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Norwegian School of Economics

Bergen, Autumn 2023

How has the Russia-Ukraine conflict "Pushed" or "Pulled" Renewable Energy Deployment in the EU?

A qualitative study focusing on mapping the EUs renewable energy landscape in the light of the consequences from the Russia-Ukraine conflict.

Aslak Midtsand Hovland and Justin Alexander

Supervisor: Pr. Linda Orvedal

Master thesis, Economics and Business Administration

Major: Economics

NORWEGIAN SCHOOL OF ECONOMICS

Acknowledgements

This thesis was written as part of our master's degree at the Norwegian School of Economics (NHH). We have had the opportunity to be tasked with writing on the contemporary topic of the 2022 Russian invasion of Ukraine and investigating how the ongoing events would reshape the renewable energy landscape in Europe. Although this thesis had proved to be very challenging at times, it has always remained an educational and interesting process. Taking on this topic was challenging as new developments occurred daily and the notion of the topic having such a broad range of subject matter to investigate. Therefore, we would like to start by acknowledging everyone that has contributed to helping us on this journey. First, we would like to particularly thank Pr. Linda Orvedal for her work in pointing us in the right direction for our thesis and encouraging us to investigate such a comprehensive topic.

As a partnership made up of master's students from Canada and Norway, we are particularly thankful for both Canadian and Norwegian schools, Ivey Business School and the Norwegian School of Economics (NHH) that have allowed us to make this collaboration between two students from different schools possible. A special thanks to the Double Degree representative Hilde Rusten that has sorted out administratively the collaboration between the two universities, making this possible. Finally, we would like to thank our friends, family, and loved ones that have supported us in our thesis and educational journey.

Thank you.

Norwegian School of Economics

Bergen, Autumn 2023

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Aslak Midtsand Hovland **Justin Alexander**

Abstract

In this thesis, we have conducted a qualitative study to investigate how consequences from - and the subsequent responses to - the Russia-Ukraine conflict have impacted key areas and factors that influence the renewable energy deployment in the EU. We have contextualized the situation by firstly, providing comprehensive historical records of the energy relations between the EU and Russia, whilst also analyzing the key developments in energy policy in the EU. Secondly, by analyzing previous literature that investigates how distinct factors are influencing RES, we have identified key areas and factors that serve as potential bottlenecks or accelerators in the context of renewable energy deployment in the EU. Followingly, we present both direct and indirect consequences from the Russian invasion to prepare the reader for the subsequent policy responses from the EU and implications of the consequences on key input factors in the renewable energy industry. Lastly, we present a discussion where we juxtapose our findings with the previous literature to assess how the Russia-Ukraine conflict have "pushed" or "pulled" renewable energy deployment in the EU.

The thesis demonstrates that the key developments in energy policy, through legal frameworks and energy strategies, in the pre-invasion decade, provided a necessary fundament for the EUs ability to swiftly implement changes, strategy, and funding. Whilst highlighting that the overarching policy trend pre-invasion was addressing the sustainability dimension of the energy trilemma, the invasion moved the energy policy discussion towards 'Energy security'.

The key areas we identified as bottlenecks pre-invasion were, firstly, the permitting process for RES projects, spanning from 4,5 to 9 years for solar and wind respectively in the pre-invasion period. And, secondly, the need for several grid-enhancements to stabilize, transport and store energy from intermittent RES. The key areas for acceleration were improving energy security, strengthening supply chains, and promoting energy efficiency. All of these were addressed by various policy responses from the EU, with the 'RePower EU' plan as an overarching policy umbrella. We see clear tendencies to solar PV deployment to have been accelerated by the invasion, whilst the situation for wind is more nuanced.

However, the indirect consequences from the invasion, manifesting itself in increased input factor prices and interest rates, have complicated the outlook on renewable deployment by rendering certain large-scale RES projects *currently* unprofitable. Furthermore, the overdependence on certain countries in the supply chain raises questions regarding energy security over the long-run in

a high-RES EU – for instance, moving from Russian fossil fuel dependence to Chinese mineral dependence.

Abbreviations

BCM – Billion Cubic Meters

CBAM – Carbon Border Adjustment Mechanism

CRMA – Critical Raw Materials Act

CSIS - Center for Strategic and International Studies

EASE – European Association for Storage of Energy

ECFR – European Council on Foreign Relations

EEA - European Environment Agency

EEAS - European External Action Service

EED – Energy Efficiency Directive

EIC – European Innovation Council

ERC – European Research Council

ESIA – European Solar Industry Alliance

EU – European Union

EU ETS – European Union Emissions Trading System

FE-2SLS – Fixed Effects Two Stage Least Squares

GDP – Gross Domestic Product

GHG – Green House Gas

GPR – Geopolitical Risk

GW – Gigawatts

IEA – International Energy Agency

IRA – Inflation Reduction Act

LNG – Liquified Natural Gas

LNG – Liquified Natural Gas

MS – Member States

MSCA – Marie Sklodowska Curie Actions

MW – Megawatts

NECP - The National Energy and Climate Plans

NIMBY – Not In My Back Yard

OECD - Organization for Economic Co-operation and Development

PPA – Power Purchase Agreement

PV – Photovoltaic

QCA - Qualitative Comparative Analysis

QQ – Quantile on Quantile

R&D – Research and Development

RED – Renewable Energy Directive

RED II – Renewable Energy Directive (updated)

RES – Renewable Energy Systems

RRF – Recovery and Resilience Facility

UNFCCC- United Nations Framework Convention on Climate Change

VAT – Value Added Tax

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1.0 Introduction

1.1 Background and Motivation

The Russian invasion of Ukraine on February 24, 2022, had profound repercussions within the European Union, fundamentally reshaping the geopolitical dynamics in the area. It ended a period of regional stability and has left a lasting impact on the European Union.
Prior to the invasion of Ukraine, Russia was a key energy supplier for Europe, providing a significant amount of fossil fuels. However, the onset of the conflict has required the EU to act swiftly and re-evaluate the reliability of energy supply to the region.
Secondly, the consequences of the Russian invasion have manifested itself in several other key areas that impact the energy sector. This includes the disruption of various global supply chains, rising energy related costs, and new trade partnerships being developed. As a result, the Russian invasion of Ukraine has introduced new dimensions to the discourse regarding energy, leading to the questions surrounding how the consequences from the Russia-Ukraine conflict have impacted the renewable energy landscape in EU. The topic of environmental concerns from the global climate crisis is omnipresent, and the transition towards a sustainable energy system is of utmost importance for global governments. Studying the impact of unforeseen events like the invasion have on the deployment of RES is contributing to examining the resilience of deploying these energy sources in the EU. Hence our research question is:
'How has the Russia-Ukraine conflict "Pushed" or "Pulled" renewable deployment in the EU?'.

We aim to provide insights to this by asking and identifying:
'what key areas and factors are serving as bottlenecks or potential accelerators to renewable deployment in the EU?' and ask how these key areas and factors have have been affected by the direct and indirect consequences of the invasion. This will lead us to asking *'How has the EU policy responses in the wake of the Russian invasion addressed and impacted these key areas and factors?',*

1.2 Scope

The renewable energy sources (RES) we are going to consider are primarily limited to the solar PV industry and wind industry, however we will also have secondarily focus on hydrogen due to its possible supporting qualities to the intermittent RES.

We will look at the RES policy landscape in EU before the invasion and contextualize by examining policy responses post-invasion. Furthermore, due to the deployment of these RES being connected to other sectors will we also be examining the consequences for supporting mechanisms including the power-grid and gas pipelines, as these are crucial for expansion for RES and may serve as bottlenecks for deployment. Moreover, we will also examine how input factors like critical minerals and electricity prices have been impacted by the invasion, as they are determining the cost of manufacturing for RES and assess profitability.

By examining these factors, we aim to present a holistic overview on how RES have been impacted by the consequences of the Russia-Ukraine conflict. Thus, it will culminate in being able to provide insights in which direction RES deployment are “Pushed” and “Pulled” by distinct factors, and how they might overlap.

In summary, the significance of this study lies in its ability to provide insights into how a major geopolitical event like the Russia-Ukraine conflict can influence RES policies and deployment in the EU, with implications for energy security, supply diversification, and global supply chain resilience – and guide towards areas that should be further examined by researchers.

2.0 Methodology

This section details the methodology for examining whether the development of Renewable Energy Sources (RES) in the European Union has been "pushed" or "pulled" following the Russian invasion of Ukraine. Considering the scarcity of post-invasion data on relevant factors and the infancy of the post-invasion time-period, the study will adopt a qualitative approach to analyze whether the RES deployment has been “Pushed” or “Pulled” by the Russian invasion of Ukraine. Given also the recent nature of the Russian invasion, the situation is fluid and rapidly

evolving, hence the use of qualitative research with an exploratory approach provides the flexibility to explore and adapt to these changes, which could be present us with problems by strictly using structured quantitative methodologies. (Saunders et al 2019, p.187)
Moreover, when the theoretical framework suggests that outcomes are not determined by isolated variables but rather by combinations of factors, qualitative comparative analysis (QCA) becomes a suitable method. In this context, using QCA to study renewable deployment in the EU post-invasion would allow for the analysis of different configurations of factors including, but not limited to energy security, energy efficiency, fossil fuels, infrastructure, and investments. (Rihoux & Ragin, 2009, p.6)
Hence, this approach is well-suited to understanding complex and multifaceted situations where different combinations of factors may lead to similar outcomes, or where the same factor may lead to different outcomes in different contexts.

2.1 Research Design

Our research design, crafted to assess the impact of the Russian invasion of Ukraine on the deployment of renewable energy sources (RES) in the EU. Considering the qualitative essence of our thesis, to ensure our research strategy aligns with our research question, we see concentrating on archival and documentary research methods is fitting. (Saunders et al., 2019)

This paper is structured in three interconnected segments. We will start by conducting a thorough review of historical records and policy documents. This review aims to delineate the evolution of energy policies in Europe with a specific focus on facilitation and deployment of RES. It includes an examination of trends of various renewable energy targets pre-invasion, providing a baseline for subsequent analysis (Section 3).
Subsequently, we will engage in a comprehensive analysis of existing academic literature (Section 4). This step is aimed at understanding the established knowledge regarding key factors influencing RES deployment and the direction of these factors. By synthesizing insights from previous studies, we will create a framework for analyzing the impact of the geopolitical event, identify key areas that potentially could accelerate RES deployment.

In the final part (Section 5-6), we will specifically focus on policy responses from the EU, in the aftermath of the Russian invasion of Ukraine. Here, we will analysis, contrasting the emergent RES deployment scenario in the EU with the pre-invasion years, the consequences of the Russian invasion of Ukraine. This comparison will link back to the findings established from our literature review to comprehensively understanding the invasion's potential direct and indirect impact on the EU's RES deployment strategies and contextualize the EU's response within a historical framework whilst comparing key statistics pre- and post-invasion.

By integrating these methods, we want to offer a holistic view of how the consequences from the Russian invasion of Ukraine may have 'pushed' or 'pulled' the deployment of renewables in the EU. This serves to underline which obstacles and trends renewable energy in the EU are facing, whilst providing new areas for further research.

2.2 Data collection

Data collection in this thesis is relevant documents that provide insights into EU energy policies and RES deployment trends. This includes policy documents, official reports, legislative texts, and historical records from both pre- and post-invasion periods. Sources for these documents include EU official websites, governmental archives, reliable news sources and relevant international organizations.

A review of academic literature and key statistics will be conducted using studies published in peer-reviewed journals and academic books. We utilized online databases such as Ember, Eurostat, ScienceDirect, Research gate and Google Scholar to ensure comprehensive coverage of existing research related to factors that influenced RES deployment and geopolitical impacts on energy strategies.

2.2.1 Data reliability

To ensure the reliability of our data, we aim to assess the credibility of sources and the relevance of the information from documents and literature and our research objectives.
Since we will gather data from a variety of sources, including academic journals, government reports, industry publications, and credible think tanks, we aimed by utilizing multiple sources to cross-verify information will provide a comprehensive understanding of the subject matter. This also includes assessing the reputation of the publication, the credentials of the authors, and the transparency of their data collection and analysis methodologies. (Schneider & Wagemann, 2012, pp.397-418)

2.2.2 Data Accuracy and Representation

Given our reliance on secondary sources, it is important to ensure the accuracy and fair representation of the data. This involves critically assessing the credibility of sources and presenting the information in a manner that faithfully reflects the original context and meaning. Misrepresentation or misinterpretation of secondary data could lead to incorrect conclusions and ethical breaches. (Atlan, 2023)

2.2.3 Bias and Subjectivity

Recognizing and mitigating personal biases is crucial in qualitative research. Our efforts are made to approach the analysis objectively, ensuring that personal views or preconceptions do not skew interpretation of the data. Our commitment to objectivity is detrimental to the credibility and reliability of the research findings. (Galdas, 2017)

3.0 Literature Review

3.1 Historical Overview of energy relations between Russia and European Union

In this section, we will provide a detailed overview of the historical energy relations between Russia and the European Union. This will include an examination of the key events that have been sources of tension in these relationships.

The Russian energy imports have historically been a cornerstone for the European Union. The relationship has been colored by interdependency, which evolved from the Cold War era, when Western Europe began importing Soviet natural gas, into a significant economic and political connection after the dissolution of the Soviet Union in 1991. Russia, with its vast natural gas and oil reserves, became a crucial energy supplier to the EU, while the EU provided a stable and lucrative market for Russian energy exports. (EEAS, 2022)

3.1.1 Deepening Interdependence

The 2000s marked a period of deepening interdependence. The EU's energy demand continued to grow, leading to an increased reliance on Russian gas. Major gas pipelines like Nord Stream and Yamal-Europe became symbols of this interconnectedness. (Shagina & Westphat, 2021) Simultaneously, the Russian economy, heavily reliant on energy exports, found a stable and lucrative market in the EU. This mutual dependence was not just economic but also strategic, as energy became a key element in the EU-Russia dialogue. (Cebotari, 2022)

3.1.2 Challenges and Tensions in the Relationship

As the 21st century progressed, the EU-Russia energy relationship faced several challenges. Periodic disputes between Russia and transit countries like Ukraine led to temporary disruptions in gas supplies to Europe. These incidents exposed the vulnerabilities of the EU's energy supply chain and sparked debates over energy security within the bloc. In response, the EU began to explore alternative energy sources and routes, reducing its dependency on Russian gas.

