such a support system.

I would also like to recognize and thank my supervisor, Olena M. Koval, for her invaluable guidance, expertise, and feedback over the past several months. Writing this thesis was a challenging task, and I am grateful that I had such an excellent supervisor.

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List of Abbreviations

DNV: Det Norske Veritas

DOF: degrees of freedom

DSC: dynamic surface control

DTU: Technical University of Denmark

EERE: Office of Energy Efficiency and Renewable Energy

EPSRC: Engineering and Physical Sciences Research Council

ERDF: European Regional Development Fund

FOWT: floating offshore wind turbine

GWEC: Global Wind Energy Council

HOME: Holistic Operation and Maintenance for Energy

IFAC: International Federation of Automatic Control

IPCC: Intergovernmental Panel on Climate Change

IRENA: International Renewable Energy Agency

JBI: Joanna Briggs Institute

LCOE: levelized cost of energy

LQR: linear quadratic regulator

MPC: model predictive control

NREL: National Renewable Energy Laboratory

O&M: Operations & Maintenance

ORCA: Offshore Robotics for Certification of Assets

ORE: offshore renewable energy

OWC: oscillating water column

OWT: offshore wind turbine

PAS: pitch actuator stuck

PCC: population, concept, context

PRISMA-ScR: Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for scoping reviews

RAI: robotics and artificial intelligence

RBFNN: radial-based functional neural network

RNA: rotor-nacelle assembly

RTHS: real-time hybrid simulation

SDG: Sustainable Development Goal
TLP: tension-leg platform
TSM: terminal sliding mode
WEC: wave energy converter

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Chapter 1: Introduction

It is a widely recognized fact that climate change, fueled by carbon emissions, poses a serious threat to the well-being of people around the world. This is explained in reports published by such organizations as the Intergovernmental Panel on Climate Change (IPCC) and the International Renewable Energy Agency (IRENA). The IPCC's *AR6 Climate Change 2022: Mitigation of Climate Change* report and IRENA's *World Energy Transitions Outlook 2022: 1.5℃ Pathway* report both highlight the importance of reducing emissions in order to stay on track for keeping 2050 global temperature increases below 1.5°C or 2°C. Renewable, low-emissions energy sources play a significant and indisputable role in meeting either of these goals, and wind is among the most important sources of renewable energy that can be exploited for that purpose (IPCC, 2022; IRENA, 2022). Floating offshore wind power in particular has gained a lot of attention recently, as it provides opportunities to harvest more wind power in deeper waters, which are inaccessible for fixed offshore wind developments (Aegir Insights, 2022; Anamiati et al., 2022; Det Norske Veritas [DNV], 2022; Global Wind Energy Council [GWEC], 2022; IPCC, 2022; IRENA, 2022; Kang et al., 2019; Shah et al., 2021). These offshore environments are inherently risky and may pose a threat to both energy production and the safety of on-site personnel (Kang & Guedes Soares, 2020; Shah et al., 2021). This thesis investigates how such risks may be dealt with by studying the concept of resilience as it has been applied to floating offshore wind technology.

The remainder of this introductory chapter is as follows: the first section will give a brief overview of recent trends in floating wind energy; the second section briefly introduces resilience and some related concepts; the third section will present the research question and objectives; the fourth section provides the rationale for the use of the scoping review methodology to answer the research question; the fifth section explains the relevance of this study; the sixth section describes the scope of the review; and the seventh section presents the structure of the remainder of the thesis.

1.1: Floating Wind Power – General Trends

As mentioned above, floating offshore wind power is gaining a lot of attention, largely due to the fact that 80% of offshore wind potential lies in areas where the water depth is greater than 60 meters (Aegir Insights, 2022; GWEC, 2022; Shah et al., 2021). Since such depths do not allow for the economically feasible development of fixed offshore wind turbines, floating offshore wind turbines (FOWT) offer the best possibility for harvesting this abundant resource (Anamiati et al., 2022; DNV, 2022; IRENA, 2022; IPCC, 2022; Kang et al., 2019). In some countries, floating wind power has already developed into a mature technology, with multiple projects completed and several more in the pipeline. For example, the UK has 78 MW of floating wind power in total, which includes the 49 MW Kincardine farm (GWEC, 2022; Micallef & Rezaeiha, 2021). Other major players include Portugal (25 MW), Norway (5.9 MW), China (5.5 MW), Japan (5 MW), and France (2 MW) (GWEC, 2022). Additionally, Equinor has begun construction on the Hywind Tampen project, which will add 88 MW of floating wind power to Norway (Micallef & Rezaeiha, 2021). In other countries, floating wind power is still a budding opportunity – among these are the Philippines, California (USA), Ireland, Italy, and Morocco (Aegir Insights, 2022). Although floating wind markets haven’t taken off all around the globe yet, the growing FOWT markets in countries such as the UK are expected to lead to increases in knowledge and experience and reductions in cost, making floating wind even more feasible for new markets (Aegir Insights, 2022; Anamiati et al., 2022).

GWEC (2022) reports that 2021 was a good year for floating wind power: a total of 57 MW of floating wind was installed worldwide, resulting in a total of 121.4 MW of total global floating wind power. Moreover, it is expected that by 2030, total floating installations will reach 18.9 GW – accounting for 6% of total offshore wind capacity, compared to today’s 0.2% (GWEC, 2022). Looking further into the future, DNV (2022) predicts that by 2050, floating offshore wind capacity will be 264 GW and will provide 15% of total offshore wind power and 2% of total global power production.

Despite the optimistic outlook on future growth and cost reductions, FOWT are still expensive, more expensive than fixed offshore and onshore turbines: DNV (2022) reports that operating expenses for FOWT are five times higher than for fixed offshore turbines. Similarly, floating foundations cost significantly more than their fixed counterparts. These expenses are expected to be reduced over time, as industry knowledge and experience grow (DNV, 2022).

It is also well-documented that Operations & Maintenance (O&M) costs are a significant factor in FOWT expenses, accounting for 25-30% of total project costs and contributing to a high cost of energy – expressed by the levelized cost of energy (LCOE) – for floating wind (Clark &

DuPont, 2018; DNV, 2022; GWEC, 2022; Kang & Guedes Soares, 2020; Kang et al., 2019; Nandi et al., 2017; Shah et al., 2021). Offshore turbine failures can be costly in terms of both time and money: turbines' remote offshore locations make maintenance operations more expensive, and the weather requirements for on-site operations constrain accessibility (Burton et al., 2011; Clark & DuPont, 2018; Kang & Guedes Soares, 2020). FOWT O&M costs therefore pose an obstacle to widespread implementation – reducing these expenses can contribute to the success of floating wind power around the globe. One way to do this is by improving FOWT resilience.

Improving the resilience of essential infrastructure is part of the UN's Sustainable Development Goals (SDGs), specifically goal #9: Industry, Innovation and Infrastructure. One of the targets of the goal is to "develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all" (United Nations [UN], 2023b). FOWT fall under this call for resilient infrastructure, especially as they provide clean energy, contributing to the achievement of global emissions reduction goals (including SDG #7: Affordable and Clean Energy (UN, 2023a)).

In addition to supporting the pursuit of these SDGs, enhanced resilience could positively affect FOWT affordability and feasibility in markets around the globe, leading to greater implementation. However, in order to improve resilience in FOWT systems, it is essential to first understand what resilience is and how it is defined and used in this specific context.

1.2: Resilience and Related Concepts

The term *resilience* is used across multiple domains, and there is no universally determined and accepted definition – in fact, it is unlikely that there ever will be (Hassler & Kohler, 2014; Nemeth et al., 2009). Similarly, there is no single, well-defined way to objectively measure the resilience of a system (Hollnagel, Pariès et al., 2011; Langeland et al., 2016; Yodo & Wang, 2016). This thesis does not seek to solve either of these problems, but rather to explore how resilience is understood and applied in the design and operation of FOWT systems and to identify possible trends or knowledge gaps in the FOWT resilience literature.

In order to provide background knowledge and to demonstrate the variety of existing resilience definitions, the following subsections present some definitions of resilience and related concepts in the risk management field.

1.2.1: Resilience

According to Aven and Thekdi (2022), resilience is the ability of a system to maintain or restore performance and functionality following an adverse event, even one that was previously unknown. However, as mentioned above, there are several different definitions of resilience, which vary from field to field. This particular definition comes from the field of risk management. It is expected that other definitions will appear in this scoping review. This definition is given to support the author's choice of both search terms and inclusion criteria, which will be presented and explained in detail in Chapter 3.

The importance of resilience in managing risks has been noted in the literature: Aven (2019) writes that in the risk management field, resilience was originally seen as a way to increase safety without having to go through complicated probability and loss calculations. By eliminating the need to know *exactly* which events might occur in order to prepare for them, resilience can allow for better handling of unforeseen circumstances or failures. Although the conditions faced by FOWT are fairly well understood, there is always room for surprises, and events may occur which were not at all considered or prepared for. Additionally, the changing climate may bring about more severe weather events on an unprecedented scale, and resilience in FOWT systems may prove essential for system survival. As Aven says, "In the face of uncertainties and the potential for surprises, we need to develop resilient systems" (2019, p. 1200).

Although risk management is important, resilience has been defined for a variety of fields. Other popular definitions of resilience come from ecology (a system's ability to absorb change or stress without losing or changing fundamental characteristics (Hassler & Kohler, 2014; Langeland et al., 2016)), psychology (an individual's ability to recover from trauma (Langeland et al., 2016)), and resilience engineering – "the intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions" (Hollnagel, Pariès et al., 2011, p. xxxvi).

Interestingly, in the field of resilience engineering emphasis is placed on the importance of human actions and decision making in system performance – the technical aspects of a system are not the only matters of importance for resilience studies (Hollnagel, 2014). People are an inextricable part of socio-technical systems, which involve complex interactions between humans and technology (Hollnagel, 2014). The roles that people play therefore affect a system's ability to operate, adapt, and recover (Hassler & Kohler, 2014; Hollnagel, 2014). The importance of considering human abilities, behavior, and learning when conducting resilience and risk assessments is also noted by Steen and Aven (2011).

In a similar vein, Langeland et al. (2016) point out the importance of examining the resilience of different aspects of a system, in order to form a holistic and comprehensive view of system resilience (Langeland et al., 2016). This requires going beyond the purely technical aspects of a system and examining factors like organizational decision making, human behavior, and economic or financial matters.

1.2.2: Robustness

The concept of *robustness* is similar to resilience; however, the main focus of robustness is the ability of a system to absorb known, foreseeable fluctuations or hazards. Since these hazards and fluctuations are known, systems can be designed to accommodate them. Renn (2008) and Steen and Aven (2011) emphasize this distinction between resilience and robustness: robustness is targeted towards a *known* event, whereas resilience is concerned with *any* possible known or unknown events.

1.2.3: Reliability

Another related concept is *reliability*. Aven and Thekdi (2022) define reliability as a system's ability to function as it should; similarly, unreliability is concerned with the system's probability of failure. It follows from these definitions that reliability is related to resilience (in that a resilient system may demonstrate reliability under unexpected adverse conditions), but a reliable system is not necessarily resilient – reliability has nothing to do with a system's ability to *recover* from a disruption.

1.2.4: Implications

As shown by the definitions given above, resilience, while related to robustness and reliability, is a distinct concept. The focus of this thesis is resilience and resilience alone; it is not concerned with robustness and reliability in FOWT.

1.3: Objective and Research Question

The objective of this thesis is to develop a thorough understanding of how resilience is defined and how the concept is applied within the context of FOWT design and operation. In order to achieve this objective, a scoping review of resilience in the FOWT literature was conducted to explore the following: the degree to which FOWT literature addresses resilience, the various interpretations and definitions of resilience that are employed in FOWT research, and how those definitions of resilience are applied to FOWT.

It is not the object of this thesis to determine which definition of resilience is the best or most appropriate for FOWT applications, but rather to map how definitions and characteristics of resilience are applied to FOWT, as well as to identify potential gaps in FOWT resilience research and knowledge. It is the author’s hope that this thesis will provide a good starting point for future efforts to improve resilience in FOWT systems.

The issues and objectives presented above lead to the question this thesis seeks to answer:

> **How is resilience understood and applied in the context of FOWT design and operation?**

The context of “FOWT design and operation” is understood as follows. The design phase covers the process of designing FOWT and the consideration of environmental factors, hazards, threats, and operations, prior to deployment. Operation is considered to be all time between initial installation and final decommissioning, including periods of downtime due to damage or maintenance.

1.4: Scoping Review Rationale

Because the goals of this review are to explore conceptualizations of resilience, map the knowledge pertaining to resilience in the particular context of FOWT design and operation, and identify potential research and knowledge gaps in the literature, a scoping review methodology has been chosen as an appropriate tool. In contrast to a systematic review, it is not within the scope of a scoping review to assess or judge which approach, definition, or concept is the best, most appropriate, or best-suited to the issue in question (Peters, Godfrey et al., 2022; Peters, Marnie et al., 2020). The scoping review methodology is instead meant to provide a transparent approach to a broad, comprehensive, and systematic review of a pool of research or body of literature in order to map or summarize research approaches, conceptual definitions, findings, or applications with regard to a particular issue (Khalil et al., 2016; Peters, Godfrey et al., 2022; Peters, Marnie et al., 2020).

The JBI scoping review methodology, which is summarized by Khalil et al. (2016); Peters, Godfrey et al. (2022); Peters, Marnie et al. (2020); and Pham et al. (2014), was employed to carry out the research for this thesis, and, in addition, the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for scoping reviews (PRISMA-ScR) checklist, developed by Tricco et al. (2018), is used to ensure that this thesis meets all the requirements of a transparent, systematic scoping review. The PRISMA-ScR checklist can be found in **Appendix A.1**.

1.5: Purpose and Relevance of Thesis

In addition to laying a foundation for future studies and improvements of resilience for FOWT, this thesis also fills a current gap in FOWT and resilience literature: although there are several reviews of resilience in fields such as ecology and resilience engineering – e.g., Hassler and Kohler (2014), Hollnagel, Pariès et al. (2011), Langeland et al. (2016), Nemeth et al. (2009), and Yodo and Wang (2016) – there do not yet seem to be any reviews of resilience specific to FOWT. The results of this scoping review may therefore be relevant to FOWT researchers, as well as others who work with, design, and manage FOWT and related technology.

Developing resilient FOWT systems would mean that instead of having to consider *every possible* thing that could go wrong, a general preparedness and ability to respond and adapt could allow for successful navigation of stressful and challenging situations. Cultivating a better understanding of resilience in FOWT may allow for improvements in the resilience of FOWT, therefore leading to reduced maintenance requirements, fewer on-site operations involving personnel, and reduced risk to maintenance workers on floating platforms. On a larger scale, improved resilience of FOWT could contribute to a stable, clean, and affordable energy supply, which serves the purpose of both combatting global warming and providing energy security. This thesis may serve as a stepping-stone for achieving these goals.

1.6: Scope of Study

As mentioned above in relation to the research question, this review is concerned with a particular *concept* – resilience – within a particular *context* – FOWT design and operation. Other technologies related to sustainability efforts or renewable energy sources will not be included. Further, as specified in the research question, it is *only* the design and operational phases of the FOWT life cycle that are of concern to this thesis. Although the installation and decommissioning phases no doubt pose interesting problems and challenges, in order to maintain feasibility and focus in this thesis, they are not considered. Further, only the FOWT, including the rotor, nacelle, tower, floating foundation, and mooring systems shall be studied. The power export and transmission systems are not part of this study.

1.7: Structure of Thesis

The remainder of this thesis is structured as follows: Chapter 2 presents background information about FOWT technology, Chapter 3 provides a detailed description of the methodology employed in this review, Chapter 4 presents the results of the scoping review, Chapter 5 offers a discussion of the results and their implications, as well as possible limitations of the study, and Chapter 6 provides some concluding remarks, including possible directions for future research.

Chapter 2: Background Information – Floating Offshore Wind Turbines

This chapter presents some information, terminology, and concepts that are essential for a basic understanding of FOWT technology and operation. First, different types of wind turbines will be introduced, and the advantages and disadvantages of FOWT will be discussed. Different types of FOWT will also be introduced. In the second section, general terminology will be presented. The third section will give a very brief introduction to various components and technologies that are employed in wind turbines.

The information in this chapter is by no means in-depth: the purpose is to provide enough background knowledge for the reader to understand concepts that are widely employed and discussed in FOWT research, design, and operation. It also provides a foundation for the discussion of the results of this review, in terms of popular study objectives and systems which receive a lot of attention in the literature.

2.1: Types of Wind Turbines

The purpose of this section is to explain differences between various types of wind turbines, especially between different types of FOWT. This grants the reader insight into various factors that must be taken into account for the design and operation of floating wind turbines, and it also provides basic knowledge that enhances understanding of the results to be discussed later.

2.1.1: Onshore, Fixed Offshore, and Floating Offshore Turbines

The main differences between these three types of wind turbines – onshore, fixed offshore, and floating offshore – are in the name: onshore wind turbines are built and operate on land, fixed offshore wind turbines are in coastal waters, at an average depth of 14.6 m (Díaz & Guedes Soares, 2020), and floating offshore wind turbines operate in much deeper waters, held in place by mooring lines and anchoring systems (Butterfield et al., 2005). This subsection will therefore mainly present the advantages and disadvantages associated with each, with a particular focus on FOWT.

Compared to onshore turbines, offshore turbines present more of a challenge: they are more difficult to access for maintenance, they can be more difficult and expensive to install, crews and vessels necessary for maintenance operations are expensive, and their harsher environments affect both maintenance availability and design requirements (Burton et al., 2011; Kang et al., 2019; Kang & Guedes Soares, 2020). Of course, there are also advantages associated with offshore turbines: less surface roughness leads to less turbulence, the mean wind speed is higher than onshore due to the lack of obstructions, large areas are available for development with relatively little environmental impact, and there is reduced noise and visual impact (Burton et al., 2011).

Considerations for fixed offshore turbines and floating turbines are more similar, but there are also some key differences between the two. As mentioned in the introduction, FOWT offer the possibility of harvesting abundant deep water wind resources which would otherwise be inaccessible (Aegir Insights, 2022; DNV, 2022; IPCC, 2022; Shah et al., 2021). Other advantages of FOWT over fixed offshore turbines include more flexible construction and installation procedures, less sensitivity to water depth, higher wind speeds farther from shore, and less noise and visual pollution (Kang et al., 2019). There are some disadvantages associated with this opportunity, however: operating expenses and floating foundation costs are about five times higher for FOWT than for fixed offshore turbines (DNV, 2022). (This discrepancy is expected to be reduced as the industry gains more knowledge and experience.) Moreover, FOWT are affected by the increased movement of the floating platform and harsher environmental conditions, which adds to design considerations and could increase maintenance needs and costs (Shah et al., 2021). The movement of FOWT in response to environmental factors depends on the type of floating platform used – different platform types are introduced below.

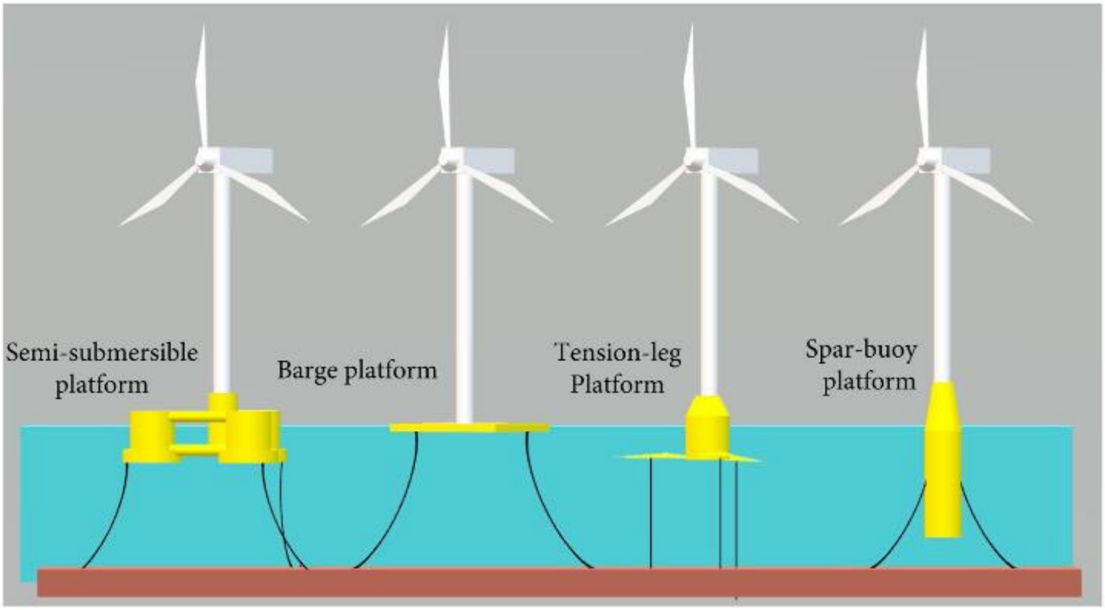
2.1.2: Types of Floating Platforms

There is no universal or standard floating platform design; rather, there are four main types of floating platform, each of which has its own advantages and disadvantages and is best-suited to different types of environments (Butterfield et al., 2005; Clark & DuPont, 2018). The four types of floater, illustrated in Figure 2.1, are semi-submersibles, barges, tension-leg platforms (TLPs), and spar buoys (Aegir Insights, 2022; Butterfield et al., 2005; DNV, 2021a, 2021b, 2022; Micallef & Rezaeiha, 2021; Ramboll, 2021; Shah et al., 2021).

Semi-submersibles and barge platforms are both loosely tethered to the seabed and rely on buoyancy for stability (Shah et al., 2021). TLPs are more tightly anchored to the seabed, and their stability comes from the tension between a buoyant base and the downward, anchoring forces from the tendons (Shah et al., 2021). Because of the tight mooring lines, TLP movements are more restricted than other platform types (DNV, 2021a, 2021b; Ellul et al., 2016). Spar buoys have a much deeper draft than the other platforms, and it is this depth and the use of a ballast tank that provide stability (Shah et al., 2021). Table 2.1, adapted from Aegir Insights (2022), presents and allows for a comparison of the advantages and disadvantages associated with the different floating platform types.

Figure 2.1

Types of floating platforms



Note. From "A synthesis of feasible control methods for floating offshore wind turbine system dynamics" by Shah et al., 2021, *Renewable and Sustainable Energy Reviews, 151*, p. 5

The pros, cons, and limitations of various platform types need to be taken into consideration when planning and designing floating wind developments. A floating platform that is appropriate for one site may not work as well for another. Moreover, the design concepts presented here do not represent all possible FOWT platform designs, just the main classifications. The results of this review revealed several studies which examined other types of platforms, including slight variations on the four types above, as well as hybrid platforms, which support the harvesting of both wind and wave energy (e.g., Yang, Bashir, Li, and Wang (2021) and Zhou et al. (2023)). More information on these modified platform designs will be given in Chapter 4.

Table 2.1

Comparison of floating platform types

Semi-submersible	Barge	TLP	Spar buoy
Overview			
▪ Most popular concept ▪ Stability comes from buoyancy distribution over wide water plane	▪ Shallowest draft of all floating platform concepts	▪ Stability comes from mooring line tension with a submerged buoyancy tank ▪ Specialized installation vessel required	▪ Simplest concept ▪ Minimum depth of 80 m for the entire installation process ▪ Ballast below main buoyancy tank gives stability
Benefits			
▪ Reduced heave (see section 2.2) ▪ Depth and soil condition don't matter ▪ Mooring and anchoring systems are cheap and simple ▪ Simple installation and broad weather window for installation	▪ Appropriate for depths of at least 30 m ▪ Can handle complex seabed conditions ▪ Simple shape and simple fabrication	▪ High stability, low motions ▪ Fairly flexible with respect to water depth ▪ Small seabed footprint and short mooring lines ▪ Simple and light structure makes O&M operations easier, as well as lowering material costs	▪ Stability advantages make it suitable for higher sea states ▪ Soil conditions don't matter ▪ Mooring and anchoring systems are cheap and simple
Challenges			
▪ Greater wave exposure results in reduced stability and greater impacts on the turbine ▪ Labor-intensive, long lead time, and complicated fabrication ▪ Lateral movement is less restrained and could lead to problems	▪ Greater motions can result from high wave exposure ▪ Requires more robust mooring systems, leading to increased complexity	▪ Unstable during assembly ▪ Most expensive type of floating platform ▪ Mooring and anchoring systems are complicated and expensive ▪ High reliance on anchoring and mooring systems for stability means that soil conditions are very important	▪ Expensive ▪ Weighs a lot, requires long mooring lines ▪ Needs to be assembled in sheltered deep water; specialized installation vessels are required ▪ Considerable motions ▪ Deep draft results in large seabed footprint

Note. Adapted from *Floating Offshore Wind - A Global Opportunity* by Aegir Insights, 2022

2.2: General Terminology and Concepts

This section presents terminology which is used in FOWT research and will also be used throughout this thesis. Additionally, concepts that relate to the operation, production capacity, and protection and control of FOWT are explained.

2.2.1: Movement of FOWT

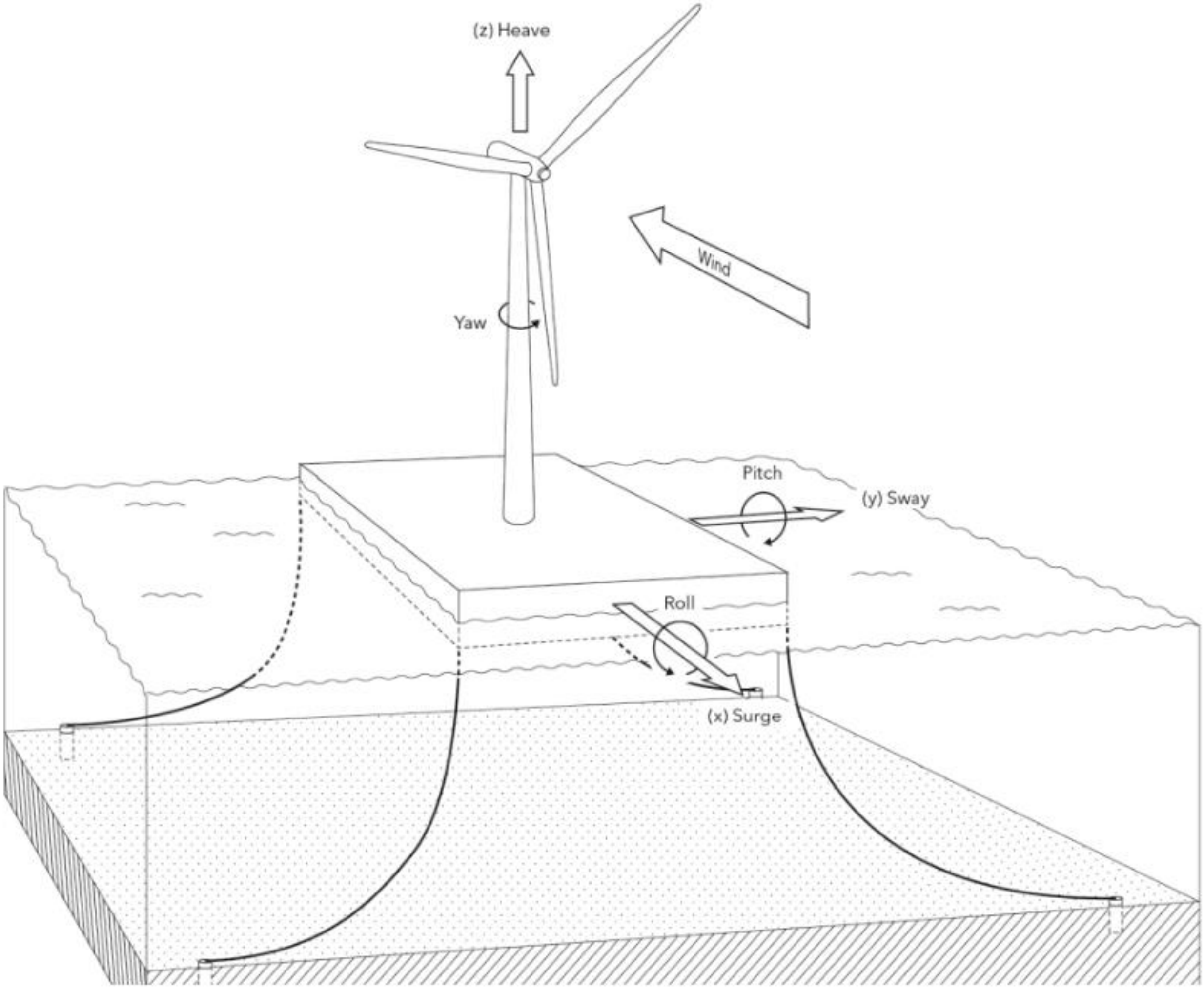
Although fixed and floating offshore wind turbines are both subject to impacts and stresses from waves and currents, FOWT exhibit a great deal more movement resulting from these forces. It is often noted that FOWT have six *degrees of freedom* (DOF), or ways in which they can move (DNV, 2021a, 2021b; Shah et al., 2021). These DOF are listed below and illustrated in Figure 2.2. (Definitions are from Anamiati et al. (2022), DNV (2021a, 2021b), and Shah et al. (2021).)

- Surge: fore-aft motion of the turbine; motion along the x-axis in Figure 2.2.
- Sway: side-to-side motion of the turbine; motion along the y-axis in Figure 2.2.
- Heave: vertical motion of the turbine; motion along the z-axis in Figure 2.2.
- Roll: side-to-side tilting motion of the turbine; rotation around the x-axis.
- Pitch: forward tilting motion of the turbine; rotation around the y-axis.
- Yaw: rotation of the turbine around the vertical (z) axis.

Different floater types are subject to motion to varying degrees: for example, TLPs are more restrained in terms of heave, roll, and pitch (DNV, 2021a, 2021b; Ellul et al., 2016). Similarly, the ballast weights of spar buoys create resistance to rolling and pitching motions, and the deep draft helps to reduce heave motion (Butterfield et al., 2005). On the other hand, the buoyancy of barge platforms is distributed on the surface, which results in greater susceptibility to motion from wave forces (Butterfield et al., 2005). The different ranges of movement of various floating platforms is an important factor that must be taken into consideration when designing FOWT. As will be discussed in Chapter 4, the dynamic behavior of FOWT is the object of multiple studies included in this review (e.g., Ma et al., 2019; Zhou et al., 2023).

Figure 2.2

DOF of FOWT



Note. From *Floating wind turbine structures* by DNV, 2021a, p. 15

2.2.2: Environmental Effects

Wind is highly variable, and a lot of that variability comes in the form of *turbulence*, which is very short-term (on a scale of 10 minutes or less) fluctuations in wind speed. Turbulence can cause fatigue loading and stress, which can gradually wear down turbine components (Burton et al., 2011).

Another environmental effect that contributes to loading and stress and which needs to be taken into consideration in the design of FOWT is *wake*. Wakes are produced by turbines and are characterized by reduced wind speeds and increased turbulence – the effects of turbine wake on downwind turbines is very important to consider when designing wind farms, as it affects both energy production and turbine loading (Anamiati et al., 2022; Burton et al., 2011). This issue is addressed in one of the sources included in this review (Del Pozo González & Domínguez-García, 2022).

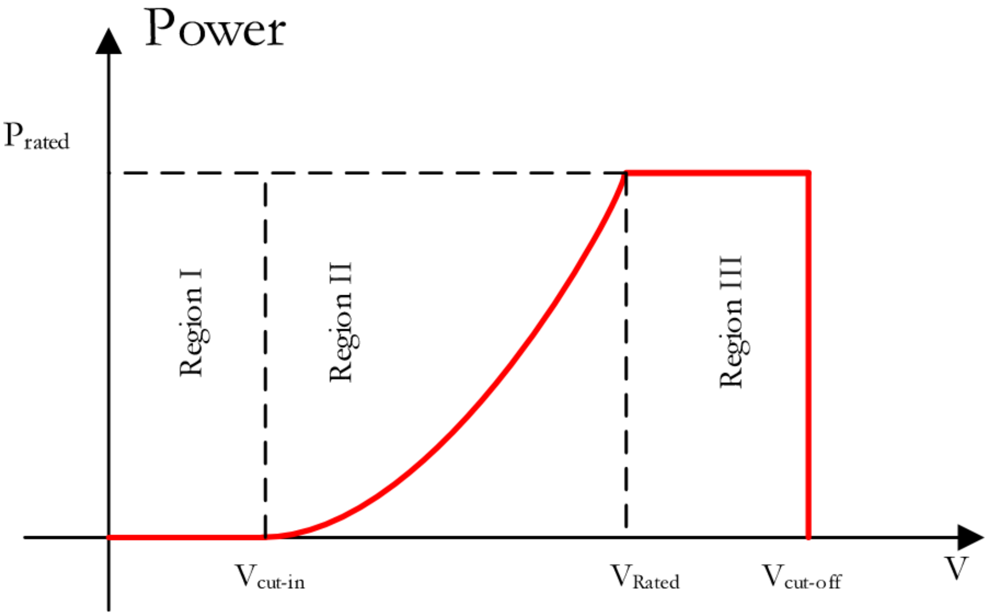
2.2.3: FOWT Operation

In order to ensure safe and effective operation of FOWT, operating limits are established (DNV, 2021c). These limits include the *cut-in* and *cut-out wind speeds*, which are, respectively, the minimum and maximum wind speeds in which a FOWT operates and produces power (DNV, 2021c). These concepts are also presented by Burton et al. (2011), Shah et al. (2021), and Zhu and Genton (2012) – these works describe the use of power curves to represent FOWT operation and energy production in varying wind speeds. An example of a power curve is given in Figure 2.3. Another important value is the *rated wind speed*, which is the minimum constant wind speed at which *rated power* is produced, where rated power is the maximum power output a turbine is designed to produce (DNV, 2021c; Zhu & Genton, 2012).

Figure 2.3 depicts how power production (y-axis) varies as a function of wind speed (x-axis). The three regions depicted in the figure are described by both Shah et al. (2021) and Zhu and Genton (2012). In Region I, power is not produced, because the wind speed is below the cut-in speed. In Region II, production begins at the cut-in speed and increases as wind speed increases, until the rated wind speed is reached. After that, Region III depicts constant production of rated power, until the cut-out speed is reached and power production ceases in order to protect the turbine and reduce the probability of damages.

Figure 2.3

FOWT power curve



Note. From “A synthesis of feasible control methods for floating offshore wind turbine system dynamics” by Shah et al., 2021, *Renewable and Sustainable Energy Reviews, 151*, p. 5

The objectives of the FOWT control system depend on the current operating region: in Region II, the objective is to *maximize* power production, whereas in Region III, the goal is to *regulate* power production to prevent overloading the turbine (Burton et al., 2011; Shah et al., 2021). The control system pursues the objectives given above by adjusting the *generator torque* and the *blade pitch angle*: in Region II, generator torque control maximizes power generation while the blade pitch angle is fixed, and in Region III, blade pitch control regulates the speed of the rotor to prevent overloading (Burton et al., 2011; Richards et al., 2015; Shah et al., 2021). Blade pitch angle refers to the angle of the turbine blades, which affects how the blades catch the wind and can be adjusted to either increase or decrease rotation. When the blades are *feathered*, the lift force is reduced in order to minimize rotation – this is a form of aerodynamic braking (Burton et al., 2011; Shah et al., 2021).

Burton et al. (2011) also describe how FOWT can be in states of non-operation: *parking* or *idling*. When in park, a turbine’s mechanical brake is engaged, and the rotor does not move. A

FOWT is put in park for maintenance operations. In the idling state, a rotor may still spin, but the generator is not engaged, and power is not generated. A FOWT may be put into idle to reduce braking loads.

The terminology and concepts that have been presented here allow for a basic understanding of FOWT operation and factors that must be taken into consideration when designing and operating FOWT. Key FOWT components are described in the following section.

