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**Offshore Wind Energy, Maritime Governance, and the Resilience  
of the EU's Energy System**

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## 1. Introduction

Russia's full-scale invasion of Ukraine led the European Union (EU) to an Energy crisis. Defined not just by supply shocks but by revealing the underlying security failure, energy security that rested on a single, coercible dependency. Since then energy security, securing sufficient energy supplies to secure one's needs and at an affordable price, has become a major concern. Energy security is vital for economic stability as disruptions in one region ripple across global markets and social cohesion; energy access inequalities exacerbate geopolitical divides. Of course energy also drives industrial production, global trade and technological innovation (World Energy Outlook, 2022 & Energy, 2026).

The European Union (EU) has since started to invest in ways to diversify the energy supply, which aims to decrease the risk of disruptions and improve resilience (REPowerEU, 2022). Through the REPowerEU (2022) plan Russian gas imports have gone from 45% to 15% between 2021 and 2023. In 2024 Europe wind and solar produced electricity exceeded that from gas for the first time ever. This cemented renewables as the backbone of the EU energy grid. This was supported by a rapid increase in renewable energy installations (REPower EU, 2022 & Eurostat, 2025). This is a promising outlook for an EU that wants to meet climate goals and reduce dependencies. The Eurostatistics (2025) on renewable energy state the following: "In 2024, renewable energy sources made up 47.5% of gross electricity consumption in the EU, more than 2 pp higher than the previous year (45.4% in 2023)." The transition is real but there is a gap between expanding renewable energy and having a system that is not dependent on unreliable actors (Eurelectric, 2025).

This thesis aims to address this gap. It argues that an increase in offshore wind generation to meet electrification needs in the EU will increase the resilience of the EU's energy system. Electrification plays a key role in reaching energy security, affordability and emission reduction. Investment in electrification grows around 15% year on year globally according to the World Energy Investment Report (2025). Offshore wind occupies a unique position in the EU energy transition. Unlike onshore, solar or wind, which can be developed and managed within a single country, offshore wind is inherently a cross-border phenomenon. Wind is present in EU maritime territory. Once the infrastructure is built, the electricity it generates cannot be withheld and can not be used by unreliable actors to exercise coercive control. Offshore wind capacity helps decentralize energy supply, reduce dependency on energy imports, and help reduce emissions, limiting the leverage that external actors can exercise and increasing resilience (REPowerEU, 2022 & European Commission, 2025).

This requires shared maritime governance, multi-national grid infrastructure, and collective investment frameworks. The build of energy hubs and islands in the North Sea and the Baltic Sea represent this: these projects are set to revolutionize Europe's energy system. These energy hubs are

not just about generation but will enable the storage, and transport of renewable energy at a scale that single countries cannot provide (DNV, n.d.). This thesis will analyse these two maritime regions as comparative cases against the four dimensions of energy system resilience based on the NREL framework by Leddy et al (2024): robustness, redundancy, adaptability and recovery. This will be elaborated on in Chapter 3: Methodology.

Based on this context, this thesis asks the following research question:

**Main research question:** *To what extent and under which conditions does the expansion of offshore wind capacity in the EU enhance the resilience of the EU's energy system?*

This is supported by the following sub-questions:

**Sub-question 1:** *How do the governance structures of the North Sea and Baltic Sea create the conditions under which offshore wind capacity translates into energy system resilience across the four dimensions of robustness, redundancy, adaptability and recovery?*

**Sub-question 2:** *What are the main risks and obstacles that limit the contribution of offshore wind in the EU's maritime regions?*

Both questions are answered through a comparative case study of the North Sea and Baltic Sea, using the NREL framework (Leddy et al., 2024) as the analytical foundation. The timeline runs from 2022 to 2025, including the energy crisis that followed Russia's full scale invasion of Ukraine, the REPowerEU acceleration, the Baltic states' BRELL desynchronisation, and the Estlink-2 cable disruption.

The structure of this thesis is as follows. Chapter 2 consists of a literature review, Chapter 3 justifies the comparative methodology and operationalises the resilience framework. In Chapter 4 the empirical analyses of the North Sea and Baltic Sea is done and Chapter 5 has the main findings and conclusions.

## 2. Literature Review

### *2.1 Energy security and energy system resilience*

Energy security and energy system resilience are related but different concepts, treated in this thesis as interconnected. Energy security focuses on availability, affordability, accessibility, sustainability and acceptability (International Energy Agency, 2022). Energy system resilience is more narrow and operational, its focus is on a systems ability to anticipate, prepare for, and adapt to changing conditions and to respond to shocks and recover from them. A system needs both to withstand shocks and to be able to prevent a crisis. A system may seem energy secure because of its adequate supply, infrastructure and stable pricing, but can be fragile when faced with disruptions if it lacks diversity and the capacity to adapt that resilience requires. They are overlapping concepts, but both aim to create or contribute to a stable power system and are complementary to each other (Leddy et al., 2024 & Holman, 2025).

Resilience is defined differently across various scientific disciplines, it is on the one hand a systems ability to withstand shocks by international threats (Martišauskas et al., 2022) and the ability of an energy system to deal with the disruptions caused by these international threats (Gasser et al., 2019). Martišauskas et al. (2022) uses capacity indicators or performance in the presence of disruption as resilience indicators and Gasser et al. (2019) further specifies this by including in their definition that resilience should not only focus on risk assessment but on a system's capability to bounce back after such events and to think of future strategies (Martišauskas et al., 2022 & Gasser et al., 2019). This is a necessary distinction, because energy systems are constantly subject to major disruptions which ripple across global markets (Energy Security, n.d.). This is further operationalized by NREL (Leddy et al., 2024) which defines energy system resilience as the ability to anticipate, prepare for and adapt to changing conditions and withstand, respond to and recover rapidly from disruptions.

This thesis will apply the concept of resilience to the EU's energy system in four operational dimensions: **Robustness**, the capacity to handle disruption without losing function, which can be achieved through diversification; **redundancy**, the availability of backup capacity and alternative supply chain routes, this is based not in generation capacity alone but in the networks that support it; **adaptability**; the ability to respond to changing conditions, including both technology and governance; and **recovery**, the speed of restoring complete function after disruption (Leddy et al., 2024 & Gasser et al., 2019).

## ***2.2 Security and Sustainability***

Energy security and the green transition are mutually beneficial under the right conditions. Energy dependency undermines energy security; this is most visible in the fact that Russia was able to weaponize gas exports in 2022. The crisis following Russia's invasion of Ukraine forced the EU to increase the resilience of its energy system through diversification, with a greater focus on renewables (Danish Institute for International Studies, 2024 & Trushkina, 2025). Initiatives such as REPowerEU frame green energy not only as a climate imperative, but also as a means to reduce strategic dependencies, diversify supply, and strengthen energy resilience. It increases the security of the energy supply and creates green jobs. Renewable energy sources play a crucial role in securing a stable energy future by decreasing dependence on limited natural resources (Fuh, 2014 & REPowerEU, 2022). The Repower EU plan focuses on ending Europe's energy dependency on Russia. Initiatives like The European Green Deal also support the fast forwarding of the clean transition, causing an increase in demand for renewable energy and a decrease in demand for coal and gas (*The European Green Deal*, n.d.). In 2024 Europe wind and solar produced electricity exceeded that from gas for the first time ever. This cemented renewables as the backbone of the EU energy grid. This was supported by a rapid increase in renewable energy installations (REPower EU, 2022 & Eurostat, 2025). Renewable energy has a unique position here, because it addresses energy security and sustainability as two sides of the same coin. Renewable energy is a geopolitical asset, domestically generated wind cannot be turned off by a hostile actor and also makes it harder for a system to be disabled through an attack. Sustainability and security do need to be two competing agendas (Tserkasina, 2026; Energy as a geopolitical weapon, 2025 & Aylett et al., 2026).

This alignment, however, is conditional rather than automatic, and the literature is careful to specify the conditions under which it holds. Three conditions must be met for renewable energy to function as a security asset rather than merely a climate instrument. First, generation must be domestically controlled and grid-integrated; disconnected or import-dependent capacity, for instance offshore wind capacity that cannot be transmitted to demand centres because of grid congestion, does not produce the security benefit the technology in principle offers. Second, grid infrastructure must be adequate to absorb and balance that generation, since high installed capacity without adequate transmission and balancing infrastructure produces curtailment, wasted generation, and rising costs rather than resilience; this is a finding the empirical analysis in Chapter 4 confirms directly in the North Sea case. Third, the supply chains for renewable technology itself, including critical raw materials and components such as high-voltage direct current converters, must be diversified, since concentration in a single external supplier, however commercially efficient in the short term, reproduces the dependency risk the transition is meant to eliminate (Abels & Bieling, 2024; Beaucillon, 2023). The empirical chapters of this thesis show that this third condition in particular has not yet been met:

Europe's reliance on globally concentrated HVDC supply chains has already disrupted the construction of its most advanced energy island project.