3.1.3 Gas Disputes 2006-2014

Despite the economic benefits, this relationship was not devoid of challenges. Issues of energy security, concerns over supply disruptions, and political disputes occasionally strained the relationship. Notable incidents, such as the Russia-Ukraine gas disputes in the late 2000s, highlighted the EU's vulnerability due to its energy reliance on Russia.

The gas disputes between Russia and Ukraine in the late 2000s were a series of conflicts involving pricing and transit of natural gas. These disputes were primarily between Naftogaz Ukrayiny, Ukraine's oil and gas company, and Gazprom, Russia's state-owned gas supplier.

The disputes had roots in political change following Ukraine's 2004 Orange Revolution, which brought a pro-Western government to power, altering its relationship with Russia. (Reuters, 2009) The first major dispute led to Russia cutting off gas supplies to Ukraine in 1. January 2006. This conflict was over pricing and transit fees, and Gazprom accused Ukraine of stealing gas from export pipelines - reflecting the broader political tensions between the two countries. Gazprom, however, turned the gas on again 2. January 2006, the day after the initial cut off.

Controversies had been cumulating in the years following as well, and in 2008, Russia was halting the supplies through the country due to Gazprom claiming Naftogaz had a debt of $1.5 billion in supplies when they were paying roughly $130 per Trichloromethane (back in 2007), however the supplies were again shortly resumed when Naftogaz paid off their debts. (Reuters, 2009)

A more severe crisis occurred in 2009 when negotiations over gas prices and transit fees again failed. Putin accused Ukraine of stealing gas and Gazprom proposing to increase prices for gas to make Ukraine pay-off their debts, whilst Ukraine characterized it as blackmail to extract an unjustifiable high price. This created a predicament for Europe as Russia stopped gas supplies to Ukraine on 7. January 2009 and the halt lasted for 13 consecutive days, before the pipelines were open again. (CSIS, 2009) The cut-off impacted several European countries that depended on gas transiting through Ukraine. At that time, 80% of Russia's gas exports to Europe passed through Ukraine, which represented 20% of its total need, but far more concerning was that particularly the new EU member states (MS) of that time Eastern European were completely reliant on Russian gas supplies. (CSIS, 2009) Tensions heightened again in the summer of 2014, the catalyst surrounding the annexation of Crimea as a result of the ousting of the pro-Russian government by the anti-corruption pro-western rallies in Ukraine. Gazprom changed spiked the gas prices by roughly 80%, intensifying the political tension between the countries, supplies to Ukraine however continued, while sides could not agree on a price. On 16 June 2014, the disputes between Gazprom and Naftogaz culminated in lawsuits at the Stockholm Court of Arbitration concerning the agreement of supply and later transit agreements and supplies to Ukraine eventually stopped. (Filippenko, 2019) This led the EU to become a mediator amended up guaranteeing the payment for Ukraine's gas supplies from Russia through their own funds and

IMF, whilst the deal would secure that it would not be any supply disruptions to other countries in the EU who depended on fossil fuels from Russia. (Ostryzniuk, 2014)

These actions, particularly in 2009, alarmed EU states, as it led to rationing of natural gas in Bulgaria – a EU MS. In response, Russia developed alternative gas pipelines to the West, bypassing Ukraine. This included the Nord Stream 1 and 2 pipelines (Nord Stream, n.d.), launched in 2012 and 2021, and the South Stream project, later reconfigured as the Turkish Stream after the EU blocked its original route to Bulgaria under the Black Sea.
These events highlighted the need for the EU to pursue a diversification strategy, seeking alternative energy sources and routes, and investing in renewable energy and energy efficiency. However, a study conducted in 2020 (Rodriguez-Fernandez et al, 2020) analyzed energy security in the EU and showcased that gas supply security after 2010 among EU-countries were hardly improved making ‘Russian gas’ making reliant countries extremely vulnerable against a weaponization of energy. (Rodriguez-Fernandez et al., 2020)

3.2 Key historical developments in Policy

This section examines key historical developments in European Union (EU) energy policy, particularly focusing on the evolution post the Lisbon Treaty of 2009, which significantly restructured the EU's constitutional framework, introducing Article 194 which explicitly positioned energy as a crucial policy area. These policy developments, shaped partly by the backdrop of the EU-Russia energy dynamics and the need for diversification, but also the on-going discussions regarding climate change, lay the fundament to understand the EU's current stance on renewable energy and its response to recent geopolitical events.

3.2.1 Lisbon Treaty and subsequent policies

The Lisbon Treaty, effective from December 2009, significantly reformed the constitutional structure of the EU, including its approach to energy policy. This treaty recognized the critical importance of a coherent energy policy for the EU, addressing several aspects crucial to energy security.

A key provision, Article 194, explicitly states energy as a policy area, allowing the EU to promote energy efficiency and renewable energy, and ensuring security of energy supply (Europa, n.d.) This article also granted Member States (MS) the right to determine their energy mix and the structure of their energy supply, thus accommodating national preferences within an overarching EU framework and is seen as the basis of European energy policy. (Jordan, 2014) Main objectives related to energy from the treaty were ensuring security of energy supply and developing renewable energy forms whilst also stating the necessity for the EU to promote the interconnection of energy networks between MS. (Dorthe Wolfsgruber & Gunnar Boye Olesen, 2010)

The Lisbon Treaty, while not solely a response to the Russian gas disputes of the late 2000s, indirectly addressed the EU's vulnerabilities highlighted by these disputes.
The Lisbon Treaty reiterated existing decision-making rules in the sphere of energy, which was significant in the context of the EU's response to external energy crisis. (Maltby, 2013)

3.2.2 Climate and Energy Package

Although not explicitly targeting the Russian gas disputes, the Treaty's focus on energy security and renewable energy laid the groundwork for the EU's subsequent energy policies. A notable one being the “Climate and Energy Package”, committing the EU to binding legislation in regard to the “20-20-20" targets, which stated a 20% reduction in greenhouse gas emissions from 1990 levels, raising the share of EU energy consumption produced from renewable resources to 20%, and 20% improvement in the EU's energy efficiency – all of this being reached within 2020. (European Parliament, 2009)
Furthermore, a key component from this package was the legislative act ‘Renewable Energy Directive’(RED) which set binding national targets for Renewable energy across EU members. And this was shortly followed by the legislative “The Third Energy Package” which sought to

further liberalize the internal energy market of the EU, by focusing on cross-border cooperation[1]. (European Commission, n.d. a)

3.2.3 Energy Roadmap 2050 and Energy Efficiency Directive

As this baseline for policy was forming, the EU continued developing their policies which touched upon renewable energy. The Energy Roadmap 2050, introduced by the European Commission in 2011, outlines a strategic framework aiming at transforming the European Union into a more secure, competitive, and low-carbon energy system by 2050 and reducing GHG by 85-90% from 1990-levels. (European Commission, 2011a)
The document underscored the need for immediacy on implementing policy changes to stimulate more RES in the energy mix and it featured an in-depth analysis of multiple scenarios to assess the impact of transitioning to a carbon-free energy system, considering various policy frameworks. (European Commission, 2011b)

The roadmap underscores the necessity for more investment in renewable energy sectors. It identifies these investments as critical for meeting the 2050 low-carbon objectives, acknowledging that substantial financial backing is needed to support the growth and innovation in this field. This included a significant emphasis on increasing investment in R&D in the renewable energy field, whilst also outlining how an increased implementation of RES would let sectors like wind and solar enjoy the benefits of economies of scale (Elia et al. 2021). Scholars have discussed the association of economies of scale with the increase in module plant size, particularly in renewable energy technologies like wind and solar photovoltaic (PV) systems. It notes that cost reductions have been observed in these technologies in the past, indicating that as production scales up, costs tend to go down, which may also reflect the technological advancements in these fields. (Elia et al. 2021)

The IEA argues that the roadmap is demand-led, indicating that the level of decarbonization highly depends on changes in demand. (IEA, 2022)
Thus, the road map was complimented by the Energy Efficiency Directive (EED), introduced in 2012 and updated both in 2018 and 2023 by the European Union. It established a framework of

[1] Effectivizing how gas and electricty are transported through respective pipelines and grids

binding measures to achieve the energy efficiency target set out. These challenges encompass issues like insufficient initial financing, limited knowledge, and awareness among consumers regarding the importance and methods of energy conservation, and for example the misalignment in incentives between property owners responsible for paying for energy-saving measures in their buildings and tenants who stand to gain from these improvements. (Climate Action Network, 2021) The energy efficiency aspect is highly emphasized in the future policy frameworks, as a key for the green transition was that EU's MS needed to sufficiently reduce their energy consumption to help the EU to reach its renewables target.

3.2.4 EU Framework for Climate and Energy

In January 2014, the EU constructed an energy framework for the period 2020 to 2030.
It aimed to simplify the European energy policy framework, provide flexibility for MS in their low-carbon transition and strengthen regional cooperation. (European Commission, 2014)
In relation to RES, the framework initially stated a clear target of 27% share of renewables but was later revised to 32% later with the 'Clean Energy for All Europeans Package' implemented in 2019. The goal of achieving a 32% share of renewable energy in the EU's energy consumption by 2030, was binding at the EU level but not binding on individual Member States and the target was proposed by the European Commission in the context of the EU's broader efforts to reduce greenhouse gas emissions by 40% (European Commission 2014). The overhauling of the energy policy framework was aimed at fulfilling the goals set by the Paris Agreement signed by 196 countries in 2015 (UNFCCC, n.d). As the member states were provided flexibility within the measures to reach goals set by the energy policy framework, governance was done through 'The National Energy and Climate Plans (NECPs)'. NECPs are the principal documents produced by EU Member States detailing their key climate targets and actions for the next decade and beyond, and these draft NECPs, along with nationally announced policies, provide insights into whether EU member states are planning sufficient wind and solar build-out to meet EU energy targets and climate commitments. (European Commission, 2019)

3.2.5 Pre-Invasion years: The European Green Deal and subsequent 'Fit for 55'

In 2019, the European Commission issued 'The European Green Deal' which stated 'It is a new growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases in 2050 and where economic growth is decoupled from resource use' (European Commission, 2019b, Introduction section, para 2). It is particularly aimed at designing transformative policies for renewable and clean supply of energy across a multitude of sectors and communicated the 'net zero by 2050' target.

3.2.6 Legislative

Subsequently these targets were solidified by legislative measures with the introduction of the 'European Climate Law' in 2020. The European Climate Law, enacted as part of the European Green Deal, set legally binding targets of achieving climate neutrality by 2050, making MS legally compliant to this target (EU, 2020). By the end of 2020 the EU had presented numerous different strategies which are being regularly updated, and notably also a 'Hydrogen Strategy' was presented. (European Commission, 2020)

Furthermore, a new legislative package was introduced named 'Fit for 55'which aimed to increase the previously stated emission-reduction by 2030 from 40% to 55%.
This initiative holds significant importance for the EU's journey to achieve climate neutrality by the year 2050. A key element of this strategy involved updating the Renewable Energy Directive (RED II). The amended RED II is instrumental in attaining the revised objectives for reducing greenhouse gases. Originally, RED II set a goal for the EU to ensure a minimum of 32% of its energy consumption was derived from renewable energy sources (RES) by the year 2030, but the 'Fit for 55' package has advanced these requirements, establishing a higher EU benchmark of at least a 40% contribution from RES in overall energy consumption by 2030 (Widuto, 2023). Which amounted to approximately 1067 GW under the 'Fit for 55'. (European Commission, n.d. b)

On one hand, the gas disputes did raise concerns regarding energy security, leading to policies aiming to further strengthen cross-border cooperation in energy transport. On the other hand, the overarching narrative in the EUs energy policy were related to environmental aspects and less on diversifying energy supplies.

3.2.7 Horizon Europe - Funding

There were several funding schemes and programs introduced prior to the Russian invasion of Ukraine which has further facilitated the growing RES climate in Europe. A particularly significant one is the new Horizon Europe program. (European Commission, n.d. c)
It is the continuation of the EU's foremost funding program for research and innovation (R&D) and is spanning from 2021 to 2027 with a substantial budget of approximately €95.5 billion. (EC, n.d. c) And its main purpose is to create synergies within research in the EU and consists of *three main pillars:*

The first pillar focuses on fostering high-quality, pioneering research and to provide training and career development opportunities for researchers. (European Commission, n.d. c) By doing so it strengthens Europe's global scientific leadership. It supports researchers through various initiatives like the European Research Council (ERC), Marie Skłodowska-Curie Actions (MSCA), and research infrastructures. (Horizon Europe, n.d.)

The second pillar addresses societal challenges and by organizing joint research centers in clusters. The goal is to direct research and innovation efforts towards the significant issues facing society where 'climate, energy & mobility' is a featured cluster. (Horizon Europe, n.d.)

The last pillar is focusing on Europe's innovation capacity, where a key The European Innovation Council (EIC) is a key component of this pillar, offering funding, advice, and networking opportunities to innovators, entrepreneurs, small companies, and scientists. (Horizon Europe, n.d.)
These pillars are designed to work in tandem, each contributing to the overall goal of Horizon Europe to ensure Europe's global competitiveness in R&D.