2.3: Turbine Components

Although on the outside, a wind turbine may appear to be fairly simple, it is a complex system, with several interrelated components. This section provides a brief overview of the components of a FOWT that are relevant to this thesis: as mentioned in the introduction (section 1.6), the scope of this study is restricted to the turbine, tower, floating platform, and station-keeping system. The power export and transmission systems will not be introduced here. The components introduced here are those which are discussed or studied in the sources that were included in this review; this section thus serves to supply the reader with a basic understanding of systems that will be referred to later.

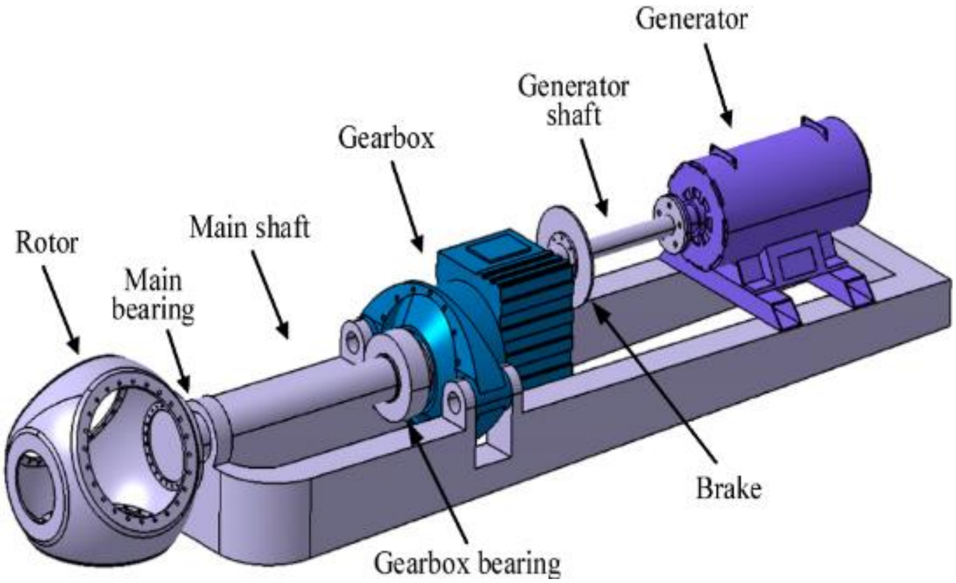
Generally, everything beneath the turbine is referred to as the *support structure*, including the tower, floating platform, and station-keeping system (DNV, 2021a, 2021b). The *station-keeping system* (also referred to as the *mooring system*) is what holds the platform in place, using tendons or mooring lines, depending on the platform type (DNV, 2021a, 2021b). Tendons and mooring lines are guided to their attachment to the platform by *fairleads* (DNV, 2021a). Tendons, also referred to as tethers, are held at higher tensions and are used for TLP foundations, whereas mooring lines, used for other types of platforms, can be either taut or loose (DNV, 2021a, 2021b). These lines are then anchored to the seabed.

On the platform, the *tower* supports and provides access to the *rotor-nacelle assembly* (RNA), which consists of the *blades*, *hub*, and *nacelle* (Ramboll, 2021; Office of Energy Efficiency and Renewable Energy [EERE], n.d.). The blades and the hub comprise the rotor, which rotates in response to wind forces. The nacelle contains the *drive train*, *generator*, *blade pitch mechanism*, *yaw mechanism*, and *mechanical brake* (Burton et al., 2011; EERE, n.d.).

Before describing the drive train, it is important to point out that there are two types of wind turbines: they can be either *direct-drive turbines* or *gearbox turbines* (Burton et al., 2011; IRENA, 2022; EERE, n.d.). Direct-drive turbines have increased reliability, because they have no gearbox. Gearboxes do not fail often, but when they do, the resulting downtime is significant (Burton et al., 2011). In a gearbox turbine, the drive train consists of a *low-speed shaft* (also referred to as the *main shaft* or *rotor shaft*), which connects the rotor to the *gearbox* (Burton et al., 2011; EERE, n.d.). The gearbox increases the rotational speed so that it's suitable for the generator; the *high-speed shaft* (also called the *drive shaft* or *generator shaft*) then connects the gearbox to the *generator*, which converts the rotational motion to electric current (Burton et al., 2011; EERE, n.d.). These components and their configuration are illustrated in Figure 2.4 below.

Figure 2.4

Gearbox drive train

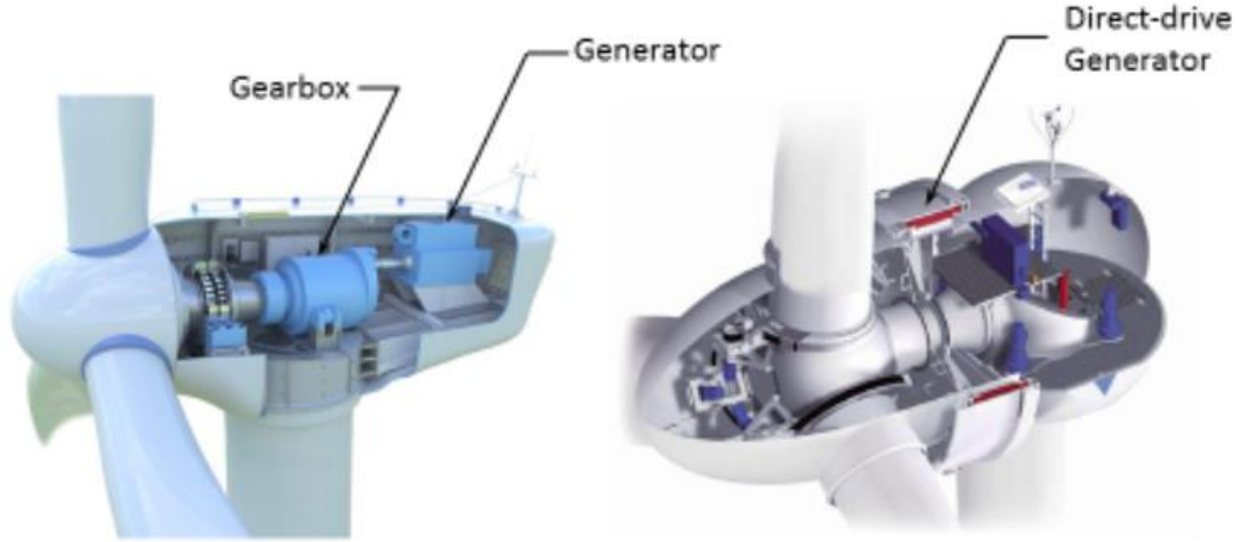


Note. From "Estimating Health Condition of the Wind Turbine Drivetrain System" by Qian et al., 2017, *Energies*, *10(10)*, p. 2

In a direct-drive turbine, the main shaft – supported by the *rotor bearing* (also called the *main shaft bearing*) – directly connects the hub to the generator (EERE, n.d.). Because of the increased reliability and reduced weight that results from the elimination of the gearbox, most offshore turbines are direct-drive; however, due to the slower rotational speeds, the generators used are heavier, and they require the use of certain rare earth elements, which are expensive and heavy (IRENA, 2022; EERE, n.d., 2019). Given this tendency toward the use of direct-drive turbines for FOWT, it may be expected that the research should have a greater focus on direct-drive than geared-drive turbines. Whether this is indeed the case will be examined in Chapter 4. Figure 2.5 illustrates the difference between direct-drive and gearbox turbines: it is easy to see that the generator in the direct-drive turbine is directly connected to the hub.

Figure 2.5

Gearbox and direct-drive turbines



Note. From “Advanced Wind Turbine Drivetrain Trends and Opportunities” by EERE, 2019

In addition to the drive train, the nacelle also contains the control mechanisms mentioned in section 2.2 which allow for the fulfillment of the operating objectives, as well as sensors (such as a wind vane and anemometer) to monitor operating conditions. Based on feedback signals from the sensors, the *pitch control system*, the *torque control*, and the *yaw control* can respond and adjust as necessary, in accordance with current operational objectives. The pitch control system adjusts the pitch angle of the blades and, as mentioned above, is used for power regulation and aerodynamic braking. The system can either control all of the blades together (*collective pitch control*), or it can adjust each blade pitch angle individually (*individual pitch control*) (Burton et al., 2011). Interestingly, in the case of individual pitch control, aerodynamic braking capabilities are redundant: if the blade pitch mechanism on one blade fails, the remaining others can still provide the necessary braking function (Burton et al., 2011). Generator torque control regulates the amount of energy that is produced. The yaw control controls the direction the turbine is facing, and it communicates with the wind vane to determine appropriate adjustments based on wind direction (EERE, n.d.).

This chapter has presented valuable background information on FOWT technologies, systems, and design considerations. This information sets the stage for the coming discussion on how the concept of resilience is applied to FOWT design and operation. After the following chapter on the methodology of this thesis, the results of the review will be presented and discussed, with especial focus on how resilience is defined and to which systems and components it is applied in FOWT research.

Chapter 3: Methodology

This chapter describes the methodology employed for this scoping review of resilience in FOWT. It describes the process that was followed throughout the research, including the search process itself, inclusion criteria for potential sources, the source selection process, and the data that were extracted and are reported in the review.

The purpose of this chapter is to allow for transparency and reduce concerns about bias. As recommended by Peters, Marnie et al. (2020) and Tricco et al. (2018), the level of detail given is such that the search process may be repeated with similar results (with the recognition that it is, of course, impossible to account for sources that may be published after the time of writing and submission of this thesis).

Additionally, in order to enhance the validity of this thesis and scoping review, the Preferred Reporting Items for Systematic reviews and Meta-Analysis extension for scoping reviews (PRISMA-ScR) checklist was used to guide research and writing. PRISMA-ScR, as a reporting guideline, describes a minimum set of items to include in scoping review reports, in order to ensure that methodological requirements are met and to ensure transparency (Tricco et al., 2018). The PRISMA-ScR checklist can be found in **Appendix A.1**.

Protocols are often written for scoping reviews, to serve as a guide and to clarify the established plan for the review process (Khalil et al., 2016; Peters, Godfrey et al., 2022; Peters, Marnie et al., 2020). In the case of this thesis, this chapter was written prior to conducting the literature search and review, in order to serve as such a guide. Since deviations from the original plan/protocol are noted in this chapter, the protocol is not included in this thesis.

In order to answer the research question, *How is resilience understood and applied in the context of FOWT design and operation?*, the literature survey was broad, comprehensive, and systematic – these are characteristics of a scoping review (Khalil et al., 2016), and in accordance with methodological recommendations from Peters, Godfrey et al. (2022), Peters, Marnie et al. (2020), and Tricco et al. (2018), the process that was followed is given in detail in the remainder of this chapter.

3.1: Search Strategy

The established methodology states that a search strategy should be defined, in order to guide the search process and ensure that it is transparent and systematic (Khalil et al., 2016; Peters, Godfrey et al., 2022; Peters, Marnie et al., 2020). This section presents the search strategy employed in this thesis, namely *where* the sources were found (i.e., which databases were used), *how* they were found (i.e., which search terms were used), and *how* the search was conducted.

The two literature databases that were selected for this review were GreenFILE, which is available through EBSCO, and ScienceDirect. ScienceDirect and GreenFILE provide access to literature from engineering and technology domains, and GreenFILE additionally has a particular focus on research relating to sustainability and renewable energy issues. These two databases were selected from the list of research databases that are available through the University of Stavanger Library, based on the descriptions of their contents, and based on a preliminary "pre-search" which suggested that, compared with other available databases, they contain a greater amount of relevant sources. There are undoubtedly other valuable databases that could have been selected, but in the interest of feasibility, the review was limited to these two.

3.1.1: Search terms

The search terms were decided by the author, having learned about resilience and related concepts – see section 1.2, as well as Aven and Thekdi (2022), Renn (2008), and Steen and Aven (2011) – and having read about and become familiar with FOWT technology and important terms and concepts (see Chapter 2). They are presented in Table 3.1 below.

The use of only two terms (which are essentially the same) for the concept of resilience is due to the fact that, as taught in this risk management master's program (see Aven and Thekdi (2022) and Renn (2008)), although there are several concepts that are *similar* to resilience – e.g., robustness and reliability– these concepts are not the same, and they should not be treated as such (Aven & Thekdi, 2022; Renn, 2008; Steen & Aven, 2011).

The FOWT Search Terms denote various ways of referring to FOWT which may be used throughout the literature. The last four terms are included in order to avoid inadvertently excluding articles which discuss both fixed and floating offshore turbines under the umbrella term *offshore wind*.

Table 3.1

Scoping review search terms

Resilience Search Terms	FOWT Search Terms
Resilience	Floating offshore wind turbine
Resilient	Floating offshore turbine
	Floating wind turbine
	Floating turbine
	Floating wind power
	Floating offshore wind
	Floating offshore wind power
	Floating offshore wind farm
	Floating wind farm
	Floating wind energy
	Offshore wind farm
	Offshore wind power
	Offshore wind turbine
	Offshore wind energy

It was allowed that if, in the course of the search, the author became aware of possible new search terms to use, this list could be expanded – Peters, Marnie et al. (2020) state that such additions are acceptable, as long as the search strategy remains transparent. This was not the case, however, and these original search terms are the only ones that were used.

3.1.2: Inclusion criteria

Once a search strategy was identified and outlined, the source selection criteria – criteria based on which potential sources are either excluded or included – needed to be specified. The JBI methodology for scoping reviews recommends that the mnemonic PCC – Population, Concept, Context – is used to develop and focus inclusion criteria when selecting sources for the review (Khalil et al., 2016; Peters, Godfrey et al., 2022; Peters, Marnie et al., 2020). Because this study is not concerned with a particular group of people (as may be the case in medical studies, for example), the population term is not relevant. The concept with which the review was concerned is resilience, and the context is FOWT, specifically their design and operation. Using these two points as a starting point, the following inclusion criteria were established. (The criteria and their justifications are summarized in Table 3.2.)

Sources must be published no earlier than 2009. The reasoning for this is that the first FOWT was deployed in 2009 (Aegir Insights, 2022; DNV, 2022; GWEC, 2022) – by allowing such a long time period (almost 15 years at the time of research and writing), it is hoped that this review will allow for an understanding of how interest in improving resilience for FOWT has developed since their debut. Since the author's only fluent language is English, and since translation attempts may be unreliable and lead to a slightly warped understanding of sources, non-English sources were excluded. There was no restriction on quantitative vs. qualitative studies: there is a wide variety of ways to measure resilience, and excluding one or the other form of research could affect the completeness of the review. Additionally, sources need not be peer-reviewed or academic studies. It was possible that searches could reveal non-academic sources, which reflect industry knowledge or operational best practices for FOWT and which may have provided valuable information for the review – such sources should not be excluded. However, included sources were restricted to academic papers, book chapters, and relevant government or industry documents, standards, reports, or regulations. Editorials and opinion pieces or news articles were excluded. It is also important to ensure that irreputable sources are excluded. For this matter, the author's judgments on factors such as author or publishing entity, references cited, and potential conflicts of interest were used to exclude unreliable and poor-quality sources.

The above inclusion criteria describe general characteristics of potential sources; the next three criteria relate to the actual content of the sources. First, the source must discuss or mention resilience, as that is the concept of interest of this review. Second, the source must mention or discuss FOWT design and/or operation, but not necessarily exclusively. This relates to the context of the review. Sources which discuss other technologies, such as fixed offshore turbines, onshore turbines, or wave energy conversion, *in addition to FOWT,* are acceptable. Similarly, sources which discuss FOWT planning, installation, or decommissioning, *in addition to design or operation*, are acceptable. Lastly, the source needn't discuss the entire FOWT system – as long as it mentions or discusses *at least one* component, system, or subsystem that is part of the overall FOWT, it may be included. This requirement is tied to the context of the review, but it also reflects the fact that resilience improvements or studies need not necessarily be directed at a complex system in its entirety. Resilience research with applications to specific subsystems or components must also be included in order to determine any possible distribution of interest across the components that comprise the whole FOWT system.

It was allowed that if during the course of the search process it became apparent that other considerations should be included, the inclusion criteria may be edited accordingly. The last criterion in Table 3.2 was added during the in-depth analysis phase (discussed below), in line with the research question and objectives, when the author realized that some articles which did mention both resilience and FOWT failed to discuss them in relation to one another and therefore were not relevant to the research question and should not be included in the review.

Table 3.2

Scoping review inclusion criteria

Criterion	Rationale
Source must be published in 2009 or later	The first FOWT was deployed in 2009 (Aegir Insights, 2022; DNV, 2022; GWEC, 2022) – this review should cover all developments related to FOWT resilience since then.
Source must be written in English	Ensures comprehension by reviewer
Research methods may be qualitative, quantitative, or a combination of the two	Resilience is measurable in a variety of ways, so it is important to not exclude a particular type of research.
Source may be a scientific paper, book chapter, or government or industry document, standard, report, or regulation that reflects knowledge, design requirements, or best practices	Restricting the review to academic-only sources may result in the exclusion of important industry knowledge or requirements.
Source does not necessarily need to be peer-reviewed, but only reputable sources shall be included	Avoids exclusion of relevant industry knowledge while ensuring quality of information to be included in the synthesis
Source must mention or discuss resilience	Relates to concept
Source must mention or discuss FOWT design and/or operation (but not necessarily exclusively)	Relates to context
Source must discuss at least one aspect or component of FOWT, but need not discuss the whole FOWT system	Relates to context
Source must discuss resilience *in relation to* some FOWT component, subsystem, or aspect of design or operation	Relates to research question and objective

3.1.3: Search process

In order to ensure that the search was comprehensive, thorough, and systematic, all combinations of Resilience Terms with FOWT Terms (presented in Table 3.1) were used, combined by the AND operator (e.g., resilience AND "floating offshore wind turbine"). This gave a total of 28 searches, to be repeated across both databases. It was expected that there would be considerable overlap among search terms and possibly across databases, therefore, it was not expected that the total results and material selected for review would be of an unreasonable amount given the time constraints.

In GreenFILE, the options to "apply related words" and "also search within the full text of the articles" were selected. Applying related words in a search allows for the inclusion of both singular and plural forms, e.g., "floating offshore wind turbine" and "floating offshore wind turbines" (EBSCOhost, n.d.). In ScienceDirect, plurals are included in results for singular search terms (e.g., "floating offshore wind turbine" automatically includes "floating offshore wind turbines" results) (ScienceDirect, 2021).

All searches were conducted on 20 March 2023, and the following information was recorded for each search:

- Search terms used
- Number of results.

This information is presented in **Appendix A.2**.

3.1.4: Data management

Zotero and Rayyan were used to keep track of sources during the selection and review process. Zotero is a source and citation management program, and Rayyan is an online tool developed specifically for conducting systematic (scoping) reviews. Excel was used to record the search information above and to record information extracted from sources that were ultimately included in the review.

3.2: Selection and Screening Process

Although ideally a minimum of two people would conduct the literature search and selection process to ensure reliability and a lack of bias (Khalil et al., 2016; Peters, Godfrey et al., 2022; Peters, Marnie et al., 2020), due to the nature of this thesis as a solo project, the only party involved in reviewing the available literature and selecting sources for this review was the author. Adherence to the established methodology and the research plan outlined in this chapter, along with transparency regarding all stages of the process, should serve to alleviate concerns about bias.

Sources were selected based on the inclusion criteria given above. Duplicate sources were removed first, first automatically by Rayyan, then any remaining duplicates were manually removed upon review by the author. Sources that did not meet the date requirement were removed next. It was found that all sources were written in English, so there were no removals on the basis of language.

A review of titles and abstracts comprised the first selection round. Titles and abstracts were reviewed in Rayyan. There were many sources which mentioned FOWT or offshore wind power as the object of study, but sources that explicitly mentioned resilience in the title or abstract were far fewer. Since it was difficult to determine whether sources mentioned or discussed resilience from the abstract alone, all sources which discussed FOWT design or operation were included for the full-text screening. Sources that discussed FOWT with sole regard to planning and siting, environmental impacts, and socio-political issues, opinions, or impacts were not included, as they did not meet the design or operation criterion. The few sources whose titles or abstracts explicitly mentioned resilience in conjunction with offshore energy, wind energy, or renewable energy were included to determine whether there was a specific application to FOWT.

This does represent a slight deviation from the original plan to only include sources which mentioned both resilience and FOWT in the title or abstract. The approach that was actually taken ensured that all articles mentioning both FOWT and resilience in the full text were included.

Additionally, the search results included several subject indices and abstract lists. Although such results had not been planned for, it was decided that they should be searched for any articles about FOWT, and those articles were included in the full-text screening. The articles that were selected for the full-text screening in this manner are given in **Appendix A.3**.

After the review of titles and abstracts, the full-text screening of sources was conducted. Under the full-text screening stage, sources were eliminated which failed to mention or discuss both resilience and FOWT. Information about sources which were eliminated in the full-text screening stage is provided in **Appendix A.4**, along with the rationale for exclusion. (Information about sources which were not chosen in the initial title and abstract screening process is not included.)

It had originally been the author's intention to include all sources which "passed" the full-text screening in the final review; however, in-depth analysis of the sources for data extraction revealed that although some sources did mention resilience and FOWT, they were not mentioned or discussed in relation to each other. There was therefore an additional round of eliminations following in-depth analysis of the selected sources – this information is given in **Appendix A.6**. The sources that remained were then included in the review.

After these rounds of elimination, there was one more round of searching for potential sources, through the review of the reference lists of those sources which were ultimately included in the review itself. This method is described by Khalil et al. (2016) and Pham et al. (2014) as an acceptable and useful way to find additional valuable resources. This reference review was only conducted on sources which were included in the final review, and it proceeded in a manner similar to the primary search: the reference lists of included articles were screened, and any articles with titles that mentioned FOWT, offshore turbines, offshore wind power, or offshore renewables (which also fit the date and language criteria) were scanned for mentions of resilience and FOWT in the full text. Sources which contained both were selected for in-depth analysis to determine whether they should be included in the review, i.e., whether resilience and FOWT were discussed in relation to one another.

This reference screening and selection process was originally intended to mirror the primary search process, with a distinct title and abstract screening stage before the full-text screening stage; however, it was determined that a full-text screening of sources whose titles mentioned FOWT or resilience would increase efficiency by combining both steps and ultimately producing the same results. The list of sources which were screened in this selection process is available in **Appendix A.5**, with exclusion rationales.

Similar to the main search results, information about sources that were selected from this reference review was recorded, and sources that were excluded following the in-depth analysis are presented in **Appendix A.6**, along with exclusion rationale. In order to preserve transparency and allow for repeatability of the study, the “original sources” in which these new “reference sources” were found are recorded. Otherwise, throughout the rest of the review, they are treated in the same manner as the “original sources.”

Given the time constraints of this study, there was no additional search towards the end of the review process to check for sources that may have been published during the review and writing phases. Seeing as the total time elapsed between the literature search and the submission of this thesis was a little less than three months, possible source omissions are deemed acceptable.

3.3: Review Process and Data Extraction

For all sources which underwent a full-text screening, the following information is recorded and presented:

- Title
- Author(s)
- Date
- Publication (i.e., journal where source was found).

This information is given both for sources that were ultimately included in the review and for those that were not. (Information about eliminated sources is presented in **Appendix A.4** and **A.5**.)

Sources that were included in the review were subject to in-depth thematic analysis, with the purpose of examining the definition of resilience that was employed and its application to FOWT, in accordance with the objective of this thesis. In addition to the data extracted from all sources that underwent full-text screenings, the following data have been recorded for the sources that were included in the final review:

- Resilience definition employed
- FOWT subsystems or components discussed

- Phase of FOWT life – design, operation, or both?
- Application of resilience to FOWT
- Type of floating platform studied
- Methodology
- Whether the study was quantitative, qualitative, or a combination of the two
- The objective of the source (i.e., what was determined *within* the source, e.g., a framework for assessing resilience in FOWT)
- The purpose of the source (i.e., what the source sought to achieve *externally*, e.g., to improve FOWT efficiency and safety by providing a resilience assessment framework)
- Outcome(s)
- Funding received
- Any other key findings related to the research question.

The author carefully read and analyzed all included sources, recording the above information in an Excel spreadsheet, and then analyzing the results thematically.

3.3.1: Thematic Analysis of Results

Thematic analysis may be used in systematic reviews in order to "bring together and integrate the findings of multiple qualitative studies" (Thomas & Harden, 2008, p. 1). It calls for the identification of patterns and themes among various sources, often through the use of coding (Hamel et al., 2021; Thomas & Harden, 2008). Coding was not done in this review – instead, the definitions and uses of resilience were extracted and manually analyzed by the author in order to identify overarching themes, similarities, and discrepancies among the included sources.

The data points presented above were used as a starting point, and by looking at the data extracted from the included sources, it was possible to discern patterns and trends, which are reported in section 4.3. These characteristics of the sources provide a glimpse into the context of FOWT resilience research, allowing for an enhanced understanding of the use of resilience in this field.

The author also examined the various definitions and interpretations of resilience across the included sources to identify key themes and elements, similar to the method utilized in Hamel et al. (2021) – these are presented in section 4.5. Although the author was the only party involved in the extraction and thematic analysis of the data, all sources were carefully read multiple times to ascertain patterns, ensure that all relevant information was included, and confirm the author's interpretations and conclusions.

The review then maps the resilience definitions that were found and the range of resilience applications across the sources. This has led to the recognition of knowledge and research gaps that should be addressed by future studies. Additionally, analyzing other variables, such as the proportion of quantitative studies in the review, provides insight into general trends in FOWT resilience research.

The following chapter presents the results of the methodology described in this chapter, as well as a detailed analysis of the findings. This sets the stage for a discussion of the results and important implications for future research.

Chapter 4: Results and Analysis

This chapter presents the results of the search that was described in the previous chapter. First, the outcome of the search and screening process is given, including the total number of sources retrieved and an illustration of how they were filtered through the selection process for inclusion in the review, as required by PRISMA-ScR (Peters, Marnie et al., 2020; Tricco et al., 2018). Second, the manner in which the results are presented is described. Next, the characteristics of and general trends among the sources are presented. Then the findings of the included sources are described, and finally the findings that relate specifically to resilience are given, setting the stage for a discussion of resilience in FOWT research in the following chapter.

4.1: Search Results

All database searches were conducted on 20 March 2023. The total number of results, from 28 searches repeated in two databases, was 12,035. 10,057 of these sources were duplicates. A further 149 fell outside of the established date range. All sources were written in English, so none were excluded on the basis of language. This left 1,829 sources to be reviewed in the first round (title and abstract screening). Among those sources was a total of 65 subject lists and abstracts, representing 56 unique issues, which, along with the subject indices of 8 books, were searched, resulting in the addition of 19 sources for the full-text screening. (26 potential sources were found, but 7 were eliminated as duplicates.) After the title and abstract screening, a further 1,533 sources had been excluded, leaving 315 to be included in the full-text screening, in which 288 were eliminated. These screening and elimination rounds resulted in a total of 27 sources to be subjected to an in-depth analysis prior to inclusion in the review. Upon this analysis, it was found that only 12 of the sources discussed resilience and FOWT in such a way that was relevant to this review. (See **Appendix A.6** for information on which sources were excluded at this point, along with the rationale for exclusion.)

Once the primary search was completed and the 12 included sources had been identified, their reference lists were screened for additional sources, as described in section 3.2. The total number of sources in the reference lists was 869. Of these, 281 were screened for mentions of resilience and FOWT, based on their title, date, and language. Only 5 mentioned both FOWT and resilience. Of those 5, one had already been analyzed in the primary search, and one was found in two different reference lists. These 2 duplicates were eliminated, leaving 3 sources to be analyzed in depth for relevance to the review. Only 1 met the eligibility criteria, in that it discussed resilience and FOWT in relation to one another. Thus, the total addition to the review from this round of reference screenings was 1 source.

The screening process and its results are illustrated in Figure 4.1, which shows the flow of sources through the elimination stages. Table 4.1 then lists the sources which were ultimately included in the review, as they were found to mention FOWT and resilience in relation to each other, after full-text screening and in-depth analysis.

Figure 4.1

Source selection process and results

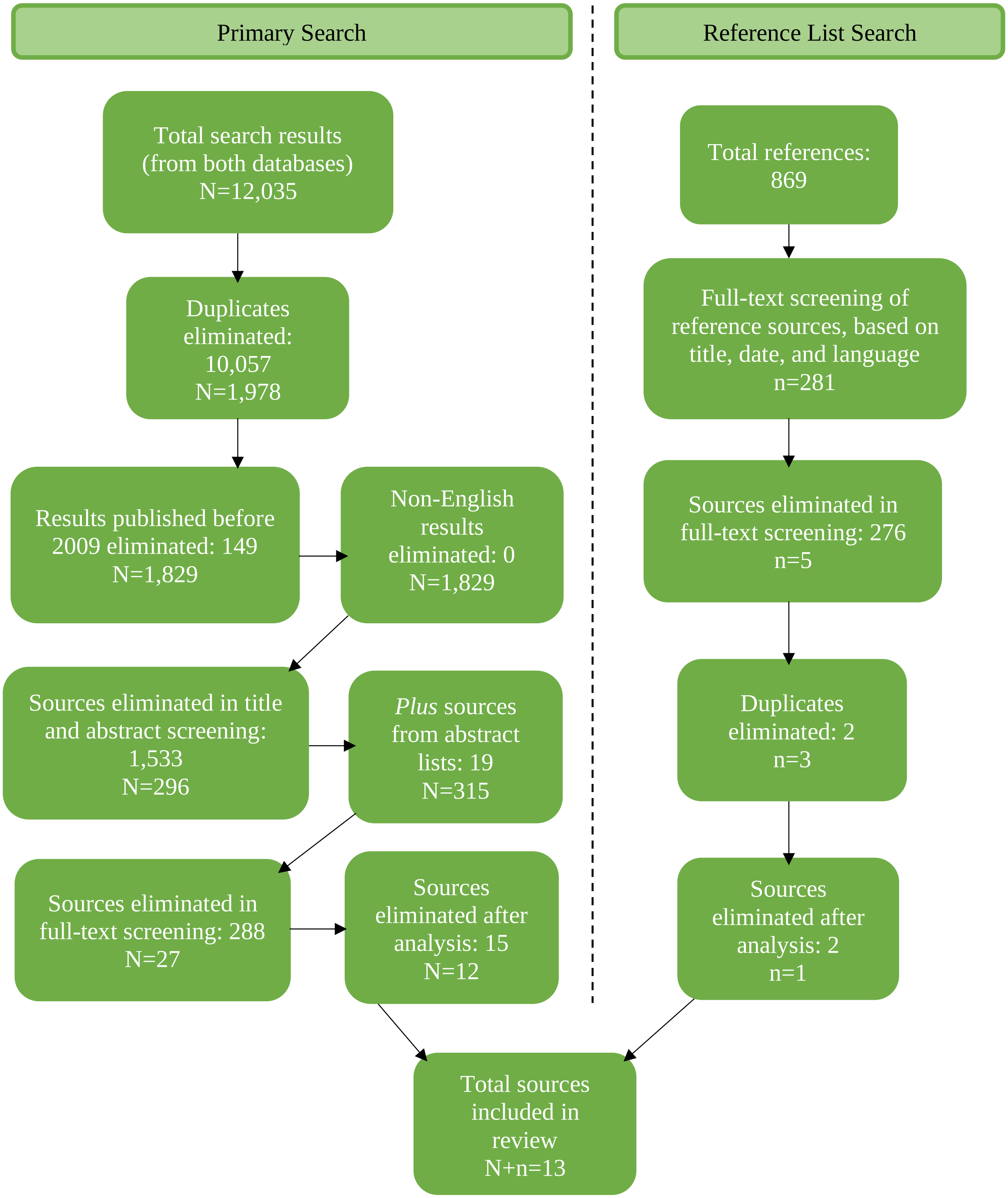


Table 4.1

Sources included

Author(s) and Date	Title	Publication
Chaloulos et al. (2021)	Seismic analysis of a model tension leg supported wind turbine under seabed liquefaction	Ocean Engineering
Del Pozo González and Domínguez-García (2022)	Non-centralized hierarchical model predictive control strategy of floating offshore wind farms for fatigue load reduction	Renewable Energy
Govindji et al. (2014)	Appraisal of the offshore wind industry in Japan	Report issued by Carbon Trust
Kappenthuler and Seeger (2019)	Addressing global environmental megatrends by decoupling the causal chain through floating infrastructure	Futures
Keighobadi et al. (2022)	Adaptive neural dynamic surface control for uniform energy exploitation of floating wind turbine	Applied Energy
Liu, Wu et al. (2020)	Fast Adaptive Fault Accommodation in Floating Offshore Wind Turbines via Model-Based Fault Diagnosis and Subspace Predictive Response Control	IFAC-PapersOnLine
Ma et al. (2019)	Experimental and numerical study on the multi-body coupling dynamic response of a Novel Serbuoys-TLP wind turbine	Ocean Engineering
Mitchell et al. (2022)	A review: Challenges and opportunities for artificial intelligence and robotics in the offshore wind sector	Energy and AI
Patryniak et al. (2022)	Multidisciplinary design analysis and optimisation frameworks for floating offshore wind turbines: State of the art	Ocean Engineering
Sun et al. (2022)	A real-time hybrid simulation framework for floating offshore wind turbines	Ocean Engineering
Yang, Bashir, Li, and Wang (2021)	Investigation on mooring breakage effects of a 5MW barge-type floating offshore wind turbine using F2A	Ocean Engineering
Yang, Bashir, Michailides et al. (2021)	Coupled analysis of a 10MW multi-body floating offshore wind turbine subject to tendon failures	Renewable Energy
Zhou et al. (2023)	Experimental investigation on an OWC wave energy converter integrated into a floating offshore wind turbine	Energy Conversion and Management

Note. Govindji et al. (2014) was found in the reference review, in the reference list of Kappenthuler and Seeger (2019).

4.2: Presentation of Findings

Since the total number of included sources is small (13), both tabular and narrative methods are used to present the information and trends across the sources. The tabular forms in particular allow the reader to easily see the patterns identified in the thematic analysis described earlier.

In accordance with the objectives and research question of this scoping review, the most important data points to be collected from the sources reviewed are (1) the definition of resilience employed and (2) how that definition of resilience is applied to FOWT. It is therefore these two things that are mapped and compared most extensively in this review, in order to determine whether there is a particular definition of resilience that seems to dominate the field (or if there is a general lack of agreement on what resilience means), or if there is a particular aspect, component, or subsystem of FOWT to which the most attention is paid. Once again, thematic analysis plays a significant role in identifying various conceptualizations and interpretations of resilience and in making connections between different sources' use of the term.

4.3: Summary of Source Characteristics

This section presents the characteristics of the sources included in this review. Before discussing the results of the review in detail, some brief summarizing figures are presented, to give a general idea of the main trends among the included sources.

Figure 4.2 depicts sources' year of publication. Clearly, it is only in recent years that FOWT research related to resilience has begun to gain attention, and slowly at that. Given that floating wind technology is relatively new, especially compared to fixed offshore and onshore wind technology (Aegir Insights, 2022), this makes sense. However, it is interesting that, after the debut of FOWT in 2009 (Aegir Insights, 2022; DNV, 2022; GWEC, 2022), it took about 10 years for resilience to start emerging in FOWT research.