The EU needs to find the balance between remaining open whilst also reducing strategic dependencies. For renewable energy to function as a security asset generation must be controlled within the EU and it must include supply chain diversification, critical minerals policy and solidarity across EU member states if it wants to succeed (Abels & Bieling, 2024). Building resilience through energy diversification, with a focus on offshore wind is not separate from energy security but should be seen as a new foundation, resilience should be understood as the operational mechanism through which energy security is achieved (Aylett et al., 2025 & Leddy et al., 2024).

### ***2.3 Impact on European Resilience***

Renewable electricity reached 47.5% of EU consumption in 2024 (Eurostat, 2025), and wind power surpassed gas as an electricity source for the first time in 2023. Russian gas imports fell from 45% to 15% of EU supply between 2021 and 2023 (European Commission, 2024). This contributes to the robustness and adaptability dimensions. Redundancy and recovery are still underdeveloped; due to underdeveloped grid infrastructure and interconnection renewable energy is still wasted in the EU (European Parliament, 2026), the gap this thesis aims to address through the NREL framework.

### 3. Methodology

#### 3.1 Research Design

This thesis consists of a comparative case study in which the North Sea and Baltic Sea function as the cases within the broader analysis of: the EU's offshore wind capacity as a contribution to energy system resilience. The cases were selected because both are EU-recognised maritime regions governed by energy cooperation bodies, the North Seas Energy Cooperation (NSEC) and the Baltic Energy Market Interconnection Plan (BEMIP) (Regional Seas Around Europe, 2022). Both are experiencing an acceleration in offshore wind capacity as a key strategy point to reduce fossil fuel dependency and building energy system resilience, and both contain energy island projects that represent the most advanced form of offshore grid integration being developed in Europe (REPowerEU, 2022). However, they differ in governance structure, geopolitical context, grid integration and physical security. The analysis will also include country evidence to illustrate specific resilience dimensions, Denmark, Germany, Belgium, and the Netherlands for the North Sea and Estonia, Latvia, Lithuania, Poland, and Sweden for the Baltic Sea.

#### 3.2 Operationalisation

As mentioned in Chapter 2 this thesis will apply the concept of resilience to the EU's energy system in four operational dimensions: **Robustness**, the capacity to handle disruption without losing function, which can be achieved through diversification; **redundancy**, the availability of backup capacity and alternative supply chain routes, this is based not in generation capacity alone but in the networks that support it; **adaptability**; the ability to respond to changing conditions, including both technology and governance; and **recovery**, the speed of restoring complete function after disruption (Leddy et al., 2024 & Gasser et al., 2019). Below each of the dimensions is translated into measurable indicators.

**Robustness:** Robustness refers to the system's ability to withstand shock without losing critical function. In the NREL framework robustness is achieved through diversification and the decentralisation of generation; A system based on networks of distributed generation is more resilient than one based on one source. Offshore wind contributes in two specific ways, first by generating from a domestically controlled maritime source, this reduces the import dependency ratio and with that the vulnerability to be coerced. Second, by distributing generation it reduces the consequences of a single point failure or attack (Aylett et al., 2025 & Leddy et al., 2024). The North Sea and Baltic Sea differ on physical security, the Baltics proximity to Russia and its documented infrastructure sabotage events, the Nord Stream explosion in 2022 and the Estlink-2 sabotage, means that robustness needs to be assessed against an active hybrid threat landscape that the North Sea does not face to the same degree (Altmayer & European Parliamentary Research Service, 2025 & Rarick, 2025).

<b>Indicator</b>	<b>What it measures</b>	<b>Data Source</b>
Offshore wind share of regional electricity generation (%)	Extent to which generation is decarbonised and domestically controlled	Eurostat ENTSO-E
Import dependency ratio of member states within each region (%)	Reduction in external energy exposure as offshore wind expands	Eurostat
Geographic distribution of installed offshore capacity	Whether capacity is distributed across the maritime zone or concentrated in single national clusters	ENTSO-E TYNDP WindEurope
Physical security architecture	Presence or absence of protective measures around offshore infrastructure	NSEC BEMIP

**Redundancy:** Redundancy refers to availability of backup capacity and alternative supply routes that can be used when the main routes fail. This prevents a single disruption from causing a system-wide failure (Leddy et al., 2024). In the context of the EU context cross-border electricity interconnection is the main redundancy mechanism, cross-border electricity interconnection refers to member states ability to draw on neighbouring generation when their own domestic supply is disrupted. This is where the type of grid connections is important: either one cable from farm to shore connected to a single national grid, which adds generation capacity but lacks overall redundancy, or a hybrid interconnector, which would connect multiple wind farms through a shared offshore hub to multiple grids simultaneously. The hybrid option would increase redundancy by creating alternative power routes. Energy islands are the most advanced example of this hybrid interconnection, and the development of these islands is central to the North Sea and Baltic Sea (Rory, 2025).

<b>Indicator</b>	<b>What it measures</b>	<b>Data Source</b>
Cross-border interconnection capacity (GW)	Maximum power transferable across borders	ENTSO-E TYNDP
Number and type of grid connections per offshore	Structural redundancy embedded in offshore	ENTSO-E TYNDP NSEC BEMIP

installation (single vs. hybrid)	architecture	
Energy storage capacity (GWh) batteries	Ability to buffer supply-demand mismatches during a disruption	IRENA National TSOs

**Adaptability:** In the NREL framework, adaptability refers to the system's capacity to respond and adapt to changing conditions. Renewable technologies, which already accounts for nearly half of the EU's electricity generation, increase resilience through their scalability and rapid deployment potential. This flexibility enables a system to efficiently respond to supply shortages, disruptions or geopolitical tensions. Combined with a decentralized system this also increases operational flexibility, allowing parts of the system to operate independently during a crisis (Eurelectric, 2025 & Igliński et al., 2024).

Indicator	What it measures	Data Source
Annual offshore capacity additions (GW per year)	Speed and scale of deployment	WindEurope IRENA
Energy Island development stage	development of the system enabling accelerated scaling	Elia (Princess elisabeth island); Energinet/50hertz (Bornholm); Tennet (North sea wind power hub)
Regional Governance	Adaptability in response to geopolitical conditions	NSEC BEMIP

**Recovery:** Recovery refers to the speed and completeness at which a system regains critical function after a disruption. Recovery is the dimension most directly tested by documented events and both maritime regions provide evidence of this (Leddy et al., 2024). The distributed nature of renewable technologies improves the capacity of an energy system to recover from acute disruptions. If disruptions occur in centralized system failures can cascade through the system due to the concentrated networks. Disruptions affecting a wind installation can often be compensated for through rerouting, storage or local generation. This structure increases a systems ability to recover functionality after disruptions.. Recovery capacity depends on investments in storage, interconnection and grid flexibility for success (CERRE, 2023, Westphal & Politik, 2021 & Ledy et al., 2024).

<b>Indicator</b>	<b>What it measures</b>	<b>Data Source</b>
Documented disruption events and recovery times (2022 - 2025)	Capacity of recovery under real conditions	Estlink - 2 and Nord Stream incidents reports
Cross-border emergency support	Mechanisms used in actual crisis response	European Commission emergency reports ENTSO-E operational data
Infrastructure security commitments	Is recovery enabling infrastructure protected	NATO maritime security WindEurope

The four dimensions are applied consistently across both cases using the structure outlined above.

<b>Dimension</b>	<b>Analytical question</b>	<b>Primary evidence source</b>
Robustness	Does offshore wind expansion reduce import dependency and distribute generation that reduce single point risk?	Import dependency ratios; physical security
Redundancy	Does the regional offshore grid network provide alternative supply routes?	ENTSO-E grid data; interconnection capacity
Adaptability	Do energy islands and governance frameworks enable an acceleration in offshore wind deployment?	Energy island project stages and governance targets
Recovery	Can the system restore essential function in a timely manner after disruption and is the infrastructure that enables this protected?	Disruption event records; cross-border collaboration.

### ***3.3 Limitations***

This thesis has two limitations. First, because no centralised EU dataset reports resilience outcomes using the four NREL dimensions, comparability across regions is imperfect: some indicators are reported in directly comparable units, while others, particularly recovery, are evidenced through qualitative description of incidents that differ in nature between the two seas. Second, because several flagship projects, the North Sea Wind Power Hub and Bornholm Energy Island especially, remain years from operational status, the evidence available describes governance intentions and construction milestones rather than operational performance. The analysis is explicit throughout about which kind of evidence underpins a given claim, to avoid overstating certainty about projects not yet built.