3.2.8 'Next GenerationEU'

Another key aspect of the funding of RES growth was the introduction of the stimulus package 'Next Generation EU'. It is the largest stimulus package to ever be introduced in the EU and was aimed at fostering the recovery of the region after the global Covid-pandemic. (European Commission, n.d. d) It amounted to €806.9 Billion, and at the heart of the Next Generation EU lies the Recovery and Resilience Facility (RRF), a key mechanism dedicated to giving grants and loans. This facility is designed to bolster reforms and investments across EU Member States, with a comprehensive funding package totaling €723.8 billion. (The additional funds were disbursed to the MS through various programs like the 'Just-transition fund' introduced in the 'Green deal', which aimed to help regions that were substantially affected by the on-going energy transition. (European Commission, n.d. e)

A significant portion of the Next Generation EU Recovery Plan, which encompasses at least 30% of its funds, is dedicated to combating climate change and supporting green projects. (European Commission, n.d. e)

Furthermore, through the NextGeneration EU, the EU introduced a stimulus package worth $730 billion, known as the Recovery and Resilience Fund (RRF) to handle the consequences from the Covid-19 pandemic. Of this, 37 percent, approximately $270.1 billion, was designated for the development of renewable energy capacity. (Psaropoulous, 2023)

An interesting note from the stimulus package was the issuance of 'green bonds' in 2021 to finance the sustainable projects including RES deployment. The initial oversubscription of these bonds demonstrated heightened interest from the market, and the 'green bond programme' was going to raise up to €250 billion by end of 2026 (Euraxcess, 2021)

3.2.9 European Union Emission Trading System (EU ETS)

The European Union Emissions Trading System (EU ETS), introduced in 2005, is a cornerstone of the EU's policy to combat climate change and its key instrument for reducing industrial greenhouse gas emissions cost-effectively. It operates based on a 'cap and trade' approach involving setting a maximum limit on the aggregate greenhouse gas emissions allowed from the installations and aircraft operators included in the system. The number of allowances is systematically lowered each year, aligning with the EU's climate objectives which results in gradual reduction ensures a consistent decrease in emissions over time. (European Commission, n.d. f)

- **Phase 1 (2005–2007):** This pilot phase aimed to establish the market's infrastructure. It faced challenges like over-allocation of allowances and a lack of robust monitoring.
- **Phase 2 (2008–2012):** Coinciding with the Kyoto Protocol's first commitment period, this phase improved the allocation process, including more gases and sectors.
- **Phase 3 (2013–2020):** Introduced a single EU-wide cap on emissions, significantly increasing the proportion of allowances auctioned.
- **Phase 4 (2021–2030):** Aims to align the EU ETS with the EU's 2030 climate targets and the European Green Deal.

The EU ETS has played a significant role in driving the growth of renewable energy within the European Union. By putting a price on carbon emissions, it has created financial incentives for power producers and industries to shift towards cleaner energy sources. Hence, it is an important aspect to monitor how the EU ETS responded to the Russian invasion of Ukraine, as incorporating it offers a comprehensive view of how geopolitical events can interplay with economic instruments and policy frameworks, ultimately influencing the path towards more renewable energy deployment in the EU.

3.3 Energy Trilemma: Energy security, affordability and sustainability

The 'Energy trilemma' is a concept which is frequently referred to in research literature related to energy and geopolitics. It refers to the complex balance between three key dimensions of energy that policymakers need to balance and works as guiding framework for designing energy policies. (Viñuales, 2023)

Energy security: Focuses on the reliable availability of energy at all times, at affordable prices, without significant interruptions. It involves ensuring a steady supply of energy resources, managing the risks related to energy production and supply (like geopolitical risks or resource depletion), and maintaining resilient energy infrastructure.

Energy Equity (Affordability): This aspect deals with the affordability and accessibility of energy across various populations and geographies. It underscores the importance of providing universal access to energy and ensuring that energy prices remain reasonable for both consumers and businesses.

Environmental Sustainability: This dimension centers on minimizing the environmental impact of energy production and consumption. It involves reducing greenhouse gas emissions, limiting pollution, and promoting the use of renewable and clean energy sources.
(Liu et al., 2022)

The energy trilemma is constantly "pushing" and "pulling" the decision making in regard to increasing RES deployment (Viñuales, 2023). For instance, there might be a both a "push" and "pull" from different dimensions at the same time. Therefore, we encourage readers to maintain an awareness of these aspects throughout their engagement with our work, as they form an essential framework for understanding the context and scope of our findings.

3.4 Connection between Energy security and renewables

Thus, in hindsight, securing the supply of energy was the main issue that arose from the gas disputes as it showcased the EU's heavy dependency on fossil fuels from Russia. A study by Khan et al., (2023) which utilized "quantile-on-quantile" (QQ) approach, showed that concerns about energy security leads to an increased interest I RES. The QQ method is particularly useful for understanding how the relationship between two variables, like energy security and renewable energy in this case, varies across different levels of each variable as it provides detailed analysis of how energy security impacts renewable energy across different levels of geopolitical risk and renewable energy adoption. During the events of the gas disputes between Ukraine and Russia there was a positive trend in RES deployment as the EU saw the need to diversify the energy mix. (Khan et al., 2023) Implying that there might be a tendency that shows that as geopolitical risks increase, renewable energy deployment tends to improve (especially in higher-income countries). This is also further supported by a study by Chu et al., (2023) which focused on the effects of energy security risks on renewable energy deployment from the top 23 energy consumers. Here they used fixed effects in panel quantile regression to help control for characteristics of each country that do not change over time and are not directly observed or measured, and they found a positive effect on renewable energy from energy security risks for high-income countries, whilst the impact is less stable in middle-income countries. (Chu et al, 2023)

Furthermore, a study by Cai and Wu (2021) confirmed that higher Geopolitical Risk (GPR) improves RES development, where they showed that shocks in GPR had a positive influence on the growth of consumption of renewable energy. By utilizing a time-varying parameter Bayesian vector autoregressive model, their analysis revealed a dynamic interaction between geopolitical risks and renewable energy consumption, hence, the modeling approach enabled the researchers to capture and analyze how the impact of geopolitical risks on renewable energy consumption changes over time. Moreover, they observed a two-way causality over the time-period (1985-2018) indicating that also the growth in RES consumption decreased GPR. Hence, it is indicated that in periods of elevated geopolitical risk, there is a notable increase in the consumption of renewable energy suggesting that as geopolitical tensions rise, countries and regions might increasingly turn to renewable energy as a strategic response, both to enhance their energy security and to reduce reliance on energy sources that could be subject to geopolitical disruptions (Cai & Wu, 2021).

On the other side, Kaplan & Bölök used data from 2000-2018 in 20 EU MS and found empirical evidence that the consumption of fossil energy, nuclear energy, and Gross Domestic Product (GDP) are significant factors driving the deployment of renewable energy. In contrast to other literature, in their study, net energy import (one indicative of energy security) and CO2 emissions do not play a substantial role in this context. (Bölök & Kapland, 2022)

3.4.1 GPR and the Supply side

If we look to studies conducted to look at the relationship between GPR and power generation from renewable energy, the supply side, it highlights the complex and intertwined nature of geopolitical factors and renewable energy development, underscoring the need for nuanced approaches in energy policy and planning.

For example, research by Su et al. (2021) explored the interplay between global GPR and renewable energy electricity generation during the period from 2000 to 2020 where their findings indicated a bidirectional relationship. The two-way causality partly detected in their study indicates that the results were varied, suggesting that the influence of geopolitical risks on renewable energy is not straightforward or consistent. In some instances, heightened geopolitical risks may accelerate renewable energy development as nations seek energy security, while in other cases, these risks could potentially hinder or complicate renewable energy projects. However, based on these varied outcomes, geopolitical risks are a significant factor in the development of renewable energy (Su et al, 2021).

3.5 Effect of EU ETS on RES

A paper discusses how international commitments like the EU directives have led to the implementation of various policies supporting RES, and how previous studies have shown mixed results regarding the effectiveness of these policies. Empirical evidence from European countries indicates that specific public policy measures, particularly policies of financial incentives/subsidies (including feed-in tariffs) and better policy processes, are significant drivers of growth in renewable energy use, whilst R&D programs, or tradable certificates, were not found to be as effective in increasing the use of renewables during the studied period. (Marques & Fuinhas, 2012) The studied period, however, was from 1990-2007, when the EUs renewable policy still in an infancy period, and the EU ETS had only been active for 2 years.

A more recent study by Yu et al. (2017) conducted a study on the impact of EU ETS on renewable growth in the EU and found significant, positive effects. (Yu et al., 2017)
The study highlighted the different impacts of the various phases of the EU ETS. For instance, Phase I (2005-2007) of the EU ETS, which was more of a trial phase, had a less significant impact on renewable energy output. In contrast, Phase II (2008-2012), which implemented stricter principles and had a higher penalty for noncompliance, showed a significantly positive impact on renewable energy output. (Yu et al., 2017)

3.6 Natural Gas and RES

A recent study by Hille (2023), which combined detailed data on bilateral trade patterns for coal, oil, and natural gas of 37 countries in Europe with data on geopolitical risks in supplier countries. It specifically focused on aggregate measures of geopolitical risk that countries are exposed to through fossil fuel imports. The main models in the study were estimated using fixed effects two-stage least squares (FE-2SLS) to account for potential simultaneity between geopolitical risk and renewable energy diffusion. (Hille, 2023)

The study found significantly positive coefficients for GPR related to coal and natural gas imports on RES deployment. This implies that higher geopolitical risks in countries supplying coal and natural gas to Europe are associated with increased efforts in these European countries to foster RES development. Furthermore, when looking at specific RES, the research found that geopolitical risks (GPR) associated with coal and natural gas imports significantly influenced the development of wind and solar energy. Wind energy was notably responsive to coal import risks, likely due to the relative space efficiency and scalability of wind projects compared to solar. Literature points towards that larger utility firms may favor wind energy for extensive renewable projects, which is a trend observed in EU countries like Denmark where RE from wind is highly deployed (Lantz et al, 2019). In contrast, solar energy's growth was more linked to the natural gas import risks, potentially because solar installations require more space. Additionally, biomass energy was impacted by GPR related to all three fossil fuels, as biomass plants can consistently generate power (baseload capability), making them a reliable option for integrating into existing power systems and reducing reliance on fossil fuel imports (Lantz et al, 2019) – which on another side points towards the importance of fossil fuels for the purpose of stabilizing power-grids. Notably, there is a positive correlation between the proportion of natural gas imports in energy consumption and the growth of wind and solar energy and is suggesting that natural gas plays a role as a transitional technology in the shift towards renewable energy. The volatility in electricity generation from wind and solar can be balanced by integrating these renewables with flexible natural gas power plants, which act as backup sources. Consequently, in countries lacking domestic natural gas production, the reliance on natural gas imports tends to rise in tandem with the growth of electricity produced by renewable energy. This aligns with the study conducted by Verdolini (2018) which displayed that due to the intermittency problem from

renewable power generation, modern fossil-based technologies, characterized by quick ramp-up times and modularity, is associated with increased investments in renewable energy. This suggests a significant complementarity between modern fossil fuels, such as natural gas and renewable energy technologies. Without economically viable storage options, the integration of renewable energy in the electricity grid is facilitated by modern mid-merit fossil-based technologies acting as backup capacity.
Hence, in a scenario where a country is already heavily reliant on imported natural gas for its energy needs, rising geopolitical risks in the countries supplying this gas may hinder further growth of renewable energy sources.

3.6.1 Fossil fuels as back-up capacity grid infrastructure effect on RES deployment

According to a study by Raymond Li and Hazel Lee (2022), using panel time-series econometric techniques, focusing on a panel comprising 20 European countries over a period ranging from 1993 to 2018, showed that the prices of fossil fuels such as coal and natural gas, play a significant role in the growth of renewable energy deployment. This had showed that an increase in the prices of fossil fuels like coal and natural gas positively influences the expansion of renewable energy capacity suggesting that higher fossil fuel prices make renewable energy sources more economically attractive, thereby encouraging investment in renewable energy infrastructure.

A notable observation was that for countries that generate electricity with equal shares of coal and natural gas, the influence of coal price increases on renewable energy capacity is approximately five times greater than that of natural gas. This could be due to a higher degree of substitution between coal and renewable energy sources, especially in meeting baseload electricity demand, whereas natural gas plants are often used for peak loads and as backup for renewable sources. (Li & Lee, 2022) This implies that the flexibility of natural gas makes it a more suitable backup option for renewable energy sources, which can be intermittent (e.g., solar and wind energy), and thus its price may serve to be impactful on the growth of renewables, regardless of the backstop price relationship between power generation from fossil fuels vs. RES. The backstop price acts as a critical economic threshold in the energy market and serves as a benchmark for when renewable energy sources become more cost-effective compared to traditional fossil fuels, thereby influencing investment, production, and policy decisions in the energy sector.

3.6.2 Natural gas investments may drive renewable investment

The study by Verdolini (2018) examined the relationship between investment in RES and modern fossil technologies in 26 OECD countries between 1990 and 2013 using regression models, controlling for numerous factors such as environmental policies, market conditions, and the existing energy infrastructure in the studied countries. A significant, complementarity relationship between the presence of modern fossil technologies and an increase in renewable energy investment was observed, which is contrary to the general perception of these as competing sources. Moreover, the study highlights their interdependent roles in a successful decarbonization process and continues to reference the bridging role for natural gas to stabilize grids when implementing more RES to the power-grid. Especially for wind-power, where the discrepancy between supply and demand is often more present. Hence, increased investment in modern fossil technologies like natural gas does not necessarily imply a substitution for RES or reprioritization, and vice versa.

3.7 Need for storage due to intermittency from RES

As previously mentioned, the need for storage capacity is detrimental to more deployment of RES. Oosthuizen & Inglesi-Lotz (2022) highlight the need for more battery storage systems in the EU as these systems are instrumental in maintaining the balance of power grids, mitigating the challenges posed by the intermittency problem of RES (Oosthuizen & Inglesi-Lotz, 2022). An article published by Cambridge University Press in 2018 did underline how it is necessary with modifications to institutional and governance frameworks for the development of infrastructure for large-scale energy storage like batteries, as the current ones were unsatisfactory. (Faunce et al, 2018)

Battery storage growth is not just a complement to renewable energy sources; but a critical component in the transition towards a more flexible and efficient grid infrastructure and serves as complementary factor likely to foster increased deployment of RES in the EU power grid.