Figure 4.2

Number of sources published per year

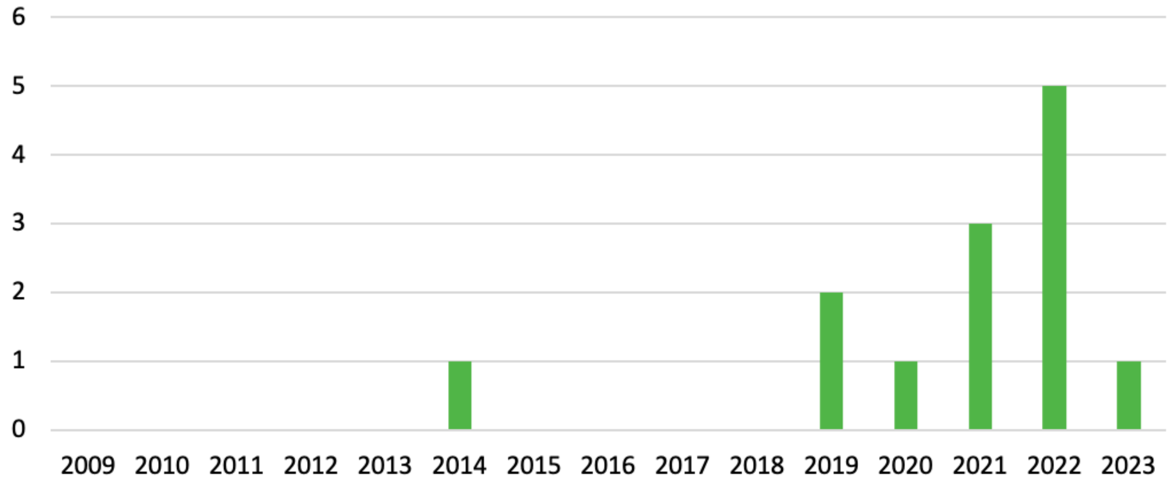


Table 4.2 contains information on where the sources were published. The most popular journal for these studies was *Ocean Engineering*, which contains studies on topics concerning engineering developments in marine environments, including floating structures (for both oil and gas and renewable energies), hydrodynamics, and structural mechanics of ocean structures (*Ocean Engineering*, 2023). FOWT clearly fit within this range of topics, and it makes sense that so many of the included sources were found here. The second-most popular journal in this review is *Renewable Energy*, which, as the name suggests, publishes articles related to the development of renewable energy sources (*Renewable Energy*, 2023). *Applied Energy* and *Energy Conversion and Management* have a similar focus on energy systems; however, their topics of focus are not restricted to renewable energy (*Applied Energy*, 2023; *Energy Conversion and Management*, 2023). *Energy and AI* is also concerned with energy applications and development, but with a special focus on the role that AI may play in supporting new energy technologies (*Energy and AI*, 2023). *Futures* is concerned with topics relating to future developments and outcomes of human society as a whole, including issues that impact sustainability (*Futures, 2023*). *IFAC-PapersOnLine* publishes papers from meetings of the International Federation of Automatic Control (IFAC), which supports research of automatic control strategies and technologies for engineering and science applications (*IFAC-PapersOnLine*, 2023; *Welcome — IFAC · International Federation of Automatic Control*, 2016).

Finally, one of the sources is not a journal article but a report published by Carbon Trust, a non-profit organization which supports the goal of achieving global sustainability (Govindji et al., 2014). Although these journals mostly share a focus on (renewable) energy issues, the dominating background is engineering and technology.

Table 4.2

Publications where sources were found

Journal	Number of Results
Ocean Engineering	5
Renewable Energy	2
Applied Energy	1
Energy and AI	1
Energy Conversion and Management	1
Futures	1
IFAC-PapersOnLine	1
Report – Carbon Trust	1

Information on the sources' funding is given in Table 4.3. This information sheds light on countries or regions where FOWT research is of greatest interest. Figure 4.3 illustrates the distribution of funding by country or region – it is clear that European and Chinese funding have contributed the most to the research included in this review. This reflects the trend noted in the Global Wind Energy Council's *Global Offshore Wind Report 2022* (GWEC, 2022), that China and Europe are the leading markets for offshore wind. It makes sense that they would also dominate the research in this area.

Table 4.3

Funding of sources

Source	Funded By
Chaloulos et al. (2021)	Greece and the EU (European Social Fund)
Del Pozo González and Domínguez-García (2022)	EU's Horizon 2020 Programme
Kappenthuler and Seeger (2019)	No funding information given
Keighobadi et al. (2022)	No funding information given
Govindji et al. (2014)	British Embassy in Tokyo
Liu, Wu et al. (2020)	EU support, via a Marie Skłodowska-Curie Action
Ma et al. (2019)	Fundamental Research Funds for the National Key Research and Development Program of China, the Central Universities, and the National Natural Science Foundation of China
Mitchell et al. (2022)	Offshore Robotics for Certification of Assets (ORCA) and Engineering and Physical Sciences Research Council (EPSRC) Holistic Operation and Maintenance for Energy (HOME) for offshore wind farms
Patryniak et al. (2022)	University of Strathclyde REA 2022, UK
Sun et al. (2022)	Louisiana State University Research Grant and the Louisiana Board of Regents
Yang, Bashir, Li, and Wang (2021)	European Regional Development Fund (ERDF), Interreg Atlantic Area; the EU's Horizon 2020 research and innovation programme under a Marie Skłodowska-Curie grant agreement; the National Natural Science Foundation of China; the Science and Technology Commission of Shanghai Municipality; and the Royal Society
Yang, Bashir, Michailides et al. (2021)	ERDF, Interreg Atlantic Area; Shanghai Puijang Program; the EU's Horizon 2020 research and innovation programme under a Marie Skłodowska-Curia grant agreement; the Royal Society; the National Natural Science Foundation of China; and the Science and Technology Commission of Shanghai Municipality
Zhou et al. (2023)	National Natural Science Foundation of China; Liaoning Revitalization Talents Program; Liaoning BaiQianWan Talents Program, and Fundamental Research Funds for the Central Universities

The reader may note that in Figure 4.3, the total number of sources funded is 15, not 13. This is due to the fact that two sources (Yang, Bashir, Li, and Wang, 2021; Yang, Bashir, Michailides et al., 2021) received funding from both China and the EU, therefore, they are counted twice in the figure.

Figure 4.3

Number of sources funded by region

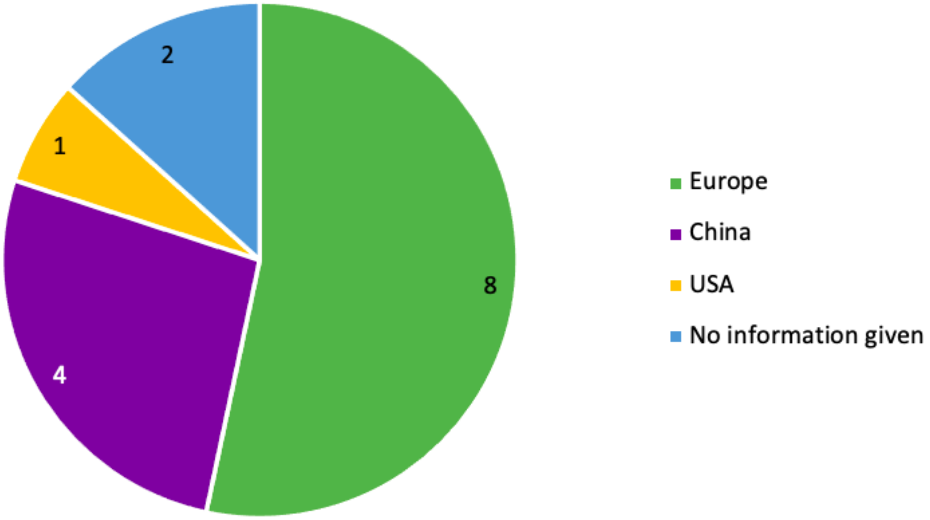


Figure 4.4 shows the proportions of the various methodologies employed in the different studies. Two studies conducted reviews; the majority of the studies (nine in total) used numerical analysis, either on its own or in conjunction with physical model testing, to simulate FOWT performance and behavior. The remaining two sources, which fall under the *Other* category, represent a report (Govindji et al., 2014) and a study in which a causal chain was developed and used to illustrate large-scale global trends related to climate change (Kappenthuler & Seeger, 2019). These methodologies will be discussed in depth later.

Figure 4.4

Methodologies of sources

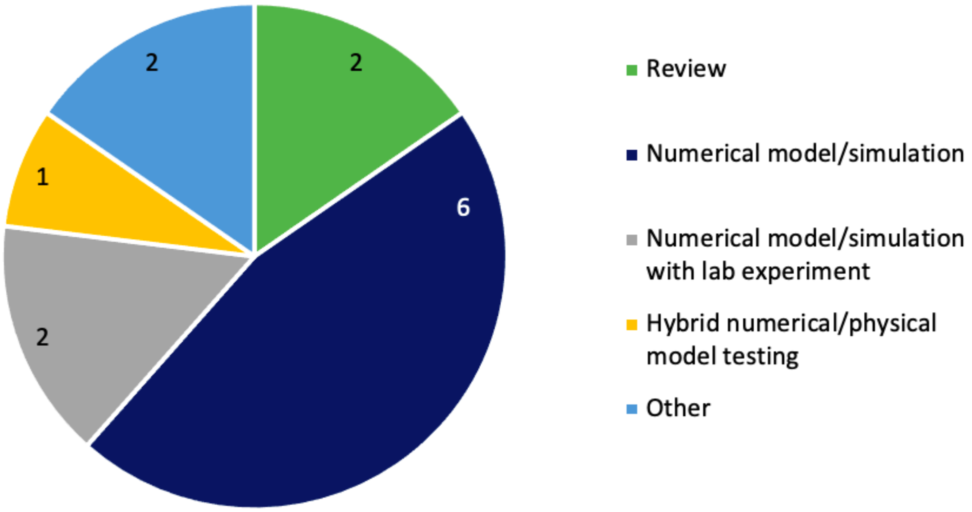
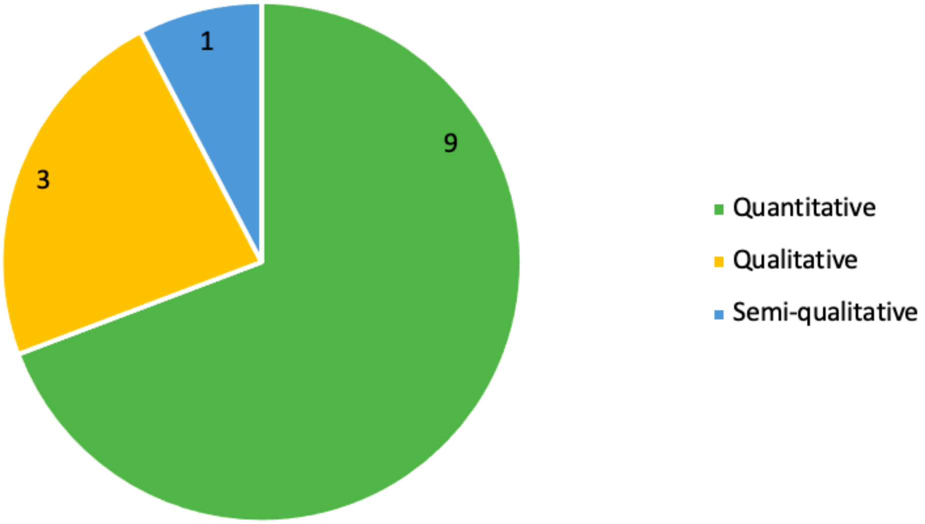


Figure 4.5 illustrates the proportions of quantitative and qualitative studies that were reviewed. The majority of the sources included in the review took a quantitative approach, which, given the popularity of numerical simulation studies in this review and the focus on engineering challenges, makes abundant sense. Three of the remaining four sources were purely qualitative, and the last one was semi-qualitative.

Figure 4.5

Qualitative vs. quantitative studies



For those studies which were quantitative, the analytical tools employed were recorded. They are presented in Table 4.4 below. This includes information from all of the quantitative studies, except for Zhou et al. (2023), which did not describe the use of a specific tool in the development and implementation of their numerical model.

Table 4.4

Analytical tools used in quantitative studies

Tool	Description	Number of Uses	Used In
OpenFAST/ FAST	Wind turbine numerical simulation package (*OpenFAST*, 2016)	3	Liu, Wu et al. (2020); Yang, Bashir, Michailides et al. (2021) & Yang, Bashir, Li, and Wang (2021)
F2A	Coupled aero-hydro-servo-elastic framework, based on AQWA and FAST (Yang, Bashir, Michailides et al., 2021; Yang, Bashir, Li et al., 2021)	2	Yang, Bashir, Michailides et al. (2021) & Yang, Bashir, Li, and Wang (2021)
MATLAB		2	Keighobadi et al. (2022) & Sun et al. (2022)
AQWA	Simulates hydrodynamic behavior of offshore structures (*Ansys Aqwa*, 2021)	1	Ma et al. (2019)
DUTMST	Time domain simulation tool, based in MATLAB (Ma et al., 2019)	1	Ma et al. (2019)
FLAC3D	Numerical modeling tool for geotechnical analysis of soil, rock, groundwater, constructs, and ground support (*Itasca FLAC3D Example*, n.d.)	1	Chaloulos et al. (2021)
Gurobi	Optimization solver (*Gurobi Optimizer*, n.d.)	1	Del Pozo González and Domínguez-García (2022)
Mathworks Simulink	Simulation and modeling tool (*Simulink - Simulation and Model-Based Design*, n.d.)	1	Liu, Wu et al. (2020)
MoorDyn	Mooring dynamics simulation tool for floating offshore structures (Hall, 2017)	1	Sun et al. (2022)
NTUA-Sand	Models the behavior of sand under stress conditions (Andrianopoulos et al., 2017)	1	Chaloulos et al. (2021)
SimWindFarm	MATLAB/Simulink toolbox for wind farm simulations, specifically control design (Grunnet, 2018)	1	Del Pozo González and Domínguez-García (2022)
TurbSim	Turbulence simulation tool, used in conjunction with FAST (Kelley & Jonkman, 2007)	1	Sun et al. (2022)
YALMIP	MATLAB toolbox for optimization modeling (*YALMIP*, 2012/2023)	1	Del Pozo Gonzáles and Domínguez-García (2022)

The most popular tools used were OpenFAST/FAST, F2A, and MATLAB. Seeing as FAST represents earlier versions of OpenFAST, and as of FAST v8.16, it was renamed OpenFAST (*OpenFAST*, 2016), the two are grouped together. OpenFAST was used to validate F2A in both instances it was used. Additionally, it should be noted that tools such as DUTMST, which are based in MATLAB, are not included in the number of uses of MATLAB. If such cases had been included in the MATLAB count, then the total MATLAB uses would increase to 5.

Figure 4.6 shows which phases of the FOWT life cycle were studied. Some sources also addressed installation or decommissioning, but since neither are the focus of this study, information about those phases is not included. Since this study is only concerned with FOWT design and operation, it was only determined which of those two phases were discussed. The vast majority of the included sources were concerned with the operation of FOWT, addressing topics such as control strategies during operation and responses of the FOWT to various environmental conditions and events.

Figure 4.6

FOWT phase of life studied

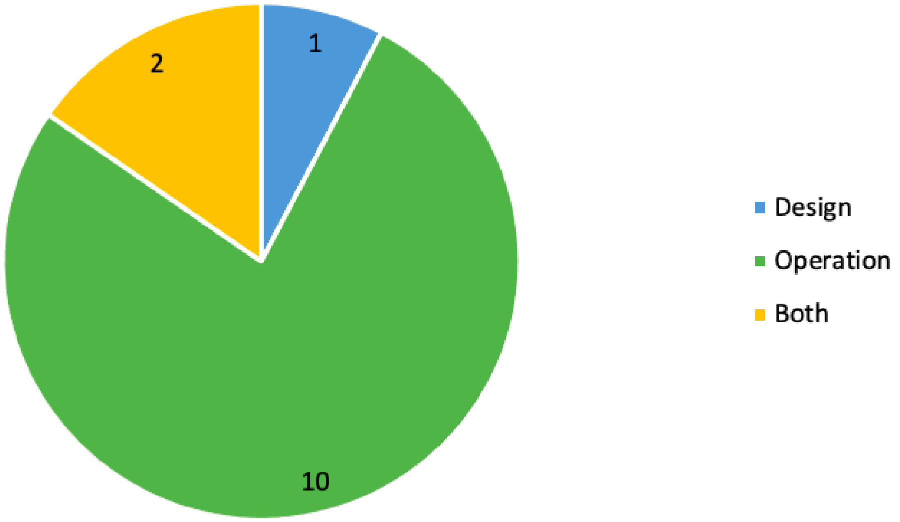
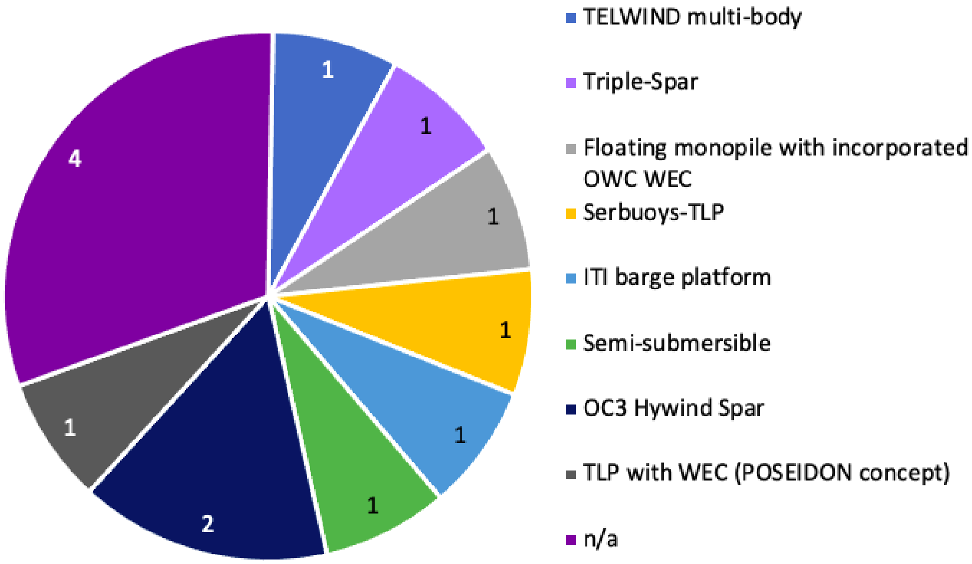


Figure 4.7 shows the types of floating platforms that were studied. The most popular platform studied was the OC3 Hywind Spar (design specified by Jonkman (2010)); however, as there were only two studies which used it, this doesn't say much. Those studies which did not model or study a specific platform were the qualitative and review studies. More detail about the platform types will be given in the following section – see section 2.1 for an overview of FOWT platform types.

Figure 4.7

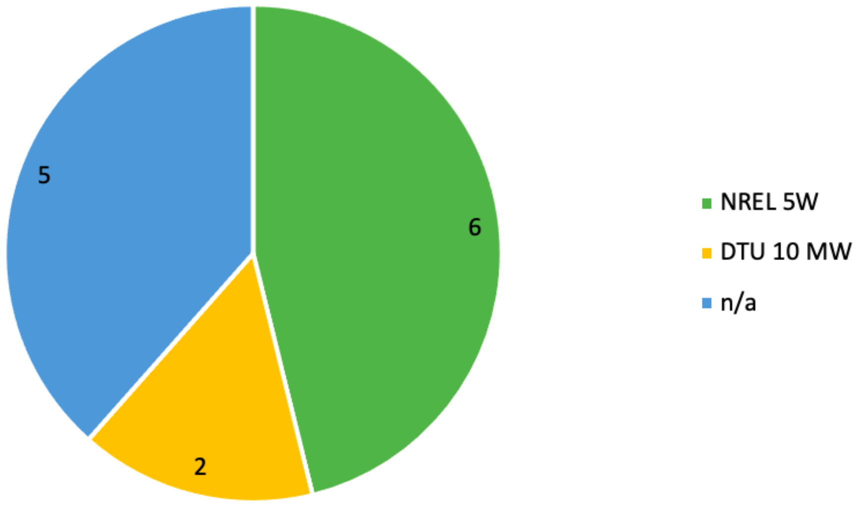
Type of floating platform studied



In contrast to the variety of floating platforms, the choice of wind turbine in these studies was rather limited. Figure 4.8 shows the proportions of the different types of wind turbine models that were employed in the studies. More than half of the studies specified which type of turbine was being studied. Those that did not were the qualitative and semi-qualitative studies and one quantitative study (Zhou et al., 2023) with the purpose of modeling only platform motion, without taking the effects of the turbine into consideration.

Figure 4.8

Type of turbine studied

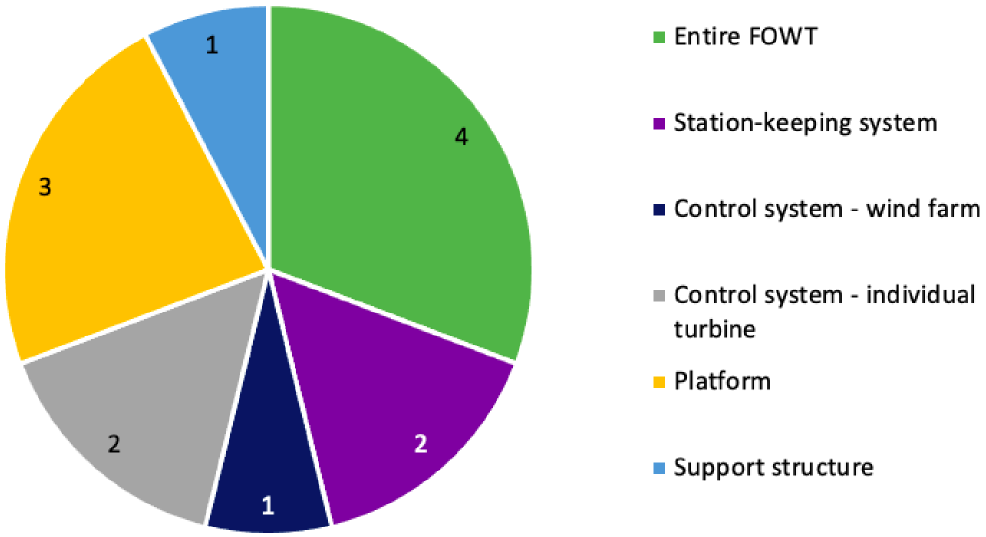


Of the studies which did specify a turbine model, the majority used the NREL 5MW turbine, based on Jonkman et al. (2009). One of the studies (Del Pozo González & Domínguez-García, 2022) examined a 180 MW wind farm consisting of 36 NREL 5MW turbines. The other two studies (Liu, Wu et al., (2020) and Yang, Bashir, Michailides et al. (2021)) used the DTU 10 MW turbine model from Bak et al. (2013). Interestingly, both of these turbine models have a geared drive, not a direct drive (Bak et al., 2013; Jonkman et al., 2009). This contradicts the trend described in section 2.3, where FOWT designs tend to be direct-drive rather than using a gearbox, due to the reliability gains that come with eliminating the gearbox (IRENA, 2022; EERE, n.d., 2019).

Figure 4.9 shows the various FOWT components which were studied, and it can be seen that there is considerable variation. (See section 2.3 for an overview of various FOWT components and subsystems.) Although the most popular focus was on the FOWT system as a whole, this was mostly among the qualitative studies: only one of the quantitative, numerical-model-based studies (Sun et al., 2022) addressed the behavior of the whole FOWT. The floating platform received a good deal of focus, as did the control system, both for individual turbines and the wind farm as a whole. It should be noted that, although the platform and station-keeping system are technically part of the FOWT support structure, they are mentioned specifically as the object of several studies and thus are not listed as "support structure" studies. The one study (Patryniak et al., 2022) that is listed as “support structure” discussed support structures in general, focusing on the whole, rather than on specific components.

Figure 4.9

FOWT components discussed



It may be expected that the focus of FOWT research articles would reflect failure rates of FOWT components, such that more research is done on those components which fail more frequently or severely, in order to solve the most serious problems faced by FOWT. Interestingly, this expectation is not met: this distribution of FOWT components studied does *not* agree with data about offshore wind turbine component failure rates, taken from Carroll et al. (2016). According to Carroll et al. (2016), the pitch and hydraulic systems account for the largest proportion of offshore turbine failures – about 13% – however, only Liu, Wu et al. (2020) examined pitch failure, which gives a total of 7.7% in this review. Keighobadi et al. (2022) did mention turbine pitch, yaw, and torque control, but their study didn’t address possible failure modes so much as a general control strategy. Carroll et al.’s (2016) control system failure rate is 5.2%, in contrast to the 15.4% of control studies in this review (Del Pozo González and Domínguez-García (2022) and Keighobadi et al. (2022)). However, given the importance of the control system in monitoring and adjusting power generation as needed, in order to maximize production while maintaining turbine safety and operating limits (see section 2.2), the focus on control strategies is worthwhile.

Moreover, the components with the second-, third-, fourth-, and fifth-highest failure rates – “other components,” generator, gearbox, and blades, respectively, according to Carroll et al. (2016) – are not the topic of *any* studies included in this review. (The second-highest failure category – “other components” – consists of ladders, hatches, seals, etc.)

The Carroll et al. (2016) study is used as a comparison due to its comprehensive scope and because it is widely cited in offshore wind research, but it should be noted that it is *fixed* offshore wind turbines which are studied – no mention is made of FOWT or floating foundations. The failure rates may therefore not accurately reflect FOWT component failure rates. Other considerations, such as the floating foundation, station-keeping system, and increased movements, may account for the discrepancy between Carroll et al.’s (2016) failure rates and the various components studied in this review. It may also be that this sample size (13) is too small to accurately reflect the entire body of FOWT resilience research, and a wider search may have produced results that correspond with Carroll et al.’s (2016) failure rates.

Table 4.5 summarizes the figures above. The sources will be described more thoroughly below.

Table 4.5

Summary of source characteristics

Source	Methodology	Quantitative /Qualitative	FOWT Phase of Life	Platform Type	Turbine Type	FOWT Component
Chaloulos et al. (2021)	Numerical model with simulation	Quantitative	Operation	TLP with WEC (POSEIDON concept)	NREL 5MW	Station-keeping system – pile anchors
Del Pozo González and Domínguez-García (2022)	Numerical model with simulation	Quantitative	Operation	OC3 Hywind Spar	NREL 5MW (x36)	Control system – wind farm
Govindji et al. (2014)	Other - report	Qualitative	Design and operation	n/a	n/a	Entire FOWT
Kappenthuler and Seeger (2019)	Other – develop model to illustrate global trends; discussion and analysis	Qualitative	Operation	n/a	n/a	Entire FOWT
Keighobadi et al. (2022)	Numerical model with simulation	Quantitative	Operation	Semi-submersible	NREL 5MW	Control system – individual turbine
Liu, Wu et al. (2020)	Numerical model with simulation	Quantitative	Operation	Triple-Spar	DTU 10MW	Control system – individual turbine
Ma et al. (2019)	Numerical model with physical experiment	Quantitative	Operation	Serbuoys-TLP	NREL 5MW	Platform
Mitchell et al. (2022)	Review	Semi-qualitative	Design and operation	n/a	n/a	Entire FOWT
Patryniak et al. (2022)	Review	Qualitative	Design	n/a	n/a	Support structure
Sun et al. (2022)	Hybrid numerical/physical model testing	Quantitative	Operation	OC3 Hywind Spar	NREL 5MW	Entire FOWT
Yang, Bashir, Li, and Wang (2021)	Numerical model with simulation	Quantitative	Operation	ITI barge	NREL 5MW	Station-keeping system – mooring lines
Yang, Bashir, Michailides et al., (2021)	Numerical model with simulation	Quantitative	Operation	TELWIND multi-body	DTU 10 MW	Platform
Zhou et al. (2023)	Numerical model with physical experiment	Quantitative	Operation	Floating monopile with incorporated OWC WEC	n/a	Platform

4.4: Summary of Sources and Findings

This section describes the objective, purpose, and findings of the included sources, as well as the definition of resilience that was employed and how it relates to the design or operation of FOWT.

Chaloulos et al. (2021) examined the behavior of pile anchors (part of the station-keeping system) of a TLP with integrated wind energy converters (WECs, designed by Mazarakos et al., (2014)) under conditions of soil liquefaction from seismic activity. This study addressed a gap in previous research, which had only focused on the behavior of stable soil under seismic conditions. It was demonstrated that during the period of seismic activity and soil liquefaction, the pile anchors' resistance to pulling out was reduced but that once soil conditions were stable again, the anchors regained their stability. Moreover, the stability was shown to reach a higher level compared to before the shaking. This was referred to as "seismic resilience" (Chaloulos et al., 2021, p. 10). Although no explicit definition is given, it is strongly implied that seismic resilience is the ability to withstand and recover from stress due to seismic activity.

Del Pozo González and Domínguez-García (2022) proposed a non-hierarchical model predictive control (MPC) approach to optimize fatigue loading across a floating wind farm, such that it is distributed more evenly among individual turbines. The turbines are grouped into clusters, which produce power as required by the upper-level controller, but within the clusters, adjustments can be made based on individual turbine fatigue. This strategy also takes into account wake generated by upwind turbines in the cluster – as mentioned in section 2.2, wake affects both the fatigue loading and the energy production of downwind turbines and is therefore very important to consider in wind farm design. It was hoped that this novel control strategy would contribute to prolonged FOWT lifetimes and reduced maintenance needs, due to fewer breakdowns from turbines that experience a disproportionate amount of fatigue. The study demonstrated that by reducing the power production of the upwind turbines, their fatigue loads were in turn reduced. The wake effects felt by downwind turbines were also reduced, leading to greater power production and more equal fatigue loading across the farm. Although no definition of resilience was given, it was stated that centralized control strategies *decrease* the resilience of large wind farms (Del Pozo González & Domínguez-García, 2022, p. 249). This study sought to find an alternative to this type of control strategy. The proposed strategy allows for adjustment within turbine clusters to prevent uneven fatigue loading. It could therefore be that this new non-centralized strategy may *improve* the resilience of floating wind farms. Further, from the discussion in the article, it can be inferred that resilience is related to appropriate responses and adjustments to environmental conditions, in order to effect long-term damage prevention.

Govindji et al. (2014) wrote a report on the state of the Japanese offshore wind industry in 2014, taking into consideration future prospects and challenges to be overcome. The report provides insight on factors related to the energy market, policy and regulations, social opinions, and technology. The conclusion of the report is that offshore wind, including FOWT to a large degree, is essential to the future of Japanese energy production, and that despite several policy and technical obstacles and design challenges, the outlook was positive. Not much is said about resilience, aside from a brief mention of Japan's GOTO FOWT project off the coast of Kabashima Island, which could provide opportunities to test for typhoon resilience. It was stated that in September 2012 a typhoon caused considerable damage onshore, but the FOWT stationed there "emerged relatively unscathed" (Govindji et al., 2014, p. 22). Of course, this mention of FOWT resilience gives hardly any information about what it means to be resilient, other than being able to survive a typhoon. The interest in *testing for resilience*, however, suggests that resilience should be designed for and ensured in FOWT systems.

Kappenthuler and Seeger (2019) first presented a causal chain that describes global trends related to climate change and then discussed how floating infrastructure (including FOWT) may break various links in that chain in order to mitigate the effects of climate change, specifically sea level rise. The purpose of this article was to highlight areas of research and future improvements with regard to coping with climate change. Floating power was mentioned as being resilient to flooding, seismic activity, and, in deep waters (>100m), damage from tsunamis. Although resilience was not explicitly defined, flood resilience can be understood as immunity to the effects of flooding and is associated with minimizing damage from severe events. The value of this article (in the context of this review) is limited, however, as resilience was mostly discussed with regard to floating urban infrastructure, and FOWT were mentioned only briefly.

Keighobadi et al. (2022) proposed a novel controller for maintaining FOWT stability under operation, thus allowing for uniform energy production, even in strenuous conditions. The controller – which manipulates turbine yaw, generator torque, and blade pitch angle – was described as a combination of the best qualities of three different approaches: dynamic surface control (DSC), radial-based functional neural network (RBFNN), and terminal sliding mode (TSM). DSC is well-suited to controlling unpredictable, nonlinear systems; RBFNN is suitable for creating an adaptive controller; and TSM has been found to provide "resilient dynamic system control" (Keighobadi et al., 2022, p. 2). The purpose of this study was to contribute to future research and design efforts for FOWT and control systems by providing an improved control concept which can handle uncertainty and irregularities. It was demonstrated that, when implemented for the NREL 5MW turbine supported by a semisubmersible platform (design specifications from Robertson et al. (2014)), this novel controller allowed for improved, more effective control compared to a classical linear quadratic regulator (LQR) controller. As in other sources, no explicit definition of resilience was given, but the resilience of control systems for FOWT was mentioned. However, it is unclear whether this refers to a control system which is itself resilient or which rather contributes to the resilience of the whole FOWT system. Regardless, based on the context and purpose of the study, it can be inferred that resilience is related to making appropriate control adjustments in response to environmental disturbances, in order to provide a steady supply of energy.

Liu, Wu et al. (2020) described a new blade pitch actuator control system to reduce blade loading in normal conditions and to more efficiently react to a particular type of fault – pitch actuator stuck (PAS) – when it occurs. It is able to determine which pitch actuator has failed and then adjust the individual pitch angles of the remaining functional blades in order to maintain operation while avoiding damage. This approach should contribute to improvements in FOWT performance and reductions in O&M costs resulting from PAS faults. In the case study simulation which was carried out for a DTU 10MW turbine supported by a Triple Spar floating foundation (a hybrid between a spar and semi-submersible platform, designed by Lemmer et al. (2016)), the control strategy was seen to reduce blade loading under fault conditions to a greater degree than a control strategy which was not able to locate the specific blade experiencing the fault. Additionally, the time needed to detect and address the fault was reduced, leading to the avoidance of further damage and improved potential for sustained power generation. As regards resilience, no definition was given; however, in the introduction it is stated that "the reliability, safety and resilience of the pitch systems have received increasing attention" (Liu, Wu et al., 2020, p. 12650), since pitch system failures account for a significant proportion of offshore wind turbine failures. Seeing as this article represents an effort to improve the performance of the pitch system (and FOWT as a whole) in the case of PAS faults, it can be seen as an effort to improve pitch system reliability, safety, and resilience. Unfortunately, no distinctions are made between these three concepts. Based on the discussion in the article, it could be said that resilience relates to the ability to adapt to stress, tolerate faults, and maintain operation; however, some of these aspects could also be associated with reliability, so clarification is needed.

Ma et al. (2019) proposed a novel TLP design which incorporates buoys tethered to the tension legs of the platform (Serbuoys-TLP). This design addresses a problem found in standard TLP designs: while the heave movement of TLPs is typically restrained due to the tight mooring lines, the platform’s horizontal motions are not so constrained, and in severe environmental conditions, that horizontal movement could affect the loading and performance of the turbine. The purpose of this study was to analyze the effects of the buoys on the dynamic behavior of the TLP in order to examine to what degree they constrain horizontal motion of the platform. This coupled analysis, wherein the TLP and buoys were treated as separate linked bodies, rather than one, led to a better understanding of the behavior of this design in operating conditions. It was demonstrated that the Serbuoys-TLP exhibited suppressed responses to waves, in comparison with a standard TLP. In this study, resilience was related to the turbine’s “horizontal restoring force” (Ma et al., 2019, p. 7) under wave loading conditions. The Serbuoys-TLP exhibited a greater restoring force, or movement back to equilibrium (*Restoring Force*, n.d.), than the standard TLP – resilience in this case is thus related to resisting and recovering from displacement.

Mitchell et al. (2022) conducted a review of robotics and artificial intelligence (RAI) in offshore wind sector applications, including challenges and opportunities, as well as requirements for expansion and improvement. Current RAI capabilities were discussed in relation to offshore wind farms’ and (floating) offshore wind turbines’ needs with regard to lifecycle management. The purpose of this review was to contribute to the improvement of lifecycle management approaches and techniques for offshore wind farms. A definition of resilience is given in this article: “the capability to adapt and survive in an autonomous mission in response to internal and external variables” (Mitchel et al., 2022, p. 19). While this definition applies to RAI, it is indirectly related to FOWT – RAI mission resilience affects turbine availability. Resilient RAI may face fewer mission disruptions, which could contribute to greater turbine availability and more reliable energy production. Although resilience was mostly discussed in relation to RAI, it was found that RAI has a lot to offer offshore wind: as turbines move further from the shore in order to exploit greater wind resources (requiring the use of floating platforms), RAI can help increase weather resilience by providing on-site O&M capabilities without having to send people out on risky operations. Turbine weather resilience is presumably related to maintenance and recovery times following extreme or damaging weather events. Improved weather resilience can lead to increased windows of operation, and the use of RAI for O&M can increase turbine productivity and availability, as well as personnel safety. Monitoring and sensing technologies are also described as resilient to the environment if they are able to maintain operations despite disturbances, unaffected by challenging conditions (e.g., smoke, mist, and rain). This resilience could again contribute to O&M mission success and improved turbine availability. More generally, Mitchell et al. (2022) state that the expansion of offshore renewable energy (ORE) will ensure the resilience of that sector. No explanation is given, however, for what increased resilience in the offshore renewables sector might entail.