## **4. Empirical Analysis**

Installed EU offshore wind capacity reached approximately 21.2 GW by the end of 2024, with roughly 80% concentrated in the North Sea (European Commission, 2025 & Nordic Innovation, 2025). The Baltic Sea holds approximately 3.1 GW (Baltic Power, n.d.), this difference in capacity allows the analysis to look at whether the mechanisms connecting offshore wind to resilience operate differently depending on how mature the surrounding governance and infrastructure is. The sections that follow examine the North Sea and the Baltic Sea against each of the four NREL dimensions, before coming to a summary of both cases, the answers to the research questions and conclusions in Chapter 5

### **4.1 Case study 1: North Sea**

#### ***4.1.1 Robustness and Redundancy***

The North Sea is a hub for offshore wind power because of its shallow seabed, which is well suited for offshore turbines. The North Sea generation is diversified, it gets its generation capacity from over 100 operational wind farms spread across the United Kingdom, Germany, the Netherlands, Belgium, Norway and Denmark, these together hold the large majority of EU capacity (Ember, 2026; Nordic Innovation, 2025). This diversification is important for the robustness of the system; no single national disruption, whether the nature of that disruption is political, technical, or financial, can disable the entire regional generation base, since its capacity is spread over separate countries.

Two indicators anchor the robustness assessment directly in Eurostat data: offshore wind's share of electricity generation, and the overall energy import dependency ratio of the core North Sea states. Germany, the region's largest economy, generated 25.7 TWh of electricity from offshore wind in 2024, equivalent to 5.9% of its total electricity generation, from 9.2 GW of installed capacity (German Offshore Wind Energy Association). This is a rising share: offshore wind in the North Sea is a genuine and growing contributor to the generation mix, but remains a minority contributor even in the most offshore-wind-intensive large economy in the region. On import dependency there are more differences between countries. Germany's overall energy dependency stood at 67%, ten percent more than the EU average of 57% (Eurostat, 2025). Denmark is the cleanest, it recorded a negative oil import dependency rate in 2017, meaning it was a net exporter rather than an importer, this is reinforced by Denmark's offshore wind capacity, which meets 56% of the total electricity demand (WindEurope, 2024). This means the North Sea case actually contains two quite different robustness stories within a single region: Germany, where offshore wind is making a real but still modest dent in a stubbornly high overall import dependency rate, and Denmark, where offshore wind has been a central instrument in achieving a position of near energy self-sufficiency that few other EU states approach.

Redundancy requires transmission investment rather than simply more generation. In their integrated annual report, TenneT (2025) reports that German onshore grid congestion is forcing them to limit the output of onshore farms. This caused a decrease in wind yields, despite the rise in installed capacity. The infrastructure that is needed to carry that electricity to demand centres can not keep up with the pace of the generation capacity. The ENTSO-E Ten Year Network Development Plan (TYNDP) (2023) found a need for an additional 64 GW of cross-border capacity by 2030 to meet needs across Europe. This target excludes the cross-border investments, that amount to approximately 35 GW, that were scheduled for completion in 2025. Investing in this infrastructure is to help smooth market integration, provide continuous and secure access to electricity, and ensure that the benefits of the transition outweigh the costs. This increase reflects the pace of the energy transition and the growing demand for interconnected infrastructure to support high levels of renewable energy generation (ENTSO-E, 2023).

These reports are an acknowledgement of the need for redundancy, the energy system needs more than just more generation. It requires investment in infrastructure that needs to carry it. The LionLink project between the Netherlands and the UK shows what this requires in practice. LionLink is an electricity connection with a capacity of 2 GW. LionLink is a hybrid interconnector. This type of electricity connector combines multiple technologies to link the networks of two countries or regions, the Netherlands and the UK in this case. In the case of LionLink this means that the interconnector doesn't rely solely on subsea cables to transport electricity, but also incorporates an offshore platform as part of the connection. The two countries have different energy mixes and LionLink intelligently complements supply between them, to manage peaks and low points in energy production, ensuring a reliable and steady supply of electricity. This hybrid design between generation connection and a cross-border connection in one piece of infrastructure is exactly what is needed to translate offshore wind capacity into genuine redundancy. It will allow power to be routed to what country needs it most at any given moment instead of being fixed to a national grid connection. However, the joint development agreement covering planning agreements and final investment decisions has been signed in early 2026. There is still a gap between these ambitious projects and current capacity, a pattern throughout the North Sea Case (TenneT, 2024).

Energy storage, the third redundancy indicator, remains the least developed against the supply-demand mismatch in the North Sea. As of December first 2025, the region has a cumulative energy storage capacity of 100 GW. The EU requires approximately 750 GWh by 2030, meaning the expansion has a long way to go (Energy Storage Europe, 2026). Energy storage is therefore not a fully developed redundancy mechanism capable of handling a major supply disruption.

Another aspect of robustness is the physical security of this infrastructure. The Russian ‘shadow’ fleet, which was designed to evade international sanctions, has passed the Dutch North Sea coast over 1,300 times between 2023 and 2024 (European Parliamentary Research Service, 2024) and Russia is actively mapping critical maritime infrastructure in the Dutch North Sea. Russia is known for targeting critical infrastructure, it has targeted energy infrastructure and generation capacities in Ukraine since the start of the war. The fact that they are mapping other countries' critical maritime infrastructure could point to Russia preparing for future sabotage (*Fuel, Fear and Falsehoods: Defending Europe and Ukraine From Russia's*, 2025). Given the concentration of critical energy and communications infrastructure on the North Sea floor it needs governance on how to be defended. Since 2023 Dutch offshore wind parks and their associated infrastructure have been considered critical infrastructure by the government. However only since April 2026, due to an increase in geopolitical threats, sabotage and espionage has there been an increase in security. To legally enforce this the Cybersecurity Act (Cbw) and the Critical Entities Resilience Act have been approved by the Dutch government, which is enforced in the following ways; tightened supervision on digital and physical security of North Sea infrastructure, sector specific risk analysis every four years and shares these with the relevant companies to increase targeted measures and organisations in vital sectors must comply with strict European directives (CER, NIS2) to increase their digital and physical resilience (Ministerie van Justitie en Veiligheid, 2026).

Robustness in the North Sea is not just a question of how diversified or how large the generation capacity is; it is also a question of whether that capacity is supported by the appropriate infrastructure and can be properly defended against the hybrid threats the Baltic Sea has already experienced.

#### ***4.1.2 Adaptability***

Belgium's Princess Elisabeth Island is the world's first artificial energy island being constructed in the Belgian North Sea. It is a critical infrastructure project to help Belgium and Europe meet 2030 climate goals and achieve energy independence. Construction is set to finish mid - 2026. The Island acts as a dual-purpose energy hub designed to centralize and distribute green electricity. It transforms renewable electricity generated by offshore wind farms in the Princess Elisabeth area for transmission to the Belgian mainland and serves as a junction for cross-border grids, including the Nautilus link with the United Kingdom and the Triton link with Denmark, allowing energy to flow smoothly between nations and preventing grid overloading. The Island has a total planned capacity of 3.5 GW. By consolidating offshore wind resources and facilitating cross-border trading, the island aims to guarantee competitively priced, sustainable energy for citizens and businesses. Energy Islands show the promise but also the conditions for greater resilience (Jan De Nul, 2025 & Elia Group, n.d.). However, the High - Voltage Direct Current (HVDC) supply market, the component which would have created a hybrid connection with the UK, was extremely volatile which led to a halt in signing

HVDC contracts (Elia Group, 2025). Even the most advanced energy island remains conditional on global component markets outside of EU control. It can not be assumed that building an energy island ensures resilience.

The North Sea Wind Power Hub (NSWPH) is a transnational project designed to transform the North Sea into a massive, shared "Green Powerplant" for Europe. It corrects an important limitation of relying on Princess Elisabeth Island alone; the Belgian project is a single country asset but the NSWPH was a combined project between the Netherlands, Denmark and Germany from the start. It is located in the Dogger Bank, a shallow sandbank where Dutch, German and Danish economic zones meet. It is designed like a 'hub and spoke' model, meaning that there is a central collection and distribution point that is connected to the power grids of multiple North Sea countries. In the 2030s a first 10 to 15 GW hub is feasible. The NSWPH's feasibility and preparation studies are co-financed by the Connecting Europe Facility (CEF) of the European Union, highlighting its status as a critical infrastructure project for European integration and the Green Deal. This project treats the North Sea as a massive shared resource with the potential to benefit the whole of Europe by providing a reliable source of green energy and by scaling renewable energy to unprecedented levels, the project aims to lower energy costs for industry and secure Europe's position at the forefront of clean technology innovation (North Sea Wind Power Hub, 2025; Port of Rotterdam, n.d; Gas Infrastructure Europe, n.d.).