3.7.1 Hydrogen

In recent years, hydrogen has been analyzed as being an alternative to natural gas as back-up capacity for intermittent RES. (Šefčovi, 2023., p.36) Maroš Šefčovi, VP of the European Commission, stated that hydrogen implementation could serve as the missing link in EU's implementation of a bigger share of RES in the power-grid, through balancing the grid.

If we examine the literature, Elisa Ghirardi and colleagues from the University of Bergamo, Italy, presents a comprehensive analysis of the role of hydrogen in enhancing grid stability under scenarios of high penetration of renewable energy sources. The study analyzed four scenarios of renewable energy penetration (40%, 60%, 80%, and 100%) in the EU to understand how the grid balance can be maintained as the share of renewable energy increases. These scenarios primarily utilized PV solar panels and wind turbines as intermittent RES, and findings suggest that for lower levels of renewable penetration, up to 40%, compliant with the 'Fit for 55', a well-designed generator system might be sufficient. However, for higher levels of renewable penetration, large hydrogen storage capacities are necessary, requiring oversized generators and increasing system costs. (Ghirardi et al, 2023) A study by Matthew Leonard et al. (2019) showed that at high production levels by intermittent RES, daily or seasonal storage of energy becomes necessary and hydrogen storage offers the best alternative. A significant challenge lies in developing a robust infrastructure for hydrogen transport and storage. Hydrogen has different physical properties compared to natural gas, necessitating specialized pipelines, storage tanks, and handling facilities. Building such infrastructure is costly and requires careful planning and investment. It also involves regulatory and safety considerations, given hydrogen's high reactivity and flammability. (Day, 2023) On the other hand, if investments are made in these types of facilities, pipelines, and storage capacity, it is safe to say it fosters deployment of RES.

Furthermore, hydrogen pipelines facilitate cross-border energy trade within the EU, enhancing energy security and diversification of energy sources. This is particularly important for EU countries that have less access to renewable energy resources and/or are more dependent on energy imports and relates to policies stating the need for more regional cooperation between MS.

Hydrogen poses in other words an interesting future for its properties in storing energy, and potential to transport, and development in this sector would support the inclusion of more RES in the EU energy mix.

3.8 Electricity Prices Relationship with RES

Findings from literature indicate that the integration and expansion of RES in the energy mix has a considerable impact on electricity prices. Exploring the connection between renewable energy sources and electricity pricing, various studies have identified that a rise in the proportion of RES within the energy mix tends to result in a reduction of wholesale electricity prices across several markets. The effect, often referred to as the "merit-order effect" in academic studies, is linked to the relatively low marginal cost of renewable energy sources causing a shift of the electricity supply curve towards the right, resulting in a decrease in the average electricity price. (Lagarde & Lantz, 2019)

The explanation behind this is that in electricity markets, power sources are often ranked on a scale called the "merit-order" based on their marginal costs of production – the cost of producing one additional unit of electricity. Traditional fossil fuel-based sources have higher marginal costs compared to renewable sources like wind or solar, which have very low marginal costs once installed. (Burgos-Payan et al. 2016)

Furthermore, a recent study conducted by Cevik & Ninomiya in 2022, using data from 2014-2021 within 24 European countries, investigated the nonlinear effects of RES on electricity prices to account for the high volatility and sudden peaks in electricity prices. Their results confirmed that an increased share of RES in the energy mix lowers electricity price, and notably, they also found a non-linear effect as a price-dampening effect is found to be more pronounced as the share of renewables increases, compliant with the “merit-order effect”. (Cevik & Ninomiya, 2022) The relationship between RES can create a cycle where higher prices due to less renewable energy incentivize the deployment of more renewable sources, which then can lead to lower prices. However, it's important to note that the impact of higher electricity prices on renewable deployment can vary depending on the country, the existing energy infrastructure, government policies, and the maturity of the renewable energy market in that area.

Additionally, while higher prices can stimulate renewable energy deployment, they can also place a financial burden on consumers and businesses, which can be a concern for policymakers, creating a balance game regarding the energy affordability aspect of the energy trilemma.

3.9 Permitting Procedures and delays

Cevik & Ninomiya (2022) did underline a common narrative in literature regarding the relationship between RES and wholesale electricity prices which is the need to optimize electricity grids in Europe (Cevik & Ninomiya, 2022). A position paper by 'WindEurope' from 2020 underscored this importance and highlighted that new grid-optimization technologies vastly exists, the bottlenecks have, however, traditionally been created by complex planning and slow permitting processes which have resulted in curtailment of RES and congestion in the grid. (WindEurope, 2020)

Furthermore, the permitting procedures in the EU are also cumbersome for RES deployment. Acquiring a permit for wind energy projects could span up to nine years, while securing one for ground-mounted solar projects may require up to four and a half years before the invasion. (European Commission, 2023)

Moreover, a comparative analysis from the Nordic countries in Europe (Pettersson et al., 2010), point out that local environmental opposition and the complexity of permit processes can significantly affect wind power projects, and that navigating through complex and sometimes overlapping regulatory requirements from different levels of government (local, regional, national) can be time-consuming and challenging. The differences in permitting durations across various MS highlight how national regulations and administrative capabilities can introduce complexities and delays in the permitting process. Hence, an increased efficiency of EUs processes regarding permitting both infrastructure and RES projects serves as a potential driver for more RES diffusion.

3.9.2 Public opinion

As seen in the section on the development of renewable policy in the EU, the shift towards renewable energy has gained significant momentum, and the change has been driven not just by technological advancements and policy shifts but also by a powerful and often underestimated factor: public preferences. (Pew Research Center, 2016) Local opposition often leads to substantial delays, potentially jeopardizing the successful completion and implementation of energy projects. This resistance at the community level can significantly threaten the actualization of these initiatives, posing challenges to the effective execution of energy policies. (Sütterlin & Siegrist, 2017)

Hence, the collective voice plays a crucial role in shaping the energy landscape. As concerns over climate change, environmental sustainability, and energy independence intensify, public opinion increasingly favors cleaner, greener sources of energy.

3.9.2.1 High Willingness-To-Pay

A study done in Portugal researched the public opinion on renewables, showcased that it was a general positivity towards renewable energy projects, especially solar and wind power, suggests that the public is inclined to support, and possibly, advocate for the expansion of RES. (Ribeiro et al, 2023)

Given that renewable energy sources typically incur higher costs compared to conventional energy sources, mechanisms like feed-in tariffs have been established to offset these additional expenses. The financial burden of these subsidy schemes may translate into higher electricity bills for consumers, as the increased costs are passed down to them. (Ribeiro et al, 2023)

Interestingly, the research notes a significant willingness to pay more among those who perceive renewable energy as increasing electricity costs. This indicates a recognition of the value and benefits of renewable energy, despite potential cost implications.

3.9.2.2 News Resilience

A population-based survey experiment conducted by Melanee Thomas (2022) exposed interesting insights about public opinion. When the media reports the potential economic benefits of transitioning to more RES people tend to respond positively. This kind of framing aligns with the general expectation that positive news would bolster support for the transition, but more surprisingly, the study found that even when the news highlights the potential negative economic impacts of transitioning away from fossil fuels (like job losses in traditional energy sectors, transition costs, or economic challenges in the short term), there is still an increase in public support for the energy transition. This could be because such news may highlight the urgency or inevitability of the transition, or it could make people more aware of the risks associated with not transitioning. (Thomas et al, 2022)

Thus, it indicates that public opinion is rather resilient to news about the transition towards more RES in the energy mix.

3.9.2.3 Not-in-my-backyard (NIMBY)

On the other side public opinions, a directly affect the localization and acceptance of specific renewable energy projects due to the presence of 'Not-in-my-backyard' phenomenon which is a term used to describe the opposition of residents to a proposed development project, such as renewable energy installations, that they perceive to negatively impact them or their local area, even though they may recognize the need for such projects in general.

"NIMBYism" can lead to significant delays in project approvals, increased costs, and in some cases, complete cancellation of projects. This resistance can slow down the overall pace of transitioning to more RES deployment. (Xu & Lin, 2020)

3.10 Demand Management

An alternative to address the energy intermittency challenges was studied by Pina et al (2011) where they researched the impact of demand reduction in the light of renewable penetration. They argue that implementing demand management strategies is vital for a region's long-term sustainability and this includes enhancing technological energy efficiency, but also modifying consumer behaviors. The study used a scenario-based approach on a region with high-RES implementation, and they found that by implementing demand reduction strategies, they were firstly able to significantly delay the need for new RES projects, whilst secondly, also optimizing the grid-stability.

3.11 Critical Minerals

The growth of RES in the EU also hinges significantly on the availability and economics of critical minerals. Minerals essential for manufacturing key components of renewable energy technologies such as solar panels, wind turbines, and batteries and have emerged as a linchpin in the global energy landscape, hence, in this section we delve into what academic literature states about the intricate dynamics between the market of critical minerals on the deployment of RES.

3.11.1 Market effects

An article by Juan Calderon underscores how disruptions in the critical mineral market can indeed hinder the growth of RES by creating supply bottlenecks and influence policy decisions. And consequently, If the supply of these minerals cannot meet the rapidly increasing demand, it could lead to halts or de-prioritization of new RES projects. (Calderon et. Al, 2023)

Furthermore, a study examining the link between the prices of critical minerals and renewable consumption in the long run were conducted by Emannuel & Nicholas Apergis using time-series data. Cointegration relationships indicated that over the long term, the prices of rare earth minerals significantly influenced renewable energy consumption across most of the geographic regions and income classification categories studied with Europe being one of them. However, it is worth noting that when they grouped critical minerals in groups of 3 to 5, keeping consumption from RES as the explanatory variable the presence of cointegration where negative, suggesting that complex relationships might not be as significant or stable as the individual relationships between specific rare earth minerals and renewable energy consumption.
(Emannuel & Nicholas Aspergis, 2017)

3.11.2 Risks for Solar PV and Wind due to Critical Mineral dependency

A study on EU's supply of critical raw materials sourced from China, reveal distinct challenges and specific risks faced by Europe's solar (PV) and wind industries. (Rabe et al, 2017)

The solar PV sector, despite its dependence on critical materials such as tellurium, indium, and gallium sourced from China, faces comparatively lower immediate risk. This relative security can be attributed to several factors. Firstly, the sector benefits from a diverse supply and availability of alternative materials outside of China, which significantly mitigates the risk of supply bottlenecks. (Rabeet al., 2017) Secondly, industry exhibits a commendable level of adaptability, with its ability to switch to substitute materials in response to supply changes, thereby reducing its vulnerability to potential disruptions. (Rabe et al., 2017)
In contrast to the solar PV sector, the EU wind industry, particularly the offshore wind segment, is faced with more acute risks. This heightened vulnerability stems primarily from the sector's

reliance on critical materials such as neodymium and dysprosium, which are essential for the magnets used in wind turbines. (Rabe et al., 2017) The precarious position of the wind industry is largely a result of China's dominant market position, where Chinas near-monopoly over the supply of these materials has led to significant dependency, leaving the EU wind industry with limited alternatives for sourcing these crucial elements.
Furthermore, this dependence exposes the industry to the whims of supply and price volatility. Fluctuations in the availability and cost of neodymium and dysprosium could lead to disruptions in the supply chain and unpredictable production costs, thereby adversely impacting the competitiveness of the EU industry (Rabe, et al., 2017).

In other words, both the EU solar PV and wind-industry face significant supply-chain risks regarding critical minerals that potentially negatively impact RES deployment, with the wind industry being especially exposed to these risks.

3.11.3 Recycling Policies

Notably, Aspergis highlighted how implementation of recycling policies could smooth out the impact of rare earth material prices on the renewable energy industry, ensuring more stable and sustainable growth in this sector. And this is further emphasized in a report by the Kleinman center for Energy policy, which states that the recycling systems are currently underdeveloped and better policies are critical to stimulate RES being implemented faster and in a sustainable way. (Serpell, Paren & Chu, 2021)

The European Raw Material Initiatives, launched back in 2008, did underscore the dependence on imports of rare earths for the transition towards more RES, paving the way for policy development in the field. It had a major focus on recycling raw materials; however, it did not explicitly state anything about the demand for recycling systems for rare earths. (European Commisson, 2008)

3.12 Financing and Investments

3.12.1 GPR shocks on Financing RES

A study on how GPR influences the investment in green projects found an inverse correlation between GPR and investment in clean energy. As GPR increases, the study observed a stabilization in the green finance sector. This suggests that higher levels of GPR are associated with decreased risk in investments for RES projects, highlighting the potential for GPR to positively influence investments in RES. (Dong, et al. 2023)

3.12.2 Technological advancements

There are studies that examine if innovation is driving RES growth. Notably, a recent study by Khan et al. (2022) focusing on Germany unveils a significant, albeit complex, causal relationship between technology advancements and RES. The key findings of the article underscore the reciprocal nature of this relationship. It is noted that technological innovations are not only crucial for the advancement of renewable energy but also that the growth in renewable energy significantly influences technology innovation. (Khan et al, 2022)

This suggests a synergistic interplay where advancements in one domain fuel progress in the other. Specifically, the study finds that as renewable energy technologies advance, they lead to increased investments in broader technological innovations, reinforcing a cycle of mutual growth and development, hence, increased R&D spending might be purely a driver to growth in RES.

3.12.2.1 Overestimating effects from technological, and underestimating interest rates

As outlined by the section regarding policies influencing renewable energy deployment, significant backing for the development of wind and solar power has been a central aspect of renewable energy policy. Coupled with governmental support for research and development and aided by low interest rates across the economy, these efforts have led to notable reductions in the costs of wind and solar technologies. (Egli et al. 2018) However, a dynamic analysis of financing conditions for renewable energy technologies, showed that historically there might have been too much emphasize on the technological learning curve on the cost-reduction of renewables, and underestimating that RES are highly vulnerable to interest rate changes. (Egli et al. 2018)

3.13 Identified areas that could accelerate RES deployment

After examining the literature on RES deployment, the following areas are identified as accelerators:

- Creating resilient, supply chains for key RES technologies
- Optimizing energy grid infrastructure and increasing storage solutions
- Efficiency permitting process to accelerate the development of renewables
- Improving energy efficiency
- Improving energy security

However, we note that these areas are influencing each other, with energy security being an overarching area.