Patryniak et al. (2022) reviewed state-of-the-art multi-disciplinary design analysis and optimization approaches as related to FOWT support structure design, examining 12 FOWT design optimization studies. Several insights into current best practices and potential improvements are provided, which may ultimately reduce LCOE, thus improving FOWT feasibility and implementation. It is stated that resilience is one of the design objectives that should be sought after, along with reliability, affordability, and safety. Unfortunately, no definition of resilience is given, nor any explanation of the distinctions between resilience, reliability, and safety, or how to achieve or measure those objectives.

Sun et al. (2022) studied the structural performance of FOWT under wind and wave loading and proposed a new real-time hybrid simulation (RTHS) framework which resolves scaling challenges associated with the aero- and hydrodynamic modeling of FOWT. This study addresses a previous research gap by examining the errors between a scaled FOWT RTHS and the full-scale FOWT and how delays, noises, and wind-wave conditions affect those errors. In order to resolve this issue, a hybrid numerical/physical model was constructed, where the tower and turbine behavior were simulated numerically and the platform behavior was simulated by a physical scale model of the OC3 Hywind Spar concept. It was found that this approach is suitable for studying FOWT behavior. No definition of resilience was given, but it was stated that, “To achieve safe and resilient offshore wind farms, it is imperative to develop clear understanding of the complex dynamic behavior of OWTs under multiple loading effects via numerical modeling and experimental testing” (Sun et al., 2022, p. 2). It is unclear what it means for an offshore wind farm to be resilient; however, since this article does seek to develop a better understanding of FOWT behavior as described in the quote, it does mark an effort to achieve resilience in FOWT.

Yang, Bashir, Li, and Wang (2021) studied the dynamic behavior and response of a FOWT on an ITI barge foundation with an incorporated OWC WEC (designed by Vijfhuizen (2006)) and its remaining tendons after a sudden mooring line breakage. In doing so, they contributed to and expanded the body of knowledge regarding the performance of a barge-type FOWT under mooring system damage conditions. It was found that in response to a breakage, the tensions on adjacent mooring lines increased before evening out, but since the maximum mooring line tension was not reached, the risk of progressive mooring line failure was judged to be negligible, even under extreme conditions. Resilience was, once again, not defined, but Yang, Bashir, Li, and Wang did write that “the resilience of the FOWT can be enhanced by installing more than [one] mooring line for each fairlead to avoid collision to its adjacent platforms under mooring breakage scenarios” (2021, p. 2). This means that, at least in this case, system resilience can be improved by adding redundancies and extra preventive measures to a particular subsystem, and resilience is related to protective measures that help mitigate the effects of failure.

Yang, Bashir, Michailides et al. (2021) examined the response of the TELWIND multi-body FOWT platform under tendon breakage scenarios, with especial focus given to the remaining intact tendons. The TELWIND multi-body platform, first presented by Dankelmann et al. (2016), consists of an upper buoyancy tank which supports the turbine and tower and is tethered to a lower ballast tank. It is the tendons between these two tanks that were the object of this study. The goal of the study was to understand the response of the platform under damage conditions, with the purpose of contributing to the development of structural health monitoring systems for FOWT tendons, which may in turn contribute to reductions in FOWT LCOE. The findings were encouraging: even when one tendon breaks, the tension increase experienced by the remaining tendons is not sufficient to cause further breakages. Additionally, surge and pitch motion signals from the upper tank can be used to identify tendon damage in the multi-body platform. While no definition of resilience was given, the statement, “the resilience of the platform is weaker at higher wind speed conditions" (Yang, Bashir, Michailides et al., 2021, p. 100), referring to greater tendon responses to breakage under higher wind speeds, indicates that resilience is related to the sensitivity of the remaining tendons to a breakage in a neighboring tendon. Resilience is also related to the response of the neighboring tendons to increased stress from the breakage and to the ability of the platform to recover its stability, even in the presence of challenging environmental conditions.

Finally, Zhou et al. (2023) proposed a design for a multi-purpose platform for floating wind and wave energy and examined its behavior in operating conditions, in order to provide guidance for future designs. The platform design employed was a floating monopile platform. The performance of the floating platform, both with and without a WEC, was studied. It was found that incorporating a WEC into the FOWT platform can increase the platform's heave resilience, reducing vertical platform motion. Heave resilience is thus related to stability, but no further elaborations were given.

4.5: Resilience in the Research

Although the sources for the most part did not provide explicit definitions of resilience, it is possible to figure out how resilience may be understood in the articles, based on how it is discussed and the context of the article. This section describes these possible meanings and interpretations of resilience, and the information is summarized in Table 4.6. By "Application of Resilience," it is meant the way in which resilience is used when talking about FOWT, including the component(s) studied.

Table 4.6

Resilience definitions and applications

Source	Resilience Definition	Application of Resilience
Chaloulos et al. (2021)	Seismic resilience: the ability to withstand and recover from stress due to seismic activity*	Pile anchors supporting TLP demonstrate seismic resilience.
Del Pozo González and Domínguez-García (2022)	Resilience is related to making appropriate adjustments in response to environmental conditions in order to preserve system health*	Centralized control strategies decrease resilience of wind farms – by investigating a non-centralized control strategy, this study represents an effort to improve resilience.

Source	Resilience Definition	Application of Resilience
Govindji et al. (2014)	Typhoon resilience: survive a typhoon with relatively little damage*	Resilience of the entire FOWT discussed with regard to typhoons; typhoon resilience should be tested for.
Kappenthuler and Seeger (2019)	Flood resilience: immunity to the effects of flooding; ability to minimize damage from severe events*	Flood and tsunami resilience of floating energy infrastructure (including FOWT) – related to the ability to provide a steady energy supply, even under stress.
Keighobadi et al. (2022)	Resilience is related to making appropriate control adjustments in response to external forces*	Resilient FOWT control strategies are mentioned, but it is unclear whether the FOWT is understood as resilient, or just the control system.
Liu, Wu et al. (2020)	Ability to adapt to stress, tolerate faults, and maintain operation under fault conditions*	The study can be understood as an effort to improve the reliability, safety, and resilience of FOWT pitch systems, but there is no clarification of the distinctions between these three terms.
Ma et al. (2019)	Resilience is related to resisting and recovering from horizontal displacement*	Resilience of floating platform with respect to wave loading and horizontal motion.
Mitchell et al. (2022)	Definition of resilience (for RAI): “the capability to adapt and survive in an autonomous mission in response to internal and external variables” (Mitchell et al., 2022, p. 19)	RAI can help increase weather resilience of FOWT; expansion of ORE can lead to improved resilience. No direct explanation given for either weather resilience or what it means for ORE resilience to improve.
Patryniak et al. (2022)	n/a	Resilience is one of the design objectives that should be achieved (others are reliability, affordability, and safety); no explanation of the distinctions between these objectives.
Sun et al. (2022)	n/a	The study marks an effort to achieve or improve FOWT resilience, but what exactly it means to have a resilient system is not specified.
Yang, Bashir, Li, and Wang (2021)	Resilience is related to barriers or protective measures, which mitigate the consequences of failure*	FOWT resilience is affected by tendon performance and protective measures.
Yang, Bashir, Michailides et al. (2021)	Resilience is related to maintaining or recovering equilibrium after a disturbance and can be affected by external conditions*	Tendon resilience to stress and system damage (i.e., breakage of a neighboring tendon).
Zhou et al. (2023)	Resilience is related to stability and motion suppression*	Platform resilience and dynamic behavior under loading conditions.

Note. Definitions marked by (*) are inferred from the context of the article; they are not given explicitly.

One of the first things to notice in this table is that only one explicit definition is given, and it does not even relate directly to FOWT resilience, but rather to RAI resilience. The vast majority of the definitions that are presented have instead been inferred by the author, based on the discussions of the articles and the ways in which resilience was mentioned. Two articles did not even have sufficient context to infer a definition – they simply mentioned resilience in passing.

Among those sources from which a definition of resilience could be derived, it can be seen that there is a range of different interpretations of resilience. They are as follows:

- Withstanding and/or recovering from stress, from both fault or damage conditions and external natural events and conditions (Chaloulos et al., 2021; Govindji et al., 2014; Kappenthuler & Seeger, 2019; Liu, Wu et al., 2020; Yang, Bashir, Michailides et al., 2021)
- Restoration of equilibrium after displacement; resistance to displacement (Ma et al., 2019; Zhou et al., 2023)
- Adapting and maintaining operations under stress or damage conditions (Del Pozo González & Domínguez-García, 2022; Keighobadi et al., 2022; Liu, Wu et al., 2020; Mitchell et al., 2022)
- Mitigating failure or damage consequences through implementation of barriers and defense mechanisms (Yang, Bashir, Li, and Wang, 2021)

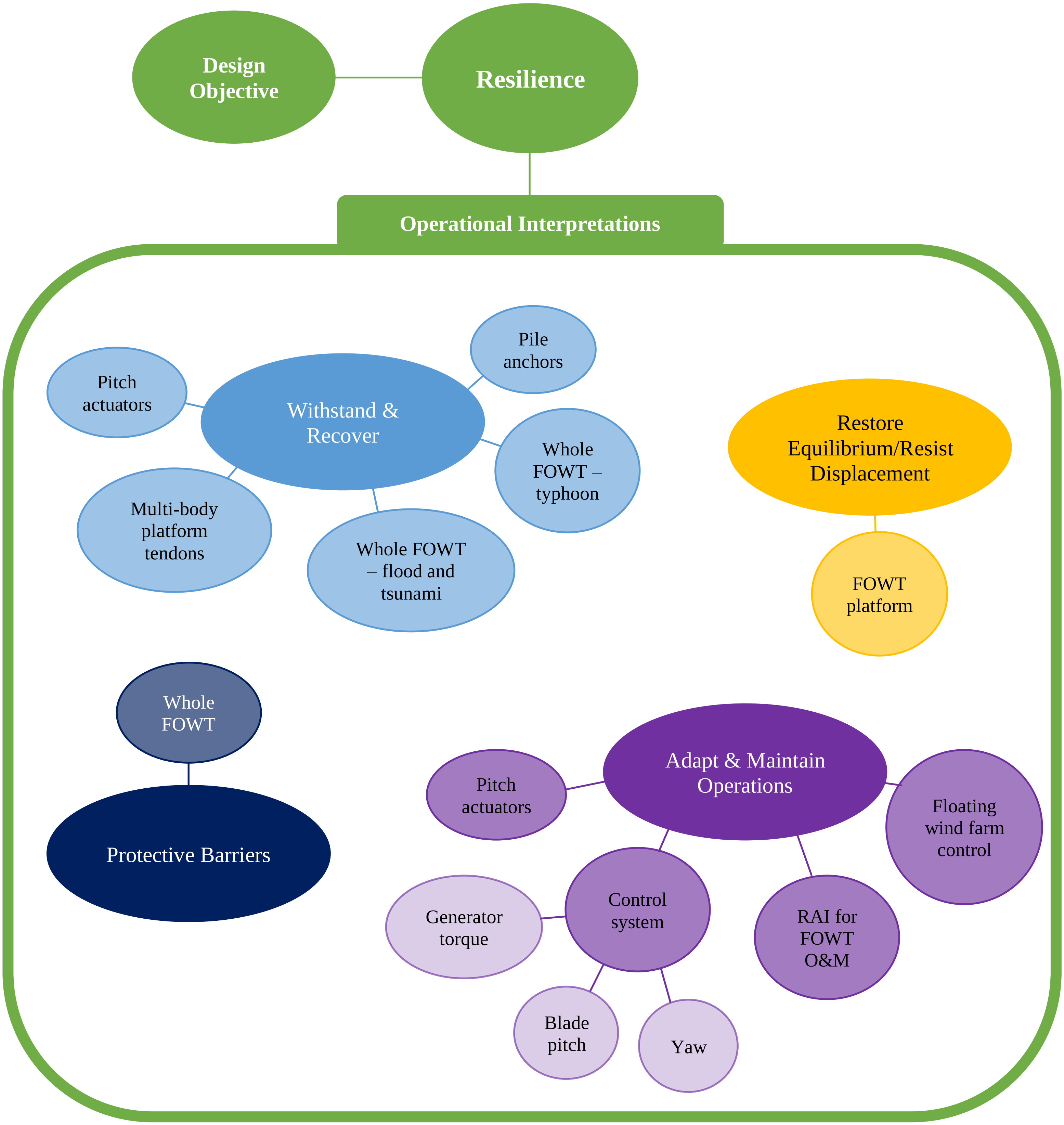
Additionally, in Govindji et al. (2014), Liu, Wu et al. (2020), Patryniak et al. (2022), and Sun et al. (2022), resilience is identified as a design objective, something which should be achieved for FOWT, but no specifics are given with regard to *how* resilience can be achieved for FOWT (with the exception of Sun et al. (2022) stating that it requires an understanding of the complex system behaviors of FOWT). Similarly, no explanation is given for what it means for FOWT to *be* resilient.

Figure 4.10 below maps the resilience definitions, interpretations, and applications that have been introduced here, to illustrate the current state of FOWT resilience research, research gaps, and possible future directions. In the sources reviewed here, resilience was identified as both a design objective and a characteristic of FOWT systems under operation. Unfortunately, no explanations were given for what resilience means as a design objective, but operational interpretations of resilience were given with a bit more detail and with some specific applications. Those applications of resilience are grouped around the four interpretations that are introduced above, in order to illustrate how each of those interpretations are used among the sources.

It may be noticed that there is not much of a trend regarding the grouping of applications around the four interpretations. The applications of the “withstand and recover” interpretation range from the entire FOWT system to the integrity of the platform to the blade pitch system. Similarly, the “adapt and maintain operations” interpretation is applied to floating wind *farm* control systems, *individual* turbine control systems, maintenance operations, and the blade pitch system. This indicates that both interpretations may be useful for practically every aspect and subsystem of FOWT, from the large to the small scales. This also indicates that there is a lot of potential future research to undertake, which warrants a look at the gaps in FOWT resilience research.

Figure 4.10

Mapping of resilience interpretations and applications

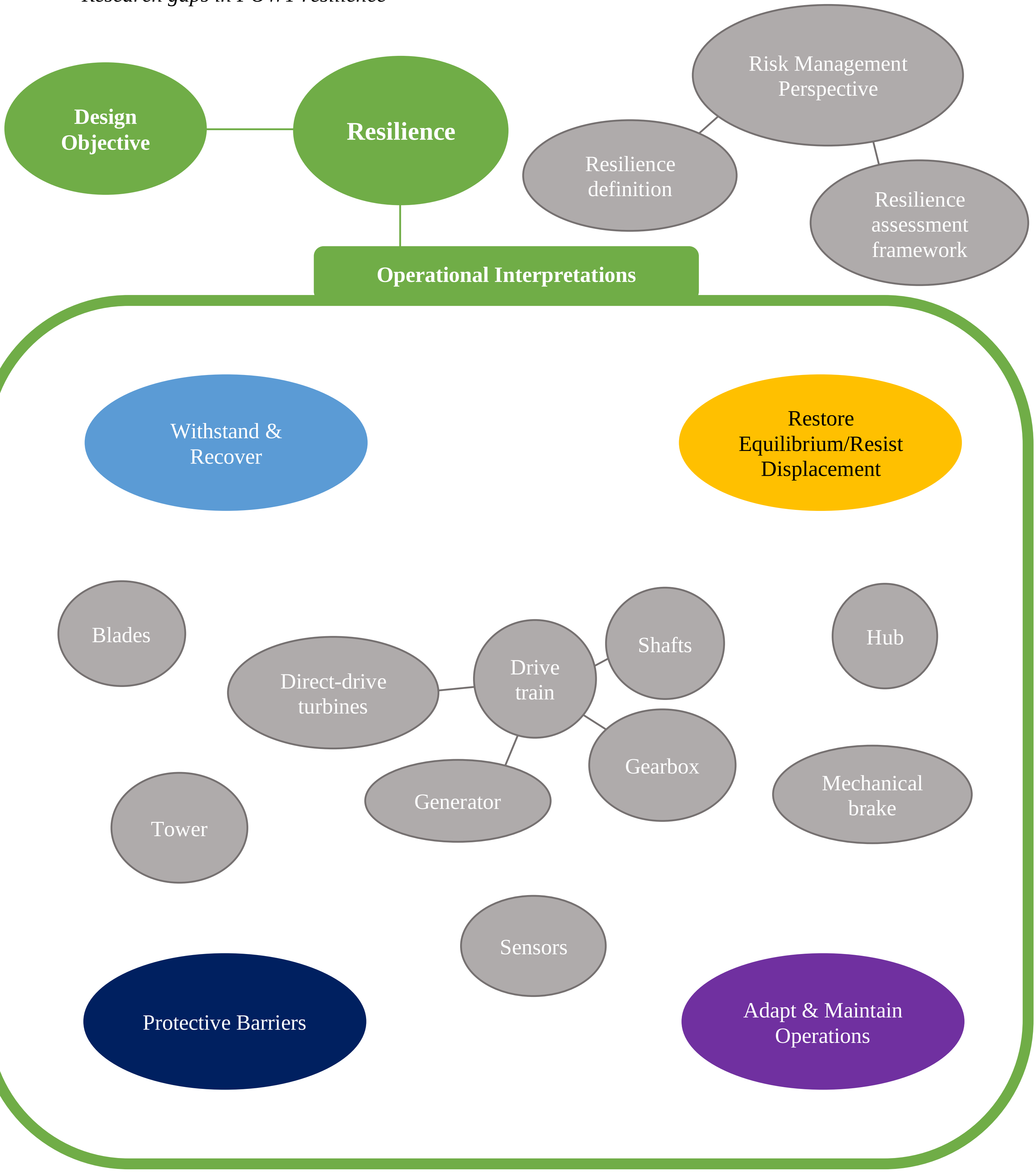


In Figure 4.11, attention is drawn to the areas where resilience research is still lacking, especially with regard to components that were identified by Carroll et al. (2016) as having relatively high failure rates. The gray bubbles represent gaps in the research, including components that were not discussed in the review sources.

In the top right corner, the “Risk Management Perspective” bubbles reflect the fact that none of the included sources took a risk management approach to resilience, but rather took an engineering approach to solve an engineering problem. This is of course acceptable and valuable and provides necessary insight into technical and engineering challenges facing FOWT; however, the design and operation of FOWT would benefit from a more holistic approach to resilience, including input from the field of risk management and/or resilience engineering. Section 1.2 provides some background information on various system aspects which should be considered when assessing resilience, including human behavior and learning and the interactions between people and the system’s technology. Additionally, Aven (2019, 2021) and Steen and Aven (2011) propose a resilience perspective that takes risk management into account. The benefits and importance of a risk management perspective for resilience and FOWT will be discussed in the next chapter, along with some possible reasons for the lack of attention toward resilience in the FOWT industry which has been uncovered in this review.

Figure 4.11

Research gaps in FOWT resilience



Chapter 5: Discussion

This chapter offers a discussion of the results presented above: out of 1,829 unique sources, only 12 articles and one report were found which mentioned or discussed the resilience of FOWT. These results clearly indicate considerable gaps in FOWT resilience research. The following discussion considers the interpretations of resilience that were found among the 13 included sources, the lack of explicit and consistent resilience definitions, and some similarities between conceptualizations of resilience in FOWT and other areas of research.

First, the interpretations of resilience which were introduced in section 4.5 are examined with respect to other fields. Second, possible reasons for the lack of explicit definitions are considered. The third section then discusses the importance of defining resilience in various research applications. In the fourth section, the value of a risk management perspective on resilience in FOWT is discussed, addressing another significant research gap uncovered in the results. Finally, the discussion concludes by presenting considerations regarding the validity, reliability, and limitations of this study.

5.1: Resilience Applications to FOWT and Other Research

There are some interesting agreements between some of the definitions found in this review and other conceptualizations of resilience found outside of FOWT literature. For example, the resilience engineering literature posits that resilient systems must be able to *respond* to internal and external changes, *monitor* system and external conditions, *learn* from mistakes and successes, and *anticipate* future trends or developments (Hollnagel, Pariès et al., 2011; Nemeth et al., 2009; Steen & Aven, 2011). The last two are not featured in the sources here, but the first two – responding and monitoring – are discussed quite a bit. Del Pozo González and Domínguez-García (2022), Keighobadi et al. (2022), and Liu, Wu et al. (2020) propose control systems or strategies that are able to monitor changes in the FOWT operating environment and respond accordingly. Mitchell et al. (2022) emphasize the importance of monitoring capabilities to maintain an updated awareness of FOWT structural health. Based on their study of the responses of a multi-body floating platform to damage and environmental conditions, Yang, Bashir, Michailides et al. (2021) develop a method for monitoring tendon integrity. Additionally, the "adapt and maintain operations" interpretation from Del Pozo González and Domínguez-

García (2022), Keighobadi et al. (2022), Liu, Wu et al. (2020), and Mitchell et al. (2022) coincides with the resilience engineering definition of resilience, given in section 1.2.

The findings of Keighobadi et al. (2022) in the previous section raised a question: what exactly is meant by "resilient control?" Gao and Liu (2021) answer this question – they write that resilient control requires designing control strategies "such that the adverse influences from faults can be mitigated, ensuring the system to work normally even under faulty conditions, which may not necessarily induce an immediate component replacement or [repair] for non-vital faults" (2021, p. 5). Although this article is not included in the review, as it was not found in either the primary or the reference search, it does shed light on how resilience is used in Keighobadi et al. (2022). Moreover, it validates the author's interpretation of the use of resilience in both Keighobadi et al. (2022) and Liu, Wu et al. (2020), both of which, according to the definition above, seek to design resilient control strategies for FOWT.

Another example of congruence between the definitions found in this review and elsewhere in the literature comes from Steen and Aven (2011), who discuss the importance of *barriers* that should be taken into account for resilience assessments. The use of such barriers is mentioned in Yang, Bashir, Li, and Wang (2021), where it is stated that increasing the number of mooring attachments per fairlead may lead to improved resilience in the case of a mooring line breakage. Barriers may serve to mitigate the consequences of an unwanted event or prevent the event from occurring. In the case of Yang, Bashir, Li, and Wang (2021), additional mooring lines serve to mitigate the consequences of a mooring line breakage, in order to prevent a FOWT from straying and colliding with other turbines or structures.

Overall, the definitions and interpretations of resilience that have been found in this review do not allow for a conclusive statement of what resilience is or is not in FOWT design and operation applications. There is unfortunately a lot of ambiguity. Looking at the broader research scale, the results are not encouraging: only 12 out of 248 articles with either FOWT or floating wind farms as their object of study (labelled as such in Rayyan, during the primary search) discuss or mention resilience related to FOWT. If the results from the two databases that were searched in this review are taken to be representative of the total body of research relating to FOWT, this means that less than 5% of FOWT literature addresses resilience related to design and operation. Despite the fact that resilience does not seem to be a priority among FOWT researchers, there is a lot of potential for growth and progress to be made in this particular field of research. The next section contemplates possible reasons for the lack of attention to resilience and the lack of an explicit definition in the FOWT industry.

5.2: Lack of Resilience Definition

The results presented in the previous chapter point to a general lack of a resilience definition for widespread, consistent use in the FOWT industry. The vast majority of the definitions and interpretations that were extracted from the included sources had to be inferred from context. In only one article (Mitchell et al., 2022) was a definition of resilience given explicitly, and it related only indirectly to FOWT. This lack of definition marks a serious gap or shortcoming in the research, and it may be due to a number of reasons, which are laid out below.

It should first be noted that even in industry standards, like those provided by DNV, no mention of resilience is made. For example, in the standard *Floating wind turbine structures*, which lays out design requirements and guidance for FOWT support structures, resilience is not mentioned once (DNV, 2021a). There is, however, a definition for *redundancy*, which is the “ability of a component or system to maintain or restore its function after a failure of a member or connection has occurred” (DNV, 2021a, p. 22). This definition bears a resemblance to two of the interpretations of resilience identified in section 4.5 – withstand and recover from stress and adapt and maintain operations under stress. This concept of redundancy also appears in the DNV standard *Control and protection systems for wind turbines*, where it is stated that “a single failure of any component within the control system, protection system or a braking system, e.g. a sensor, shall not lead to the loss of a protection function” (DNV, 2021c, p. 16). This use of redundancy echoes the emphasis placed by Yang, Bashir, Li, and Wang (2021) on the importance of protective barriers to minimize or mitigate the effects of a failure. It is evident that importance is placed on a system’s coping ability and protective measures, both in the industry and in the research community, but this recognition does not seem to stretch to resilience. It could be that the lack of mentions in industry standards is related to the identification of resilience as low-priority, not needing further research or development, despite the fact that related topics (protection, survival, reliability, etc.) are considered. It could also be that resilience itself is simply called something else throughout the industry – e.g., redundancy – and this may be reflected in the research community as well.

Another important factor to consider is that, as evidenced by the journals the included sources were published in, the research included in this review utilizes an engineering perspective for the most part. The prominence of this engineering perspective is indicated in section 4.5. Resilience engineering focuses on developing systems and tools that allow for adaptation, maintaining safety, and sustaining operations, as well as designing and managing resilient systems (Hollnagel, Woods, and Leveson, 2006; Nemeth et al., 2009), and it is different from the engineering fields from which most of the included research hails. The kinds of questions investigated by the included sources were associated with hydro- and aerodynamic forces on the wind turbines and platforms, how the FOWT responded in various situations (including damage scenarios), and how to control the FOWT such that both power generation and structural health and safety were ensured. While resilience may be useful in answering some aspects of these questions, they also require mechanical, electrical, and systems engineering approaches, and it is these approaches that were dominant in the review. Resilience may not yet have a prominent place within these engineering fields, and that may be part of the reason why the results of this review are so limited. It could also be that within these engineering fields and perspectives, the concept of resilience is indeed employed and studied but is referred to as something else, such as redundancy or reliability. Determining whether this is the case would require conducting a review on similar and related concepts in engineering domains in order to compare them to definitions of resilience found in other fields.

Interestingly, it seems that this lack of resilience research is not restricted to FOWT: Mitchell et al. (2022) found in their review that resilience was one of a few topics within the RAI field that needs more attention. This finding points to the possibility that the issue may not be that resilience hasn’t yet gained attention as an important topic for FOWT, but that it simply hasn’t gained much attention at all. Hopefully, reviews such as this one and the one conducted by Mitchell et al. (2022) will serve to raise awareness about the importance of resilience, for FOWT as well as other technologies.

It could also be that the literature search for this review was simply conducted in the wrong place. Perhaps other databases would have provided a greater number of sources relevant to this review, whether they focused on engineering solutions or not, and perhaps those sources would have defined resilience for FOWT. In order to determine whether this is the case, further scoping reviews should be conducted, with a broader literature search.

Finally, the lack of resilience definitions found in this review may be due to the fact that resilience has already been suitably defined for the offshore wind or ORE industries in general. Based on the information gathered in this review, it cannot be determined whether that is indeed the case, but if it were, then defining resilience specifically for FOWT may be redundant and unnecessary. Unfortunately, determining whether this is actually the case is beyond the scope of this review, as the search was restricted to sources which discuss FOWT, not fixed offshore turbines or other related technologies, in accordance with the research question and objectives. Given the design and loading differences between FOWT and fixed turbines, it seems reasonable to think that there may be additional factors to account for when considering resilience. However, there are also several similarities, which may make the opposite true. Further research is required to determine whether there is already a consistent definition of resilience that is used in the wider wind or ORE industries, and whether such a definition may also be used in FOWT applications.

An example of an article which discusses offshore wind energy and resilience can be found in Liu, Qin et al. (2022). Although this article was not included in the review due to the fact that it does not mention FOWT, it does prove that resilience is at least a topic of research for fixed offshore turbines. Moreover, Liu, Qin et al. provide an explicit definition of resilience: “the ability of systems to sustain [performance] and recover from disturbance” (2022, p. 2). The article describes the use of probabilities, failure assessments, and economic assessments to investigate the resilience of offshore wind farms, describing a “resilience failure” as the point at which economic reserves are depleted after turbine failure, and required maintenance and repair operations cannot be completed (Liu, Qin et al., 2022, p. 5). In this case, the farm cannot recover. The article presents an interesting and comprehensive resilience perspective, incorporating decision-making and economic factors into the analysis and case study. This is just one example of how resilience may be discussed in the fixed offshore wind literature. It may be that there are other similar articles which have provided in-depth discussions on resilience related to (fixed) offshore wind turbines and that such articles may be applicable to FOWT. If this is in fact the case, then there may not be a need to develop resilience definitions and interpretations specially for FOWT applications.

5.3: The Importance of Defining Resilience

This section discusses the importance of defining resilience in FOWT applications, offering two examples of studies in which this is done. By defining resilience specifically for their applications, these two articles allowed for enhanced clarity in their contributions to FOWT resilience knowledge. Moreover, the differences between the definitions in these articles and the sources included in this review highlight the variety of ways in which resilience may be understood and the need to therefore define resilience in FOWT studies.

Section 1.2 quotes Aven (2019) as saying that more resilient systems need to be developed. In their article on resilience assessments for wind farms in the Arctic, Mustafa and Barabadi (2021) respond to this need. They provide an example of a system resilience assessment which takes into account uncertainties and possible surprises, proposing a probabilistic model to calculate the resilience of an onshore wind farm in both normal Arctic conditions and highly disruptive, highly unlikely Arctic conditions. They first provide a definition of resilience, which takes into account human abilities, logistics issues, and organizational factors and can be expressed quantitatively, then they explain how to quantitatively measure system resilience and use those measurements to pinpoint system weaknesses and areas of improvement. Although the framework was applied to onshore turbines rather than offshore turbines, it is nevertheless a valuable example of how resilience studies can lead to a greater understanding of the challenges faced by wind turbine systems and ways to improve turbine performance and availability in the face of those challenges.

The article from Liu, Qin et al. (2022) introduced above also serves as a valuable example of the importance of defining and exploring resilience: the definition provided in their introduction allows for a clear understanding of the analysis and framework, as well as resilience failures that are discussed. Furthermore, Liu, Qin et al.’s (2022) perspective demonstrates that resilience requires an understanding of not only mechanical and technical issues, but managerial and economic issues as well.

In contrast to the uses of resilience in Liu, Qin et al. (2022) and Mustafa and Barabadi (2021), the uses of resilience in the review sources were entirely oriented around mechanical, technical, and safety issues. Throughout the sources, mentions are made of specific types of resilience, such as “seismic resilience” (Chaloulos et al., 2021, p. 10), “typhoon resilience” (Govindji et al., 2014, p. 22), flood resilience (Kappenthuler & Seeger, 2019), resilient control (Keighobadi et al., 2019), and weather resilience (Mitchell et al., 2022). None of these sources explicitly stated and clarified what was meant by these specific types of resilience, although Chaloulos et al. (2021) did strongly imply a definition of seismic resilience (see Table 4.6). Of course, the mechanical and engineering issues discussed in the review sources are important, but they present a relatively narrow perspective of resilience. Expanding that perspective could prove beneficial to the FOWT industry.

The two articles from Liu, Qin et al. (2022) and Mustafa and Barabadi (2021) serve as examples of how resilience can be assessed in a more holistic and comprehensive manner (as discussed in section 1.2), rather than only focusing on technical failures and performance. Liu, Qin et al.'s (2022) resilience failure analysis focused a great deal on financial resources, managerial decision making, and the financial failure which can arise as a result of decisions made, and Mustafa and Barabadi's (2021) resilience assessment addressed organizational, human, and logistical factors, in addition to the possibility of technical failure and environmental challenges. This variety – between Liu, Qin et al. (2022) and Mustafa and Barabadi (2021) on the one hand and the sources included in this review on the other – demonstrates that there are multiple types of resilience or ways in which resilience may be applied to improve and strengthen FOWT performance.

The variety of ways in which resilience can be interpreted and used can be a strength, especially for managing risks and uncertainties while operating in harsh environments, as FOWT do. This variety also highlights the importance of defining resilience and the way in which it is used in studies in order to enhance understanding.

5.4: FOWT Resilience and Risk Management

This section addresses the lack of risk management research that was found in the review and presents some suggestions for future work. As stated above, the research uncovered by this review leaned heavily towards engineering perspectives, not risk management. This means that the concept of resilience is not being used to its full potential for FOWT. As discussed by Aven (2021), resilience has a lot to offer risk management, and vice versa. Resilience-based strategies for managing risk could serve to enhance FOWT risk management, which could in turn have positive effects on turbine availability and energy production, as well as maintenance-related personnel safety.

Adopting a risk management perspective of resilience would require recognizing the uncertainties that are inherent in any future operations, internal and external events, and the related consequences. According to Aven (2019), resilience is included in the concept of risk, where risk is the consequences of an event, as well as the associated uncertainties. In this conceptualization, resilience can be thought of as the consequences and uncertainties of an event, *given that that particular event occurs*, but the event need not be known or thought of beforehand. In other words, resilience is related to how a system responds to a disrupting event that has occurred, especially without prior knowledge of the disruption (Aven, 2019). Renn also emphasizes the need to cope with the unexpected and unforeseen, writing that it is a hallmark of resilient systems that they are able to “withstand or even tolerate surprises” (2008, p. 179).

Resilience studies that are based on a risk management perspective should therefore investigate the ability of FOWT systems to cope with unexpected, challenging events for which they may not necessarily be designed. Developing an understanding of FOWT behavior and adaptive capabilities in novel scenarios characterized by uncertainty would serve to improve FOWT’s survival ability, performance, and energy production. Additionally, Renn (2008) offers some suggestions on how resilience in systems may be improved. These suggestions include additional safety factors or barriers (as mentioned in Yang, Bashir, Li, and Wang (2021)) to mitigate negative impacts, which may be more severe than expected, and “technical redundancy” for protective measures (Renn, 2008, p. 194). Renn admits that redundancy, extra barriers, and protective measures may be costly, but that the higher costs may prove worthwhile if the risk events or hazards occur frequently or are more severe than anticipated. This sentiment is echoed by Mustafa and Barabadi (2021), who point out that, while resilience assessments may reveal potential areas of improvement, implementing those improvements (e.g., additional safety measures or barriers) should be carefully considered in terms of costs, benefits, and uncertainties. Given the challenges posed by climate change, it does not seem unreasonable to prepare FOWT for weather events and conditions that may be more intense than predicted, and extra protective measures or barriers may be a worthwhile means of improving resilience.

Although the sources included in the review do seek to contribute to improvements in FOWT technology and operation, they tend to disregard uncertainty and the potential for extreme events. For example, in Liu, Wu et al. (2020), the pitch control strategy is only tested for one kind of fault (PAS), and only one PAS fault at a time is tested – no considerations are made regarding the possibility of multiple simultaneous PAS faults. Similarly, when Yang, Bashir, Li, and Wang (2021) tested mooring line breakage scenarios, they only considered scenarios with one breakage. The likelihood of multiple mooring line breakages at the same time was considered to be too low to warrant consideration. However, a risk management perspective would demand that that uncertainty be recognized and that the severity of the consequences of multiple breakages be examined. It would also demand that the assumption of a negligible probability of multiple breakages be examined to determine whether that assumption is indeed reasonable. Returning once again to the examples of Liu, Qin et al. (2022) and Mustafa and Barabadi (2021), it can be seen that emphasis is placed on understanding potential failures and their consequences and on examining even highly unlikely (but potentially devastating) scenarios. The studies included in this review – and any future FOWT resilience studies – would benefit from exploring more than one failure possibility in order to develop a better understanding of the system's resilience.