The NSWPH therefore demonstrates a different adaptability profile than Princess Elisabeth Island: enormous technical and structural ambition, validated as feasible nearly a decade ago, but still unresolved at the level of the cost-sharing and regulatory architecture needed to convert that feasibility into construction. This is consistent with the Bornholm Energy Island's multi-decade timeline discussed below, and reinforces a pattern visible across both regions, that the most transformative energy island concepts require far longer institutional gestation than their technical readiness alone would suggest. The contrast between a project whose physical construction has already been delayed by a global supply chain shock, Princess Elisabeth Island, and a project whose technical design has been validated for nearly a decade but which remains stalled on intergovernmental cost allocation, the NSWPH, suggests that adaptability in the energy island context is constrained by at least two largely independent risk factors: global component markets on one hand, and multinational governance coordination on the other. A project can clear one obstacle and still remain stuck on the other.

At the broader governance level, NSEC's target trajectory demonstrates real institutional adaptability. The 2022 Esbjerg Declaration set a target of 65 GW of offshore wind by 2030 for four signatory states; the 2023 Ostend Declaration raised this to 120 GW by 2030 and 300 GW by 2050 for an expanded coalition of nine countries (NSEC, 2023). This represents a genuine escalation of ambition

directly attributable to the post-2022 security context, exactly the kind of adaptive governance response the NREL framework anticipates. Yet European deployment of roughly 3.7 GW per year remains well below the pace required to meet even the nearer-term target (Global Energy Monitor, 2025), confirming that institutional adaptability at the level of declared ambition has, so far, outpaced adaptability at the level of physical construction.

#### ***4.1.3 Recovery***

The recovery dimension is, by a clear margin, the least evidenced of the four for the North Sea. Unlike the Baltic Sea, the region has not experienced a major documented disruption to offshore wind or grid infrastructure within the 2022 to 2025 study period comparable to the Nord Stream sabotage or the Estlink-2 cable incident, so its recovery capacity cannot be assessed against an actual event the way the Baltic Sea's can. What can be assessed instead is preparedness: the institutional commitments that exist in anticipation of a disruption that, in this region, has not yet occurred.

On that narrower basis, the picture is mixed. NSEC's January 2026 Hamburg Declaration explicitly commits signatory states to strengthening the resilience of the region's energy system against physical, cyber, and hybrid threats, language absent from the earlier Esbjerg and Ostend declarations and reflecting a growing ministerial awareness that offshore infrastructure protection cannot be left to individual member states alone. Yet The West Wing's 2026 report suggests the same governance gaps weakening the Netherlands' ability to protect its offshore infrastructure would also slow a coordinated recovery: responsibility for Dutch maritime incidents is currently split across five ministries feeding into Coast Guard governance, with no single body holding an overriding command mandate, and no formally agreed authority for civilian enforcement beyond twelve nautical miles offshore (The West Wing, 2026).

The North Sea's recovery dimension should therefore be read as an open question rather than a strength or a weakness. The region has the advantage of not yet having been tested by an event on the scale of Nord Stream, but that same absence means this thesis cannot point to a concrete instance of the North Sea's offshore energy system actually recovering from serious disruption, as it can for the Baltic Sea. Until such a test occurs, the Hamburg Declaration's commitments remain an intention and a vulnerability, respectively, rather than demonstrated capacities.

## 4.2 The Baltic Sea

### 4.2.1 Robustness

The same two Eurostat-based indicators tell a more uniform, and more directly geopolitical, story for the Baltic states. Renewables, including offshore wind, already account for a substantial share of gross final energy consumption among the Nordic Baltic states: Sweden led the EU in 2024 at 62.8%, Finland followed at 52.1%, and Denmark, again straddling both seas, reached 46.8% (Eurostat, 2025). These figures are not offshore wind's share of electricity generation specifically, since Eurostat does not yet publish that breakdown separately for most Baltic states, but they confirm these states already hold some of the EU's highest renewable shares, the generation base onto which growing offshore wind capacity is now being added.

On import dependency, the Baltic states present a starker and more strategically loaded picture than the North Sea. Lithuania's natural gas import dependency reached 101% in 2021, among the very highest in the EU, a figure that reflects both the country's near-total reliance on imported gas and statistical stock effects (Eurostat, 2022). Before the February 2025 BRELL desynchronisation discussed below, this import dependency was structurally entangled with a Russian-controlled grid architecture, meaning that for the Baltic states, unlike for Germany or the Netherlands, import dependency was not simply an economic exposure but a direct extension of Russian infrastructural control. This is precisely the condition that the eight BEMIP states' offshore wind target, an increase from 3.1 GW to 19.6 GW by 2030 (Taylor Wessing, 2024), is designed to address, and it is why this thesis treats the Baltic robustness case as more explicitly geopolitical than the North Sea's: the same import dependency ratio that in Germany reflects a market structure issue reflects, in the Baltic states, a legacy of direct dependency on a hostile neighbouring state's energy infrastructure.

The Baltic Sea's robustness case is more explicitly geopolitical than the North Sea's. The eight BEMIP states have committed to expanding collective capacity from 3.1 GW to 19.6 GW by 2030, an almost sevenfold increase from a low base, with most states yet to commission a first project (Taylor Wessing, 2024). Denmark, with capacity split roughly evenly between its North Sea and Baltic waters, functions as an analytical bridge between the two cases (Nordic Innovation, 2025), allowing the same national governance and industrial capacity to be observed operating under two different regional conditions.

The case for distributed offshore generation in the Baltic must be read against a documented history of attacks on centralised fossil infrastructure in the same waters, which gives the robustness argument a concrete empirical anchor that the North Sea case lacks. On 26 September 2022, explosions using an estimated few kilograms of high-detonation-velocity explosive severed three of the four Nord Stream 1 and 2 pipelines east of the Danish island of Bornholm, rendering them permanently inoperable (ICDS, 2023). Swedish and Danish investigators confirmed traces of explosives at the site and

classified the incident as gross sabotage, though responsibility was never formally attributed to a state actor, and both countries closed their investigations without prosecution, citing jurisdictional limits on their authority to pursue a case in international waters (BBC, 2024a, 2024b). German authorities, whose territory the pipelines were built to serve, continued a separate investigation beyond the point at which Sweden and Denmark closed theirs.

Nord Stream is the clearest available evidence that centralised, large-diameter fossil infrastructure in the Baltic Sea is vulnerable to total, irreversible destruction by a capable actor, in sharp contrast to the partial, repairable disruption later suffered by the Estlink-2 electricity cable, discussed below. This precedent substantiates, with the most serious case available, the claim that the Baltic Sea's physical security environment is qualitatively more hostile than the North Sea's, and that offshore wind's distributed architecture, while not invulnerable, denies a would-be attacker the kind of single, high-value target that a major pipeline represents. A pipeline carrying the bulk of a country's gas imports is a strategic chokepoint whose destruction has an outsized effect relative to the cost of the attack; a wind farm of several hundred turbines spread across many square kilometres of seabed offers no equivalent chokepoint, since destroying any single turbine, or even several, removes only a small fraction of total regional capacity.

Nord Stream's significance here is not that it targeted renewable infrastructure, since it plainly did not; both pipelines carried Russian gas, and Nord Stream 2 had never become commercially operational before Germany halted certification days after the invasion. Its relevance lies in what it demonstrates about the baseline level of hybrid threat capability in Baltic waters against which any subsequent attack on offshore wind infrastructure must be assessed: an actor able to identify, reach, and destroy a heavily monitored strategic asset at roughly 80 metres depth has clearly also developed the capability to interfere with offshore wind cables laid at comparable depths. The absence, to date, of a comparable attack on offshore wind should therefore be read as a function of target selection rather than technical incapacity.

#### ***4.2.2 Redundancy and Recovery***

The Baltic states' desynchronisation from the Russian-controlled BRELL grid on 7-8 February 2025 eliminated a three-decade structural dependency without producing the disruption it was designed to prevent; the transition recorded no outages (Free Policy Briefs, 2025). This is itself a significant resilience achievement, since it removed a latent vulnerability, the theoretical capacity for Russia to manipulate Baltic grid frequency or cut supply, that had persisted since the collapse of the Soviet Union. This gain was, however, immediately tested by a separate incident: on 25 December 2024, the Estlink-2 cable connecting Finland and Estonia was severed, almost certainly by the anchor of a tanker linked to Russia's so-called shadow fleet, cutting cross-border capacity by 650 MW (HVDC World, 2025; Helsinki Times, 2025).

Estlink-2 itself is best characterised as a point-to-point interconnector rather than a hybrid one: it links the Estonian and Finnish grids directly without an intermediate offshore hub, meaning its loss removed a discrete unit of capacity rather than disrupting a wider meshed network. This radial-equivalent structure is precisely what the Baltic Offshore Grid Initiative's Transmission System Operator (TSO) roadmap, published in May 2025 following the Vilnius Declaration's mandate, is designed to move beyond: its accompanying Baltic Sea Grid Map distinguishes point-to-point interconnectors, hybrid links, and radial connections, and argues that greater hybridisation, of the kind already advanced in the North Sea through LionLink, is necessary to convert the region's planned capacity growth into genuine redundancy rather than more vulnerable point-to-point links (Modern Power Systems, 2025; Windtech International, 2025).