For instance, strengthening supply chains and streamlining the permitting process would improve energy security.

Or optimizing the energy grid --> *improves energy efficiency* --> *which then will strengthen energy security.*

3.14 Renewable Levels pre-invasion.

This section is dedicated to presenting an overview of key statistics pertinent to the renewable energy sector. These metrics, which were established prior to the invasion, serve as reference points for our analysis. They provide essential context and baseline data, enabling a thorough understanding of the RES sectors state before the geopolitical upheaval.

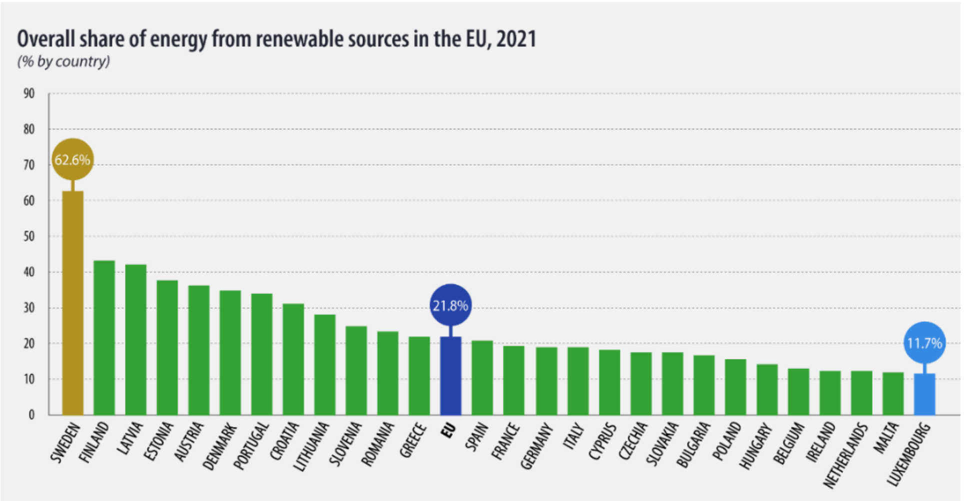

Figure 3.1: Overall share of energy from renewable sources in the EU, 2021 (EurObserv‘Er, 2023a)

RES share, Wind, and solar capacity

As we can see from the figure above, did the EU manage to reach overarching 20% energy consumption target from the ’Climate and Energy package, and by 2021 the total share from RES was 21,8%. Moreover, EUs installed capacity from solar and wind in 2021 amounted to 162GW (EurObserv‘Er, 2023a) and 236 GW (EurObserv‘Er, 2023b) respectively.

Energy Source	Capacity Added in 2021 (GW)	Total Capacity by End of 2021 (GW)
Solar Power	26.5	162.6
Wind Power	11.3	188.3

Table 3.1: Total capacity of Wind- and Solar power pre-invasion (EurObserv’er 2023 a.b.)

3.14.1 Hydrogen development pre-invasion

Although, there is not too much information regarding the exact tons of hydrogen produced or consumed, a ‘Hydrogen Strategy’ was communicated from the European Commission in 2020.

This Communication outlines the EU's strategy to deploy clean hydrogen for decarbonization, targeting the installation of at least 6 GW of renewable hydrogen electrolyzers by 2024 and expanding to 40 GW by 2030. (EC, 2020) And from 2020 to 2024, the plan was to produce up to 1 million tons of renewable hydrogen. (EC, 2020)

4.0 Contextual background and immediate consequences

In the following section, we will provide an overview of the Russian invasion of Ukraine, focusing particularly on its immediate impact on key factors for the renewable energy sector.

4.1 Russian Invasion

In the months leading up to the 2022 invasion, Russia amassed a large number of troops and military equipment near Ukraine's borders, under the guise of military exercises, and on February 24. 2022 Russia launched a full-scale invasion of Ukraine, initiating attacks from multiple directions, including from the territory of Belarus.

In a concerted response, the EU, alongside its allies, quickly imposed a series of sanctions aimed at undermining Russia's financial stability and access to key markets. The initial sanctions were soon followed by more targeted and comprehensive measures, particularly against the Russian energy sector designed to erode Russia's economic strength and military capabilities, with a strategic objective to disrupt the funding mechanisms that could potentially support Russia’s war in Ukraine.
These sanctions had severe impacts on the climate for RES in the EU, both directly, but also indirectly.

4.1.2 Sanctions

4.1.2.1 Oil and Coal

The sanctions included bans on the import of Russian oil (covering 90% of oil imports from Russia) and coal, which were major revenue sources for Russia. In 2021, the EU imported €71 billion worth of oil from Russia, including both crude oil and refined oil products and accounted for a large part of the energy share in the EU. (EC, 2023)

4.1.2.3 Natural gas

The EU were raising concerns to reduce its imports of Russian natural gas through pipelines, as the period before the invasion saw increasingly less gas flows from the Nord Stream and Yamal-Europe pipeline[2]. (Golubkova et al., 2021)

After the invasion of Ukraine in 2022, the Nord Stream pipelines, which was a major conduit for Russian natural gas to Europe, became a focal point in the energy dynamics between Russia and the EU. The pipeline experienced a series of events that significantly impacted gas flows. These included planned maintenance works, but also disruptions and reductions in gas flow, which were attributed to various technical and political reasons. (Adomaitis, 2023)
Followingly, the Nord Stream pipelines were damaged in a series of explosions on September 26, 2022. These incidents, which occurred in the Baltic Sea, affected both the Nord Stream 1 and Nord Stream 2 pipelines. The nature of these explosions led to widespread speculation and investigation into sabotage or terrorist attacks, though the exact motives and perpetrators remained unclear. (Adomaitis, 2023)

The reduction in energy imports posed significant threats to the EUs energy security, as previously, Russian energy constituted a significant 42.6% of the EU's total energy imports, surpassing contributions from any other country. (Yanatma, 2023)
Moreover, these measures led to a tighter supply in the energy market and EU needing to find new suppliers, contributing to higher prices for both natural gas and oil, which had domino effects on other key factors for the RES market in the EU.

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2 In late 2021 and early 2022, the Yamal-Europe pipeline, typically used for transporting Russian gas to Europe, operated in reverse mode on several occasions.

4.1.2 Impact on Electricity Markets

Especially the reduction in natural gas flows and coal sanctions impacted the EU wholesale electricity price as those accounted for approximately 40% of the electricity generation in EU in 2021. (Ember, 2023) This dynamic is rooted in the pricing mechanism of the energy market, which is heavily influenced by the cost of marginal fuel. In this context, natural gas and coal serve as a marginal fuel, thus its price directly impacts the electricity market pricing structure. (EC, 2023)

If we look to February 23, 2022 (the day before the conflict started) and July 31, 2022, Gas prices increased by 115%, and electricity prices by 237% (Ember, 2023) and coal prices followed a similar trend by rising 97% in the first 6 months of the invasion. (Ember, 2023) Thus, the cost of input factors for industries and heating costs for households skyrocketed in the aftermath.

4.1.3 Supply chain disruptions

Furthermore, the invasion disrupted supply chains on a global, regional, and local scale, which exacerbated the operational issues already brought about by the COVID-19 pandemic and other substantial challenges.

The conflict affected the global shipping and logistics industries, complicating the transportation of materials and finished goods. With increased fuel prices, imposed sanctions, and rerouted shipping lanes it contributed to delays and higher transportation costs. For instance, it caused a standstill in rail transportation between China and Europe, disrupting efficient and low-cost rail transportation and multiple ships were locked-in the Black Sea in the months following the invasion. (Arts et al., 2023) Supply chain disturbances like these led to heightened freight costs, a scarcity of containers, and a reduction in available warehouse space, concurrently interrupting the transport of critical materials between different regions. Russia is a major exporter of critical minerals for the renewable sector in the EU, with Aluminum, Copper and Nickel and various other rare earths like Palladium and Platinum, all of which detrimental for RES, hence it shone light on supply chain dependency for input factors to expanding RES (Hansens et al., 2023)

To summarize, the sanctions and subsequent events in the energy markets exerted upward pressure on the EU's wholesale electricity prices, combined with the widespread disruptions in global logistics and supply chains are compounding factors significantly contributed to escalating costs across industries and households. Thereby contributing to inflationary pressures within the EU - posing significant threats to the RES market and have tightened financing conditions with rising interest rates in the region.

5.0 Findings

5.1 Policy Responses

In this section are we going to assess the policy responses conducted by the EU as a response to the Russian invasion of Ukraine, and examine how they relate to the deployment of RES

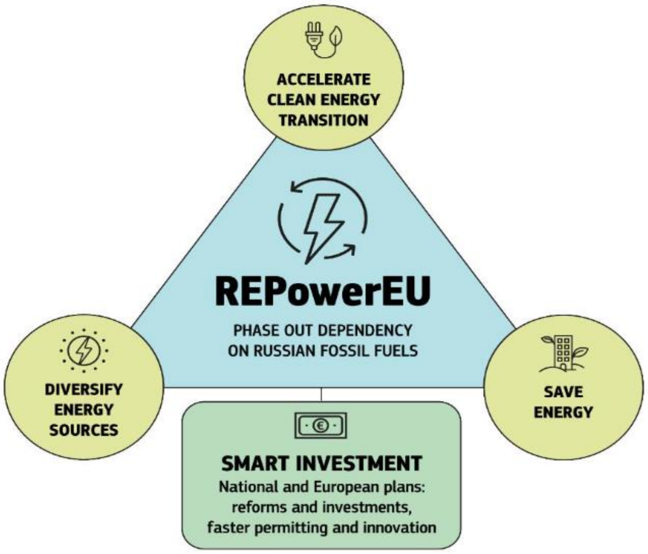

Figure 5.1: RePower EU: Objectives (European Commission, 2022)

RePowerEU, introduced by the European Commission 19th May 2022, represents a strategic and robust response from the European Union to address the energy security challenges which the Russian invasion of Ukraine amplified. It is the overarching policy response and is a comprehensive plan developed by the European Commission designed to address the challenges posed by the Russian invasion of Ukraine and the consequent need to reduce reliance on Russian fossil fuels. (EC, 2022) The plan serves as a cornerstone of the EU's efforts to reduce its dependency on Russian fossil fuels, particularly natural gas, and to accelerate the implementation of RES.

The three pillars of the plan indicated by the figure above:

- Reduce demand
- Implement more RES
- Increase energy security by diversifying energy supplies

5.1.1 Funding

The REPowerEU Plan outlined a multifaceted approach to funding, combining EU level initiatives, flexibility for Member States in reallocating their resources, and leveraging existing frameworks that the decade before the invasion have developed. A significant portion of the funding for REPowerEU will come from the RRF from the NextGeneration EU recovery instrument, and a minor part from the EU ETS. Additionally, a considerable amount of financing is expected to be procured from the private sector. (European Commission, 2022)

15.1.2 Increasing Targets from 'Fit for 55'

In the light of renewable energy deployment, the REPowerEU plan emphasizes speeding up renewable energy projects and grid infrastructure improvements, including revising the REDII proposal. The plan suggests raising the 2030 target for the share of renewables in the EU's energy mix from the current goal of 40% to 45%. To achieve this target, the EU needs to add significant new renewable energy capacities. Specifically, this would involve an increase of approximately 169 gigawatts (GW) to the previously anticipated target under the 'Fit for 55'. With the new Repower EU proposal, this target would be revised upwards, requiring a total of about 1236 GW of renewable energy capacity by 2030. (European Commission, 2023)

5.1.3 RED revision

Given the urgency of speeding up the EU's deployment of RES, the RED was revised during 2023 and entered into force on the 20th of November 2023 legally binding EU and its MS to increase their share of RES in the energy mix from 32% to 42,5% in 2030 (European Commission, 2023) - which means that the EU needs to approximately double their current capacity in less than a decade.

5.1.4 Changes to the NECP drafts

Due to the new target set by RePower EU, the MS needed to deliver new drafts of their respective NECPs by 30th of June 2023 which served to communicate how the respective MS were to contribute to the 2030 target (European Commission, 2023). A majority of submissions were substantially delayed, but as of December 2023, only Bulgaria, Ireland, Latvia and Poland remain to submit their drafts. Compared to the NECPs of 2019, the data available shows that targets for solar PV and wind power increased by 64% and 49% respectively in the EU MS. (Ember, 2023)

The updated RES capacity in the drafts are insufficient to deliver on targets set by the European Green Deal and the RePower EU, but do show a significant increase from pre-invasion levels, where estimations by Ember show the solar fleet in the EU nearly tripling and the wind capacity doubling by 2030. (Ember, 2023)

5.1.5 Permitting Process

The previously slow permitting procedures in RES projects are also set to be faster and simpler through a legislative proposal in the EU RePower Plan (EC, 2022). The EU identified that the varying permitting time due to high levels of bureaucracy and differing legislative frameworks among MS, and issued a recommendation on a streamlined permitting process which all MS were to implement.

5.1.5.1 Overriding public interest

A key aspect of the new regulatory framework of the permitting process is the principle of “overriding public interest” which is a principle that recognizes RES projects as having a priority over certain other considerations due to their significant benefits to the public, such as environmental protection, reducing carbon emissions, and advancing sustainable energy goals. (EC, 2023)

The regulatory framework presumes that renewable energy projects are of significant public interest and benefit, particularly in the context of environmental legislation. Under this framework, projects for renewable energy are generally presumed to serve public health and safety and are given priority in the planning and permit-granting processes. This means that when legal interests are balanced in individual cases, renewable energy projects are more likely to be favored. (EC, 2023) The aim is to streamline the authorization processes and remove bottlenecks that have historically slowed down the development of renewable energy infrastructure.