In short, FOWT and resilience research would benefit from an emphasis on risk management. Giving proper attention to uncertainty and developing resilience-based risk management strategies, as mentioned in Renn (2008), could lead to improved FOWT performance, production, and safety, thereby reducing costs and contributing to more widespread implementation. Moreover, developing a risk-based resilience assessment framework for FOWT could contribute to FOWT resilience research by highlighting important factors and questions to consider related to risk and resilience for FOWT and by allowing researchers to pinpoint system weaknesses and possible improvements.

5.5: Validity, Reliability, and Limitations

This section presents a brief discussion of the validity, reliability, and limitations of this study. The first two are important because they affect the value of this review and the degree to which its results may be depended upon to guide future research and decision making. The limitations are important to consider as well, because they provide a foundation for improvements and future research, as well as potential biases which should be taken into account.

5.5.1: Validity

Neuman (2014) writes that validity is concerned with how well the data and conclusions of a study agree with reality. In this case, validity relates to whether this review has actually captured an accurate glimpse of the state of current FOWT resilience research. The literature search for this scoping review was comprehensive and broad, exploring all of the sources and literature related to FOWT resilience which could be found in the ScienceDirect and GreenFILE databases. Given the thoroughness of the search and the screening process, it is reasonable to claim that the results of this study are indeed valid, to the extent that ScienceDirect and GreenFILE are representative of the total body of literature and research on FOWT and resilience. As will be discussed below, there may be additional valuable sources outside of these two databases – but such sources are beyond the scope of this review.

5.5.2: Reliability

Reliability is strongly related to the repeatability of a study and the consistency of the results (Neuman, 2014): if this scoping review were conducted once more, would the results be the same? It is the author's firm belief that this would be the case, seeing as the search, screening, and selection processes were carefully recorded, as were the databases and the restrictions applied to the searches. Sufficient detail is given that the process could be repeated exactly.

Furthermore, all deviations from the intended plan are also given in Chapter 3, e.g., the addition of a round of in-depth analysis and screening following the full-text screening and the addition of the last inclusion criterion to ensure that all included sources were relevant to the research question and objectives. Although this marks a slight deviation from standard scoping review methodology, which only calls for title-and-abstract and full-text screenings, it was done to ensure that the results were relevant and meaningful. Given the transparency of the process, such deviations should not detract from the reliability of this review.

Both the validity and reliability of this review are bolstered by adherence to the requirements of the PRISMA-ScR checklist (**Appendix A.1**): since all required items are included and reported in this thesis, it meets the standard for transparency and proper reporting of scoping reviews (Tricco et al., 2018).

5.5.3: Limitations

While this review did aim to be as thorough and comprehensive as possible in order to obtain representative, accurate, and meaningful results, there are some limitations that should be taken into account – they are presented below.

First, it was impossible to search all relevant databases, and only two were selected to ensure that the literature search and review process could be completed within the required timeframe. The expansion of the search to include more databases may have revealed additional relevant sources. Similarly, a search of the gray literature was excluded in order to maintain feasibility, and no additional literature search was conducted toward the end of the review and writing process to check for additional sources that had been published after the primary search. If time had not been an issue, and if the review and writing process had covered a longer time span, then both of these additional steps may have been done as well.

Second, only including FOWT research may have resulted in the omission of valuable fixed offshore or onshore wind turbine research, which may contain further insights or background knowledge for FOWT, including important definitions or conceptualizations of resilience. In a similar vein, only focusing on FOWT design and operation and the exclusion of the power export cable and transmission system may have resulted in the exclusion of valuable information. However, given the focus of the research question and objectives, this is justifiable.

Third, the author was the only party involved in screening and selecting the sources and charting the data from included sources. Although every effort was made to be thorough and to include all relevant articles and data, mistakes and biases are possible. Having an additional reviewer may have served to assuage these concerns; however, this thesis was completed as a solo project.

Finally, it is recommended by Pham et al. (2014) to include an expert consultation as part of the review process. This expert consultation may be done to ensure that all relevant search terms are included, assist with selection of relevant sources, ensure correct interpretation of results, and offer general commentary (Pham et al., 2014). Such a consultation was not undertaken for this review – future studies may benefit from doing so.

Chapter 6: Conclusions and Recommendations for Future Research

This scoping review explored the research question: *How is resilience understood and applied in the context of FOWT design and operation?* In answering this question, the following conclusions have been drawn.

- Four main interpretations of resilience were found among the results from the 13 included sources: withstand and recover from stress, restore equilibrium and resist displacement, adapt and maintain operations, and mitigate negative consequences through protective barriers.
- Resilience is a desirable design objective for FOWT, but clarification on what exactly this means, how to design resilient FOWT, and how to test for resilience in FOWT is lacking.
- It is not common in FOWT design and operation research to clearly define resilience and explain how it is used and understood.
- FOWT resilience research employs a predominantly engineering perspective, rather than a risk management perspective.

The objectives of this thesis and scoping review were to investigate the interpretations and applications of resilience within FOWT design and operation, map the trends and uses of resilience among FOWT research, and identify research and knowledge gaps. The purpose was to contribute to improved FOWT resilience, performance, and safety, within a wider context of global sustainability efforts, by providing a foundation for future FOWT resilience research.

Out of thousands of articles that were found in the systematic literature search, only 13 discussed resilience and FOWT in relation to one another, and of those 13, only 1 offered an explicit definition of resilience. However, it was possible to discern various interpretations of resilience from the sources included in the review, and those sources revealed interesting trends and perspectives in FOWT design and operation research related to resilience.

Based on these findings, several recommendations for future research can be made. First, the understanding and use of resilience in other related areas, such as fixed offshore wind turbines, should be explored in order to identify similarities or overlap in resilience conceptualizations. Of course, the findings of this review may also be augmented by conducting further reviews of resilience in FOWT, perhaps with broader searches. Second, effort should be made to develop resilience assessment frameworks (as done in Liu, Qin et al. (2022) and Mustafa and Barabadi (2021)) for FOWT. Alternatively, existing resilience assessment frameworks should be applied to FOWT. Third, risk management approaches should be utilized in order to broaden the engineering perspective which currently dominates the research and to allow for a more holistic understanding of resilience in FOWT. Finally, the field may benefit from more focused efforts to build resilience among those components or subsystems which are most susceptible to failure or which are the most demanding (in terms of time and other resources) to repair. Such efforts may lead to reduced O&M costs, which would improve FOWT implementation and contribute to securing a sustainable future.

This scoping review has provided an overview of the trends in resilience-related research for FOWT design and operation, and it may serve as a valuable foundation for future research in the directions given above.

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Appendix A.1: PRISMA-ScR Checklist

This checklist is from Tricco et al. (2018). The page numbers provided are links to the referenced material.

Section	Item	PRISMA-ScR checklist item	Reported on page #
Title			
Title	1	Identify the report as a scoping review.	i
Abstract			
Structured summary	2	Provide a structured summary including, as applicable: background, objectives, eligibility criteria, sources of evidence, charting methods, results and conclusions that related to the review question(s) and objective(s).	ii-iii
Introduction			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review question(s)/objective(s) lend themselves to a scoping review approach.	6-7
Objectives	4	Provide an explicit statement of the question(s) and objective(s) being addressed with reference to their elements (e.g., population or participants, concepts and context), or other relevant key elements used to conceptualize the review question(s) and/or objective(s)).	6
Methods			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., web address), and, if available, provide registration information including registration number.	21
Eligibility criteria	6	Specify the characteristics of the sources of evidence (e.g., years considered, language, publication status) used as criteria for eligibility, and provide a rationale.	23-25
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with authors to identify additional sources) in the search, as well as the date the most recent search was executed.	22, 26
Search	8	Present the full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	26
Selection of sources of evidence	9	State the process for selecting sources of evidence (i.e., screening, eligibility) included in the scoping review.	27-29

Section	Item	PRISMA-ScR checklist item	Reported on page #
Data charting process	10	Describe the methods of charting data from the included sources of evidence (e.g., piloted forms; forms that have been tested by the team before their use, whether data charting was done independently, in duplicate) and any processes for obtaining and confirming data from investigators.	30-31
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	29-30
Critical appraisal of individual sources of evidence	12	*If done*, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	n/a
Summary measures	13	*Not applicable for scoping reviews.*	n/a
Synthesis of results	14	Describe the methods of handling and summarizing the data that were charted.	36
Risk of bias across studies	15	*Not applicable for scoping reviews.*	n/a
Additional analyses	16	*Not applicable for scoping reviews.*	n/a
Results			
Selection of sources of evidence	17	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	32-34
Characteristics of sources of evidence	18	For each source of evidence, present characteristics for which data were charted and provide the citations.	36-48
Critical appraisal within sources of evidence	19	*If done*, present data on critical appraisal of included sources of evidence (see item 12).	n/a
Results of individual sources of evidence	20	For each included source of evidence, present the relevant data that were charted that relate to the review question(s) and objective(s).	49-55

Section	Item	PRISMA-ScR checklist item	Reported on page #
Synthesis of results	21	Summarize and/or present the charting results as they relate to the review question(s) and objective(s).	55-61
Risk of bias across studies	22	*Not applicable for scoping reviews.*	n/a
Additional analyses	23	*Not applicable for scoping reviews.*	n/a
Discussion			
Summary of evidence	24	Summarize the main results (including an overview of concepts, themes, and types of evidence available), explain how they relate to the review question(s) and objective(s), and consider the relevance to key groups.	62-70
Limitations	25	Discuss the limitations of the scoping review process.	71-72
Conclusion	26	Provide a general interpretation of the results with respect to the review question(s) and objective(s), as well as potential implications and/or next steps.	73-74
Funding			
Funding	27	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	38-40, 74

Appendix A.2: Search Information

All searches were conducted on 20 March 2023.

	Number of Results	
Search Terms	**ScienceDirect**	**GreenFILE**
Resilience AND “floating offshore wind turbine”	28	467
Resilience AND “floating offshore turbine	2	360
Resilience AND “floating wind turbine”	41	399
Resilience AND “floating turbine”	21	239
Resilience AND “floating wind power”	5	619
Resilience AND “floating offshore wind”	57	440
Resilience AND “floating offshore wind power”	0	672
Resilience AND “floating offshore wind farm”	13	472
Resilience AND “floating wind farm”	18	406
Resilience AND “floating wind energy”	5	762
Resilience AND “offshore wind farm”	453	1
Resilience AND “offshore wind power	215	4
Resilience AND “offshore wind turbine”	244	1
Resilience AND “offshore wind energy”	235	1
Resilient AND “floating offshore wind turbine”	20	466
Resilient AND “floating offshore turbine”	2	358
Resilient AND “floating wind turbine”	30	398
Resilient AND “floating turbine”	12	238
Resilient AND “floating wind power”	1	619
Resilient AND “floating offshore wind”	42	439
Resilient AND “floating offshore wind power”	1	671
Resilient AND “floating offshore wind farm”	10	471
Resilient AND “floating wind farm”	15	405
Resilient AND “floating wind energy”	1	762
Resilient AND “offshore wind farm”	347	1
Resilient AND “offshore wind power”	169	1
Resilient AND “offshore wind turbine”	200	1
Resilient AND “offshore wind energy”	173	2

Appendix A.3: Sources from Indices and Abstract Lists

Author(s)	Title	Date	Publication
Aggarwal et al.	Nonlinear short term extreme response of spar type floating offshore wind turbines	2017	Ocean Engineering
Antonutti et al.	An investigation of the effects of wind-induced inclination on floating wind turbine dynamics: Heave plate excursion	2014	Ocean Engineering
Bae and Kim	Coupled dynamic analysis of multiple wind turbines on a large single floater	2014	Ocean Engineering
Barrera et al.	Mooring system fatigue analysis of a floating offshore wind turbine	2020	Ocean Engineering
Borg and Collu	Frequency-domain characteristics of aerodynamic loads of offshore floating vertical axis wind turbines	2015	Applied Energy
Castro-Santos et al.	Economic comparison of technological alternatives to harness offshore wind and wave energies	2017	Energy
Duan et al.	Experimental comparisons of dynamic properties of floating wind turbine systems based on two different rotor concepts	2016	Applied Ocean Research
Fan et al.	Study on the application of energy storage system in offshore wind turbine with hydraulic transmission	2016	Energy Conversion and Management
Lefebvre and Collu	Preliminary design of a floating support structure for a 5MW offshore wind turbine	2012	Ocean Engineering
Nikitas et al.	Wind power: A sustainable way to limit climate change	2019	Managing Global Warming
Pacheco et al.	An evaluation of offshore wind power production by floatable systems: A case study from SW Portugal	2017	Energy
Pham et al.	Dynamic modeling of nylon mooring lines for a floating wind turbine	2019	Applied Ocean Research
Qu et al.	Comparative study of short-term extreme responses and fatigue damages of a floating wind turbine using two different blade models	2020	Applied Ocean Research
Sang et al.	Experimental investigation of the cyclic pitch control on a horizontal axis wind turbine in diagonal inflow wind condition	2017	Energy
Shen et al.	Study of the unsteady aerodynamics of floating wind turbines	2018	Energy
Si and Karimi	Gain Scheduling H2/H∞ Structural Control of a Floating Wind Turbine	2014	IFAC Proceedings Volumes
Silva et al.	Nonlinear dynamics of a floating offshore wind turbine platform via statistical quadratization – Mooring, wave and current interaction	2021	Ocean Engineering
Uzunoglu and Guedes Soares	Hydrodynamic design of a free-float capable tension leg platform for a 10 MW wind turbine	2020	Ocean Engineering
Wang and Sweetman	Multibody dynamics of floating wind turbines with large-amplitude motion	2013	Applied Ocean Research

Appendix A.4: Full-Text Screening Eliminations – Primary Search

Title	Author(s)	Year	Publication	Exclusion Rationale
Europe eyes coatings for offshore wind turbines		2014	Focus on Powder Coatings	No specific mention of FOWT
Evaluation of internal force superposition on a TLP for wind turbines.	Adam, Frank; Myland, Thomas; Schuldt, Burkhard; Großmann, Jochen and Dahlhaus, Frank	2014	Renewable Energy: An International Journal	Did not mention resilience
Nonlinear short term extreme response of spar type floating offshore wind turbines	Aggarwal, Neeraj; Manikandan, R. and Saha, Nilanjan	2017	Ocean Engineering	Did not mention resilience
Modal dynamics and flutter analysis of floating offshore vertical axis wind turbines.	Ahsan, Faraz and Griffith, D. Todd and Gao, Ju	2022	Renewable Energy: An International Journal	Did not mention resilience
Occupational Safety Management in the Offshore Wind Industry - Status and Challenges	Albrechtsen, Eirik	2012	Energy Procedia	Did not mention resilience
Atmospheric boundary-layer simulation for the built environment: Past, present and future	Aly, Aly Mousaad	2014	Building and Environment	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Design of monopiles for offshore and nearshore wind turbines in seismically liquefiable soils: Methodology and validation	Amani, Sadra; Prabhakaran, Athul and Bhattacharya, Subhamoy	2022	Soil Dynamics and Earthquake Engineering	No specific mention of FOWT
No transition without transmission: HVDC electricity infrastructure as an enabler for renewable energy?	Andersen, Allan Dahl	2014	Environmental Innovation and Societal Transitions	Resilience not discussed with respect to FOWT; no specific mention of FOWT
An investigation of the effects of wind-induced inclination on floating wind turbine dynamics: heave plate excursion	Antonutti, Raffaello; Peyrard, Christophe; Johanning, Lars; Incecik, Atilla and Ingram, David	2014	Ocean Engineering	Did not mention resilience
The effects of wind-induced inclination on the dynamics of semi-submersible floating wind turbines in the time domain.	Antonutti, Raffaello; Peyrard, Christophe; Johanning, Lars; Incecik, Atilla and Ingram, David	2016	Renewable Energy: An International Journal	Did not mention resilience
Floating Offshore Wind Power Taking Hold.	Appleyard, David	2013	Renewable Energy World	Did not mention resilience
Modeling of near wake characteristics in floating offshore wind turbines using an actuator line method.	Arabgolarcheh, Alireza; Jannesarahmadi, Sahar and Benini, Ernesto	2022	Renewable Energy: An International Journal	Did not mention resilience
Coupled dynamic analysis of multiple wind turbines on a large single floater	Bae, Y. H. and Kim, M. H.	2014	Ocean Engineering	Did not mention resilience
Performance changes of a floating offshore wind turbine with broken mooring line.	Bae, Y.H.; Kim, M.H. and Kim, H.C.	2017	Renewable Energy: An International Journal	Did not mention resilience
A data-driven algorithm for online detection of component and system faults in modern wind turbines at different operating zones	Bakdi, Azzeddine; Kouadri, Abdelmalek and Mekhilef, Saad	2019	Renewable and Sustainable Energy Reviews	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Mooring system fatigue analysis of a floating offshore wind turbine	Barrera, Carlos; Battistella, Tommaso and Guanche, Raül and Losada, Iñigo J.	2020	Ocean Engineering	Did not mention resilience
Scale model technology for floating offshore wind turbines.	Bayati, Ilmas; Belloli, Marco; Bernini, Luca; Giberti, Hermes and Zasso, Alberto	2017	IET Renewable Power Generation (Wiley-Blackwell)	Did not mention resilience
Measuring the long run technical efficiency of offshore wind farms	Benini, Giacomo and Cattani, Gilles	2022	Applied Energy	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Emergence of floating offshore wind energy: Technology and industry.	Bento, Nuno and Fontes, Margarida	2019	Renewable & Sustainable Energy Reviews	Did not mention resilience

Use of offshore wind farms to increase seismic resilience of Nuclear Power Plants	Bhattacharya, S. and Goda, K.	2016	Soil Dynamics and Earthquake Engineering	Resilience not discussed with respect to FOWT
Global growth in offshore wind turbine technology.	Bilgili, Mehmet and Alphan, Hakan	2022	Clean Technologies & Environmental Policy	Resilience not discussed with respect to FOWT
Gyroscopic effects on a large vertical axis wind turbine mounted on a floating structure	Blusseau, Pierre and Patel, Minoo H.	2012	Renewable Energy: An International Journal	Did not mention resilience
Enhancing drought resilience and energy security through complementing hydro by offshore wind power - The case of Brazil	Borba, Paula Conde Santos; Sousa, Wilson C.; Shadman, Milad and Pfenninger, Stefan	2023	Energy Conversion and Management	Resilience not discussed with respect to FOWT
Frequency-domain characteristics of aerodynamic loads of offshore floating vertical axis wind turbines	Borg, M. and Collu, M.	2015	Applied Energy	Did not mention resilience
Offshore floating vertical axis wind turbines, dynamics modelling state of the art. Part III: Hydrodynamics and coupled modelling approaches.	Borg, Michael and Collu, Maurizio	2015	Renewable & Sustainable Energy Reviews	Did not mention resilience
Offshore floating vertical axis wind turbines, dynamics modelling state of the art. Part II: Mooring line and structural dynamics.	Borg, Michael; Collu, Maurizio and Kolios, Athanasios	2014	Renewable & Sustainable Energy Reviews	Did not mention resilience
Offshore floating vertical axis wind turbines, dynamics modelling state of the art. part I: Aerodynamics.	Borg, Michael; Shires, Andrew and Collu, Maurizio	2014	Renewable & Sustainable Energy Reviews	Did not mention resilience
Marine Renewable Energy Seascape	Borthwick, Alistair G.L.	2016	Engineering	Resilience not discussed with respect to FOWT
Bayesian networks in renewable energy systems: A bibliographical survey	Borunda, Mónica; Jaramillo, O.A.; Reyes, Alberto and Ibargüengoytia, Pablo H.	2016	Renewable and Sustainable Energy Reviews	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Status, plans and technologies for offshore wind turbines in Europe and North America	Breton, Simon-Philippe and Moe, Geir	2009	Renewable Energy: An International Journal	Did not mention resilience
The impact of long-term changes in air temperature on renewable energy in Poland	Canales, Fausto A.; Jadwiszczak, Piotr; Jurasz, Jakub; Wdowikowski, Marcin; Ciapała, Bartłomiej and Kaźmierczak, Bartosz	2020	Science of The Total Environment	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Second-order responses of a conceptual semi-submersible 10 MW wind turbine using full quadratic transfer functions.	Cao, Qun; Xiao, Longfei; Guo, Xiaoxian and Liu, Mingyue	2020	Renewable Energy: An International Journal	Did not mention resilience
Experimental investigation on the dynamic response of an innovative semi-submersible floating wind turbine with aquaculture cages.	Cao, Shugang; Cheng, Youliang; Duan, Jinlong and Fan, Xiaoxu	2022	Renewable Energy: An International Journal	Did not mention resilience
Cost assessment methodology for combined wind and wave floating offshore renewable energy systems.	Castro-Santos, Laura; Martins, Elson and Guedes Soares, C.	2016	Renewable Energy: An International Journal	Did not mention resilience
Economic comparison of technological alternatives to harness offshore wind and wave energies	Castro-Santos, Laura; Martins, Elson and Guedes Soares, C.	2017	Energy	Did not mention resilience
Review of model experimental methods focusing on aerodynamic simulation of floating offshore wind turbines.	Chen, Chaohe; Ma, Yuan and Fan, Tianhui	2022	Renewable & Sustainable Energy Reviews	Did not mention resilience
Coupled aero-hydro-servo-elastic methods for floating wind turbines	Chen, Jiahao; Hu, Zhiqiang; Liu, Geliang and Wan, Decheng	2019	Renewable Energy	Did not mention resilience
Experimental study on dynamic responses of a spar-type floating offshore wind turbine.	Chen, Jianbing; Liu, Zenghui; Song, Yupeng; Peng, Yongbo and Li, Jie	2022	Renewable Energy: An International Journal	Did not mention resilience
A 3D parallel particle-in-cell solver for extreme wave interaction with floating bodies	Chen, Qiang; Zang, Jun; Ning, Dezhi; Blenkinsopp, Chris and Gao, Junliang	2019	Ocean Engineering	Did not mention resilience
Numerical analysis of unsteady aerodynamic performance of floating offshore wind turbine under platform surge and pitch motions.	Chen, Ziwen; Wang, Xiaodong; Guo, Yize and Kang, Shun	2021	Renewable Energy: An International Journal	Did not mention resilience

A comparison of extreme structural responses and fatigue damage of semi-submersible type floating horizontal and vertical axis wind turbines.	Cheng, Zhengshun; Madsen, Helge Aagaard; Chai, Wei; Gao, Zhen and Moan, Torgeir	2017	Renewable Energy: An International Journal	Did not mention resilience
Effect of the number of blades on the dynamics of floating straight-bladed vertical axis wind turbines.	Cheng, Zhengshun; Madsen, Helge Aagaard; Gao, Zhen and Moan, Torgeir	2017	Renewable Energy: An International Journal	Did not mention resilience
A fully coupled method for numerical modeling and dynamic analysis of floating vertical axis wind turbines.	Cheng, Zhengshun; Madsen, Helge Aagaard; Gao, Zhen and Moan, Torgeir	2017	Renewable Energy: An International Journal	Did not mention resilience
Fault detection and diagnosis of a blade pitch system in a floating wind turbine based on Kalman filters and artificial neural networks.	Cho, Seongpil; Choi, Minjoo; Gao, Zhen and Moan, Torgeir	2021	Renewable Energy: An International Journal	Did not mention resilience
Model-based fault detection, fault isolation and fault-tolerant control of a blade pitch system in floating wind turbines.	Cho, Seongpil; Gao, Zhen and Moan, Torgeir	2018	Renewable Energy: An International Journal	Did not mention resilience
Fault detection and anti-icing technologies in wind energy conversion systems: A review	Choe Wei Chang, Clifford; Jian Ding, Tan; Jian Ping, Tan; Ariannejad, Mohammadmahdi; Chia Chao} Kang and Samdin, Siti Balqis	2022	Energy Reports	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Sequence-based modeling of deep learning with LSTM and GRU networks for structural damage detection of floating offshore wind turbine blades.	Choe, Do-Eun; Kim, Hyoung-Chul and Kim, Moo-Hyun	2021	Renewable Energy: An International Journal	Did not mention resilience
Comparative CFD analysis of Vertical Axis Wind Turbine in upright and tilted configuration.	Chowdhury, Abdullah Mobin; Akimoto, Hiromichi and Hara, Yutaka	2016	Renewable Energy: An International Journal	Did not mention resilience
An analytical cost model for co-located floating wind-wave energy arrays	Clark, Caitlyn E.; Miller, Annalise and DuPont, Bryony	2019	Renewable Energy	Did not mention resilience
Subsea superconductors: The future of offshore renewable energy transmission?	Cullinane, M.; Judge, F.; O'Shea, M.; Thandayutham, K. and Murphy, J.	2022	Renewable & Sustainable Energy Reviews	Did not mention resilience
Dynamics of hybrid offshore renewable energy platforms: Heaving point absorbers connected to a semi-submersible floating offshore wind turbine.	da Silva, L.S.P.; Sergiienko, N.Y.; Cazzolato, B. and Ding, B.	2022	Renewable Energy: An International Journal	Did not mention resilience
Curing agents improve rotor production	Daun, Gregor	2009	Reinforced Plastics	No specific mention of FOWT
Assessment of current developments and future prospects of wind energy in Canada	Dehghani-Sanij, A.R.; Al-Haq, A.; Bastian, J.; Luehr, G.; Nathwani, J.; Dusseault, M.B. and Leonenko, Y.	2022	Sustainable Energy Technologies and Assessments	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Wind energy conversion technologies and engineering approaches to enhancing wind power generation: A review	Desalegn, Belachew; Gebeyehu, Desta and Tamirat, Bimrew	2022	Heliyon	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Fault detection of offshore wind turbine drivetrains in different environmental conditions through optimal selection of vibration measurements.	Dibaj, Ali; Gao, Zhen and Nejad, Amir R.	2023	Renewable Energy: An International Journal	Did not mention resilience
The feasibility of 100% renewable electricity systems: A response to critics	Diesendorf, Mark and Elliston, Ben	2018	Renewable and Sustainable Energy Reviews	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Comparative analysis of different criteria for the prediction of vortex ring state of floating offshore wind turbines.	Dong, Jing and Viré, Axelle	2021	Renewable Energy: An International Journal	Did not mention resilience
The aerodynamics of floating offshore wind turbines in different working states during surge motion.	Dong, Jing and Viré, Axelle	2022	Renewable Energy: An International Journal	Did not mention resilience

Analysis the vortex ring state and propeller state of floating offshore wind turbines and verification of their prediction criteria by comparing with a CFD model.	Dong, Jing; Viré, Axelle and Li, Zhangrui	2022	Renewable Energy: An International Journal	Did not mention resilience
Design, analysis and test of a model turbine blade for a wave basin test of floating wind turbines.	Du, Weikang; Zhao, Yongsheng; He, Yanping and Liu, Yadong	2016	Renewable Energy: An International Journal	Did not mention resilience
Experimental comparisons of dynamic properties of floating wind turbine systems based on two different rotor concepts	Duan, Fei; Hu, Zhiqiang; Liu, Geliang and Wang, Jin	2016	Applied Ocean Research	Did not mention resilience
Evaluating capital and operating cost efficiency of offshore wind farms: A DEA approach.	Ederer, Nikolaus	2015	Renewable & Sustainable Energy Reviews	Did not mention resilience; no specific mention of FOWT
Improving global accessibility to offshore wind power through decreased operations and maintenance costs: a hydrodynamic analysis	Edesess, Ariel J.; Kelliher, Denis; Borthwick, Alistair G.L. and Thomas, Gareth	2017	Energy Procedia	Did not mention resilience; no specific mention of FOWT
Protection techniques with renewable resources and smart grids - A survey	Eissa, M.M. (SIEEE)	2015	Renewable and Sustainable Energy Reviews	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Prediction of long-term extreme response of two-rotor floating wind turbine concept using the modified environmental contour method.	El Beshbichi, Omar; Rødstøl, Henrik; Xing, Yihan and Ong, Muk Chen	2022	Renewable Energy: An International Journal	Did not mention resilience
Application of machine learning for wind energy from design to energy-water nexus: A Survey	Elyasichamazkoti, Farhad and Khajehpoor, Abolhasan	2021	Energy Nexus	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Study on the application of energy storage system in offshore wind turbine with hydraulic transmission	Fan, Yajun; Mu, Anle and Ma, Tao	2016	Energy Conversion and Management	Did not mention resilience
A study on the aerodynamics of a floating wind turbine rotor.	Farrugia, R. and Sant, T. and Micallef, D.	2016	Renewable Energy: An International Journal	Did not mention resilience
Investigating the aerodynamic performance of a model offshore floating wind turbine.	Farrugia, R.; Sant, T. and Micallef, D.	2014	Renewable Energy: An International Journal	Did not mention resilience
Resilience design method based on meta-structure: A case study of offshore wind farm	Feng, Qiang; Zhao, Xiujie; Fan, Dongming; Cai, Baoping; Liu, Yiqi and Ren, Yi	2019	Reliability Engineering & System Safety	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Site-specific optimizations of a 10 MW floating offshore wind turbine for the Mediterranean Sea.	Ferri, Giulio and Marino, Enzo	2023	Renewable Energy: An International Journal	Did not mention resilience
Platform and mooring system optimization of a 10 MW semisubmersible offshore wind turbine.	Ferri, Giulio; Marino, Enzo; Bruschi, Niccolò and Borri, Claudio	2022	Renewable Energy: An International Journal	Did not mention resilience
Reducing rotor speed variations of floating wind turbines by compensation of non-minimum phase zeros.	Fischer, Boris	2013	IET Renewable Power Generation (Wiley-Blackwell)	Did not mention resilience
How sensitive is a carbon-neutral power sector to climate change? The interplay between hydro, solar and wind for Portugal	Fortes, Patrícia; Simoes, Sofia G.; Amorim, Filipa; Siggini, Gildas; Sessa, Valentina; Saint-Drenan, Yves-Marie; Carvalho, Sílvia; Mujtaba, Babar; Diogo, Paulo and Assoumou, Edi	2022	Energy	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Optimal layout design of floating offshore wind farms.	Froese, Gabrielle; Ku, Shan Yu; Kheirabadi, Ali C. and Nagamune, Ryozo	2022	Renewable Energy: An International Journal	Did not mention resilience
Study on aerodynamic performance and wake characteristics of a floating offshore wind turbine under pitch motion.	Fu, Shifeng; Li, Zheng; Zhu, Weijun; Han, Xingxing; Liang, Xiaoling; Yang, Hua and Shen, Wenzhong	2023	Renewable Energy: An International Journal	Did not mention resilience
SEM-REV offshore energy site wind-wave bivariate statistics by hindcast.	Gaidai, Oleg; Xu, Xiaosen; Wang, Junlei; Ye, Renchuan; Cheng, Yong and Karpa, Oleh	2020	Renewable Energy: An International Journal	Did not mention resilience

A semi-coupled aero-servo-hydro numerical model for floating vertical axis wind turbines operating on TLPs.	Gao, Ju; Griffith, D. Todd; Sakib, Mohammad Sadman and Boo, Sung Youn	2022	Renewable Energy: An International Journal	Did not mention resilience
Dynamic response and power production of a floating integrated wind, wave and tidal energy system.	Gao, Yan; Yuan, Zhiming; Day, Sandy; Li, Liang and Hu, Zhiqiang	2018	Renewable Energy: An International Journal	Did not mention resilience
Real-time monitoring, prognosis, and resilient control for wind turbine systems	Gao, Zhiwei and Sheng, Shuangwen	2018	Renewable Energy	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Preventive maintenance scheduling of multi energy microgrid to enhance the resiliency of system	Gargari, Milad Zamani; Hagh, Mehrdad Tarafdar and Zadeh, Saeid Ghassem	2021	Energy	No specific mention of FOWT
Structural capacity and the 20 MW wind turbine.	Garvey, S. D.	2010	Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power & Energy (Sage Publications, Ltd.)	Did not mention resilience
Compensation of a hybrid platform dynamics using wave energy converters in different sea state conditions.	Gaspar, J.F.; Kamarlouei, M.; Thiebaut, F. and Guedes Soares, C.	2021	Renewable Energy: An International Journal	Did not mention resilience
Human reliability assessment for complex physical operations in harsh operating conditions.	Golestani, Nima; Abbassi, Rouzbeh; Garaniya, Vikram; Asadnia, Mohsen and Khan, Faisal	2020	Process Safety & Environmental Protection: Transactions of the Institution of Chemical Engineers Part B	Did not mention resilience; no specific mention of FOWT
Experimental observations of active blade pitch and generator control influence on floating wind turbine response.	Goupee, Andrew J.; Kimball, Richard W. and Dagher, Habib J.	2017	Renewable Energy: An International Journal	Did not mention resilience
Wind turbine unsteady aerodynamics and performance by a free-wake panel method.	Greco, Luca and Testa, Claudio	2021	Renewable Energy: An International Journal	Did not mention resilience
Intersecting near-optimal spaces: European power systems with more resilience to weather variability	Grochowicz, Aleksander; van Greevenbroek, Koen; Benth, Fred Espen and Zeyringer, Marianne	2023	Energy Economics	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Chapter 5 - Reshaping Equilibria: Renewable Energy Mega-Projects and Energy Security - Low-carbon Energy Security from a European Perspective	Gruenig, M. and O'Donnell, B.	2016		No specific mention of FOWT
Effect of coupled platform pitch-surge motions on the aerodynamic characters of a horizontal floating offshore wind turbine.	Guo, Yize; Wang, Xiaodong; Mei, Yuanhang; Ye, Zhaoliang and Guo, Xiaojiang	2022	Renewable Energy: An International Journal	Did not mention resilience
Hydrodynamics-based floating wind turbine support platform optimization: A basis function approach.	Hall, Matthew; Buckham, Brad and Crawford, Curran	2014	Renewable Energy: An International Journal	Did not mention resilience
Platform position control of floating wind turbines using aerodynamic force.	Han, Chenlu and Nagamune, Ryozo	2020	Renewable Energy: An International Journal	Did not mention resilience
Seeking for a climate change mitigation and adaptation nexus: Analysis of a long-term power system expansion	Handayani, Kamia; Filatova, Tatiana; Krozer, Yoram and Anugrah, Pinto	2020	Applied Energy	Resilience not discussed with respect to FOWT; no specific mention of FOWT
LQG control for hydrodynamic compensation on large floating wind turbines.	Hawari, Qusay; Kim, Taeseong; Ward, Christopher and Fleming, James	2023	Renewable Energy: An International Journal	Did not mention resilience
Multi-body dynamics modeling and TMD optimization based on the improved AFSA for floating wind turbines.	He, Jiao; Jin, Xin; Xie, S.Y.; Cao, Le; Lin, Yifan and Wang, Ning	2019	Renewable Energy: An International Journal	Did not mention resilience
Integrating renewable sources into energy system for smart city as a sagacious strategy towards clean and sustainable process	Hoang, Anh Tuan; Pham, Van Viet and Nguyen, Xuan Phuong	2021	Journal of Cleaner Production	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Surge analysis on wind farm considering lightning strike to multi-blade.	Hosseini, S.M Amin; Mohammadirad, Amir; Shayegani Akmal, Amir Abbas	2022	Renewable Energy: An International Journal	Resilience not discussed with respect to FOWT;

				no specific mention of FOWT
Towards the next generation of smart grids: Semantic and holonic multi-agent management of distributed energy resources	Howell, Shaun; Rezgui, Yacine; Hippolyte, Jean-Laurent; Jayan, Bejay and Li, Haijiang	2017	Renewable and Sustainable Energy Reviews	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Implementation and evaluation of control strategies based on an open controller for a 10 MW floating wind turbine.	Hu, Ruiqi; Le, Conghuan; Gao, Zhen; Ding, Hongyan and Zhang, Puyang	2021	Renewable Energy: An International Journal	Did not mention resilience
Fully coupled aero-hydrodynamic analysis of a biomimetic fractal semi-submersible floating offshore wind turbine under wind-wave excitation conditions.	Huang, Haoda; Liu, Qingsong; Yue, Minnan; Miao, Weipao; Wang, Peilin and Li, Chun	2023	Renewable Energy: An International Journal	Did not mention resilience
A generic method for analyzing the risks to energy systems	Hughes, Larry; de Jong, Moniek and Wang, Xiao Qin	2016	Applied Energy	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Dedicated large-scale floating offshore wind to hydrogen: Assessing design variables in proposed typologies.	Ibrahim, Omar S.; Singlitico, Alessandro; Proskovics, Roberts; McDonagh, Shane; Desmond, Cian and Murphy, Jerry D.	2022	Renewable & Sustainable Energy Reviews	Did not mention resilience
Prediction of dynamic response of semi-submersible floating offshore wind turbine using augmented Morison's equation with frequency dependent hydrodynamic coefficients.	Ishihara, Takeshi and Zhang, Shining	2019	Renewable Energy: An International Journal	Did not mention resilience
Method for spatiotemporal wind power generation profile under hurricanes: U.S.-Caribbean super grid proposition	Itiki, Rodney; Manjrekar, Madhav; Di Santo, Silvio Giuseppe and Itiki, Cinthia	2023	Renewable and Sustainable Energy Reviews	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Lightweight design of direct-drive wind turbine electrical generators: A comparison between steel and composite material structures	Jaen-Sola, Pablo; McDonald, Alasdair S. and Oterkus, Erkan	2019	Ocean Engineering	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Effects of heave plates on the global performance of a multi-unit floating offshore wind turbine.	Jang, Ha-Kun; Park, Sewan; Kim, Moo-Hyun; Kim, Kyong-Hwan and Hong, Keyyong	2019	Renewable Energy: An International Journal	Did not mention resilience
Unsteady aerodynamics of offshore floating wind turbines in platform pitching motion using vortex lattice method.	Jeon, Minu; Lee, Seungmin and Lee, Soogab	2014	Renewable Energy: An International Journal	Did not mention resilience
A lifecycle financial analysis model for offshore wind farms.	Judge, Frances; McAuliffe, Fiona Devoy; Sperstad, Iver Bakken; Chester, Rachel; Flannery, Brian; Lynch, Katie and Murphy, Jimmy	2019	Renewable & Sustainable Energy Reviews	Did not mention resilience
Experimental study of wave energy converter arrays adapted to a semi-submersible wind platform.	Kamarlouei, M.; Gaspar, J.F.; Calvario, M.; Hallak, T.S.; Mendes, M.J.G.C.; Thiebaut, F. and Guedes Soares, C.	2022	Renewable Energy: An International Journal	Did not mention resilience
Fault Tree Analysis of floating offshore wind turbines.	Kang, Jichuan; Sun, Liping and Guedes Soares, C.	2019	Renewable Energy: An International Journal	Did not mention resilience
Modeling aspects of a floating wind turbine for coupled wave-wind-induced dynamic analyses	Karimirad, Madjid	2013	Renewable Energy: An International Journal	Did not mention resilience
V-shaped semisubmersible offshore wind turbine: An alternative concept for offshore wind technology.	Karimirad, Madjid and Michailides, Constantine	2015	Renewable Energy: An International Journal	Did not mention resilience
Floating offshore wind - Economic and ecological challenges of a TLP solution.	Kausche, Michael; Dahlhaus, Frank; Adam, Frank and Großmann, Jochen	2018	Renewable Energy: An International Journal	Did not mention resilience
Numerical analysis and comparison study of the 1:60 scaled DTU 10 MW TLP floating wind turbine.	Kim, T.; Madsen, F.J.; Bredmose, H. and Pegalajar-Jurado, A.	2023	Renewable Energy: An International Journal	Did not mention resilience
Offshore wind farms as additional coolant power sources to enhance seismic resilience of nuclear power plants - A case study	Kolli, Sumaja; Dammala, Pradeep Kumar; Bhattacharya, Subhamoy; Fan, Chen; Wang, Tao and Cui, Liang	2023	Nuclear Engineering and Design	Resilience not discussed with respect to FOWT