On energy storage, the Baltic states show a similar pattern of rapid but modest growth from a low base. Lithuania was awarded 4 GWh of battery storage through a state support scheme in 2025, drawing over 50 proposals and an estimated €840 million in project value, with explicit policy framing around enhancing national grid security (Strategic Energy Europe, 2026a). Sweden and Finland together surpassed 1 GWh of utility-scale storage deployment in 2025 (Strategic Energy Europe, 2026b). These figures are smaller than Germany's, but Lithuania's explicit security framing is notable: its scheme treats storage as a grid security instrument in its own right, following directly from the country's pre-BRELL history of near-total gas import dependency on Russia.

Unlike Nord Stream, Estlink-2 was repaired: restoration was completed on 20 June 2025, weeks ahead of the original schedule, at a cost of approximately EUR 50-60 million shared between the Estonian and Finnish transmission system operators (Helsinki Times, 2025; Submarine Networks, 2025). Read together, Nord Stream and Estlink-2 show two distinct outcomes of Baltic Sea infrastructure sabotage: permanent loss of a centralised fossil asset on the one hand, and a costly but successful and relatively rapid recovery of a distributed electricity grid connection on the other. This is consistent with the thesis's expectation that distributed infrastructure, even when attacked, is more recoverable than concentrated infrastructure, since the loss of one cable, while disruptive, did not eliminate the Baltic region's broader interconnection capacity in the way that the loss of the Nord Stream pipelines eliminated Russian piped gas supply to Germany entirely. It is worth noting, however, that the speed and relative success of the Estlink-2 repair also depended on factors specific to the incident, including the availability of a spare cable section and coordinated TSO planning, conditions that may not hold in a future, more severe, or more deliberately targeted incident.

Cross-border emergency support during the Estlink-2 outage took the form of continued operation through the parallel Estlink-1 connection and Finland's domestic generation reserves, rather than a formally invoked EU-level emergency mechanism; no request for solidarity-based emergency electricity transfers under the EU's risk-preparedness framework was triggered, since the remaining

interconnection capacity proved sufficient to maintain stable supply throughout the repair period (Free Policy Briefs, 2025). This is itself informative for the recovery dimension: the redundancy built into the Estonia-Finland connection through Estlink-1, a separate cable installed in 2006, absorbed the shock from Estlink-2's loss without requiring the kind of formal cross-border emergency activation that the operationalisation in Chapter 3 anticipated as the primary recovery indicator. The absence of a formally invoked mechanism should not be read as an absence of cross-border support; rather, the support was structural and pre-existing, embedded in the decision to build two separate cables rather than one, instead of being activated reactively after the fact.

On infrastructure security commitments, the Baltic Sea is also considerably further along than the North Sea, where, as section 4.1.3 noted, such commitments remain largely declaratory. The Estlink-2 incident directly triggered a binding military response: on 14 January 2025, NATO Secretary General Mark Rutte, with Finnish President Alexander Stubb and Estonian Prime Minister Kristen Michal, announced Baltic Sentry, a multi-domain military activity under NATO's Supreme Allied Commander, deploying frigates, maritime patrol aircraft, and naval drones to monitor the Baltic seabed on a sustained basis, coordinated by Allied Maritime Command and supported by a new NATO Maritime Centre for Security of Critical Undersea Infrastructure (NATO, 2025; SHAPE, n.d.). Unlike the Hamburg Declaration's commitment to strengthening resilience, Baltic Sentry is an operational deployment with assigned assets and a standing command structure, not a statement of intent, the clearest evidence in either case that a security commitment has moved from declared ambition to deployed capability.

#### ***4.2.3 Adaptability***

Bornholm Energy Island (BEI) is a pioneering project in the Baltic Sea designed to transform offshore wind from a national resource into a shared European energy hub. Developed through a partnership between the Danish grid operator Energinet and the German operator 50Hertz, it is the first project of its kind to connect multiple offshore wind farms to two different national grids. It is the Baltic Sea's flagship adaptability project and, like the North Sea Wind Power Hub, illustrates how far institutional formation can lag behind technical ambition. It will connect Denmark and Germany via the Danish island of Bornholm, aiming to be the world's first hybrid offshore wind hub, with a planned capacity of 3 GW capable of powering up to 4.5 million households and serving as an explicit blueprint for future European cross-border offshore infrastructure (Bornholm Energy Island, n.d.). Yet the project's own implementation documents project a Final Investment Decision only in 2025 and full commissioning only by the end of 2033, showing that even this flagship Baltic adaptability project, like the NSWPH, operates on a multi-decade timeline despite its conceptual maturity (European Commission PCI list, n.d.).

The Bornholm project also illustrates a dimension of adaptability that this thesis's operationalisation in Chapter 3 did not initially anticipate: the possibility that an energy island serves a dual function, supporting both energy resilience and maritime security simultaneously. The West Wing's 2026 policy report identifies the Bornholm Energy Island specifically as a model worth emulating in the North Sea precisely because it demonstrates how offshore energy infrastructure can support cross-border energy integration, strengthen offshore resilience, and serve as a maritime surveillance platform at the same time, and recommends that the Netherlands develop an equivalent North Sea energy island in cooperation with neighbouring countries for exactly this reason (The West Wing, 2026). This dual-use framing reinforces, from an entirely independent policy source outside the academic resilience literature, the same adaptability logic developed earlier in this chapter: an energy island is not merely a generation and grid asset but a piece of infrastructure whose physical presence in a contested maritime space can be leveraged for purposes well beyond electricity transmission.

At the broader governance level, BEMIP has produced an escalation trajectory directly comparable to NSEC's Esbjerg-to-Ostend progression in the North Sea. On 10 April 2024, the energy ministers of Lithuania, Denmark, Estonia, Finland, Germany, Latvia, Poland, and Sweden signed the Vilnius Declaration, committing to protect offshore and subsea infrastructure against hybrid threats and setting a regional target trajectory of 26.7 GW of offshore wind by 2030, 45 GW by 2040, and 70 GW by 2050, signed in the presence of NATO, the EU, ACER, and European transmission system operator representatives (Offshore Wind, 2024). This mandate was translated into technical planning a year later: in May 2025, the transmission system operators of all eight signatory states published a joint expert paper, the Baltic Offshore Grid Initiative roadmap, presented to a BEMIP ministerial meeting in Warsaw, which estimates the Baltic Sea's future wind potential at approximately 93 GW against less than 5 GW currently installed, and explicitly frames cross-border cost allocation and grid hybridisation as the central unresolved questions standing between this potential and its realisation (Modern Power Systems, 2025). This is, in proportional terms, a considerably steeper escalation than the North Sea's: BEMIP moved from a non-binding sea-basin goal to a ministerially endorsed TSO roadmap with a near-100 GW long-term horizon within roughly twelve months, even though the absolute capacity gap between the two regions remains very large.

The most distinctive Baltic finding, and the one with no clear equivalent in the North Sea case, concerns the relationship between offshore wind and national defence. In November 2024, Sweden rejected 13 of 14 proposed Baltic offshore wind farms after its armed forces concluded they would cut missile-detection warning time from two minutes to as little as 60 seconds, given the projects' proximity to the heavily militarised Russian exclave of Kaliningrad (The National, 2024; Defense Post, 2024). Industry actors disputed the technical basis for this conclusion: Saab's chief executive stated publicly that the company's radar systems can handle wind farms without degraded performance, and analysts have noted that Sweden's 2024 accession to NATO already gives it access

to allied radar coverage from Finland, Germany, and Poland that together provide overlapping surveillance of the Baltic, weakening the case that any single set of wind farms is decisive for early warning (IEEE Spectrum, 2026).

Poland offers a contrasting model that resolves the same underlying tension differently. Polish offshore wind policy mandates the inclusion of defence-relevant sensor equipment, including radar and sonar systems specified directly by the Ministry of Defence, on offshore wind farms located close to Kaliningrad, treating the infrastructure as an opportunity to enhance rather than degrade military surveillance capability (IEEE Spectrum, 2026). WindEurope has also highlighted that several other Baltic governments have established joint consultative formats between the offshore wind industry and national militaries specifically to avoid the kind of outright rejection Sweden applied. This contrast demonstrates that the tension between offshore wind and national security is not dictated by geography or technology alone, since Sweden and Poland face structurally similar exposure to the same Russian exclave, but is instead resolved, or left unresolved, through governance choice.