5.1.5.2 Renewable “Go-to areas”

Another key introduction from these new recommendations was the introduction of “Renewable go-to areas.” These locations, found both on land and at sea, are uniquely suited for setting up renewable energy facilities, excluding those that burn biomass. The deployment of certain types of renewable energy in these areas is not anticipated to cause substantial environmental impacts, considering the unique characteristics of the chosen regions. (EC, 2023) The EC states that national authorities of MS should not overdue a permitting procedure of 12 months in these “go-to areas”, whilst outside the process should not exceed 24 months. (European Parliament, 2023)

5.1.5.3 Public Opinion: Early evidence shows that public support is increasing

Resistance from the public is also a cause of delaying renewable projects, however, surveys done in various European countries show that the support for RES is growing after the invasion.

A survey conducted in Germany after the invasion by the Renewable Energies Agency, known as the ‘Acceptance Survey,’ revealed a significant increase in the German population's support for renewable energy, this heightened support is largely influenced by concerns over energy supply security, dependence on autocratic states, and inflation. (Kyllmann, 2022)
Approval rates for renewable energy projects in close proximity to people's homes have risen across all types of systems. Ground- and roof-mounted solar PV installations, as well as wind turbines, received the highest acceptance rates. Additionally, 20% of respondents, who were previously not supportive of wind energy, now view its expansion favorably due to the energy crisis following Russia's war in Ukraine. (Kyllmann, 2022)
Furthermore, a study by Steffen & Patt (2023) on surveys done in Switzerland, that the war appears to have acted as a catalyst, heightening public awareness and concern about energy

independence and sustainability, leading to increased endorsement of policies aimed at phasing out fossil fuels and promoting renewable energy alternatives. (Steffen & Patt, 2023)
Moreover, unlike in many other policy areas, the support for transitioning towards renewable energy and reducing reliance on fossil fuels transcends traditional political divides, indicating a broad consensus on the importance of these issues. (Steffen & Patt,2023)
This shift in public opinion is particularly significant, considering Switzerland's historical dependence on energy imports and the broader implications for European energy policy. (EDA, n.d.)

Public resistance has historically been a factor in delaying renewable energy projects. However, recent surveys conducted in different regions indicate a growing trend of support for these initiatives following the invasion. This shift in public sentiment is a positive sign, especially due to the elevated energy price for the public and is suggesting an increasing alignment between renewable energy development and the broader public's priorities and concerns.

5.2 EU solar strategy

RePower EU plan states that due to the fast roll-out of solar (PV), an increased attention is given to this RES. (EC, 2023) Through the EU solar strategy, the EU will by 2025, aim to see more than 320 GW of newly installed PV capacity, surpassing the current level by more than double. Looking ahead to 2030, the ambition is even greater, targeting nearly 600 GW of solar capacity (European Commission, 2022) and also, they aim to re-shoring 30GW of the Solar PV annually (InnoEnergy,2023)

5.2.1 European Solar Rooftop Initiative

To reach the newly updated PV capacity target, one of the central goals of this initiative is to leverage underutilized space available on rooftops across Europe. Rooftops of residential, commercial, industrial, and public buildings represent an untapped resource for PV, and through the European Solar Rooftop Initiative, the EU makes it legally binding to install PV technologies on all new buildings by 2029. (European Parliament, 2023)

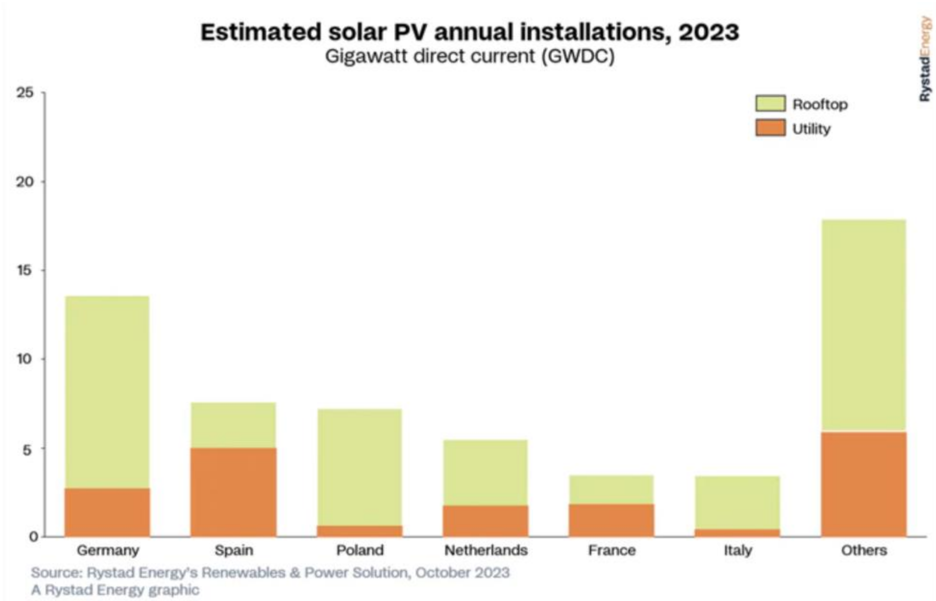

Figure 5.2: Estimated solar PV annual Installations, 2023 (Rystad Energy, 2023)

The initiative has, however, significantly helped increase the domestic PV generation in the EU already. Rystad Energy presented a report on the 26th of October 2023, stating that PV installations are exceeding all expectations in the EU. According to Rystad Energy's modeling, the anticipated increase in new solar capacity installations for this year is expected to reach 30% higher than that of 2022, with 70% stemming from rooftop installations. (Rystad Energy, 2023) The significant rise points towards that the policy is de-facto increasing the deployment of RES in the EU. If we look towards the IEA, the recent policy measures implemented across various European nations have prompted them to adjust their forecasts for the increase in renewable energy capacity within the European Union for the years 2023 and 2024 which now anticipate a 40% higher growth rate compared to their projections prior to the onset of the war. (IEA, 2023)

5.2.3 European Solar Industry Alliance (ESIA)

Another important part of the EU solar strategy was the launch of the ESIA, which represents the interests of various stakeholders in the solar industry, including manufacturers, installers, project developers, and other related entities. It was officially launched on 9th of December 2022 as a strategic move by the European Union to bolster its resilience and strategic autonomy in the solar PV sector. (European Commission, 2023) ESIA's objectives will revolve around identifying and addressing the challenges in scaling up domestic manufacturing, aiming to increase production efficiency. Alongside this, there is a significant emphasis on improving financial accessibility and identify bottlenecks in the scale-up of manufacturing (ESMC, 2022), which as a result will establish clear pathways for the commercialization of domestic solar panel manufacturing.

Another critical aspect of the plan is maintaining strong international partnerships and building resilient global supply chains, ensuring a steady and secure flow of materials and knowledge within the industry. The alliance is dedicated to developing a cooperative framework to support the growth and uptake of solar PV technologies to foster collaboration across the sector. (ESMC, 2022) In addition to these aspects, the plan includes a strong focus on enhancing communication and initiatives centered on circularity and recycling, highlighting the untapped potential of a more circular approach to raw materials in RES (EEA, 2023).

Additionally, the alliance is working towards diversifying the international solar PV value chain, including the components and raw materials, to secure and broaden the supply sources for solar PVs, where the EU historically have been heavily reliant on imports. (ESMC, 2022)

Hence, the initial priorities of the alliance include securing financing for solar photovoltaic manufacturing projects within Europe and ensuring a sustainable level playing field. (InnoEnergy, 2023)

5.2.4 Challenges to Reshoring

Regardless of how the ESIA communicates ways to increase manufacturing, those clear pathways towards more domestic production of solar in the EU are proving to face several hurdles in its way. Firstly, materials used for solar panels in EU have traditionally been sourced from China, accounting for over 90%, making the region highly dependent already. (EC, 2023) Furthermore, industry leaders in Solar manufacturing states that the cost of acquiring those same materials in Europe at this point in time is approximately twice as expensive, highlighting that to start a solar industry in Europe almost from scratch is going to be an immense challenge. (Reuters, 2030)

Secondly, even though that earlier this summer the ESIA stated the EU was on a great path towards reaching future reshoring targets by 2025, CEO of the interest organization ’SolarPower Europe’, Wallburga Hemetsberger, stated in a crisis letter to the European Parliament this fall that the domestic Solar PV manufacturers are facing risks of insolvency. (Hemetsberger, 2023) Since the beginning of this year, there has been a notable decrease in the prices of PV modules, with a reduction of more than 25%. The combination of robust global demand and intense competition among Chinese suppliers has spurred significant new investments in the solar PV supply chain. This has led to an excess supply, resulting in rapidly declining prices for raw materials like silicon and extending down the supply chain to include modules, inverters, and batteries. (SolarPower, 2023)
The prices are now even lower than those seen before the Covid pandemic, and such a drastic drop in prices is posing significant challenges for European PV manufacturing companies, as it becomes increasingly hard for them to market their products competitively. The situation is dire enough that there is a real risk of insolvency for these companies, especially given the likely need to devalue their substantial inventories. (Reuters, 2023)

5.3 Wind Strategy

The EC states in the communication on the Repower EU plan that Offshore wind energy presents a promising future, due to its consistent and abundant resources and highlights that it has generally higher public acceptance. (EC, 2023) Recognizing that the region is a global leader in this field, Europe is well-positioned to capitalize further on offshore wind, but to do so they need to enhance the EU’s worldwide competitiveness in the field and to meet the ambitious goals of REPowerEU. Hence, they underline that for rapid wind energy deployment, it is crucial to bolster supply chains, level the international playing field and speed up the permitting process - the same as for Solar PV. (EC, 2023)

5.3.1 Capacity installed and targets

The target for wind power capacity by 2030 was increased from 190GW to 480GW in 2030. In 2022, wind power installations across the EU achieved a notable milestone with the addition of a record 16 GW, marking a substantial 47% increase from the 11 GWH installations in 2021. (EC,

2023) However, these new installments were almost solely onshore wind (WindEurope, 2023), and despite this significant growth, the pace still falls short of the 37 GW per year that is necessary to meet the EU's 2030 target set by the Repower EU. (EC, 2023)
And currently, the industry is also facing detrimental repercussions from the aftermath of the Russian invasion of Ukraine.

5.3.2 Challenges

Aside from the slow-permitting process, the wind industry faces numerous other challenges to growth after the invasion:

5.3.2.1 Increased costs due to electricity prices and supply chain disruption

It is reasonable to assume that higher energy prices would stimulate the wind-sector growth, however, this serves not to be the case in the wind industry. Historically, when the costs associated with developing wind projects were lower, many developers entered into long-term contracts, Power Purchase Agreements (PPAs) or similar contracts, committing to sell electricity at fixed, often low, prices. However, the recent surge electricity prices have rendered these fixed-price contracts increasingly unviable, leading to several complications (Chestney & Twidale, 2023). For instance, Aldermyrberget wind farm are one among other Swedish wind farms that recently filed for bankruptcy due to unprofitable PPAs based on pre-invasion prices. (Tigerstedt, 2023) Furthermore, the manufacturing of wind turbines is energy-intensive, involving processes like steel fabrication, casting, and precision engineering. The increase in electricity prices raises the operational costs, coupled with extensive supply chain disruptions, are inflating the overall production cost of wind turbines.

When it comes to the production side, currently, the majority of wind turbines used in Europe are manufactured within Europe itself. This is largely due to the region’s early and sustained investment in wind energy technology, resulting in a well-established wind turbine manufacturing industry.
However, due to the perfect storm of increased input costs, the cost of producing wind turbines domestically has increased by up to 40%, making producers from other regions more attractive.

(WindEurope, 2023)

5.3.2.2 Decreased Investment

As a result, the European wind industry experienced a significant downturn in investment in 2022, with the total investment in new capacity amounting to €17 billion, indicating a decrease of over 58% from 2021. (WindEurope, 2023) Such a dramatic year-on-year drop is notable, particularly in the context of the growing emphasis on RES to combat climate change and reduce dependency on fossil fuels. The 2022 investment level being the lowest since 2009 is particularly concerning, as it suggests a regression to the levels seen over a decade ago, despite technological advancements and increasing urgency of transitioning to renewable energy.

5.4 Energy Efficiency

The EU's 2030 binding energy savings target is increased to 13%, up from 9% as stated by the EED, in the new RePower EU plan. (IEA, 2023) Saving energy, which is considered the most cost-effective, safest, and cleanest way to reduce reliance on fossil fuel imports, whilst it also facilitating RES implementation in the energy mix. The plan encouraged EU member states to voluntarily reduce gas usage across the EU by 15% during the winter through the" Save gas for a safe winter" which included 1st of August 2022 until 31. March 2023. (EC, 2023) This target which was not only met but exceeded, with an 18% reduction in gas demand between August 2022 and March 2023 and the 15% target was extended by the member states for an additional year. (Reuters, 2023)

5.4.1 Heat pumps paving the way

The invasion of Ukraine and subsequent energy crisis have significantly accelerated the adoption of heat pumps in Europe, marking a notable shift in the energy transition landscape. The demand for heat pumps has surged, evident in the substantial growth in sales across various European countries. The Repower EU plan stated that the deployment rate of individual heat-pumps needed to be doubled over the next 5 years and as a response the MS have established various financial support schemes to encourage the adoption of heat pumps. These incentives include low-interest loans, grant programs, and reduced VAT rates. (EC, 2023)

Eastern European countries like Poland, which traditionally has been seen as slower in adopting climate policies, recorded a remarkable 120% growth in heat pump sales in 2022, whilst allover growth in the EU was 38% for 2022. (Hockenos, 2023)

5.4.2 Future outlook

The rising costs of fossil fuels have made heat pumps a more economical option compared to gas or oil heating systems and despite a decrease in oil and gas prices from last year's peak, a return to the lower prices of the past seems unlikely. According to IEA heat pumps are highly efficient, being three to five times more efficient than gas, and have no emissions when run on RES like solar PV and wind (IEA, 2023), thus heat-pumps are going to contribute the most to heating needs in the path towards ’net-zero’ according to both Mckinsey and IEA whilst lowering energy demand. (McKinsey, 2023)
Additionally, the EU ETS is set to introduce carbon pricing for heating fuels starting in 2027, which is expected to further improve the cost-effectiveness of heat pumps, which paints a promising picture for further decreasing energy demand whilst ensuring energy affordability (World Economic Forum, 2023).