Offshore wind energy: A comparative analysis of UK, USA and India	Kota, Sandhya; Bayne, Stephen B. and Nimmagadda, Sandeep	2015	Renewable and Sustainable Energy Reviews	Resilience not discussed with respect to FOWT
Simulation of the impact of parameter manipulations due to cyber-attacks and severe electrical faults on Offshore Wind Farms	Kulev, Nikolai and Torres, Frank Sill	2022	Ocean Engineering	Resilience not discussed with respect to FOWT; no specific mention of FOWT
The transitional states of a floating wind turbine during high levels of surge.	Kyle, Ryan and Früh, Wolf-Gerrit	2022	Renewable Energy: An International Journal	Did not mention resilience
Reversible solid oxide cell coupled to an offshore wind turbine as a poly-generation energy system for auxiliary backup generation and hydrogen production	Lamagna, Mario; Ferrario, Andrea Monforti; Astiaso Garcia, Davide; Mcphail, Stephen and Comodi, Gabriele	2022	Energy Reports	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Life-cycle cost analysis of floating offshore wind farms.	Laura, Castro-Santos and Vicente, Diaz-Casas	2014	Renewable Energy: An International Journal	Did not mention resilience
Effects of platform motions on aerodynamic performance and unsteady wake evolution of a floating offshore wind turbine.	Lee, Hakjin and Lee, Duck-Joo	2019	Renewable Energy: An International Journal	Did not mention resilience
Preliminary design of a floating support structure for a 5MW offshore wind turbine	Lefebvre, Simon and Collu, Maurizio	2012	Ocean Engineering	Did not mention resilience
The influence of different wind and wave conditions on the energy yield and downtime of a Spar-buoy floating wind turbine.	Lerch, Markus; De-Prada-Gil, Mikel and Molins, Climent	2019	Renewable Energy: An International Journal	Did not mention resilience
Future material requirements for global sustainable offshore wind energy development	Li, Chen; Mogollón, José M.; Tukker, Arnold; Dong, Jianning; von Terzi, Dominic; Zhang, Chunbo and Steubing, Bernhard	2022	Renewable and Sustainable Energy Reviews	Resilience not discussed with respect to FOWT design or operation
Experimental and numerical investigation of nonlinear diffraction wave loads on a semi-submersible wind turbine.	Li, Haoran and Bachynski, Erin E.	2021	Renewable Energy: An International Journal	Did not mention resilience
A developed failure mode and effect analysis for floating offshore wind turbine support structures.	Li, He; Diaz, H. and Guedes Soares, C.	2021	Renewable Energy: An International Journal	Did not mention resilience
Full-coupled analysis of offshore floating wind turbine supported by very large floating structure with consideration of hydroelasticity.	Li, Liang	2022	Renewable Energy: An International Journal	Did not mention resilience
Model test research of a semisubmersible floating wind turbine with an improved deficient thrust force correction approach.	Li, Liang; Gao, Yan; Hu, Zhiqiang; Yuan, Zhiming; Day, Sandy and Li, Haoran	2018	Renewable Energy: An International Journal	Did not mention resilience
Investigation on long-term extreme response of an integrated offshore renewable energy device with a modified environmental contour method	Li, Liang; Yuan, Zhi-Ming; Gao, Yan; Zhang, Xinshu and Tezdogan, Tahsin	2019	Renewable Energy	Did not mention resilience
Short-term extreme response and fatigue damage of an integrated offshore renewable energy system.	Li, Liang; Yuan, Zhiming; Gao, Yan and Cheng, Zhengshun	2018	Renewable Energy: An International Journal	Did not mention resilience
State-of-the-art review of the flexibility and feasibility of emerging offshore and coastal ocean energy technologies in East and Southeast Asia.	Li, Ming; Luo, Haojie; Zhou, Shijie; Senthil Kumar, Gokula Manikandan; Guo, Xinman; Law, Tin Chung and Cao, Sunliang	2022	Renewable & Sustainable Energy Reviews	Resilience not discussed with respect to FOWT
Long-term assessment of a floating offshore wind turbine under environmental conditions with multivariate dependence structures.	Li, Xuan and Zhang, Wei	2020	Renewable Energy: An International Journal	Did not mention resilience
Long-term fatigue damage assessment for a floating offshore wind turbine under realistic environmental conditions.	Li, Xuan and Zhang, Wei	2020	Renewable Energy: An International Journal	Did not mention resilience
Transient response of a SPAR-type floating offshore wind turbine with fractured mooring lines.	Li, Yan; Zhu, Qiang; Liu, Liqin and Tang, Yougang	2018	Renewable Energy: An International Journal	Did not mention resilience

Flexible dynamic modeling and analysis of drive train for Offshore Floating Wind Turbine.	Li, Zhanwei; Wen, Binrong; Wei, Kexiang; Yang, Wenxian; Peng, Zhike and Zhang, Wenming	2020	Renewable Energy: An International Journal	Did not mention resilience
Energy utilisation strategy in an offshore floating wind system with variable production of fresh water and hybrid energy storage.	Lilas, Theodoros; Dagkinis, Ioannis; Stefanakou, Afrokomi-Afroula; Antoniou, Evanthia; Nikitakos, Nikitas; Maglara, Artemis and Vatistas, Athanasios	2022	International Journal of Sustainable Energy	Did not mention resilience
Investment needs for climate change adaptation measures of electricity power plants in the EU	Lise, Wietze and van der Laan, Jeroen	2015	Energy for Sustainable Development	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Design loads for a large wind turbine supported by a semi-submersible floating platform.	Liu, Jinsong; Thomas, Edwin; Goyal, Anshul and Manuel, Lance	2019	Renewable Energy: An International Journal	Did not mention resilience
Fault diagnosis of the 10MW Floating Offshore Wind Turbine Benchmark: A mixed model and signal-based approach.	Liu, Yichao; Ferrari, Riccardo; Wu, Ping; Jiang, Xiaoli; Li, Sunwei and Wingerden, Jan-Willem van	2021	Renewable Energy: An International Journal	Did not mention resilience
Developments in semi-submersible floating foundations supporting wind turbines: A comprehensive review.	Liu, Yichao; Li, Sunwei; Yi, Qian and Chen, Daoyi	2016	Renewable & Sustainable Energy Reviews	Did not mention resilience
Establishing a fully coupled CFD analysis tool for floating offshore wind turbines.	Liu, Yuanchuan; Xiao, Qing; Incecik, Atilla; Peyrard, Christophe and Wan, Decheng	2017	Renewable Energy: An International Journal	Did not mention resilience
Hydrodynamic coefficients and pressure loads on heave plates for semi-submersible floating offshore wind turbines: A comparative analysis using large scale models.	Lopez-Pavon, Carlos and Souto-Iglesias, Antonio	2015	Renewable Energy: An International Journal	Did not mention resilience
Review of control technologies for floating offshore wind turbines.	López-Queija, Javier; Robles, Eider; Jugo, Josu and Alonso-Quesada, Santiago	2022	Renewable & Sustainable Energy Reviews	Did not mention resilience
Lost generation: Reflections on resilience and flexibility from an energy system architecture perspective	Lowe, Robert J.; Chiu, Lai Fong; Pye, Steve; Cassarino, Tiziano Gallo; Scamman, Daniel and Solano-Rodriguez, Baltazar	2021	Applied Energy	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Scaling of slow-drift motion with platform size and its importance for floating wind turbines	Lupton, R. C. and Langley, R. S.	2017	Renewable Energy	Did not mention resilience
Complex but negligible: Non-linearity of the inertial coupling between the platform and blades of floating wind turbines.	Lupton, Richard C. and Langley, Robin S.	2019	Renewable Energy: An International Journal	Did not mention resilience
On the resilience of modern power systems: A complex network perspective	Ma, Xiangyu; Zhou, Huijie and Li, Zhiyi	2021	Renewable and Sustainable Energy Reviews	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Wave forecast and its application to the optimal control of offshore floating wind turbine for load mitigation.	Ma, Yu; Sclavounos, Paul D.; Cross-Whiter, John and Arora, Dhiraj	2018	Renewable Energy: An International Journal	Did not mention resilience
Analyzing scaling effects on offshore wind turbines using CFD.	Make, Michel and Vaz, Guilherme	2015	Renewable Energy: An International Journal	Did not mention resilience
Mapping of the levelised cost of energy for floating offshore wind in the European Atlantic.	Martinez, A. and Iglesias, G.	2022	Renewable & Sustainable Energy Reviews	Did not mention resilience
The impact of downtime over the long-term energy yield of a floating wind farm.	Martini, M.; Guanche, R.; Losada-Campa, I. and Losada, I.J.	2018	Renewable Energy: An International Journal	Did not mention resilience
Operation and maintenance for floating wind turbines: A review.	McMorland, J.; Collu, M.; McMillan, D. and Carroll, J.	2022	Renewable & Sustainable Energy Reviews	Did not mention resilience
Horizontal and vertical axis wind turbines on existing jacket platforms: Part 2 - Retrofitting activities	Mendes, Paulo; Correia, José A.F.O.; Arrojado, João; Heo, Taemin; Fantuzzi, Nicholas and Manuel, Lance	2022	Structures	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Experimental study of floating wind turbine control on a TetraSub floater with tower velocity feedback gain.	Meng, Fanzhong; Lio, Wai Hou; Pegalajar-Jurado, Antonio; Pierella, Fabio; Hofschulte, Eric Nicolas; Santaya, Alex Gandia and Bredmose, Henrik	2023	Renewable Energy: An International Journal	Did not mention resilience

Analytical study on the aerodynamic and hydrodynamic damping of the platform in an operating spar-type floating offshore wind turbine.	Meng, Qingshen; Hua, Xugang; Chen, Chao; Zhou, Shuai; Liu, Feipeng and Chen, Zhengqing	2022	Renewable Energy: An International Journal	Did not mention resilience
A new resilient risk management model for Offshore Wind Turbine maintenance	Mentes, Ayhan and Turan, Osman	2019	Safety Science	No specific mention of FOWT
Floating offshore wind turbine aerodynamics: Trends and future challenges.	Micallef, Daniel and Rezaeiha, Abdolrahim	2021	Renewable & Sustainable Energy Reviews	Did not mention resilience
Loading effects on floating offshore horizontal axis wind turbines in surge motion.	Micallef, Daniel and Sant, Tonio	2015	Renewable Energy: An International Journal	Did not mention resilience
Experimental study of the functionality of a semisubmersible wind turbine combined with flap-type Wave Energy Converters.	Michailides, Constantine and Gao, Zhen and Moan, Torgeir	2016	Renewable Energy: An International Journal	Did not mention resilience
Sustainable development of energy, water and environmental systems in the changing world	Mikulčić, Hrvoje; Baleta, Jakov; Zhang, Zhien and Klemeš, Jirí Jaromír	2023	Journal of Cleaner Production	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Sources of grid reliability services	Milligan, Michael	2018	The Electricity Journal	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Dynamic response and power performance of a combined Spar-type floating wind turbine and coaxial floating wave energy converter	Muliawan, Made Jaya; Karimirad, Madjid and Moan, Torgeir	2013	Renewable Energy: An International Journal	Did not mention resilience
Levelised cost of energy for offshore floating wind turbines in a life cycle perspective.	Myhr, Anders; Bjerkseter, Catho; Ågotnes, Anders and Nygaard, Tor A.	2014	Renewable Energy: An International Journal	Did not mention resilience
17 - Modeling and evaluation of power system vulnerability against the hurricane - Decentralized Frameworks for Future Power Systems	Nasri, Amirhossein; Abdollahi, Amir; Rashidinejad, Masoud and Peng, Wei	2022		Resilience not discussed with respect to FOWT; no specific mention of FOWT
7 - Fatigue as a design driver for composite wind turbine blades - Advances in Wind Turbine Blade Design and Materials (Second Edition)	Nijssen, R.P.L. and Brøndsted, P.	2023		Did not mention resilience; no specific mention of FOWT
16 - Wind Energy - Future Energy (Third Edition)	Nikitas, Georgios; Bhattacharya, Subhamoy and Vimalan, Nathan	2020		Resilience not discussed with respect to FOWT
10 - Wind power: A sustainable way to limit climate change - Managing Global Warming	Nikitas, Georgios; Bhattacharya, Subhamoy; Vimalan, Nathan; Demirci, Hasan Emre; Nikitas, Nikolaos and Kumar, Prashant	2019		Did not mention resilience
Effects of meteorological and climatological factors on extremely high residual load and possible future changes	Ohba, Masamichi; Kanno, Yuki and Bando, Shigeru	2023	Renewable and Sustainable Energy Reviews	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Uncertainty modeling in reliability analysis of floating wind turbine support structures.	Okpokparoro, Salem and Sriramula, Srinivas	2021	Renewable Energy: An International Journal	Did not mention resilience
Robust predictive sensorless control method for doubly fed induction generator controlled by matrix converter.	Ortatepe, Zafer and Karaarslan, Ahmet	2020	International Transactions on Electrical Energy Systems	Did not mention resilience; no specific mention of FOWT
An evaluation of offshore wind power production by floatable systems: A case study from SW Portugal	Pacheco, A.; Gorbeña, E.; Sequeira, C. and Jerez, S.	2017	Energy	Did not mention resilience
Research on variable pitch control strategy of direct-driven offshore wind turbine using KELM wind speed soft sensor	Pan, Lin; Xiong, Yong; Zhu, Ze and Wang, Leichong	2022	Renewable Energy	No specific mention of FOWT
Technical challenges in floating offshore wind turbine upscaling: A critical analysis based on the NREL 5 MW and IEA 15 MW Reference Turbines.	Papi, F. and Bianchini, A.	2022	Renewable & Sustainable Energy Reviews	Did not mention resilience

Dynamic modeling of nylon mooring lines for a floating wind turbine	Pham, Hong-Duc; Cartraud, Patrice; Schoefs, Franck; Soulard, Thomas and Berhault, Christian	2019	Applied Ocean Research	Did not mention resilience
Modes of response of an offshore wind turbine with directional wind and waves	Philippe, M.; Babarit, A. and Ferrant, P.	2013	Renewable Energy: An International Journal	Did not mention resilience
Maintenance optimization in industry 4.0	Pinciroli, Luca; Baraldi, Piero and Zio, Enrico	2023	Reliability Engineering & System Safety	Resilience of offshore turbines discussed; no specific mention of FOWT
Optimization of the Operation and Maintenance of renewable energy systems by Deep Reinforcement Learning	Pinciroli, Luca; Baraldi, Piero; Ballabio, Guido; Compare, Michele and Zio, Enrico	2022	Renewable Energy	No specific mention of FOWT
Synthesis of a regenerative energy system - beyond carbon emissions neutrality	Potrč, Sanja; Nemet, Andreja; Čuček, Lidija; Varbanov, Petar Sabev and Kravanja, Zdravko	2022	Renewable and Sustainable Energy Reviews	No specific mention of FOWT
3.04 - Renewable Energy Resources - Ocean Energy: Wind-Wave-Tidal-Sea Currents - Climate Vulnerability	Pryor, S.C. and Barthelmie, R.J.	2013		Resilience not discussed with respect to FOWT; no specific mention of FOWT
Control of power generated by a floating offshore wind turbine perturbed by sea waves.	Pustina, L.; Lugni, C.; Bernardini, G.; Serafini, J. and Gennaretti, M.	2020	Renewable & Sustainable Energy Reviews	Did not mention resilience
A novel resonant controller for sea-induced rotor blade vibratory loads reduction on floating offshore wind turbines.	Pustina, L.; Serafini, J.; Pasquali, C.; Solero, L.; Lidozzi, A. and Gennaretti, M.	2023	Renewable & Sustainable Energy Reviews	Did not mention resilience
Resilience evaluation of maritime liquid cargo emergency response by integrating FRAM and a BN: A case study of a propylene leakage emergency scenario	Qiao, Weiliang; Ma, Xiaoxue; Liu, Yang and Deng, Wanyi	2022	Ocean Engineering	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Comparative study of short-term extreme responses and fatigue damages of a floating wind turbine using two different blade models	Qu, Xiaoqi; Li, Yan; Tang, Yougang; Chai, Wei and Gao, Zhen	2020	Applied Ocean Research	Did not mention resilience
CFD simulation of a floating offshore wind turbine system using a variable-speed generator-torque controller.	Quallen, Sean and Xing, Tao	2016	Renewable Energy: An International Journal	Did not mention resilience
Ocean renewable energy development in Southeast Asia: Opportunities, risks and unintended consequences	Quirapas, M.A.J.R. and Taeihagh, A.	2021	Renewable and Sustainable Energy Reviews	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Resilience assessment of offshore structures subjected to ice load considering complex dependencies	Ramadhani, Adhitya; Khan, Faisal; Colbourne, Bruce; Ahmed, Salim and Taleb-Berrouane, Mohammed	2022	Reliability Engineering & System Safety	Resilience not discussed with respect to FOWT; no specific mention of FOWT
A multivariate model to estimate environmental load on an offshore structure	Ramadhani, Adhitya; Khan, Faisal; Colbourne, Bruce; Ahmed, Salim and Taleb-Berrouane, Mohammed	2023	Ocean Engineering	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Experimental and numerical study of dynamic responses of a new combined TLP type floating wind turbine and a wave energy converter under operational conditions.	Ren, Nianxin; Ma, Zhe; Shan, Baohua; Ning, Dezhi and Ou, Jinping	2020	Renewable Energy: An International Journal	Did not mention resilience
Design optimization of dynamic inter-array cable systems for floating offshore wind turbines.	Rentschler, Manuel U.T.; Adam, Frank and Chainho, Paulo	2019	Renewable & Sustainable Energy Reviews	Did not mention resilience
Wake interactions of two tandem floating offshore wind turbines: CFD analysis using actuator disc model.	Rezaeiha, Abdolrahim and Micallef, Daniel	2021	Renewable Energy: An International Journal	Did not mention resilience
Wake to wake interaction of floating wind turbine models in free pitch motion: An eddy viscosity and mixing length approach.	Rockel, Stanislav; Peinke, Joachim; Hölling, Michael and Cal, Raúl Bayoán	2016	Renewable Energy: An International Journal	Did not mention resilience

Dynamic wake development of a floating wind turbine in free pitch motion subjected to turbulent inflow generated with an active grid.	Rockel, Stanislav; Peinke, Joachim; Hölling, Michael and Cal, Raúl Bayoán	2017	Renewable Energy: An International Journal	Did not mention resilience
Strongly-coupled aeroelastic free-vortex wake framework for floating offshore wind turbine rotors. Part 1: Numerical framework.	Rodriguez, Steven N. and Jaworski, Justin W.	2019	Renewable Energy: An International Journal	Did not mention resilience
Strongly-coupled aeroelastic free-vortex wake framework for floating offshore wind turbine rotors. Part 2: Application.	Rodriguez, Steven N. and Jaworski, Justin W.	2020	Renewable Energy: An International Journal	Did not mention resilience
Techno-economic analysis of a hydraulic transmission for floating offshore wind turbines.	Roggenburg, Michael; Esquivel-Puentes, Helber A.; Vacca, Andrea; Bocanegra Evans, Humberto; Garcia-Bravo, Jose M.; Warsinger, David M.; Ivantysynova, Monika and Castillo, Luciano	2020	Renewable Energy: An International Journal	Did not mention resilience
A novel reduced column section approach for the seismic protection of wind turbines	Rostami, Rohollah and Tombari, Alessandro	2023	Engineering Structures	No specific mention of FOWT
"We could have been leaders": The rise and fall of offshore wind energy on the political agenda in Ireland	Roux, Jean-Pierre; Fitch-Roy, Oscar; Devine-Wright, Patrick and Ellis, Geraint	2022	Energy Research & Social Science	Resilience not discussed with respect to FOWT; no specific mention of FOWT
State of the art in fatigue modelling of composite wind turbine blades	Rubiella, Clemence; Hessabi, Cyrus A. and Fallah, Arash Soleiman	2018	International Journal of Fatigue	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Big data and stream processing platforms for Industry 4.0 requirements mapping for a predictive maintenance use case	Sahal, Radhya; Breslin, John G. and Ali, Muhammad Intizar	2020	Journal of Manufacturing Systems	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Structural health monitoring of tendons in a multibody floating offshore wind turbine under varying environmental and operating conditions.	Sakaris, Christos S.; Yang, Yang; Bashir, Musa; Michailides, Constantine; Wang, Jin; Sakellariou, John S. and Li, Chun	2021	Renewable Energy: An International Journal	Did not mention resilience
Aerodynamic dissipation effects on the rotating blades of floating wind turbines.	Salehyar, Sara and Zhu, Qiang	2015	Renewable Energy: An International Journal	Did not mention resilience
Fully-coupled time-domain simulations of the response of a floating wind turbine to non-periodic disturbances.	Salehyar, Sara; Li, Yan and Zhu, Qiang	2017	Renewable Energy: An International Journal	Did not mention resilience
Wind tunnel and numerical study of a floating offshore wind turbine based on the cyclic pitch control.	Sang, Le Quang; Li, Qing'an; Cai, Chang; Maeda, Takao; Kamada, Yasunari; Wang, Xinbao; Zhou, Shuni and Zhang, Fanghong	2021	Renewable Energy: An International Journal	Did not mention resilience
Experimental investigation of the cyclic pitch control on a horizontal axis wind turbine in diagonal inflow wind condition	Sang, Le Quang; Takao, Maeda; Kamada, Yasunari and Li, Qing'an	2017	Energy	Did not mention resilience
Chapter 18 - SCADA and smart energy grid control automation - Smart Energy Grid Engineering	Sayed, K. and Gabbar, H.A.	2017		Did not mention resilience; no specific mention of FOWT
Socio-economic impact of a 200 MW floating wind farm in Gran Canaria.	Schallenberg-Rodriguez, J. and Inchausti-Sintes, F.	2021	Renewable & Sustainable Energy Reviews	Did not mention resilience
Development of a free vortex wake method code for offshore floating wind turbines	Sebastian, T. and Lackner, M.A.	2012	Renewable Energy: An International Journal	Did not mention resilience
Review of scaling laws applied to floating offshore wind turbines.	Sergiienko, N.Y.; da Silva, L.S.P.; Bachynski-Poli𝑓á, E.E.; Cazzolato, B.S.; Arjomandi, M. and Ding, B.	2022	Renewable & Sustainable Energy Reviews	Did not mention resilience
Hydrodynamic response of a stepped-spar floating wind turbine: Numerical modelling and tank testing	Sethuraman, Latha and Venugopal, Vengatesan	2013	Renewable Energy: An International Journal	Did not mention resilience
Structural integrity of a direct-drive generator for a floating wind turbine.	Sethuraman, Latha; Venugopal, Vengatesan; Zavvos, Aristeidis and Mueller, Markus	2014	Renewable Energy: An International Journal	Did not mention resilience

A 5MW direct-drive generator for floating spar-buoy wind turbine: Development and analysis of a fully coupled Mechanical model.	Sethuraman, Latha; Xing, Yihan; Gao, Zhen; Venugopal, Vengatesan; Mueller, Markus and Moan, Torgeir	2014	Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power & Energy (Sage Publications, Ltd.)	Did not mention resilience
A fuzzy analytic network process model to mitigate the risks associated with offshore wind farms	Shafiee, Mahmood	2015	Expert Systems with Applications	Resilience not discussed with respect to FOWT; no specific mention of FOWT
A synthesis of feasible control methods for floating offshore wind turbine system dynamics.	Shah, Kamran Ali; Meng, Fantai; Li, Ye; Nagamune, Ryozo; Zhou, Yarong; Ren, Zhengru and Jiang, Zhiyu	2021	Renewable & Sustainable Energy Reviews	Did not mention resilience
Dynamic response and viscous effect analysis of a TLP-type floating wind turbine using a coupled aero-hydro-mooring dynamic code.	Shen, Macheng; Hu, Zhiqiang and Liu, Geliang	2016	Renewable Energy: An International Journal	Did not mention resilience
Study of the unsteady aerodynamics of floating wind turbines	Shen, Xin; Chen, Jinge; Hu, Ping; Zhu, Xiaocheng and Du, Zhaohui	2018	Energy	Did not mention resilience
The unsteady aerodynamics of floating wind turbine under platform pitch motion.	Shen, Xin; Hu, Ping; Chen, Jinge; Zhu, Xiaocheng and Du, Zhaohui	2018	Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power & Energy (Sage Publications, Ltd.)	Did not mention resilience
Load control and unsteady aerodynamics for floating wind turbines.	Shen, Xin; Zhu, Xiaocheng and Du, Zhaohui	2021	Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power & Energy (Sage Publications, Ltd.)	Did not mention resilience
Gain Scheduling H2/H∞ Structural Control of a Floating Wind Turbine	Si, Yulin and Karimi, Hamid Reza	2014	IFAC Proceedings Volumes	Did not mention resilience
Nonlinear dynamics of a floating offshore wind turbine platform via statistical quadratization - Mooring, wave and current interaction	Silva, L.S.P.; Cazzolato, B.; Sergiienko, N.Y. and Ding, B.	2021	Ocean Engineering	Did not mention resilience
Slow-drift of a floating wind turbine: An assessment of frequency-domain methods based on model tests.	Simos, Alexandre N.; Ruggeri, Felipe; Watai, Rafael A.; Souto-Iglesias, Antonio and Lopez-Pavon, Carlos	2018	Renewable Energy: An International Journal	Did not mention resilience
Liquid metal battery storage in an offshore wind turbine: Concept and economic analysis	Simpson, J.G.; Hanrahan, G.; Loth, E.; Koenig, G.M. and Sadoway, D.R.	2021	Renewable and Sustainable Energy Reviews	Resilience not discussed with respect to FOWT
A progressive study into offshore wind farm maintenance optimisation using risk based failure analysis	Sinha, Y. and Steel, J.A.	2015	Renewable and Sustainable Energy Reviews	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Changing landscape of India's renewable energy and the contribution of wind energy	Siram, Ojing; Sahoo, Niranjan and Saha, Ujjwal K.	2022	Cleaner Engineering and Technology	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Bow-ties use for high-consequence marine risks of offshore structures.	Slatnick, Sam; Angevine, D.; Cranefield, J. and Maddox, C.; Overstake, M.; Palmer, L. and Younan, A.	2022	Process Safety & Environmental Protection: Transactions of the Institution of Chemical Engineers Part B	Did not mention resilience; no specific mention of FOWT
Dynamic reliability analysis of a floating offshore wind turbine under wind-wave joint excitations via probability density evolution method.	Song, Yupeng; Basu, Biswajit; Zhang, Zili; Sørensen, John Dalsgaard; Li, Jie and Chen, Jianbing	2021	Renewable Energy: An International Journal	Did not mention resilience
2.10 - Electrical Parts, Control Systems and Power Electronics of Wind Turbines - Comprehensive Renewable Energy (Second Edition)	Stavrakakis, G.S. and Pouliezos, A.	2022		Did not mention resilience; no specific mention of FOWT
The German energy transition as a regime shift	Strunz, Sebastian	2014	Ecological Economics	Resilience not discussed with respect to FOWT; no specific mention of FOWT

Recent advances in experimental and numerical methods for dynamic analysis of floating offshore wind turbines - An integrated review.	Subbulakshmi, A.; Verma, Mohit; Keerthana, M.; Sasmal, Saptarshi; Harikrishna, P. and Kapuria, Santosh	2022	Renewable & Sustainable Energy Reviews	Did not mention resilience
Dynamic response analysis of floating wind turbine platform in local fatigue of mooring.	Sun, Kang; Xu, Zifei; Li, Shujun; Jin, Jiangtao; Wang, Peilin; Yue, Minnan and Li, Chun	2023	Renewable Energy: An International Journal	Did not mention resilience
Development of a reliable simulation framework for techno-economic analyses on green hydrogen production from wind farms using alkaline electrolyzers	Superchi, Francesco; Papi, Francesco; Mannelli, Andrea; Balduzzi, Francesco; Ferro, Francesco Maria and Bianchini, Alessandro	2023	Renewable Energy	Resilience not discussed with respect to FOWT; no specific mention of FOWT
SPH simulation and experimental validation of the dynamic response of floating offshore wind turbines in waves.	Tan, Zhe; Sun, Peng-Nan; Liu, Nian-Nian; Li, Zhe; Lyu, Hong-Guan and Zhu, Rong-Hua	2023	Renewable Energy: An International Journal	Did not mention resilience
Analysis of the design of experiments of offshore wind turbine fatigue reliability design with Kriging surfaces	Teixeira, Rui; O'Connor, Alan; Nogal, Maria; Krishnan, Nandakumar and Nichols, James	2017	Procedia Structural Integrity	Did not mention resilience; no specific mention of FOWT
Experimental modelling of the dynamic behaviour of a spar buoy wind turbine.	Tomasicchio, Giuseppe Roberto; D'Alessandro, Felice; Avossa, Alberto Maria; Riefolo, Luigia; Musci, Elena; Ricciardelli, Francesco and Vicinanza, Diego	2018	Renewable Energy: An International Journal	Did not mention resilience
Vibration and power regulation control of a floating wind turbine with hydrostatic transmission.	Tong, Xin and Zhao, Xiaowei	2021	Renewable Energy: An International Journal	Did not mention resilience
A flexibility-based approach for the design and management of floating offshore wind farms.	Torres-Rincón, Samuel; Bastidas-Arteaga, Emilio and Sánchez-Silva, Mauricio	2021	Renewable Energy: An International Journal	Did not mention resilience
Fully coupled aero-hydrodynamic analysis of a semi-submersible FOWT using a dynamic fluid body interaction approach.	Tran, Thanh Toan and Kim, Dong-Hyun	2016	Renewable Energy: An International Journal	Did not mention resilience
A CFD study into the influence of unsteady aerodynamic interference on wind turbine surge motion.	Tran, Thanh Toan and Kim, Dong-Hyun	2016	Renewable Energy: An International Journal	Did not mention resilience
Active control strategies for system enhancement and load mitigation of floating offshore wind turbines: A review.	Truong, Hoai Vu Anh; Dang, Tri Dung; Vo, Cong Phat and Ahn, Kyoung Kwan	2022	Renewable & Sustainable Energy Reviews	Did not mention resilience
Yaw motion of floating wind turbine platforms induced by pitch actuator fault in storm conditions.	Uzunoglu, E. and Guedes Soares, C.	2019	Renewable Energy: An International Journal	Did not mention resilience
Hydrodynamic design of a free-float capable tension leg platform for a 10 MW wind turbine	Uzunoglu, Emre and Guedes Soares, C.	2020	Ocean Engineering	Did not mention resilience
Understanding the variability of wind power costs	Valentine, Scott Victor	2011	Renewable and Sustainable Energy Reviews	Resilience not discussed with respect to FOWT; no specific mention of FOWT
15 - Offshore environmental loads and wind turbine design: impact of wind, wave, currents and ice - Wind Energy Systems	Van Der Tempel, J.; Diepeveen, N.F.B.; De Vries, W.E. and Cerda Salzmann, D.	2011		Resilience of offshore turbines discussed; no specific mention of FOWT
Meteorological conditions leading to extreme low variable renewable energy production and extreme high energy shortfall	van der Wiel, K.; Stoop, L.P.; van Zuijlen, B.R.H.; Blackport, R.; van den Broek, M.A. and Selten, F.M.	2019	Renewable and Sustainable Energy Reviews	No specific mention of FOWT
Can multi-use of the sea be safe? A framework for risk assessment of multi-use at sea	van Hoof, L.; van den Burg, S.W.K.; Banach, J.L.; Röckmann, C. and Goossen, M.	2020	Ocean & Coastal Management	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Energy critical infrastructures at risk from climate change: A state of the art review	Varianou Mikellidou, Cleo; Shakou, Louisa Marie; Boustras, Georgios and Dimopoulos, Christos	2018	Safety Science	Resilience of offshore turbines discussed; no specific mention of FOWT