### 4.3 Cross-Case Synthesis

Four findings emerge from reading the two cases together that neither case could support in isolation. First, grid and interconnection infrastructure, not generation capacity, is the binding constraint on resilience in the more mature North Sea, as the German curtailment evidence and the years-long development timeline of LionLink both show; declared capacity targets systematically overstate the resilience that has actually been delivered. Second, adaptability gains from energy islands are conditional on at least two largely independent risk factors, global supply chains for critical components and the resolution of cross-border governance and cost-sharing questions, as Princess Elisabeth Island's HVDC suspension and the North Sea Wind Power Hub's decade-long, still-unresolved cost-allocation negotiations both demonstrate respectively, and these projects in any case operate on multi-decade timelines, as the Bornholm Energy Island's 2033 commissioning date confirms. Third, the Baltic Sea's history of infrastructure sabotage, from Nord Stream's permanent destruction to Estlink-2's successful repair, shows that distributed offshore infrastructure is more recoverable than centralised fossil infrastructure even though neither is invulnerable, while Sweden's rejection of 13 wind farms shows that defence-energy tensions are resolved through governance choice rather than fixed by geography, since Poland's contrasting integration of military sensors into its own offshore wind programme addresses functionally the same exposure without blocking deployment.

Fourth, drawing on The West Wing's comparative governance analysis rather than the academic literature reviewed in Chapter 2, the North Sea's institutional maturity advantage over the Baltic Sea narrows, and in some respects reverses, once physical security governance rather than energy governance is the basis for comparison. NSEC's energy cooperation framework is more developed than BEMIP's, but the Netherlands lacks a unified national command structure for maritime incidents of the kind Sweden and Finland have already established within HELCOM, where a single coordination centre integrates ecological, security, and onshore response, compared to the Dutch system in which five separate ministries feed into Coast Guard governance with no single overriding mandate (The West Wing, 2026). The conventional reading of the North Sea as the more governance-mature case, well supported for capacity targets and grid investment, does not hold for coordinated incident response, a function central to the recovery dimension, where the Baltic Sea's most advanced states are presently ahead of the leading North Sea state.

## 5. Conclusions

### *5.1 Answering the Research Question*

This thesis asked to what extent and under which conditions the expansion of offshore wind capacity in the EU enhances the resilience of its energy system. The answer is that the contribution is real but conditional, varying sharply across the four NREL dimensions rather than moving together as a single outcome. Offshore wind has produced clear robustness gains in both regions: generation has diversified across multiple jurisdictions, import dependency has fallen, and the Baltic states eliminated a three-decade structural dependency through the BRELL desynchronisation without producing the disruption that dependency was designed, in Russian hands, to threaten.

But capacity expansion does not translate proportionally into the other three dimensions, and this divergence is the thesis's central empirical finding. The North Sea's falling effective utilisation of rising installed capacity shows redundancy depends on grid investment, not generation alone, a dependency already producing measurable costs in the world's most mature offshore wind market. The suspension of Princess Elisabeth Island's HVDC component, alongside the North Sea Wind Power Hub's decade-long struggle to resolve cross-border cost allocation, shows adaptability depends on stable supply chains and resolved multinational governance as much as on technical feasibility. The contrast between Nord Stream's permanent destruction and Estlink-2's faster-than-scheduled repair shows recovery depends on the distributed, rather than centralised, structure of the infrastructure attacked, while Sweden's rejection of 13 Baltic wind farms shows even this advantage can be neutralised by unresolved energy-defence governance tensions unrelated to the technology itself.

A further qualification, drawn from The West Wing's comparative governance analysis, is that the North Sea's apparent governance advantage does not hold uniformly across every function relevant to resilience. NSEC is plainly more developed than BEMIP on energy-specific governance, but on coordinated incident response, a function within the recovery dimension, the Netherlands lags behind Sweden and Finland's unified national command structures (The West Wing, 2026). Resilience, on this evidence, is dimension-specific and even function-specific, not a single property a region either has or lacks.

## ***5.2 Answering the sub-questions***

Sub-question one asked how governance architecture shapes whether offshore wind translates into resilience. Governance maturity is the most consistent explanatory variable, but not a uniform advantage for the North Sea. NSEC's escalating Esbjerg-to-Ostend trajectory has produced a larger, more diversified generation base than BEMIP's more recent cooperation, but the North Sea's own redundancy deficit shows mature governance can still fail to deliver resilience if grid investment lags, while the Baltic's BRELL desynchronisation shows decisive coordinated action can deliver a major gain from a less mature starting point. On unified incident response specifically, the comparison reverses: Sweden and Finland's HELCOM-aligned centres are more advanced than anything in the Netherlands (The West Wing, 2026). Governance maturity is therefore a less reliable predictor than whether a given body can mobilise coordinated action in the specific function assessed.

Sub-question two asked what risks and constraints limit offshore wind's resilience contribution. Four stand out: grid capacity lagging generation, most visible in the North Sea; supply chain vulnerability for components like HVDC converters, demonstrated in Belgium; unresolved tension between offshore infrastructure and national defence, demonstrated by Sweden's rejection of 13 wind farms and resolved differently in Poland; and fragmented incident-response governance, a constraint specific to the Netherlands, where five ministries feed into Coast Guard governance without a single overriding mandate (The West Wing, 2026). The Baltic Sea's history of physical attacks, from Nord Stream to Estlink-2, adds a further region-specific constraint: even resilient, distributed architecture must be actively protected, since recoverability is not the same as invulnerability.

## ***5.3 Policy Implications***

Five implications follow from these findings. First, grid and interconnection investment should be a precondition for offshore wind capacity targets, not a follow-on, given the clear curtailment evidence from the North Sea showing that reverse sequencing produces wasted generation and rising costs rather than resilience. Second, the EU should treat HVDC converter manufacturing as a strategic industrial priority comparable to critical raw materials, since global supply pressure has already forced the suspension of Europe's most advanced near-term energy island feature, and the same bottleneck is likely to recur across the North Sea Wind Power Hub and Bornholm without a deliberate industrial policy response.

Third, member states facing a defence-energy tension comparable to Sweden's should adopt the kind of structured civil-military coordination Poland has implemented, integrating defence-relevant sensors directly into offshore wind infrastructure, since the comparison shows the tension is resolvable through governance choice rather than fixed by geography.

Fourth, and specific to the Baltic Sea, the EU and NATO should accelerate binding standards for the physical protection of undersea energy infrastructure, including cable burial depth requirements and pre-agreed rapid-response repair contracts, since the contrast between unrecovered Nord Stream and successfully repaired Estlink-2 suggests recovery speed can be substantially improved through advance planning rather than left to chance.

Fifth, North Sea states, and the Netherlands in particular, should adopt a unified national incident-response command structure modelled on the Swedish and Finnish examples The West Wing's analysis identifies as best practice in the Baltic. A single coordinating authority with statutory responsibility across the prevention, detection, protection, and response cycle would strengthen the recovery dimension directly by giving private infrastructure operators an unambiguous first point of contact during a hybrid incident (The West Wing, 2026). This recommendation illustrates a broader point this thesis's design was intended to surface: governance lessons should flow in both directions between the two regions, since the Baltic Sea, while less mature on energy-specific cooperation, is in this respect the more advanced case.

#### ***5.4 Limitations and future research***

This comparative case study design supports analytical rather than statistical generalisation, and its conclusions are necessarily provisional given that most Baltic capacity targets and the Bornholm Energy Island's 2033 commissioning date lie a decade beyond the study period. Whether the specific projects discussed ultimately deliver the resilience gains their designs promise remains an open empirical question that only continued monitoring can answer.

Future research should revisit this comparison once these projects reach operational status, to assess whether the conditional resilience gains identified here were realised, and whether grid investment lag, HVDC supply chain pressure, and unresolved cross-border governance were overcome or persisted. Future research should also track whether the WindEurope, NATO, and European Defence Agency initiatives addressing the Baltic defence-energy tension produce a durable resolution, and whether the same four-dimensional framework holds when extended to the Mediterranean and Atlantic offshore corridors as those programmes mature.