5.5 Electricity Grid

5.5.1 Grid-optimization

Grid optimization is a reoccurring barrier in regard to increased integration of renewable energy sources within the EU energy mix. The recently proposed 'RePower EU' plan underscores this issue, placing a considerable emphasis on objectives and investment aimed at enhancing the efficiency and capacity of the power grid. This initiative highlights the need for advanced grid infrastructure to accommodate the variable nature of renewable energy sources, such as solar and wind power. The plan delineates specific focus areas intended to modernize the grid to facilitate the increased inclusion of RES.

5.5.2 Enhancing Grid Interconnections

The Repower EU states that a key strategy is to enhance grid-interconnections, and this involves building new cross-border transmission lines and upgrading existing ones to facilitate the efficient transfer of electricity across European countries, particularly to balance the variable output from wind and solar installations. (EC, 2022)

Moreover, new high-capacity transmission lines are being constructed that can also bridge the geographical gaps between regions with high-RES production and those with high energy demand and increase energy security (EMBER, 2023). For instance, the interconnectivity between wind energy generation facilities in Northern Germany and the industrial conglomerates situated in the southern region is currently inadequate, thereby impeding the effective balancing of the national power grid through the establishment of robust interregional linkages between sites of electricity generation and principal demand locales. (Mckinsey, 2023)

5.5.3 Fast-tracking projects

Several major grid-interconnection projects in the EU have been pushed forward. For instance, the 'Aurora Line', which is focused on developing a third transmission line between Sweden and Finland to increase electricity transmission capacity and support the integration of renewable energy. (EC, 2021) The construction of the project started less than 6 months after the invasion and is set to be completed in 2025. (Fingrid, 2023 & Rapacka, 2022)

Furthermore, on 3rd of August 2023, Estonia, Latvia, and Lithuania have reached a consensus to fast-track an integration of their electricity networks with the continental European grid and to sever their grid connections with Russia and Belarus. (EC, 2023) This strategic move, set to be completed by early 2025. (EC, 2023)

5.5.4 Smart grids

Another focus area after the invasion is smart grids. Smart grids, which are a backbone of the digitalization of the energy system, are key to this transformation. Smart grids can dynamically adjust to changes in energy supply and demand, integrate distributed energy resources (like rooftop solar PV), and improve the efficiency and reliability of the grid. (EMBER, 2023) The

Digitalization of Energy Action Plan, adopted in October 2022, is focused on promoting investments in smart grids. (EC, 2022) Implying that the EU is proactive in facilitating a renaissance in their electricity-grids.

5.6 Energy Storage

5.6.1 Hydrogen

The EU highlighted 'Renewable hydrogen' as crucial for replacing natural gas, coal, and oil in hard-to-decarbonize industries in the Repower EU Plan, including optimizing the power-grid to allow for more intermittent RES. (EC, 2023) The plan sets a target for the EU to produce 10 million tons of domestic renewable hydrogen and import another 10 million tons by 2030.

5.6.1.1 Status quo

Currently, the EU consumes approximately 8 million tons of hydrogen annually, predominantly derived from natural gas, which is not renewable. (EC, 2023) In contrast, the production of renewable hydrogen in the EU is considerably lower, at less than 0.3 million tons. (EC, 2023) The installed electrolyzer capacity within the EU, essential for hydrogen production, stands at around 160MW, whilst the Repower EU plan states that they aim to build 17,5GW by 2025. Furthermore, to achieve the ambitious goal of producing 10 million tons of renewable hydrogen, the EU would need to expand its electrolyser capacity to between 80 and 100 GW. (Odenweller & Ueckerdt, 2023) This expansion would necessitate an additional 150 to 210 GW of renewable energy capacity to generate electricity at a cost-effective rate, thereby making renewable hydrogen competitive with fossil-based alternatives. (Odenweller & Ueckerdt, 2023) This illustrates that the targets from the Repower EU plan can seem a bit too ambitious, but to achieve these goals, the plan outlines several key strategies:

5.6.2.2 Hydrogen Valleys

The European Commission, as part of its REPowerEU Plan, has announced an additional investment of €200 million for the Clean Hydrogen Partnership through the Horizon Europe

Program. This investment aims to double the number of Hydrogen Valleys in Europe, a key initiative to accelerate the implementation of the hydrogen economy across the EU. (EC, 2022) These 'Hydrogen Valleys'[3] are integral to the EUs strategy to scale up renewable hydrogen production, supply, and meeting the increasing demand - whilst also demonstrating hydrogen as a viable substitute for fossil fuels.

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3 A 'Hydrogen Valley' is a specific area where clean hydrogen is produced and used by local households, transport, and industries and these 'Valleys' demonstrate the EUs hydrogen economy at a community level, potentially connecting to each other through hydrogen corridors.

5.6.2 Battery storage

2The RePowerEU plan places emphasis on the deployment of battery storage systems to store energy from RES during peak production times and releases it when needed, ensuring a consistent energy supply, reducing dependence on fossil fuels, and enhancing grid stability. (EC, 2022) The increased investment and streamlined permitting process from the plan fostered increased interest in the sector, however, the EASE (European Association for Storage of Energy) points out there is a lack of a specific energy storage strategy with defined objectives, which is unfortunate as an announcement of such a strategy would have been a significant driver for investment and would have accelerated the advancement of technology. (EASE, 2022)
On the other side, in 2022 alone, there was an expected 97% year-on-year growth in European grid-scale energy storage demand, deploying 2,8GW from previously 3,3GW installed (WoodMackenzie, 2022).
The strategic integration of peripheral European Union (EU) countries into the continental power grid marks a significant shift from the historical reliance on Russian natural gas for power generation. In this context, the role of batteries has gained prominence. This was particularly evident in November 2023, in connection with the Baltic states' scheduled integration into the European continental grid by 2025. Concurrently, the development of multiple battery parks in the region has been accelerated, with completion targets aligned with the 2025 timeline. (Tooming & Kersa, 2023)

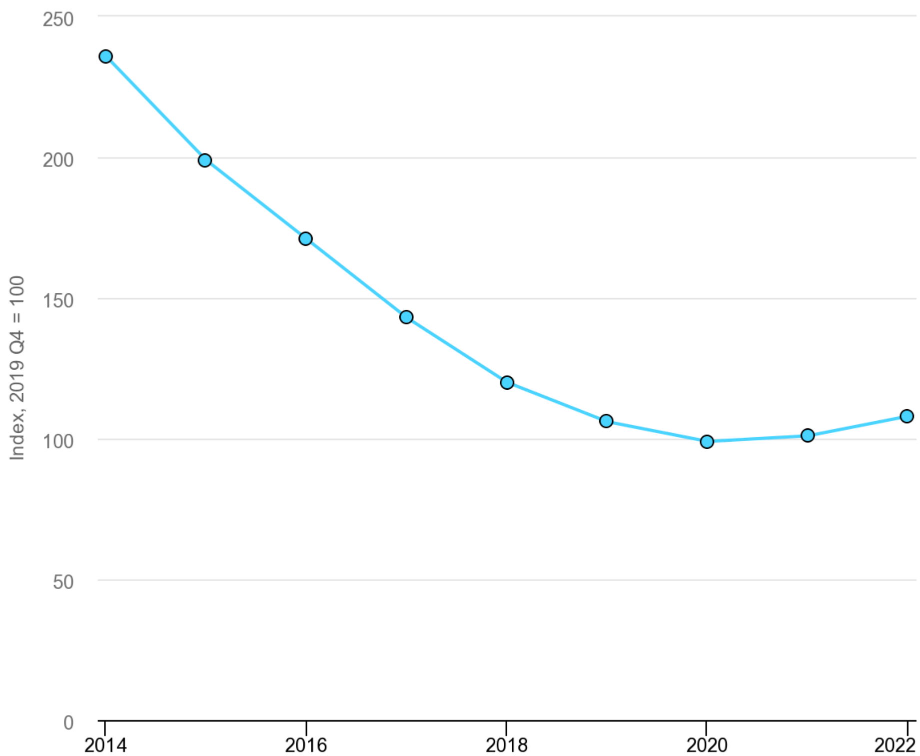

Figure 5.3: IEA clean energy equipment price index, 2014-2022 (IEA, 2023)

5.7 Critical Minerals

Given the supply dependence, and imposed costs from critical minerals are crucial for the deployment of new renewable energy technologies, are we going to elaborate on the impacts and responses observed in the market and the EU following the Russian invasion of Ukraine.

5.7.1 Prices

1The invasion not only heightened the demand for minerals but also caused significant disruptions in their supply chains, factors that are likely to exert a considerable influence on the pricing dynamics of these minerals. At first glance, the prices of most minerals seem gradually to have declined after a sharp spike around the time of the invasion, however, a detailed analysis of the point-wise causal effect of the Russian invasion on critical mineral prices revealed a notable increase in the prices of these metals due to the conflict (Khurshid et al, 2023). Specifically, the prices of cobalt, nickel, lithium, copper, and aluminum rose by 2%, 36%, 14.97%, 3%, and 15% which are all critical raw minerals to development of wind, solar and battery parks.
The IEA's clean energy equipment price index indicates that, up until the end of 2020, the costs of clean energy technologies consistently decreased, a trend attributed to advancements in technology and the benefits of economies of scale. (IEA, 2023) The trend is now gradually shifting, as illustrated by the figure above.

5.7.2 Addressing overdependence in the supply chain for RES

2As the literature pointed out: whilst critical raw materials are of utmost importance for increased RES deployment in the EU, they face high risks of supply disruptions. The European Union's demand for rare earth metals is projected to increase six-fold by 2030 and seven-fold by 2050. Similarly, the demand for lithium within the EU is anticipated to rise twelve-fold by 2030 and twenty-one-fold by 2050. (EC, 2023) Thus, an agreement was reached in record time (Vilches, 2023) to address the associated risks.

5.7.3 European Critical Raw Material Act (CRMA)

CRMA is a legislative framework proposed by the EC on 16th of March 2023, which reached an agreement in November the same year. (Yun Chee & Blenkinsopp, 2023). The CRMA focuses on increasing Europe's self-reliance by boosting domestic production, processing, and recycling of critical materials and it sets following specific targets for the EU following targets by 2030:

- The EU should extract at least 10% of its critical raw materials.

- The EU should process at least 40% of its critical raw materials.
- Recycling should cover at least 15% of the EU's needs for critical raw materials.
- The EU should not rely on imports from single countries for more than 65% of its various critical raw materials. (Council of the European Union, 2023)

The CRMA is likely to be entered as a law by early 2024, and underlines an important step towards reducing reliance on third parties for the EU MS, potentially increasing EUs energy security under more implementation of RES.

5.7.4 Sanctions on Critical Minerals

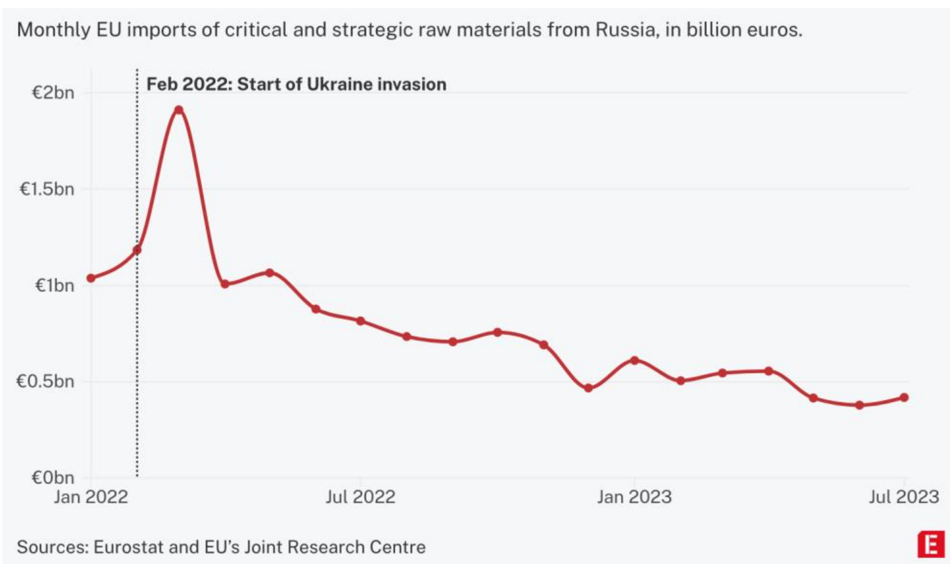

Figure 5.4: Monthly EU imports of critical and strategic raw materials from Russia (Investigate Europe, Eurostat 2023)

As Russia is a big exporter of critical minerals to EU, sanctions had the possibility to hurt the renewable development in the EU. Particularly in the case of aluminum and nickel, with each of these minerals being supplied by Russia to the extent of 17% of the EU's total consumption, additionally, Russia provides 7% of the EU's copper needs, 5% of its cobalt, and 4% of its lithium requirements. (Rizos & Righetti, 2022) Moreover, Russia is 2nd biggest producer of silicon and in the world, which is one of the key materials to produce solar panels. (Statista, 2023) Halting imports of certain metals from Russia, like copper, might seem insignificant due to their small share. However, such a cessation could lead to dramatic price increases and destabilize global markets. (Zemlianichenko, 2023)

Sanctions, as demonstrated by the figure above, have not been imposed on Russian imports of critical minerals. David O'Sullivan, the EU's special envoy for sanctions, explains this exclusion by emphasizing the "critical" nature of these minerals. (Hansens, et al., 2023)
To put this into context; to meet its net-zero emissions goal by 2050, the EU is projected to increase its consumption of copper and aluminum by about 35% and boost its silicon demand by approximately 45% compared to current levels (Zemlianichenko, 2023). This may raise concerns over Russian influence over vulnerabilities in the supply chain, as the conflict in Ukraine has demonstrated Russia's willingness of weaponizing key resources, whilst questions regarding dependency on other nations will be threatening energy security in an energy mix with more RES.