How will renewable power generation be affected by climate change? The case of a Metropolitan Region in Northwest Germany	Wachsmuth, J.; Blohm, A.; Gößling-Reisemann, S.; Eickemeier, T.; Ruth, M.; Gasper, R. and Stührmann, S.	2013	Energy	No specific mention of FOWT
Stabilization of power output and platform motion of a floating offshore wind turbine-generator system using model predictive control based on previewed disturbances.	Wakui, Tetsuya; Nagamura, Atsushi and Yokoyama, Ryohei	2021	Renewable Energy: An International Journal	Did not mention resilience
Experimental and numerical comparisons of hydrodynamic responses for a combined wind and wave energy converter concept under operational conditions.	Wan, Ling; Gao, Zhen; Moan, Torgeir and Lugni, Claudio	2016	Renewable Energy: An International Journal	Did not mention resilience
Multibody dynamics of floating wind turbines with large-amplitude motion	Wang, Lei and Sweetman, Bert	2013	Applied Ocean Research	Did not mention resilience
Performance improvement for large floating wind turbine by using a non-linear pitch system based on neuro-adaptive fault-tolerant control.	Wang, Lei; Jin, Fangjun; Chen, Jiawei; Gao, Yang; Du, Xin; Zhang, Zhihong; Xu, Zhiliang and Yang, Jiongming	2022	IET Renewable Power Generation (Wiley-Blackwell)	Did not mention resilience
OC6 phase I: Improvements to the OpenFAST predictions of nonlinear, low-frequency responses of a floating offshore wind turbine platform.	Wang, Lu; Robertson, Amy; Jonkman, Jason and Yu, Yi-Hsiang	2022	Renewable Energy: An International Journal	Did not mention resilience
Influence of variability and uncertainty of wind and waves on fatigue damage of a floating wind turbine drivetrain.	Wang, Shuaishuai; Moan, Torgeir and Jiang, Zhiyu	2022	Renewable Energy: An International Journal	Did not mention resilience
A comparative study of fully coupled and de-coupled methods on dynamic behaviour of floating wind turbine drivetrains.	Wang, Shuaishuai; Moan, Torgeir and Nejad, Amir R.	2021	Renewable Energy: An International Journal	Did not mention resilience
Effects of bedplate flexibility on drivetrain dynamics: Case study of a 10 MW spar type floating wind turbine.	Wang, Shuaishuai; Nejad, Amir R.; Bachynski, Erin E. and Moan, Torgeir	2020	Renewable Energy: An International Journal	Did not mention resilience
A review of aerodynamic and wake characteristics of floating offshore wind turbines.	Wang, Xinbao; Cai, Chang; Cai, Shang-Gui; Wang, Tengyuan; Wang, Zekun; Song, Juanjuan; Rong, Xiaomin and Li, Qing'an	2023	Renewable & Sustainable Energy Reviews	Did not mention resilience
Investigation of a new analytical wake prediction method for offshore floating wind turbines considering an accurate incoming wind flow.	Wang, Yangwei; Lin, Jiahuan and Zhang, Jun	2022	Renewable Energy: An International Journal	Did not mention resilience
Predicting the performance of a floating wind energy converter in a realistic sea.	Wang, Yingguang and Wang, Lifu	2017	Renewable Energy: An International Journal	Did not mention resilience
Establishing robust short-term distributions of load extremes of offshore wind turbines.	Wang, Yingguang; Xia, Yiqing and Liu, Xiaojun	2013	Renewable Energy: An International Journal	Did not mention resilience
Future emerging technologies in the wind power sector: A European perspective.	Watson, Simon; Moro, Alberto; Reis, Vera; Baniotopoulos, Charalampos; Barth, Stephan; Bartoli, Gianni; Bauer, Florian; Boelman, Elisa; Bosse, Dennis; Cherubini, Antonello; Croce, Alessandro; Fagiano, Lorenzo; Fontana, Marco; Gambier, Adrian; Gkoumas, Konstantinos; Golightly, Christopher; Latour, Mikel Iribas; Jamieson, Peter; Kaldellis, John; and Macdonald, Andrew	2019	Renewable & Sustainable Energy Reviews	Did not mention resilience
Need for a traceable efficiency determination method of nacelles performed on test benches	Weidinger, Paula; Dubowik, Alexander; Lehrmann, Christian; Yogal, Nijan; Kumme, Rolf; Zweiffel, Maximilian; Eich, Norbert; Mester, Christian and Zhang, Hongkun	2021	Measurement: Sensors	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Life cycle assessment of a floating offshore wind turbine	Weinzettel, Jan; Reenaas, Marte; Solli, Christian and Hertwich, Edgar G.	2009	Renewable Energy: An International Journal	Did not mention resilience
Chapter 20 - Integration Into National Grids - Wind Energy Engineering	Weiss, Jurgen and Tsuchida, T. Bruce	2017		No specific mention of FOWT
On the aerodynamic loading effect of a model Spar-type floating wind turbine: An experimental study.	Wen, Binrong; Jiang, Zhihao; Li, Zhanwei; Peng, Zhike; Dong, Xingjian and Tian, Xinliang	2022	Renewable Energy: An International Journal	Did not mention resilience

Design approaches of performance-scaled rotor for wave basin model tests of floating wind turbines.	Wen, Binrong; Tian, Xinliang; Dong, Xingjian; Li, Zhanwei; Peng, Zhike; Zhang, Wenming and Wei, Kexiang	2020	Renewable Energy: An International Journal	Did not mention resilience
Impact of climate-change scenarios on offshore wind turbine structural performance.	Wilkie, David and Galasso, Carmine	2020	Renewable & Sustainable Energy Reviews	No specific mention of FOWT
Floating offshore wind turbine fault diagnosis via regularized dynamic canonical correlation and fisher discriminant analysis.	Wu, Ping; Liu, Yichao; Ferrari, Riccardo M.G. and van Wingerden, Jan-Willem	2021	IET Renewable Power Generation (Wiley-Blackwell)	Did not mention resilience
Structural responses suppression for a barge-type floating wind turbine with a platform-based TMD.	Xie, Shuangyi; Jin, Xin; He, Jiao and Zhang, Chenglin	2019	IET Renewable Power Generation (Wiley-Blackwell)	Did not mention resilience
A novel paradigm-oriented approach towards NG-RE hybrid power generation	Xu, Jiuping; Luo, Na; Li, Meihui and Xie, Heping	2017	Energy Conversion and Management	No specific mention of FOWT
Multisensory collaborative damage diagnosis of a 10 MW floating offshore wind turbine tendons using multi-scale convolutional neural network with attention mechanism.	Xu, Zifei; Bashir, Musa; Yang, Yang; Wang, Xinyu; Wang, Jin; Ekere, Nduka and Li, Chun	2022	Renewable Energy: An International Journal	Did not mention resilience
Low voltage ride through capability for resilient electrical distribution system integrated with renewable energy resources	Yadav, Monika; Pal, Nitai and Saini, Devender Kumar	2023	Energy Reports	Resilience not discussed with respect to FOWT; no specific mention of FOWT
A gradient-descent-based method for design of performance-scaled rotor for floating wind turbine model testing in wave basins.	Yang, Can; Cheng, Zhengshun; Xiao, Longfei; Tian, Xinliang; Liu, Mingyue and Wen, Binrong	2022	Renewable Energy: An International Journal	Did not mention resilience
Coupled modeling and structural vibration control for floating offshore wind turbine.	Yang, J.J. and He, E.M.	2020	Renewable Energy: An International Journal	Did not mention resilience
Development and application of an aero-hydro-servo-elastic coupling framework for analysis of floating offshore wind turbines.	Yang, Yang; Bashir, Musa; Michailides, Constantine; Li, Chun and Wang, Jin	2020	Renewable Energy: An International Journal	Did not mention resilience
Big data driven multi-objective predictions for offshore wind farm based on machine learning algorithms	Yin, Xiuxing and Zhao, Xiaowei	2019	Energy	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Numerical modelling and dynamic response analysis of a 10 MW semi-submersible floating offshore wind turbine subjected to ship collision loads.	Yu, Zhaolong; Amdahl, Jørgen; Rypestøl, Martin and Cheng, Zhengshun	2022	Renewable Energy: An International Journal	Did not mention resilience
A hybrid risk analysis model for wind farms using Coloured Petri Nets and interpretive structural modelling	Zeinalnezhad, Masoomeh; Chofreh, Abdoulmohammad Gholamzadeh; Goni, Feybi Ariani; Hashemi, Leila Sadat and Klemeš, Jirí Jaromír	2021	Energy	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Economic and sustainability promises of wind energy considering the impacts of climate change and vulnerabilities to extreme conditions	Zhang, Di; Xu, Zhenci; Li, Canbing; Yang, Rui; Shahidehpour, Mohammad; Wu, Qiuwei and Yan, Mingyu	2019	The Electricity Journal	No specific mention of FOWT
Resilience dynamics modeling and control for a reconfigurable electronic assembly line under spatio-temporal disruptions	Zhang, Ding; Xie, Min; Yan, Hong and Liu, Qiang	2021	Journal of Manufacturing Systems	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Boosting the power grid resilience under typhoon disasters by coordinated scheduling of wind energy and conventional generators	Zhang, Heng; Zhang, Shenxi; Cheng, Haozhong; Li, Zheng; Gu, Qingfa and Tian, Xueqin	2022	Renewable Energy	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Smart control of fatigue loads on a floating wind turbine with a tension-leg-platform.	Zhang, Mingming and Li, Xin and Xu, Jianzhong	2019	Renewable Energy: An International Journal	Did not mention resilience
Load control of floating wind turbine on a Tension-Leg-Platform subject to extreme wind condition.	Zhang, Mingming; Li, Xin; Tong, Jingxin and Xu, Jianzhong	2020	Renewable Energy: An International Journal	Did not mention resilience

Erosion of wind turbine blade coatings - Design and analysis of jet-based laboratory equipment for performance evaluation	Zhang, Shizhong; Dam-Johansen, Kim and Nørkjær, Sten; Bernad, Pablo L. and Kiil, Søren	2015	Progress in Organic Coatings	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Vibration suppression of floating offshore wind turbines using electromagnetic shunt tuned mass damper.	Zhang, Zili	2022	Renewable Energy: An International Journal	Did not mention resilience
Flexibility of wind power industry chain for environmental turbulence: A matching model study	Zhao, Zhen-Yu; Zhu, Jiang and Zuo, Jian	2015	Renewable Energy	No specific mention of FOWT
Importance of platform mounting orientation of Y-shaped semi-submersible floating wind turbines: A case study by using surrogate models.	Zhou, Shengtao; Li, Chao; Xiao, Yiqing and Cheng, Po Wen	2020	Renewable Energy: An International Journal	Did not mention resilience
Exploring inflow wind condition on floating offshore wind turbine aerodynamic characterisation and platform motion prediction using blade resolved CFD simulation.	Zhou, Yang; Xiao, Qing; Liu, Yuanchuan; Incecik, Atilla; Peyrard, Christophe; Wan, Decheng; Pan, Guang and Li, Sunwei	2022	Renewable Energy: An International Journal	Did not mention resilience
A study on a floating type shrouded wind turbine: Design, modeling and analysis.	Zhu, Hongzhong; Sueyoshi, Makoto; Hu, Changhong and Yoshida, Shigeo	2019	Renewable Energy: An International Journal	Did not mention resilience
Challenges in the vulnerability and risk analysis of critical infrastructures	Zio, Enrico	2016	Reliability Engineering & System Safety	Resilience not discussed with respect to FOWT; no specific mention of FOWT
Offshore floating wind parks in the deep waters of Mediterranean Sea.	Zountouridou, E.I.; Kiokes, G.C.; Chakalis, S.; Georgilakis, P.S. and Hatziargyriou, N.D.	2015	Renewable & Sustainable Energy Reviews	Did not mention resilience

Appendix A.5: Full-Text Screening Eliminations – Reference Review

This table contains information on all sources which were full-text screened in the review of references of included sources – there are 260 unique entries here. Some sources were found in multiple reference lists; in such cases, all citing sources are listed in the **Cited In** column.

Cited In	Author(s)	Title	Date	Publication	Exclusion Rationale
Ma et al., 2019	Abaiee, Ketabdari, Ahmadi, and Ardakani	Numerical and experimental study on the dynamic behavior of a Sea-star tension leg platform against regular waves	2016	Journal of Applied Mechanical and Technical Physics	FOWT not mentioned, resilience not mentioned
Sun et al., 2022	Adam, Myland, Dahlhaus, and Großmann	Gicon-TLP for wind turbines - the path of development	2014	1st International Conference on Renewable Energies Offshore	Resilience not mentioned
Sun et al., 2022	Adam, Myland, Dahlhaus, and Großmann	Scale Tests of the GICON-TLP for wind turbines	2014	33rd International conference on Ocean, Offshore and Arctic Engineering	Resilience not mentioned
Ma et al., 2019	Adam, Myland, Schuldt, Großmann, and Dahlhaus	Evaluation of internal force superposition on a TLP for wind turbines	2014	Renewable Energy	Resilience not mentioned
Yang, Bashir, Michailides et al., 2021	Ahmed, Yenduri, and Kurian	Evaluation of the dynamic responses of truss spar platforms for various mooring configurations with damaged lines	2016	Ocean Engineering	FOWT not mentioned, resilience not mentioned
Del Pozo González and Domínguez-García, 2022	Aho, Buckspan, Laks, Fleming, Jeong, Dunne, Churchfield, Pao, and Johnson	A tutorial of wind turbine control for supporting grid frequency through active power control	2012	American Control Conference	FOWT not mentioned, resilience not mentioned
Kappenthuler and Seeger, 2019	Alexander	Marine concrete structures: Design, durability and performance	2016		Resilience not mentioned with respect to FOWT
Patryniak et al., 2022	Aliabadi and Rasekh	Effect of platform disturbance on the performance of offshore wind turbine under pitch control	2020	Wind Energy	Resilience not mentioned
Patryniak et al., 2022	American Bureau of Shipping	Guide for building and classing floating offshore wind turbine installations	2015		Resilience not mentioned
Patryniak et al., 2022	Anaya-Lara, Tande, Uhlen, and Merz	Offshore wind energy technology	2018	book	Resilience not mentioned with respect to FOWT
Del Pozo González and Domínguez-García, 2022 & Sun et al., 2022	Andersson, Anaya-Lara, Tande, Merz, and Imsland	Wind Farm Control - Part I: A Review on Control System Concepts and Structures	2014	Renewable Power Generation	Resilience not mentioned
Del Pozo González and Domínguez-García, 2022	Annoni, Bay, Johnson, Dall'Anese, Quon, Kemper, and Fleming	A framework for autonomous wind farms: wind direction consensus	2018	Wind Energy Science Discussions	FOWT not mentioned
Yang, Bashir, Michailides et al., 2021	Armesto, Jurado, Guanche, Couñago, Urbano, and Serna	TELWIND: Numerical Analysis of a Floating Wind Turbine Supported by a Two Bodies Platform	2018	ASME 2018 37th International Conference on Ocean, Offshore and Arctic Engineering	Resilience not mentioned
Patryniak et al., 2022	Ashuri, Martins, Zaaijer, van Kuik, and van Bussel	Aeroservoelastic design definition of a 20 MW common research wind turbine model	2016	Wind Energy	FOWT not mentioned, resilience not mentioned
Patryniak et al., 2022	Ashuri, Zaaijer, Martins, van Bussel, and van Kuik	Multidisciplinary design optimization of offshore wind turbines for minimum levelized cost of energy	2014	Renewable Energy	FOWT not mentioned, resilience not mentioned
Zhou et al., 2023	Aubault, Alves, Sarmento, Roddier, and Peiffer	Modeling of an oscillating water column on the floating foundation WindFloat	2011	Proceedings from the International Conference on Offshore Mechanics and Arctic Engineering	Resilience not mentioned

Sun et al., 2022	Aubault, Cermelli, and Roddier	Windfloat: a floating foundation for offshore wind turbines - Part III: structural analysis	2009	International Conference on Offshore Mechanics and Arctic Engineering	Resilience not mentioned
Patryniak et al., 2022	Bachynski	Fixed and floating offshore wind turbine support structures	2018	book	Resilience not mentioned
Patryniak et al., 2022	Bachynski and Moan	Ringing loads on tension leg platform wind turbines	2014	Ocean Engineering	Resilience not mentioned
Patryniak et al., 2022	Bachynski and Moan	Design considerations for tension leg platform wind turbines	2012	Marine Structures	Resilience not mentioned
Ma et al., 2019 & Patryniak et al., 2022	Bachynski, Kvittem, Luan, and Moan	Wind-wave misalignment effects on floating wind turbines: Motions and tower load effects	2014	Journal of Offshore Mechanical Arctic Engineering	Resilience not mentioned
Ma et al., 2019	Bae and Kim	Rotor-floater-tether coupled dynamics including second-order sum-frequency wave loads for a mono-column-TLP-type FOWT (floating offshore wind turbine)	2013	Ocean Engineering	Resilience not mentioned
Yang, Bashir, Michailides et al., 2021	Bae, Kim, and Kim	Performance changes of a floating offshore wind turbine with broken mooring line	2017	Renewable Energy	Resilience not mentioned
Patryniak et al., 2022 & Yang, Bashir, Li et al., 2021	Bahramiasl, Abbaspour, and Karimirad	Experimental study on gyroscopic effect of rotating rotor and wind heading angle on floating wind turbine responses	2018	International Journal of Environmental Science and Technology	Resilience not mentioned
Ma et al., 2019	Bangga, Guma, Lutz, and Kramer	Numerical simulations of a large offshore wind turbine exposed to turbulent inflow conditions	2018	Wind Engineering	FOWT not mentioned, resilience not mentioned
Mitchell et al., 2022	Barnes	HOME-offshore: holistic operation and maintenance for energy from offshore wind farms	2016		FOWT not mentioned, resilience not mentioned
Mitchell et al., 2022	Barnes, Brown, Carmona, Cevasco, Collu, Crabtree, Crowther, Djurovic, Flynn, Green, Heggo, Kababbe, Kazemtabrizi, Keane, Lane, Lin, Mawby, Mohammed, Nenadic, Ran, Stetco, Tang, and Watson	Technology drivers in windfarm asset management	2018	Heriot Watt University Research Gateway	Resilience not mentioned
Del Pozo González and Domínguez-García, 2022	Baros and Annaswamy	Distributed optimal wind farm control for fatigue load minimization: a consensus approach	2019	International Journal of Electrical Power and Energy Systems	FOWT not mentioned
Zhou et al., 2023	Bashetty and Ozcelik	Review on dynamics of offshore floating wind turbine platforms	2021	Energies	Resilience not mentioned
Sun et al., 2022	Belloli, Bayati, Facchinetti, Fontanella, Giberti, La Mura, Taruffi, and Zasso	A hybrid methodology for wind tunnel testing of floating offshore wind turbines	2020	Ocean Engineering	Resilience not mentioned
Ma et al., 2019	Beyer, Choisnet, Kretschmer, and Cheng	Coupled MBS-CFD simulation of the Ideol floating offshore wind turbine foundation compared to wave tank model test data	2015	Proceedings of the 25th International Ocean and Polar Engineering Conference	Resilience not mentioned
Del Pozo González and Domínguez-García, 2022	Bhattacharya	Challenges in design of foundations for offshore wind turbines	2014	Engineering & Technology Reference	Resilience not mentioned
Sun et al., 2022	Bhattacharya	Design of foundations for offshore wind turbines	2019	book	Resilience not mentioned with respect to FOWT

Mitchell et al., 2022	Blanche, Mitchell, Gupta, Tang, and Glynn	Asset integrity monitoring of wind turbine blades with non-destructive radar sensing	2020	11th IEEE Annual Information Technology, Electronics and Mobile Communication	FOWT not mentioned
Del Pozo González and Domínguez-García, 2022	Boersma, Doekemeijer, Begraad, Gleming, Annoni, Scholbrock, Frederik, and van Wingerden	A tutorial on control-oriented modeling and control of wind farms	2017	American Control Conference	Resilience not mentioned
Patryniak et al., 2022	Bortolotti, Bottasso, and Croce	Combined preliminary-detailed design of wind turbines	2016	Wind Energy	FOWT not mentioned, resilience not mentioned
Patryniak et al., 2022	Bottasso, Campagnolo, and Croce	Multi-disciplinary constrained optimization of wind turbines	2012	Multibody System Dynamics	FOWT not mentioned, resilience not mentioned
Sun et al., 2022	Bredmose, Larsen, Matha, Rettenmeier, Marino, and Saettran	Marine Renewables Infrastructure Network (MARINET) Report: Collation of Offshore Wind Wave Dynamics	2012		Resilience not mentioned
Zhou et al., 2023	Brennan and Kolios	Structural integrity considerations for the H2Ocean multi modal wind-wave platform	2014	European Wind Energy Association	Could not be accessed
Kappenthuler and Seeger, 2019	Breton and Moe	Status, plans and technologies for offshore wind turbines in Europe and North America	2009	Renewable Energy	Resilience not mentioned
Patryniak et al., 2022	Brommundt, Krause, Merz, and Muskulus	Mooring system optimization for floating wind turbines using frequency domain analysis	2012	Energy Procedia	Resilience not mentioned
Patryniak et al., 2022	Burton, Jenkins, sharpe, and Bossanyi	Wind Energy Handbook, Second Edition	2011	book	Resilience not mentioned
Sun et al., 2022	Canet, Bortolotti, and Bottasso	Gravo-aeroelastic scaling of very large wind turbines to wind tunnel size	2018	Journal of Physics: Conference Series	FOWT not mentioned, resilience not mentioned
Liu et al., 2020	Carroll, McDonald, and McMillan	Failure rate, repair time and unscheduled O&M cost analysis of offshore wind turbines	2016	Wind Energy	FOWT not mentioned, resilience not mentioned
Patryniak et al., 2022	Castro-Santos, deCastro, Costoya, Filgueira-Vizoso, Lamas-Galdo, Ribeiro, Dias, and Gómez-Gesteira	Economic feasibility of floating offshore wind farms considering near future wind resources: Case study of Iberian Coast and Bay of Biscay	2021	International Journal of Environmental Research and Public Health	Resilience not mentioned
Sun et al., 2022	Cermelli, Roddier, and Aubault	WindFloat: a floating foundation for offshore wind turbines - Part II: hydrodynamics analysis	2009	International Conference on Offshore Mechanics and Arctic Engineering	Resilience not mentioned
Sun et al., 2022	Chabaud, Steen, and Skjetne	Real-time hybrid testing for marine structures: challenges and strategies	2013	International Conference on Ocean, Offshore and Arctic Engineering	Resilience not mentioned
Mitchell et al., 2022	Cheeseman and Stefaniak	The windfarm autonomous ship project	2020	ORE Catapult	FOWT not mentioned, resilience not mentioned
Patryniak et al., 2022	Chen, Hu, Liu, and Tang	Comparison of different dynamic models for floating wind turbines	2017	Journal of Renewable and Sustainable Energy	Resilience not mentioned
Sun et al., 2022	Chen, Hu, Wan, and Xiao	Comparisons of the dynamical characteristics of a semisubmersible floating offshore wind turbine based on two different blade concepts	2018	Ocean Engineering	Resilience not mentioned
Mitchell et al., 2022	Cholteeva	Robotic technologies in offshore wind	2021	Power Technology	FOWT not mentioned
Keighobadi et al., 2022	Christiansen, Knudsen, and Bak	Extended onshore control of a floating wind turbine with wave disturbance reduction	2012	Journal of Physics: Conference Series	Resilience not mentioned
Patryniak et al., 2022	Coraddu, Oneto, Kalikatzarakis, Ilardi, and Collu	Floating spar-type offshore wind turbine hydrodynamic response characterisation: a computational cost aware approach	2020	Global Oceans 2020: Singapore - US Gulf Coast	Resilience not mentioned

Patryniak et al., 2022	Cordle and Jonkman	State of the art in floating wind turbine design tools	2011	Proc. International Offshore Polar Engineering Conference	Resilience not mentioned
Patryniak et al., 2022	Coulling, Goupee, Robertson, and Jonkman	Importance of second-order difference-frequency wave-diffraction forces in the validation of a FAST semi-submersible floating wind turbine model	2013	Proceedings from the International Conference on Ocean, Offshore and Arctic Engineering	Resilience not mentioned
Del Pozo González and Domínguez-García, 2022	Damiani	Design of Offshore Wind Turbine Towers	2016	book	Resilience not mentioned
Del Pozo González and Domínguez-García, 2022	De-Prada-Gil, Alías, and Gomis-Bellmunt	Maximum wind power plant generation by reducing the wake effect	2015	Energy Conversion and Management	FOWT not mentioned, resilience not mentioned
Kappenthuler and Seeger, 2019	Díaz, Rodrigues, and Guedes Soares	Preliminary cost assessment of an offshore floating wind farm installation on the Galician coast	2016	RENEW 2016	Resilience not mentioned
Sun et al., 2022	Dinh and Basu	Passive control of floating offshore wind turbine nacelle and spar vibrations by multiple tuned mass dampers	2015	Structural Control and Health Monitoring	Resilience not mentioned
Chaloulos et al., 2021	DNV	Design of offshore wind turbine structures	2013		Resilience not mentioned
Sun et al., 2022	DNVGL	DNVGL-ST-0126 Support Structures for Wind Turbines	2021		FOWT not mentioned, resilience not mentioned
Patryniak et al., 2022	Dobbin, Quarton, Phillips, and Reynolds	Project FORCE: Offshore wind cost reduction through integrated design	2014		Resilience not mentioned
Patryniak et al., 2022	Dou, Pegalajar-Jurado, Wang, Bredmose, and Stolpe	Optimization of floating wind turbine support structures using frequency-domain analysis and analytical gradients	2020	Journal of Physics: Conference Series	Resilience not mentioned
Patryniak et al., 2022	Duarte, Sarmento, and Jonkman	Effects of second-order hydrodynamic forces on floating offshore wind turbines	2014	32nd ASME Wind Energy Symposium	Resilience not mentioned
Mitchell et al., 2022	Elyasichamazkoti and Khajehpoor	Application of machine learning for wind energy from to energy-water nexus: A survey	2021	Energy Nexus	FOWT not mentioned
Chaloulos et al., 2021	Esfeh and Kaynia	Numerical modeling of liquefaction and its impact on anchor piles for floating offshore structures	2019	Soil Dynamics and Earthquake Engineering	Resilience not mentioned
Kappenthuler and Seeger, 2019	European Wind Energy Association	Deep water: The next step for offshore wind energy	2013		Resilience not mentioned
Zhou et al., 2023	Fenu, Attanasio, Casalone, Novo, Cervelli, Bonfanti, Sirigu, Bracco, and Mattiazzo	Analysis of a gyroscopic-stabilized floating offshore hybrid wind-wave platform	2020	Journal of Marine Science and Engineering	Resilience not mentioned
Patryniak et al., 2022	Fontanella, Al, van Wingerden, and Belloli	Model-based design of a wave-feedforward control strategy in floating wind turbines	2021	Wind Energy	Resilience not mentioned
Liu et al., 2020	Fontanella, Bayati, and Belloli	Linear coupled model for floating wind turbine control	2018	Wind Engineering	Resilience not mentioned
Patryniak et al., 2022	Fylling and Berthelsen	WINDOPT - An optimization tool for floating support structures for deep water wind turbines	2011	Proceedings from the International Conference on Offshore Mechanics and Arctic Engineering	Resilience not mentioned
Mitchell et al., 2022	GE Renewable Energy	World's most powerful offshore wind turbine: Haliade-X 12 MW	n.d.		FOWT not mentioned, resilience not mentioned
Mitchell et al., 2022	GE Renewable Energy	Blades - testing & procedures	n.d.		FOWT not mentioned, resilience not mentioned
Mitchell et al., 2022	GE Renewable Energy	Innovative wind turbine blade manufacturing	n.d.		FOWT not mentioned, resilience not mentioned

Patryniak et al., 2022	Gentils, Wang, and Kolios	Integrated structural optimisation of offshore wind turbine support structures based on finite element analysis and genetic algorithm	2017	Applied Energy	Resilience not mentioned
Patryniak et al., 2022	Ghigo, Cottura, Caradonna, Bracco, and Mattiazzo	Platform optimization and cost analysis in a floating offshore wind farm	2020	Journal of Marine Science and Engineering	Resilience not mentioned
Patryniak et al., 2022	Gilloteaux and Bozonnet	Parametric analysis foa cylinder-like shape floating platform dedicated to multi-megawatt wind turbine	2014	Proceedings fron the International Ocean and Polar Engineering Conference	Resilience not mentioned
Del Pozo González and Domínguez-García, 2022	Gonzálex-Longatt, Wall, and Terzija	Wake effect in wind farm performance: steady-state and dynamic behavior	2012	Renewable Energy	FOWT not mentioned, resilience not mentioned
Del Pozo González and Domínguez-García, 2022	Grunnet, Soltani, Knudsen, Kragelund, and Bak	Aeolus toolbox for dynamics wind farm model, simulation and control	2010	EWEC 2010	FOWT not mentioned, resilience not mentioned
Yang, Bashir, Li et al., 2021	Hall and Goupee	Validation of a lumped-mass mooring line model with DeepCwind semisubmersible model test data	2015	Ocean Engineering	Resilience not mentioned
Patryniak et al., 2022 & Sun et al., 2022	Hall, Buckham, and Crawford	Evolving offshore wind: A genetic algorithm-based support structure optimization framework for floating wind turbines	2013	MTS/IEEE Oceans - Bergen	Resilience not mentioned
Patryniak et al., 2022	Hall, Buckham, and Crawford	Hydrodynamics-based floating wind turbine support platform optimization: A basis function approach	2014	Renewable Energy	Resilience not mentioned
Yang, Bashir, Li et al., 2021	Hall, Buckham, Crawford, and Nicoll	The importance of mooring line model fidelity in floating wind turbine simulations	2011	Wind Energy	Resilience not mentioned
Sun et al., 2022	Hall, Goupee, and Jonkman	Development of performance specifications for hybrid modeling of floating wind turbines in wave basin tests	2018	Journal of Ocean Engineering and Marine Energy	Resilience not mentioned
Sun et al., 2022	Hall, Morena, and Thiagarajan	Performance specifications for real-time hybrid testing of 1:50-scale floating wind turbine models	2014	International Conference on Ocean, Offshore and Arctic Engineering	Resilience not mentioned
Sun et al., 2022	Hansen	Aerodynamics of wind turbines	2015	book	FOWT not mentioned, resilience not mentioned
Patryniak et al., 2022	Hassan	DNV GL White Paper on Definitions of Availability Terms for the Wind Industry	2017		FOWT not mentioned, resilience not mentioned
Mitchell et al., 2022	Hassan	A guide to UK offshore wind operations and maintenance	2013		Resilience not mentioned
Yang, Bashir, Li et al., 2021	He, Hu, and Zhang	Optimization design of tuned mass damper for vibration suppression of a barge-type offshore floating wind turbine	2016	Journal of Engineering for the Maritime Environment	Resilience not mentioned
Patryniak et al., 2022	Hegseth, Bachynski, and Leira	Effect of environmental modelling and inspection strategy on the optimal design of floating wind turbines	2021	Reliability Engineering and System Safety	Resilience not mentioned
Patryniak et al., 2022	Hegseth, Bachynski, and Martins	Design optimization of spar floating wind turbines considering different control strategies	2020	Journal of Physics: Conference Series	Resilience not mentioned
Patryniak et al., 2022	Hegseth, Bachynski, and Martins	Integrated design optimization of spar floating wind turbines	2020	Marine Structures	Resilience not mentioned
Keighobadi et al., 2022	Homer	Physics-based control-oriented modelling for floating offshore wind turbines	2015	MS Thesis at the University of British Columbia in Vancouver	Resilience not mentioned
Liu et al., 2020	Houtzager, van Wingerden, and Verhaegen	Wind turbine load reduction by rejecting the periodic load disturbances	2013	Wind Energy	Resilience not mentioned
Yang, Bashir, Li et al., 2021	Hu, Wang, Chen, Li, and Sun	Load mitigation for a barge-type floating offshore wind turbine via inverter-based passive structural control	2018	Engineering Structures	Resilience not mentioned
Chaloulos et al., 2021	Huang and Han	Features of earthquake-induced seabed liquefaction and mitigation strategies of novel marine structures	2020	Journal of Marine Science and Engineering	Resilience not mentioned
Del Pozo González and Domínguez-García, 2022	Huang, Wu, Guo, and Lin	Bi-level decentralised active power control for large-scale wind farm cluster	2018	Renewable Power Generation	FOWT not mentioned, resilience not mentioned

Patryniak et al., 2022	Igwemezie, Mehmanparast, and Kolios	Materials selection for XL wind turbine support structures: A corrosion-fatigue perspective	2018	Marine Structures	FOWT not mentioned, resilience not mentioned
Patryniak et al., 2022	IRENA	Future of wind: Deployment, investment, technology, grid integration and socio-economic aspects	2019		Resilience not mentioned with respect to FOWT
Mitchell et al., 2022	IRENA	Offshore innovation widens renewable energy options	2018		Resilience not mentioned
Sun et al., 2022	Jahangiri and Sun	Performance evaluation of a 3D-PTMD in offshore wind turbines under multiple hazards and damage	2019	Smart Structures and Systems	Resilience not mentioned
Sun et al., 2022	Jahangiri and Sun	Three dimensinoal vibration control of spar-type offshore wind turbines using multiple tuned mass dampers	2020	Ocean Engineering	Resilience not mentioned
Sun et al., 2022	Jahangiri and Sun	A novel three dimensional nonlinear tuned mass damper and its application in floating offshore wind turbines	2022	Ocean Engineering	Resilience not mentioned
Sun et al., 2022	Jahangiri, Sun, and Kong	Study on a 3D pounding pendulum tuned mass damper for mitigating bi-directional vibration of offshore wind turbines	2021	Engineering Structures	Resilience not mentioned
Patryniak et al., 2022	Jang, King, Park, and Jeon	FEA based optimization of semi-submersible floater considering buckling and yield strength	2019	International Journal of Naval Architecture and Ocean Engineering	FOWT not mentioned, resilience not mentioned
Yang, Bashir, Li et al., 2021	Jeon, Cho, Seo, Cho, and Jeong	Dynamic response of floating substructure of spar-type offshore wind turbine with catenary mooring cables	2013	Ocean Engineering	Resilience not mentioned
Liu et al., 2020	Jiang, Karimirad, and Moan	Dynamic response analysis of wind turbines under blade pitch system fault, grid loss, and shutdown events	2014	Wind Energy	Resilience not mentioned
Patryniak et al., 2022	Johnston, Foley, Doran, and Littler	Levelised cost of energy, A challenge for offshore wind	2020	Renewable Energy	Resilience not mentioned
Patryniak et al., 2022	Jonkman	Dynamics of offshore floating wind turbines-model development and verification	2009	Wind Energy	Resilience not mentioned
Del Pozo González and Domínguez-García, 2022	Jonkman	Definition of the Floating System for Phase IV of OC3	2010		Resilience not mentioned
Sun et al., 2022 & Yang, Bashir, Li et al., 2021	Jonkman and Matha	Dynamics of offshore floating wind turbines - analysis of three concepts	2011	Wind Energy	Resilience not mentioned
Yang, Bashir, Li et al., 2021	Jonkman and Musial	Offshore code comparison collaboration (OC3) for IEA Wind Task 23 Offshore Wind Technology and Deployment	2010		Resilience not mentioned
Patryniak et al., 2022; Del Pozo González and Domínguez-Garcia, 2022; Sun et al., 2022 & Chaloulos et al., 2021	Jonkman, Butterfield, Musial, and Scott	Definition of a 5MW Reference Wind Turbine for Offshore System Development	2009		Resilience not mentioned
Patryniak et al., 2022	Jonkman, Wright, Hayman, and Robertson	Full-system linearization for floating offshore wind turbines in OpenFAST	2018	1st International Offshore Wind Technical Conference	Resilience not mentioned
Patryniak et al., 2022	Karadeniz, Togan, and Vrouwenvelder	An integrated reliability-based design optimization of offshore towers	2009	Reliability Engineering and System Safety	FOWT not mentioned, resilience not mentioned
Patryniak et al., 2022	Karimi, Hall, Buckham, and Crawford	A multi-objective design optimization approach for floating offshore wind turbine support structures	2017	Ocean Engineering	Resilience not mentioned
Patryniak et al., 2022	Karimirad	Stochastic dynamic response analysis of spar-type wind turbines with catenary or taut mooring systems	2011	PhD Thesis at NTNU	Resilience not mentioned