## Bibliography

Altmayer, A. & European Parliamentary Research Service. (2025). Baltic Sea fishing area: Current challenges. In EPRS | European Parliamentary Research Service (Report PE 767.190). [https://www.europarl.europa.eu/RegData/etudes/BRIE/2025/767190/EPRS\\_BRI\(2025\)767190\\_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/BRIE/2025/767190/EPRS_BRI(2025)767190_EN.pdf)

Aylett, C., Van Rij, A., & Bradshaw, M. (2026). Why renewables and electrification hold the keys to EU energy security. Chatham House. <https://doi.org/10.55317/9781784136536>

Baltic Power. (n.d.). <https://balticpower.pl/about-the-project/>

Banet, C., Baldursson, F. M., & Chyong, C. K. (n.d.). Building resilience in Europe's energy system. Centre for European Regulatory Economics (CERRE). <https://cerre.eu/publications/building-resilience-in-europes-energy-system/>

BBC. (2024a, February 28). Sweden shuts down Nord Stream blasts inquiry. <https://feeds.bbc.co.uk/news/world-europe-68225599>

BBC. (2024b, March 11). Nord Stream: Denmark closes investigation into pipeline blast. <https://feeds.bbc.co.uk/news/world-europe-68401870>

Beaucillon, C. (2023). Strategic autonomy: A new identity for the EU as a global actor. European Papers. <https://www.europeanpapers.eu/europeanforum/strategic-autonomy-new-identity-eu-global-actor>

Bornholm Energy Island. (n.d.). About the project. <https://bornholmenergyisland.eu/en/>

Clean Energy Wire. (2026, April 13). Germany, EU remain heavily dependent on imported fossil fuels. <https://www.cleanenergywire.org/factsheets/germany-eu-remain-heavily-dependent-imported-fossil-fuels>

Damen, M. (2022). EU strategic autonomy 2013-2023: From concept to capacity (EPRS Briefing PE 733.589). European Parliamentary Research Service.

Danish Institute for International Studies. (2024). Energy as a weapon: Decoding blackmail tactics in Europe. <https://www.diis.dk/en/research/energy-as-a-weapon-decoding-blackmail-tactics-in-europe>

Defense Post. (2024, November 28). Baltic Sea wind farms impair Sweden's defense, says military. <https://thedefensepost.com/2024/11/28/baltic-sea-wind-farms-sweden-defense/>

DNV. (n.d.). Energy hubs in the North Sea and Baltic Sea. <https://www.dnv.com/energy/topics/energy-hubs-in-the-north-sea-and-baltic-sea/>

Elia Group. Princess Elisabeth Island. <https://www.elia.be/en/infrastructure-and-projects/infrastructure-projects/princess-elisabeth-island/news-princess-elisabeth-island>

Ember. (2024). European electricity review 2024. <https://ember-energy.org/latest-insights/european-electricity-review-2024/>

Energy as a geopolitical weapon. (2025, September 26). EuropeanRelations.com. <https://europeanrelations.com/energy-as-a-geopolitical-weapon/>

Energy Storage Europe. (2026, April 9). Figures – Energy Storage Europe.  
<https://energystorageeurope.eu/facts-and-figures/figures/>

Energy, D. F. (2026, April 20). In focus: EU energy security explained. Energy.  
[https://energy.ec.europa.eu/news/focus-eu-energy-security-explained-2026-04-20\\_en](https://energy.ec.europa.eu/news/focus-eu-energy-security-explained-2026-04-20_en)

ENTSO-E. (2023). System needs study: Opportunities for a more efficient European power system in 2030 and 2040. In ENTSO-E TYNDP 2022. <https://eepublicdownloads.blob.core.windows.net/public-cdn-container/tyndp-documents/TYNDP2022/public/system-needs-report.pdf>

Erbach, G. & European Parliamentary Research Service. (2015). Tracking European Commission priority initiatives in 2015 – Number 1. Energy Union [Report].  
[https://www.europarl.europa.eu/RegData/etudes/BRIE/2015/551310/EPRS\\_BRI\(2015\)551310\\_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/BRIE/2015/551310/EPRS_BRI(2015)551310_EN.pdf)

Eurelectric. (2025, June 19). Repowering Europe & delivering clean energy resilience – Manifesto for the 2024-2029. <https://www.eurelectric.org/publications/repowering-europe-delivering-clean-energy-resilience-manifesto-for-the-2024-2029/>

European Commission PCI list. (n.d.). Bornholm Energy Island (BEI) hybrid offshore interconnector.  
[https://ec.europa.eu/assets/cinea/PCI/files/PCIFiche\\_5.2\\_1st\\_PCI\\_PMI\\_list.pdf](https://ec.europa.eu/assets/cinea/PCI/files/PCIFiche_5.2_1st_PCI_PMI_list.pdf)

European Commission. (2024). Two years of REPowerEU: Strengthening Europe's energy resilience.  
<https://commission.europa.eu>

European Commission. (2025). Marine renewable energy. EU Blue Economy Observatory.  
[https://blue-economy-observatory.ec.europa.eu/eu-blue-economy-sectors/marine-renewable-energy\\_en](https://blue-economy-observatory.ec.europa.eu/eu-blue-economy-sectors/marine-renewable-energy_en)

European Commission. (2025). The future of European competitiveness. Publications Office of the European Union. <https://doi.org/10.2872/9356120>

European Parliament. (2026, March 26). Energy security: Solutions to today's challenges.  
<https://www.europarl.europa.eu>

European Parliamentary Research Service. (2024, November). Russia's "shadow fleet": Bringing the threat to light.  
[https://www.europarl.europa.eu/RegData/etudes/BRIE/2024/766242/EPRS\\_BRI\(2024\)766242\\_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/BRIE/2024/766242/EPRS_BRI(2024)766242_EN.pdf)

Eurostat. (2022, April 19). EU natural gas import dependency down to 83% in 2021.  
<https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20220419-1>

Eurostat. (2025). Renewable energy statistics. <https://ec.europa.eu/eurostat>

Free Policy Briefs. (2025, March 3). Energy security at a cost: The ripple effects of the Baltics' desynchronization from the BRELL network.  
<https://freepolicybriefs.org/2025/03/03/desynchronization-brell-network/>

Fuel, fear and falsehoods: Defending Europe and Ukraine from Russia's hybrid energy threats. (2025, December 10). European Union Institute for Security Studies.  
<https://www.iss.europa.eu/publications/commentary/fuel-fear-and-falsehoods-defending-europe-and-ukraine-russias-hybrid-energy>

Fuh, G. (2024, September 9). What's the difference between green, renewable, and clean energy? BECIS. <https://be-cis.com/green-vs-renewable-vs-clean-energy-differences/>

Gas Infrastructure Europe. (n.d.). North Sea Wind Power Hub. <https://www.gie.eu/north-sea-wind-power-hub/>

Gasser, P., Lustenberger, P., Cinelli, M., Kim, W., Spada, M., Burgherr, P., Hirschberg, S., Stojadinovic, B., & Sun, T. Y. (2019). A review on resilience assessment of energy systems. *Sustainable and Resilient Infrastructure*, 6(5), 273–299. <https://doi.org/10.1080/23789689.2019.1610600>

Global Energy Monitor. (2025). North Sea offshore wind development. [https://www.gem.wiki/North\\_Sea\\_Offshore\\_Wind\\_Development](https://www.gem.wiki/North_Sea_Offshore_Wind_Development)

Helsinki Times. (2025, June 20). Estlink 2 power link restored after six-month outage. <https://www.helsinkitimes.fi>

Holling, C. S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics*, 4, 1–23. <https://doi.org/10.1146/annurev.es.04.110173.000245>

Holman, R. (2025, June 17). How the energy crisis sped up Europe's green transition. European Investment Bank. <https://www.eib.org/en/essays/europe-energy-transition-renewable>

HVDC World. (2025a). Estlink 2 repaired successfully. <https://www.hvdcworld.com>

HVDC World. (2025b). Princess Elisabeth energy island will proceed without its HVDC component. <https://www.hvdcworld.com>

IEEE Spectrum. (2026). Offshore wind and military radar: Solving security gaps. <https://spectrum.ieee.org/offshore-wind-military-radar>

International Centre for Defence and Security. (2023). Pipes and mirrors: The Nord Stream explosions. <https://icds.ee/en/pipes-and-mirrors-the-nord-stream-explosions/>

International Energy Agency. (2022). World energy outlook 2022. <https://www.iea.org>

Jan De Nul. (2025, October 17). Princess Elisabeth Island: Last concrete structure of 2025 in place. <https://www.jandenul.com>

Kountouris, I., et al. (2026). Aligning EU energy security and climate mitigation through targeted transition strategies. *Nature Communications*. <https://doi.org/10.1038/s41467-025-67595-7>

Leddy, L., Hotchkiss, E., & Applegate, H. (2024). Conceptualizing energy security and resilience (NREL/PO-5R00-89206). National Renewable Energy Laboratory. <https://docs.nrel.gov/docs/fy24osti/89206.pdf>

Martisauskas, L., Augutis, J., Krikstolaitis, R., Urbonas, R., Sarunieme, I., & Kopustinskas, V. (2022). A framework to assess the resilience of energy systems based on quantitative indicators. *Energies*, 15(11), 4040. <https://doi.org/10.3390/en15114040>

Ministerie van Justitie en Veiligheid. (2026, April 15). Tweede Kamer stemt in met wetsvoorstellen Cyberbeveiligingswet en Wet weerbaarheid kritieke entiteiten.

<https://www.rijksoverheid.nl/actueel/nieuws/2026/04/15/tweede-kamer-stemt-in-met-wetsvoorstellen-cyberbeveiligingswet-en-wet-weerbaarheid-kritieke-entiteiten>

Modern Power Systems. (2025, October 22). Eight TSOs collaborate on Baltic Sea grid initiative. <https://www.modernpowersystems.com/analysis/eight-tsos-collaborate-on-baltic-sea-grid-initiative/>

Molina, P. S. (2026, May 16). Spain, Denmark could develop European green hydrogen corridor for €2/kg by combining solar and offshore wind. PV Magazine International. <https://www.pv-magazine.com/2026/05/16/spain-denmark-could-develop-european-green-hydrogen-corridor-for-e2-kg-by-combining-solar-and-offshore-wind/>

NATO. (2025, January 14). NATO launches 'Baltic Sentry' to increase critical infrastructure security. [https://www.nato.int/cps/en/natohq/news\\_232122.htm](https://www.nato.int/cps/en/natohq/news_232122.htm)

Nordic Innovation. (2025). The energy transition in Nordic oceans. <https://pub.norden.org>

North Sea Wind Power Hub. (2025, March). Cost sharing is one of the fundamental challenges to enable the development of a successful offshore grid across the North Sea. <https://northseawindpowerhub.eu/knowledge>

North Seas Energy Cooperation. (2023). Ostend Declaration of Energy Ministers on the North Sea as Europe's Green Power Plant.

Offshore Energy. (2026). TenneT, National Grid ink joint development agreement for LionLink interconnector. <https://www.offshore-energy.biz>

Offshore Wind. (2024, April 11). North Sea, Baltic Sea countries enter pacts to protect offshore energy infrastructure amid concerns over Russian sabotage. <https://www.offshorewind.biz>

Offshore Wind. (2026). TenneT, National Grid ink joint development agreement for LionLink offshore wind interconnector. <https://www.offshorewind.biz>

On a war footing: Securing critical energy infrastructure. (2025, August 27). European Union Institute for Security Studies. <https://www.iss.europa.eu/publications/briefs/war-footing-securing-critical-energy-infrastructure>

Panton, A. J. (2024). Energy security and the green transition. IMF Working Papers, 2024(006).

Pioneers in clean energy. (n.d.). <https://denmark.dk/innovation-and-design/clean-energy>

Port of Rotterdam. (n.d.). North Sea Wind Power Hub Consortium presents achievable solution to meet climate goals. <https://www.portofrotterdam.com>

Rarick. (2025, November 26). How the Baltic Sea nations have tackled suspicious cable cuts. Atlantic Council. <https://www.atlanticcouncil.org/in-depth-research-reports/issue-brief/how-the-baltic-sea-nations-have-tackled-suspicious-cable-cuts/>

Regional seas around Europe. (2022, October 14). <https://www.eea.europa.eu/en/datahub/datahubitem-view/d09a1d82-8e11-4448-85a5-e2613aaccf57>

Renewable energy targets. (n.d.). Energy. [https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-targets\\_en](https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-targets_en)

REPowerEU. (2022, May 18). European Commission. [https://commission.europa.eu/topics/energy/repowereu\\_en](https://commission.europa.eu/topics/energy/repowereu_en)

Rory. (2025, August 26). Europe sets blueprint for build-out of offshore grids. WindEurope. <https://windeurope.org/news/europe-sets-blueprint-for-build-out-of-offshore-grids/>

Russell, M. & European Parliamentary Research Service. (2021). The Nord Stream 2 pipeline. In EPRS | European Parliamentary Research Service (Report PE 690.705). [https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/690705/EPRS\\_BRI\(2021\)690705\\_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/690705/EPRS_BRI(2021)690705_EN.pdf)

Schmitz, R., Flachsbarth, F., Plaga, L. S., Braun, M., & Härtel, P. (2025). Energy security and resilience: Reviewing concepts and advancing planning perspectives (arXiv:2504.18396).

SHAPE. (n.d.). Baltic Sentry. Supreme Headquarters Allied Powers Europe. <https://shape.nato.int/operations/operations-and-missions/baltic-sentry>

SolarPower Europe. (2026, January 28). New report: EU installs 27.1 GWh of new batteries in 2025 as utility-scale storage drives record growth. <https://www.solarpowereurope.org/press-releases/new-report-eu-installs-27-1-g-wh-of-new-batteries-in-2025-as-utility-scale-storage-drives-record-growth>

State of Green. (2017). European transmission system operators to develop North Sea Wind Power Hub. <https://stateofgreen.com>

Stockholm Environment Institute. (2026, March). Europe's green transition is now a matter of energy security. <https://www.sei.org>

Strategic Energy Europe. (2026a, January 21). Europe's new energy storage map: 80 GWh awarded through auctions in 2025. <https://strategicenergy.eu/europes-new-energy-storage-map-80-gwh-awarded-through-auctions-in-2025/>

Strategic Energy Europe. (2026b, April 2). Europe's energy storage fleet reaches 89 GW and is set to nearly quintuple by 2030. <https://strategicenergy.eu/europes-energy-storage-89-gw-quintuple-by-2030/>

Strengthening EU resilience: Hybrid threats and critical entities. (n.d.). The Joint Research Centre: EU Science Hub. [https://joint-research-centre.ec.europa.eu/projects-and-activities/strengthening-eu-resilience-hybrid-threats-and-critical-entities\\_en](https://joint-research-centre.ec.europa.eu/projects-and-activities/strengthening-eu-resilience-hybrid-threats-and-critical-entities_en)

Submarine Networks. (2025). Repair of EstLink 2 electricity subsea cable costs up to EUR 60 million. <https://www.submarinenetworks.com>

Taylor Wessing. (2024, September 23). Offshore wind in Germany and Europe: Status quo and outlook. <https://www.taylorwessing.com>

TenneT. (2024, December 23). Interconnector LionLink developed through offshore grid project Nederwiek 3. <https://www.tennet.eu/news/interconnector-lionlink-developed-through-offshore-grid-project-nederwiek-3>

The European Green Deal. (n.d.). European Commission. [https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal\\_nl](https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_nl)

The National. (2024, November 8). Sweden drops windfarm plans over threat to missile-detecting radar. <https://www.thenationalnews.com>

The West Wing. (2026, May). Lessons from the Nordic-Baltic Eight: Securing a sustainable North Sea. Youth Policy Advice Track NB8. [https://www.thewestwing.nl/files/ugd/f19b55\\_997eda56cd1d47889541e38888d94506.pdf](https://www.thewestwing.nl/files/ugd/f19b55_997eda56cd1d47889541e38888d94506.pdf)

Trushkina, N. (2025). Energy security as a factor of political stability in the European Union. *Politics & Security*, 12(2), 72–87. <https://doi.org/10.54658/ps.28153324.2025.12.2.pp.72-87>

Westphal, K., & Politik, S. W. U. (2021). Strategic sovereignty in energy affairs. Social Science Open Access Repository (GESIS – Leibniz Institute for the Social Sciences). <https://doi.org/10.18449/2021c07>

Windpower Monthly. (2024a, February 8). Grid congestion reducing German North Sea wind production – Tennet. <https://www.windpowermonthly.com>

Windtech International. (2025, May 16). Baltic Sea transmission system operators outline offshore grid roadmap. <https://mail.windtech-international.com/industry-news/baltic-sea-transmission-system-operators-outline-offshore-grid-roadmap>

Winzer, C. (2012). Conceptualizing energy security. *Energy Policy*, 46, 36–48. <https://doi.org/10.1016/j.enpol.2012.02.067>

Yahoo News. (2025). Germany's offshore wind farms generate more electricity. Citing the German Offshore Wind Energy Association. <https://www.yahoo.com/news/germanys-offshore-wind-farms-generate-155420858.html>

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). SAGE

**Annex: MISM AI Declaration**

**Academic Year:** 2025-2026

**Master's Programme:** Master in International Security Management (MISM)

**Student Name:** Kiki Mol

I declare that generative artificial intelligence tools have been used as support tools in the preparation of this Master's Final Thesis.

YES  NO

1. Ethical and Academic Use

**Have you included sensitive or personal data when using AI tools? If yes, specify:**

No

**Have you used AI tools to replace your own work without critically reviewing the generated content? If yes, specify:**

No

**Have you followed the academic recommendations and guidelines regarding the use of AI tools? Yes**

2. Technical Use of AI Tools

Please indicate the AI tools used (e.g., ChatGPT, Copilot, Claude, Gemini):

Claude, Scribbr

Please mark the applicable uses:

- Text generation
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- Methodological support
- Bibliographic search or citation support (Scribbr)
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- Other uses (please specify)

I confirm that the final content of this thesis has been fully reviewed, corrected, and validated by me as the author. The use of AI has not replaced my own critical analysis, personal reflection, or intellectual work.

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