Yang, Bashir, Li et al., 2021	Karimirad	Modeling aspects of a floating wind turbine for coupled wave-wind-induced dynamic analysis	2013	Renewable Energy	Resilience not mentioned
Del Pozo González and Domínguez-García, 2022	Karimirad and Moan	Effect of aerodynamic and hydrodynamic damping on dynamic response of a spar type floating wind turbine	2010		Resilience not mentioned
Patryniak et al., 2022	Karimirad, Meissonnier, Gao, and Moan	Hydroelastic code-to-code comparison for a tension leg spar-type floating wind turbine	2011	Marine Structures	Resilience not mentioned
Patryniak et al., 2022	Katsouris and Marina	Cost modelling of floating wind farms	2016		Resilience not mentioned
Chaloulos et al., 2021	Kaynia	Seismic considerations in design of offshore wind turbines	2019	Soil Dynamics and Earthquake Engineering	Resilience not mentioned
Del Pozo González and Domínguez-García, 2022	Kazda, Merz, Tande, and Cutululis	Mitigating turbine mechanical loads using engineering model predictive wind farm controller	2018	Journal of Physics: Conference Series	FOWT not mentioned, resilience not mentioned
Yang, Bashir, Li et al., 2021 & Yang, Bashir, Michailides et al., 2021	Kim and Zhang	Transient effects of tendon disconnection on the survivability of a TLP in moderate-strength hurricane condition	2009	International Journal of Naval Architecture and Ocean Engineering	FOWT not mentioned, resilience not mentioned
Zhou et al., 2023	Konispoliatis, Katsaounis, Manolas, Soukissian, Polyzos, Mazarakos, Voutsinas, and Mavrakos	REFOS: a renewable energy multi-purpose floating offshore system	2021	Energies	Resilience not mentioned
Kappenthuler and Seeger, 2019	Lamas-Pardo, Iglesias, and Carral	A review of very large floating structures (VLFS) for coastal and offshore uses	2015	Ocean Engineering	FOWT not mentioned, resilience not mentioned
Patryniak et al., 2022	Lee and Lee	Effects of platform motions on aerodynamic performance and unsteady wake evolution of a floating offshore wind turbine	2019	Renewable Energy	Resilience not mentioned
Mitchell et al., 2022	Lee, Oh, and Son	Maintenance robot for 5MW offshore wind turbines and its control	2016	IEEE/ASME Transactions on Mechatronics	FOWT not mentioned, resilience not mentioned
Patryniak et al., 2022	Leimeister, Kolios, and Collu	Critical review of floating support structures for offshore wind farm deployment	2018	Journal of Physics: Conference Series	Resilience not mentioned
Patryniak et al., 2022	Lemmer	Low-order modeling, controller design and optimization of floating offshore wind turbines	2018	PhD Thesis at the University of Stuttgart	Resilience not mentioned
Patryniak et al., 2022	Lemmer, Müller, Yu, Schlipf, and Cheng	Optimization of floating offshore wind turbine platforms with a self-tuning controller	2017	Proceedings from the International Conference on Offshore Mechanics and Arctic Engineering	Resilience not mentioned
Patryniak et al., 2022	Lemmer, Schlipf, and Cheng	Control design methods for floating wind turbines for optimal disturbance rejection	2016	Journal of Physics: Conference Series	Resilience not mentioned
Patryniak et al., 2022	Lemmer, Yu, Müller, and Cheng	Semi-submersible wind turbine hull shape design for a favorable system response behavior	2020	Marine Structures	Resilience not mentioned
Patryniak et al., 2022	Lemmer, Yu, Schlipf, and Cheng	Robust gain scheduling baseline controller for floating offshore wind turbines	2019	Wind Energy	Resilience not mentioned
Patryniak et al., 2022	Lerch	Technical-economic analysis, modeling and optimization of floating offshore wind farms	2020		Resilience not mentioned
Patryniak et al., 2022	Leroy, Bachynski-Polić, Babarit, Ferrant, and Gilloteaux	A weak-scatterer potential flow theory-based model for the hydroelastic analysis of offshore wind turbine substructures	2021	Ocean Engineering	Resilience not mentioned
Liu et al., 2020	Li, Li, Cai, Song, and Chen	Adaptive fault-tolerant control of wind turbines with guaranteed transient performance considering active power control of wind farms	2018	IEEE Transactions on Industrial Electronics	FOWT not mentioned, resilience not mentioned

Zhou et al., 2023	Li, Ruzzo, Collu, Yan, and Arena	Analysis of the coupled dynamic response of an offshore floating multi-purpose platform for the blue economy	2020	Ocean Engineering	Resilience not mentioned
Patryniak et al., 2022	Li, Zhu, Fan, Chen, and Tan	Effects of the yaw error and the wind-wave misalignment on the dynamic characteristics of the floating offshore wind turbine	2020	Ocean Engineering	Resilience not mentioned
Yang, Bashir, Li et al., 2021 & Yang, Bashir, Michailides et al., 2021	Li, Zhu, Liu, and Tang	Transient response of a SPAR-type floating offshore wind turbine with fractured mooring lines	2018	Renewable Energy	Resilience not mentioned
Patryniak et al., 2022	Lim, Kong, and Park	A study on optimal design of filament winding composite tower for 2 MW class horizontal axis wind turbine systems	2012	International Journal of Composite Materials	FOWT not mentioned, resilience not mentioned
Patryniak et al., 2022	Loukogeorgaki, Michailides, and Angelides	"Dry" and "wet" mode superposition approaches for the hydroelastic analysis of floating structures	2014	9th International Conference on Structural Dynamics	FOWT not mentioned, resilience not mentioned
Ma et al., 2019	Low	Frequency domain analysis of a tension leg platform with statistical linearization of the tendon restoring forces	2009	Marine Structures	Resilience not mentioned
Patryniak et al., 2022	Lupton	Frequency-domain modelling of floating wind turbines	2014		Resilience not mentioned
Patryniak et al., 2022	Lupton and Langley	Harmonic linearisation of aerodynamic loads in a frequency-domain model of a floating wind turbine	2020	Wind Energy	Resilience not mentioned
Yang, Bashir, Li et al., 2021	Ma, Hu, and Xiao	Wind-wave induced dynamic response analysis for motions and mooring loads of a spar-type offshore floating wind turbine	2014	Journal of Hydrodynamics	Resilience not mentioned
Yang, Bashir, Li et al., 2021 & Yang, Bashir, Michailides et al., 2021	Ma, Zhong, Zhang, Ma, and Kang	Mechanism of mooring line breakage of floating offshore wind turbine under extreme coherent gust with direction change condition	2020	Journal of Marine Science and Technology	Resilience not mentioned
Del Pozo González and Domínguez-García, 2022	Madjidian, Mårtensson, and Rantzer	A distributed power coordination scheme for fatigue load reduction in wind farms	2011	Proceedings of the 2011 American Control Conference	FOWT not mentioned, resilience not mentioned
Yang, Bashir, Li et al., 2021 & Yang, Bashir, Michailides et al., 2021	Malayjerdi, Ahmadi, and Tabeshpour	Dynamic analysis of TLP in intact and damaged tendon conditions	2017	International Journal of Coastal & Offshore Engineering	FOWT not mentioned, resilience not mentioned
Patryniak et al., 2022	Mantadakis, Loukogeorgaki, and Karimirad	Accounting for hydroelasticity in the analysis of offshore wind turbine spar-type platforms	2019	29th International Ocean and Polar Engineering Conference	Resilience not mentioned
Mitchell et al., 2022	Marsh	The challenge of wind turbine blade repair	2011	Renewable Energy Focus	FOWT not mentioned, resilience not mentioned
Sun et al., 2022	Martin	Development of a scale model wind turbine for testing of offshore floating wind turbine systems	2011	MS Thesis at the University of Maine	Resilience not mentioned
Patryniak et al., 2022	Matha	Model development and loads analysis of a wind turbine on a floating offshore tension leg platform	2010		Resilience not mentioned
Ma et al., 2019	Matha	Model development and loads analysis of an offshore wind turbine on a tension leg platform with a comparison to other floating turbine concepts	2009		Resilience not mentioned
Patryniak et al., 2022	Matha, Sandner, and Schlipf	Efficient critical design load case identification for floating offshore wind turbines with a reduced nonlinear model	2014	Journal of Physics: Conference Series	Resilience not mentioned
Patryniak et al., 2022	Mathern, von der Haar, and marx	Concrete support structures for offshore wind turbines: Current status, challenges, and future trends	2021	Energies	Resilience not mentioned
Chaloulos et al., 2021	Mazarakos, Konispoliatis, and Mavrakos	Design of a TLP floating structure concept for combined wind and wave energy exploitation	2016	International Conference on Renewable Energies Offshore	Resilience not mentioned

Chaloulos et al., 2021	Mazarakos, Konispoliatis, Katsaounis, Polyzos, Manolas, Voutsinas, Soukissian, and Mavrakos	Numerical and experimental studies of a multi-purpose floating TLP structure for combined wind and wave energy exploitation	2019	Mediterranean Marine Science	Resilience not mentioned
Chaloulos et al., 2021	Mazarakos, Konispoliatis, Manolas, Voutsinas, and Mavrakos	Modelling of an offshore multi-purpose floating structure supporting a wind turbine including second-order wave loads	2015	European Wave and Tidal Energy Conference	Resilience not mentioned
Chaloulos et al., 2021	Mazarakos, Manolas, Grapsas, Mavrakos, Riziotis, and Voutsinas	Conceptual Design and Advanced Hydro-Aero-Elastic Modeling of a TLP Concept for Floating Wind Turbine Applications	2014	International Conference on Renewable Energies Offshore	Resilience not mentioned
Mitchell et al., 2022	Milborrow	Big turbines push down O&M costs	2020	Windpower Monthly	FOWT not mentioned, resilience not mentioned
Mitchell et al., 2022	Mueller	Getting offshore wind power on the grid	2019	T&D World	FOWT not mentioned, resilience not mentioned
Patryniak et al., 2022	Muskulus and Schafhirt	Design optimization of wind turbine support structures- a review	2014	Ocean Wind Energy	Resilience not mentioned
Patryniak et al., 2022	Myhr and Nygaard	Load reductions and optimizations on tension-leg-buoy offshore wind turbine platforms	2012	Proceedings fron the International Ocean and Polar Engineering Conference	Resilience not mentioned
Patryniak et al., 2022	Myhr, Bjerkseter, Ågotnes, and Nygaard	Levelised cost of energy for offshore floating wind turbines in a lifecycle perspective	2014	Renewable Energy	Resilience not mentioned
Patryniak et al., 2022	Namik and Stol	Individual blade pitch control of floating offshore wind turbines	2010	Wind Energy	Resilience not mentioned
Yang, Bashir, Li et al., 2021	Namik and Stol	Performance analysis of individual blade pitch control of offshore wind turbines on two floating platforms	2011	Mechatronics	Resilience not mentioned
Liu et al., 2020	Navalkar, van Wingerden, van Solingen, Oomen, Pasterkamp, and van Kuik	Subspace predictive repetitive control to mitigate periodic loads on large scale wind turbines	2014	Mechatronics	FOWT not mentioned, resilience not mentioned
Patryniak et al., 2022	Nehad, Bachynski, and Moan	Effect of axial acceleration on drivetrain responses in a spar-type floating wind turbine	2019	Journal of Offshore Mechanical Arctic Engineering	Resilience not mentioned
Ma et al., 2019	Nematbakhsh, Bachynski, Gao, and Moan	Comparison of wave load effects on a TLP wind turbine by using computational fluid dynamics and potential flow theory approaches	2015	Applied Ocean Research	Resilience not mentioned
Ma et al., 2019	Nematbakhsh, Olinger, and Tryggvason	A nonlinear computational model of floating wind turbines	2013	Journal of Fluids Engineering	Resilience not mentioned
Mitchell et al., 2022	Netland and Skavhaug	Prototyping and evaluation of a telerobot for remote inspection of offshore wind farms	2012	2nd International Conference on Applied Robotics for the Power Industry	FOWT not mentioned, resilience not mentioned
Mitchell et al., 2022	Netland, Jenssen, and Skavhaug	The capabilities and effectiveness of remote inspection of wind turbines	2015	Energy Procedia	FOWT not mentioned, resilience not mentioned
Mitchell et al., 2022	Nichenametla, Nandipati, and Waghmare	Optimizing life cycle cost of wind turbine blades using predictive analytics in effective maintenance planning	2017	Annual Reliability and Maintainability Symposium	FOWT not mentioned, resilience not mentioned
Mitchell et al., 2022	Offshore Renewable Energy Catapult	Operations & maintenance: they key to cost reduction	2016		FOWT not mentioned, resilience not mentioned
Mitchell et al., 2022	Ørsted	Burbo Bank Extension Offshore Wind Farm	2019		FOWT not mentioned, resilience not mentioned

Kappenthuler and Seeger, 2019 & Zhou et al., 2023	Pérez-Collazo, Greaves, and Iglesias	A review of combined wave and offshore wind energy	2015	Renewable and Sustainable Energy Reviews	Resilience not mentioned
Sun et al., 2022	Perveen, Kishor, and Mohanty	Off-shore wind farm development: present status and challenges	2014	Renewable and Sustainable Energy Reviews	Resilience not mentioned
Yang, Bashir, Li et al., 2021	Pham, Cartaud, Schoefs, Soulard, and Berhault	Dynamic modeling of nylon mooring lines for a floating wind turbine	2019	Applied Ocean Research	Resilience not mentioned
Patryniak et al., 2022	Pillai, Thies, and Johanning	Mooring system design optimization using a surrogate assisted multi-objective genetic algorithm	2019	Engineering Optimization	Resilience not mentioned
Sun et al., 2022	Pires, Azcona, Vittori, Bayati, Gueydon, Fontanella, Liu, de Ridder, Belloli, and van Wingerden	Inclusion of rotor moments in scaled wave tank test of a floating wind turbine using SiL hybrid method	2020	Journal of Physics: Conference Series	Resilience not mentioned
Patryniak et al., 2022	Pustina, Lugni, Bernardini, Serafini, and Gennaretti	Control of power generated by a floating offshore wind turbine perturbed by sea waves	2020	Renewable and Sustainable Energy Reviews	Resilience not mentioned
Patryniak et al., 2022	Qiu, Song, Shi, Zhang, Yuan, and You	Multi-objective optimization of semi-submersible platforms using particle swarm optimization algorithm based on surrogate model	2019	Ocean Engineering	FOWT not mentioned, resilience not mentioned
Yang, Bashir, Li et al., 2021	Qu, Li, Tang, Chai, and Gao	Comparative study of short-term extreme responses and fatigue damages of a floating wind turbine using two different blade models	2020	Applied Ocean Research	Resilience not mentioned
Mitchell et al., 2022	Ramírez, Fraile, and Brindley	Offshore wind in Europe - Key trends and statistics 2019	2019		Resilience not mentioned
Ma et al., 2019	Rao	Hydrodynamic analysis of a tension based tension leg platform	2012	Ocean, Offshore and Arctic Engineering	Resilience not mentioned
Ma et al., 2019	Ren, Li, and Ou	The effect of additional mooring chains on the motion performance of a floating wind turbine with a tension leg platform	2012	Energies	Resilience not mentioned
Patryniak et al., 2022	Rinaldi, Garcia0Teruel, Jeffrey, Thies, and Johanning	Incorporating stochastic operation and maintenance models into the techno-economic analysis of floating offshore wind farms	2021	Applied Energy	Resilience not mentioned
Patryniak et al., 2022	Rinaldi, Pillai, Thies, and Johanning	Verification and Benchmarking Methodology for O&M Planning and Optimization Tools in the Offshore Renewable Energy Sector	2018	37th International Conference on Ocean, Offshore, and Arctic Engineering	FOWT not mentioned, resilience not mentioned
Patryniak et al., 2022	Rinaldi, Thies, Walker, and Johanning	A decision support model to optimise the operation and maintenance strategies of an offshore renewable energy farm	2017	Ocean Engineering	FOWT not mentioned, resilience not mentioned
Del Pozo González and Domínguez-García, 2022	Riverso, Mancini, Sarzo, and Ferrari-Trecate	Model predictive controllers for reduction of mechanical fatigue in wind farms	2016	IEEE Transactions on Control Systems Technology	FOWT not mentioned, resilience not mentioned
Patryniak et al., 2022	Robertson, Gueydon, Bachynski, Wang, and Jonkman	OC6 Phase I: Investigating the underprediction of low-frequency hydrodynamic loads and responses of a floating wind turbine	2020	Journal of Physics: Conference Series	Resilience not mentioned
Patryniak et al., 2022	Robertson, Jonkman, Vorpahl, Popko, Qvist, Frøyd, Chen, Azcona, Uzunoglu, Soares, Luan, Yutong, Pengcheng, Yde, Larsen, Nichols, Buils, Lei, Nygaard, Manolas, Heege, Vatne, Ormberg, Duarte, Godreau, Hansen, Nielsen, Riber, Cunff, Beyer, Yamaguchi,	Offshore code comparison collaboration continuation within IEA wind task 30: Phase II results regarding a floating semisubmersible wind system	2014	Proceedings from the International Conference on Offshore Mechanics and Arctic Engineering	Resilience not mentioned

	Jung, Shin, Shi, Park, Alves, and Guérinel				
Patryniak et al., 2022 & Yang, Bashir, Li et al., 2021	Robertson, Wendt, Jonkman, Popko, Dagher, Gueydon, Qvist, Vittori, Azcona, Uzunoglu, Soares, Harries, Yde, Galinos, Hermans, Vaal, Bozonnet, Bouy, Bayati, Bergua, Galvan, Mendikoa, Sanchez, Shin, Oh, Molins, and Debruyne	OC5 Project Phase II: Validation of Global Loads of the DeepCwind Floating Semisubmersible Wind Turbine	2017	Energy Procedia	Resilience not mentioned
Mitchell et al., 2022	Röckmann, Lagerveld, and Stavenuiter	Operation and maintenance costs of offshore wind farms and potential multi-use platforms in the Dutch North Sea	2017	Aquaculture Perspective of Multi-Use Sites in the Open Ocean	FOWT not mentioned, resilience not mentioned
Sun et al., 2022	Roddier, Cermelli, and Weinstein	WindFloat: a floating foundation for offshore wind turbines - Part I: Design basis and qualification process	2009	International Conference on Offshore Mechanics and Arctic Engineering	Resilience not mentioned
Ma et al., 2019	Roddier, Cermelli, Aubault, and Weinstein	Windfloat: a floating foundation for offshore wind turbines	2010	Journal of Renewable and Sustainable Energy	Resilience not mentioned
Patryniak et al., 2022	Sandner, Schlipf, Matha, and Cheng	Integrated optimization of floating wind turbine systems	2014	Proceedings from the International Conference on Offshore Mechanics and Arctic Engineering	Resilience not mentioned
Patryniak et al., 2022	Sandner, Schlipf, Matha, Seifried, and Cheng	Reduced nonlinear model of a spar-mounted floating wind turbine	2012		Resilience not mentioned
Zhou et al., 2023	Sarmiento, Iturrioz, Ayllón, Guanche, and Losada	Experimental modelling of a multi-use floating platform for wave and wind energy harvesting	2019	Ocean Engineering	Resilience not mentioned
Sun et al., 2022	Sauder, Chabaud, Thys, Bachynski, and Sæther	Real-time hybrid model testing of a braceless semi-submersible wind turbine: Part I - The hybrid approach	2016	International Conference on Ocean, Offshore and Arctic Engineering	Resilience not mentioned
Patryniak et al., 2022	Schlipf, Schlipf, and Kühn	Nonlinear model predictive control of wind turbines using LIDAR	2013	Wind Energy	FOWT not mentioned, resilience not mentioned
Mitchell et al., 2022	Siemens	Thoroughly tested, utterly reliable Siemens wind turbine SWT-3.6-120	n.d.		FOWT not mentioned, resilience not mentioned
Mitchell et al., 2022	Siemens Gamesa	Offshore Wind Turbine SWT-7.0-154	n.d.		Resilience not mentioned
Mitchell et al., 2022	Siemens Gamesa	Offshore Wind Turbine SG 8.0-167 DD I	n.d.		FOWT not mentioned, resilience not mentioned
Mitchell et al., 2022	Siemens Gamesa	Offshore Wind Turbine SG 11.0-200 DD I	n.d.		FOWT not mentioned, resilience not mentioned
Mitchell et al., 2022	Siemens Gamesa	Offshore Wind Turbine SG 14-222 DD I	n.d.		FOWT not mentioned, resilience not mentioned
Mitchell et al., 2022	Siemens Gamesa	Servicing complex offshore needs	n.d.		FOWT not mentioned, resilience not mentioned
Zhou et al., 2023	Sijtsma	Stability assessment of a floating hybrid wind-wave platform: a frequency signal analysis	2020		Resilience not mentioned
Del Pozo González and Domínguez-García, 2022	Siniscalchi-Minna, Bianchi, De-Prada-Gil, and Ocampo-Martinez	A wind farm control strategy for power reserve maximization	2019	Renewable Energy	FOWT not mentioned, resilience not mentioned

Del Pozo González and Domínguez-García, 2022	Siniscalchi-Minna, Bianchi, Ocampo-Martinez, Domínguez-García, and De Schutter	A non-centralized predictive control strategy for wind active power control: a wake-based partitioning approach	2020	Renewable Energy	FOWT not mentioned
Ma et al., 2019	Skaare, Nielsen, Hanson, Yttervik, Havmoller, and Rekdal	Analysis of measurements and simulations from the Hywind demo floating wind turbine	2015	Wind Energy	Resilience not mentioned
Del Pozo González and Domínguez-García, 2022	Spudic, Jelavic, Baotic, and Peric	Hierarchical Wind Farm Control for Power/load Optimization	2010		Could not be accessed
Patryniak et al., 2022	Stieng and Muskulus	Reducing the number of load cases for fatigue damage assessment of offshore wind turbine support structures using a simple severity-based sampling method	2018	Wind Energy	FOWT not mentioned, resilience not mentioned
Patryniak et al., 2022	Sugita and Suzuki	A study on TLP hull sizing by utilizing optimization algorithm	2016	Journal of Marine Science and Technology	FOWT not mentioned, resilience not mentioned
Sun et al., 2022	Sun	Mitigation of offshore wind turbine responses under wind and wave loading: considering soil effects and damage	2018	Structural Control and Health Monitoring	Resilience not mentioned
Sun et al., 2022	Sun	Semi-active control of offshore wind turbines under multi-hazards	2018	Mechanical Systems and Signal Processing	FOWT not mentioned, resilience not mentioned
Sun et al., 2022	Sun and Jahangiri	Bi-directional vibration control of offshore wind turbines using a 3D pendulum tuned mass damper	2018	Mechanical Systems and Signal Processing	FOWT not mentioned, resilience not mentioned
Sun et al., 2022	Sun and Jahangiri	Fatigue damage mitigation of offshore wind turbines under real wind and wave conditions	2019	Engineering Structures	Resilience not mentioned
Kappenthuler and Seeger, 2019	Sun, Huang, and Wu	The current state of offshore wind energy technology development	2012	Energy	Resilience not mentioned
Sun et al., 2022	Sun, Jahangiri, and Sun	Adaptive bidirectional dynamic response control of offshore wind turbines with time-varying structural properties	2022	Structural Control and Health Monitoring	Resilience not mentioned
Chaloulos et al., 2021	Suroor and Arablouei	Comparison of coupled and decoupled seismic analysis of TLP piles	2019	Offshore Technology Conference	Resilience not mentioned
Patryniak et al., 2022	Tavner	Offshore wind turbines: reliability, availability and maintenance	2012		Resilience not mentioned
Sun et al., 2022	Thys, Chabaud, Sauder, Eliassen, Sæther, and Magnussen	Real-time hybrid model testing of a semi-submersible 10 MW floating wind turbine and advances in the test method	2018	International Offshore Wind Technical Conference	Resilience not mentioned
Patryniak et al., 2022	Tran and Kim	A CFD study of coupled aerodynamic-hydrodynamic loads on a semisubmersible floating offshore wind turbine	2017	Wind Energy	Resilience not mentioned
Chaloulos et al., 2021	Tsiapas, Chaloulos, Bouckovalas, and Bazaios	Performance based design of tension leg platforms under seismic loading and seabed liquefaction: A feasibility study	2021	Soil Dynamics and Earthquake Engineering	Resilience not mentioned
Sun et al., 2022	Urban and Guanche	Wind turbine aerodynamics scale-modeling for floating offshore wind platform testing	2019	Journal of Wind Engineering and Industrial Aerodynamics	Resilience not mentioned
Kappenthuler and Seeger, 2019	USDOE	A national offshore wind strategy. Creating an offshore wind energy industry in the United States	2011		Resilience not mentioned
Patryniak et al., 2022	USTUTT	Qualification of innovative floating substructures for 10MW wind turbines and water depths greater than 50 m. optimisation framework and methodology for optimized floater design	2016		Resilience not mentioned

Patryniak et al., 2022	Varj, Stewart, Stewart, Lackner, Jonkman, Robertson, and Matha	Wind/wave misalignment in the loads analysis of a floating offshore wind turbine	2014	32nd ASME Wind Energy Symposium	Resilience not mentioned
Zhou et al., 2023	Wan, Gao, and Moan	Experimental and numerical study of hydrodynamic responses of a combined wind and wave energy converter concept in survival modes	2015	Coastal Engineering	Resilience not mentioned
Ma et al., 2019	Wang	Dynamic analysis of a tension leg platform for offshore wind turbines	2014	Power Technologies	Resilience not mentioned
Kappenthuler and Seeger, 2019	Wang and Tay	Very large floating structures: Applications, research and development	2011	Procedia Engineering	FOWT not mentioned, resilience not mentioned
Del Pozo González and Domínguez-García, 2022	Wang, Du, Ni, Li, and Zhang	Coordinated predictive control for wind farm with bess considering power dispatching and equipment ageing	2018	Generation, Transmission and Distribution	FOWT not mentioned, resilience not mentioned
Patryniak et al., 2022	Wang, Robertson, Jonkman, Kim, Shen, Koop, Nadal, Shi, Zeng, Ransley, Brown, Hann, Chandramouli, Viré, Reddy, Li, Xiao, López, Alonso, Oh, Sarlak, Netzband, Jang, and Yu	OC6 Phase Ia: CFD Simulations of the Free-Decay Motion of the DeepCwind Semisubmersible	2022	Energies	Resilience not mentioned
Patryniak et al., 2022	Wang, Robertson, Jonkman, Yu, Koop, Nadal, Li, Bachynski-Polić, Pinguete, Shi, Zeng, Zhou, Xiao, Kumar, Sarlak, Ransley, Brown, Hann, Netzband, Wermbter, and López	Phase Ib: Validation of the CFD predictions of difference-frequency wave excitation on a FOWT semisubmersible	2021	Ocean Engineering	Resilience not mentioned
Zhou et al., 2023	Wang, Zhang, Michailides, Wan, and Shi	Hydrodynamic response of a combined wind-wave marine energy structure	2020	Journal of Marine Science and Engineering	Resilience not mentioned
Sun et al., 2022	Waris and Ishihara	Dynamic response analysis of floating offshore wind turbine with different types of heave plates and mooring systems by using a fully nonlinear model	2012	Coupled Systems Mechanics	Resilience not mentioned
Patryniak et al., 2022	Wen, Tian, Dong, Peng, and Zhang	On the power coefficient overshoot of an offshore floating wind turbine in surge oscillations	2018	Wind Energy	Resilience not mentioned
Mitchell et al., 2022	Wilson and Killmayer	Briefing-offshore wind energy in Europe	2020		Resilience not mentioned with respect to FOWT
Del Pozo González and Domínguez-García, 2022	Wu and Sun	Modeling and Modern Control of Wind Power	2018	book	FOWT not mentioned, resilience not mentioned
Del Pozo González and Domínguez-García, 2022	Xing, Karimirad, and Moan	Modelling and analysis of a floating spar-type wind turbine drivetrain	2014	Wind Energy	Resilience not mentioned
Yang, Bashir, Li et al., 2021 & Yang, Bashir, Michailides et al., 2021	Yang, Bashir, Michailides, Li, and Wang	Development and application of an aero-hydro-servo-elastic coupling framework for analysis of floating offshore wind turbines	2020	Renewable Energy	Resilience not mentioned
Yang, Bashir, Li et al., 2021 & Yang, Bashir, Michailides et al., 2021	Yang, Bashir, Wang, Michailides, Loughney, Armin, Hernández, Urbano, and Li	Wind-wave coupling effects on the fatigue damage of tendons for a 10 MW multi-body floating wind turbine	2020	Ocean Engineering	Resilience not mentioned

Yang, Bashir, Li et al., 2021	Yang, Bashir, Wang, Yu, and Li	Performance evaluation of an integrated floating energy system based on coupled analysis	2020	Energy Conversion and Management	Resilience not mentioned
Yang, Bashir, Li et al., 2021	Yang, He, and Hu	Dynamic modeling and vibration suppression for an offshore wind turbine with a turned mass damper in floating platform	2019	Applied Ocean Research	Resilience not mentioned
Yang, Bashir, Michailides et al., 2021	Yang, Li, Zhang, Yang, Ye, Miao, and Ye	A multi-objective optimization for HAWT blades design by considering structural strength	2016	Journal of Mechanical Science Technology	FOWT not mentioned, resilience not mentioned
Patryniak et al., 2022	Young, Goupee, Dagher, and Viselli	Methodology for optimizing composite towers for use on floating wind turbines	2017	Journal of Renewable and Sustainable Energy	Resilience not mentioned
Patryniak et al., 2022	Young, Ng, Oterkus, Li, and Johanning	Predicting failures of dynamic cables for floating offshore wind	2019	RENEW 2018	Resilience not mentioned
Patryniak et al., 2022	Zhang, Song, Qiu, Yuan, You, and Deng	Multi-objective optimization of Tension Leg Platform using evolutionary algorithm based on surrogate model	2018	Ocean Engineering	FOWT not mentioned, resilience not mentioned
Del Pozo González and Domínguez-García, 2022	Zhao, Wu, Guo, Sun, and Xue	Distributed model predictive control of a wind farm for optimal active power control Part I: Clustering-based wind turbine model linearization	2015	IEEE Transactions on Sustainable Energy	FOWT not mentioned, resilience not mentioned
Zhou et al., 2023	Zhu, Hu, Sueyoshi, and Yoshida	Integration of a semisubmersible floating wind turbine and wave energy converters: an experimental study on motion reduction	2019	Journal of Marine Science and Technology	Resilience not mentioned
Yang, Bashir, Li et al., 2021	Zuo, Song, Wang, and Song	Computationally inexpensive approach for pitch control of offshore wind turbine on barge floating platform	2013	The Scientific World Journal	Resilience not mentioned
Mitchell et al., 2022		ROMEO targets offshore wind O&M cost reduction	2017	Offshore Wind	FOWT not mentioned, resilience not mentioned
Mitchell et al., 2022		What are the advantages and disadvantages of offshore wind farms?		American Geosciences Institute	Resilience not mentioned
Mitchell et al., 2022		New UK project eyes autonomous vessels in offshore wind	2018	Safety4Sea	FOWT not mentioned, resilience not mentioned
Mitchell et al., 2022		Windfarm autonomous ship project	2018	ORE Catapult	FOWT not mentioned, resilience not mentioned
Mitchell et al., 2022		MIMRee's autonomous inspect and repair mission to offshore wind farms	2020	ON&T	FOWT not mentioned, resilience not mentioned
Mitchell et al., 2022		First robotic 'blade walk' on a wind turbine opens door to significant cost cuts in offshore renewables	2020	ORE Catapult	FOWT not mentioned, resilience not mentioned
Mitchell et al., 2022		Turbine blade test facilities	n.d.	ORE Catapult	FOWT not mentioned, resilience not mentioned

Appendix A.6: In-Depth Analysis Eliminations

Author(s)	Title	Date	Publication	Exclusion Rationale
Ahmed and Cameron	The challenges and possible solutions of horizontal axis wind turbines as a clean energy solution for the future	2014	Renewable and Sustainable Energy Review	Resilience discussed in relation to the wind industry, not FOWT
Barter, Robertson, and Musial*	A systems engineering vision for floating offshore wind cost optimization	2020	Renewable Energy Focus	Resilience not studied or discussed in relation to FOWT
Chapain and Aly	Vibration attenuation in wind turbines: A proposed robust pendulum pounding TMD	2021	Engineering Structures	One mention of FOWT; the study is done on an onshore turbine
Dincer, Cozzani, and Crivellari	Chapter 6 – Case studies – Hybrid Energy Systems for Offshore Applications	2021	Hybrid Energy Systems (book)	Resilience not studied or discussed in relation to FOWT
George, Loo, and Jie	Recent advances and future trends on maintenance strategies and optimization solution techniques for offshore sector	2022	Ocean Engineering	Resilience engineering mentioned, but not in connection with FOWT
Ghenair, Husein, Al Nahlawi, Hamid, and Bettaybed	Recent trends of digital twin technologies in the energy sector: A comprehensive review	2022	Sustainable Energy Technologies and Assessments	Resilience not studied or discussed in relation to FOWT; FOWT technologies are only mentioned in reference to other sources
James and Ros**	Floating offshore wind: Market and technology review	2015	Report issued by Carbon Trust	Resilience is mentioned only with respect to FOWT installation processes, not design or operation
Ji and Yang	Ice loads and ice-induced vibrations of offshore wind turbine based on coupled DEM-FEM simulations	2022	Ocean Engineering	One mention of FOWT, but main study carried out on a fixed offshore wind turbine
Joselin Herbert, Iniyan, and Amutha	A review of technical issues on the development of wind farms	2014	Renewable and Sustainable Energy Reviews	Resilience not studied or discussed in relation to FOWT
Kumar, Baalisampang, Arzaghi, Garaniya, Abbassi, and Salehi	Synergy of green hydrogen sector with offshore industries: Opportunities and challenges for a safe and sustainable hydrogen economy	2023	Journal of Cleaner Production	Resilience not studied or discussed in relation to FOWT
Leimeister and Kolios	A review of reliability-based methods for risk analysis and their application in the offshore wind industry	2018	Renewable and Sustainable Energy Reviews	Resilience not studied or discussed in relation to FOWT
Marsh	Greater role for composites in wind energy	2014	Reinforced Plastics	Resilience not studied or discussed in relation to FOWT
Mitchell, Blanche, Zaki, Roe, Kong, Harper, Robu, Lim, and Flynn***	Symbiotic System of Systems Design for Safe and Resilient Autonomous Robotics in Offshore Wind Farms	2021	IEEE Access	Resilience is not studied or discussed in relation FOWT
Papatheocharis, Sarvanis, Perdikaris, Karamanos, Spyros, and Zervaki	Fatigue resistance of welded steel tubular X-joints	2020	Marine Structures	Main focus of study is fixed offshore turbines; resilience is not mentioned in connection with FOWT
Rose, Wei, and Einbinder	The co-benefits of California offshore wind electricity	2022	The Electricity Journal	Resilience not studied or discussed in relation to FOWT design or operation
Sierra-Garcia, Santos, and Pandit	Wind turbine pitch reinforcement learning control improved by PID regulator and learning observer	2022	Engineering Applications of Artificial Intelligence	Mentions FOWT but study conducted on onshore turbine
Zhang, Yan, Wang, Xu, and Yan	Assessment of the offshore wind turbine support structure integrity and management of multivariate hybrid probability frameworks	2019	Energy Conversion and Management	Study conducted on fixed offshore turbine

**Found in both primary search and reference review – Patryniak et al. (2022)*

***Found in reference review – cited by Kappenthuler and Seeger (2019) and Patryniak et al. (2022)*

****Found in reference review – Mitchell et al. (2022)*