5.8 Diversifying Supply

5.8.1 Natural gas

As we have covered earlier, natural gas is identified as playing a significant role for increasing RES deployment[4], and in the wake of Russia's invasion of Ukraine in early 2022 and the subsequent Nord-stream demolition, the EU and its MS faced an unprecedented challenge: the urgent need to diversify its natural gas supplies. And while previous strategies had shed light on diversification of energy supplies, the RePower EU plan accelerated this.
In 2021, 37,6% of all heat generation stemmed from natural gas, whilst natural gas accounted

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4 Regarding grid-stabilization (especially peak-hours) and as a transitional fossil fuel.

for 20% of the electricity generation (Statista, 2023), with Russia accounting for almost half of it. Through the Repower EU plan, the EU set wheels in motion to diversify gas supplies, and even though power generation from gas is still at almost 20% (Ember, 2023), the import of gas from Russia has been reduced to 12% by the end of 2022 as we can see from the figure below. (Yanatma, 2023)

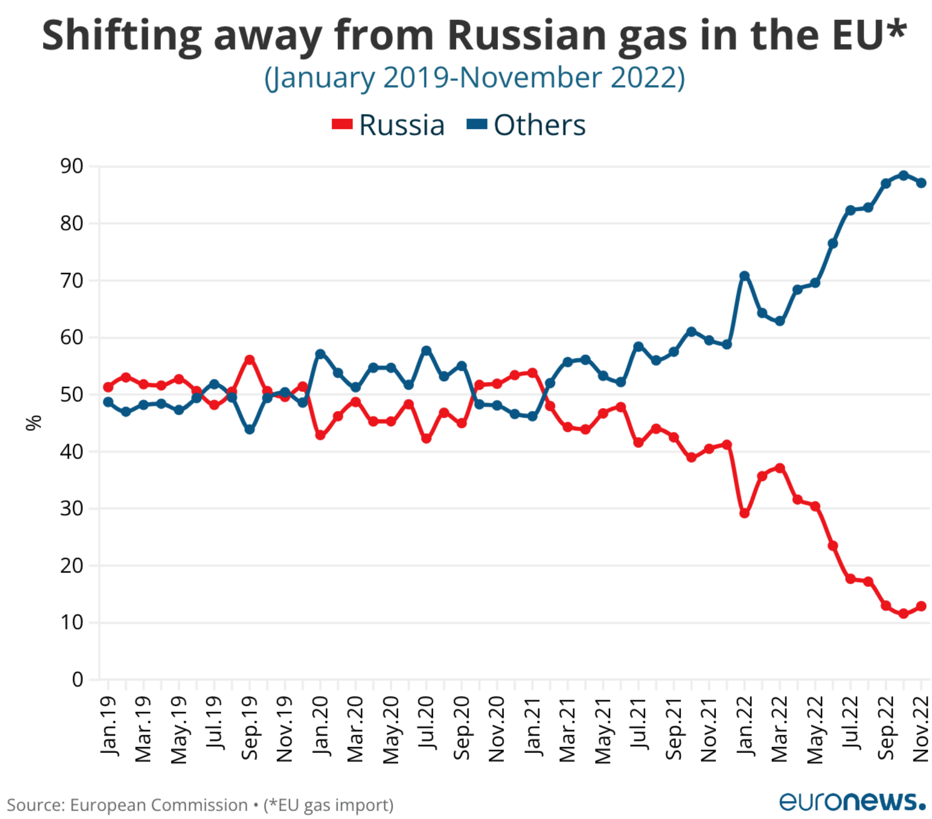

Figure 5.5: Shifting away from Russian gas in the EU (Euronews, 2023)

5.8.1.1 LNG terminals and Trade Agreements

The Repower EU plan emphasized the need for new LNG terminals and storage and earmarked a lot of investment funds towards developing them (EC, 2022).

Since the invasion, the EU has implemented six new LNG terminals,[5] alongside the expansion of an existing terminal in France - and the construction of them has been record fast, with some of them finished within 200 days. (Kurmayer, 2022) As a result, 2022 saw an 60% increase in LNG-imports from 2021, with most of the increase stemming from US exports. (IEA, 2023)

It’s not only US which are providing natural gas to Europe, EU has according to the ’EU energy deal tracker[6]’ conducted 57 natural gas deals, whereas the UAE and Qatar are becoming larger new partners, they the EU is also sourcing LNG from North Africa and Asia among others. (ECFR, 2023)

5 For regasification.

6 List was updated 11. August 2023

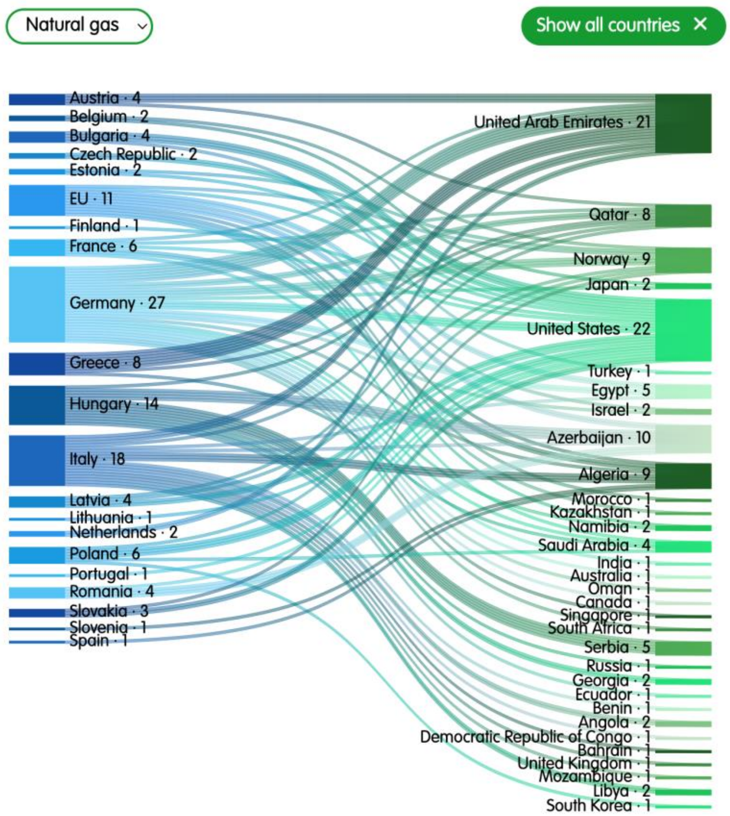

Figure 5.6: EU energy deals in natural gas since the invasion (ECFR, 2023)

Furthermore, to enhance the EU preparedness for the upcoming winter seasons the EU established a compulsory target for the EU: to fill 90% of its gas storage facilities by November 1st annually. And as of September 2023, the targets are already reached, enhancing Europe's energy security, as it has the capacity to meet up to one-third of the EU's gas requirements during the winter months. (EC, 2023)

5.8.1.2 Infrastructure – more integration

Energy connections became important to smoothly tackle the energy deficits around the region, and the Russian- invasion fostered a deeper integration of the European gas market. Firstly, 2022 saw the construction of the pipeline between Greece and Bulgaria being finished, addressing the previous gas vulnerabilities. Secondly, ‘Baltic Pipe’, designed to transport natural gas from the

Norwegian sector of the North Sea to Poland, opened in 2022, which serves to provide natural gas to other gas-dependent Eastern European states like Lithuania and Latvia. (Aasland, 2022)

Additionally, a pipeline between France, Spain and Portugal agreed to build new infrastructure. The pipeline, known as BarMar, is primarily intended for the conveyance of green hydrogen and other renewable gases. However, it will also temporarily facilitate the transport of a "restricted quantity" of natural gas, serving as a measure to mitigate the current energy crisis in Europe. (Pinedo & Carrena, 2022)

These investments in regasification and infrastructure have further solidified the EUs energy security and have prepared them for the following winter of 2024, whilst facilitating for more RES inclusion in the electricity grid - especially for areas previously dependent on Russian imports.

5.9 Coal

Prior to the sanctions, the EU was heavily dependent on Russian coal, especially for thermal coal, with Russia accounting for 70% of the EU's thermal coal imports, where a substantial amount was used for electricity generation. These sanctions, which came into effect in April 2022, led the EU to diversify their supplies and find alternative coal sources, among them Colombia, Australia, and the United States .(DW, 2022)

Furthermore, to address energy security concerns and the surge in gas prices, The EU also reopened several coal-powered plants that were previously shut down as part of climate action initiatives and as a result the EU saw a 5% rise in coal production and a 2% increase in consumption in 2022. (Eurostat, 2023)

However, the recent coal report from the IEA indicates that, despite a temporary reversal in the trend of phasing out coal, a significant decline in coal usage is anticipated after 2023 - attributed mostly to energy efficiency measures and rapid deployment of RES in the EU. (IEA, 2023)

5.10 Regulations and Policy

5.10.1 Changes to the EU ETS

Following Russia's invasion of Ukraine there was a significant decline in the cost of carbon permits within the European market. This is quite counterintuitive as the EU were forced to produce more electricity from coal plants to replace natural gas from Russia (Increased emissions), but the price decline was due to multiple factors including liquidity needs (Investors covering losses in other asset classes by selling allowances) and anticipation of lower demand from as higher energy prices would reduce industrial operating rates. (Hieminga & Patterson, 2022) However, on 18th of December of 2022 the representatives from the MS and the EP reached agreement to further increase the target from the EU ETS. Under the revised EU legislation, the target for reducing emissions in sectors covered by the EU Emissions Trading System (ETS) is set to be 62% by 2030, relative to the levels in 2005. This represents a significant increase from the previous target of 43% reduction. (European Council, 2022) Furthermore, the EU plans to progressively eliminate the free emission allowances currently provided to EU companies, with this phase-out scheduled to occur between 2026 and 2034. (European Council, 2022) We note however that it is hard to link this change directly to the Russian invasion of Ukraine, as reductions were anticipated.

5.10.2 CBAM

To avoid carbon leakage from energy-intensive industries that reside in the EU to relocating they also implemented a carbon-border adjustment mechanism (CBAM) i.e leveling the playing field between other regions, by putting a price on the carbon emissions associated with imported goods, aligning the cost of carbon for imports with that of goods produced within the EU. (Crabbendam & Bird, 2023)

These changes tick towards making it more expensive to pollute in the EU over the next periods which further incentivizes renewable deployment in the EU by protecting domestic production.

5.10.3 Inflation Reduction Act

The Inflation Reduction Act (IRA) in the United States, introduced in 2022, was a significant legislative move aimed at boosting green technology investments. With a substantial allocation of $369 billion, it's designed to advance the country's commitment to clean energy and technology. (Jurkovic, 2023) However, this act has raised concerns in Europe about its potential impact on the RE sector.

The IRA offers incentives for U.S.-based production, which could lead European clean energy businesses, such as those in the hydrogen and solar industries, to relocate to the U.S. In response, and the EU has been negotiating with the U.S. to modify the IRA to be more inclusive of EU companies. (EC, 2023) Notably, IRA enhances the appeal of the U.S. for wind and solar PV investments by offering tax credits. These credits improve the profitability of both new and existing wind and solar projects and manufacturing facilities in the U.S. This aspect of the act has rendered the U.S. a more desirable location for investments in the wind energy supply chain, particularly in comparison to EU countries, where such direct financial incentives for domestic manufacturing were not available. (Reuters, 2023)

Thus, as a response the EC president Ursula von der Leyen announced plans for the European Union to engage state aid and establish a sovereign fund specifically for renewable energy companies. This initiative could potentially prevent these companies from relocating to the United States by providing them with supportive measures and financial incentives within the EU, (Thinktank EP, 2023) mainly by permitting member states to offer subsidies for RES production. These subsidies are designed to be competitive with those available outside Europe, effectively "matching" the level of support provided in other regions, such as the United States. This strategy aims to maintain the competitiveness of EU-based green technology industries. (Bloomberg, 2023)

5.11 Key renewable metrics after invasion

Description	Data
EU Photovoltaic Capacity Added in 2022	41.4 GW
Percentage Increase in 2022	47%
Comparison with Previous Record in 2021	42% increase
Total EU Solar Power Generation Fleet	208.9 GW
Year-on-Year Fleet Growth	25%

Table 5.1: Total EU solar capacity and growth from 2021 to 2022 (SolarPower EU, 2023)

Description	Data
Total Wind Installations in 2022	19.1 GW
Onshore Wind Installations in 2022	16.7 GW
Offshore Wind Installations in 2022	2.5 GW
Year-on-Year Increase in Installations	4%

Table 5.2: Total wind capacity and growth from 2021 to 2022 (WindEurope, 2023)

- In 2022, solar and wind power generated over a fifth (22%) of EUs electricity, surpassing natural gas (20%) for the first time. (World Economic Forum, 2023)

- Solar power with record high growth of 47% overall and installing 25GWh rooftop (up from 8GWh in 2021) and is surpassing targets from the Repower EU.

- Wind Power is still seeing growth but suffering from increased costs and uncertainty among investors.

- Preliminary estimates by the EEA suggest that in 2022, renewable sources contributed to 22.5% of the total energy consumed within the European Union, up 0,6% - mostly driven by solar PV. (EEA, 2023)

6.0 Discussion

In this section, we will discuss the responses and consequences from the Russian invasion an juxtapose the findings presented in academic literature – examining whether the EU have addressed key areas and if there is any evidence that the impact of the invasion has “Pushed” or “Pulled” the deployment of RES.

6.1 Energy Security

The overarching topic in the wake of the Russian invasion was the EU’s energy security. The invasion underscored the massive dependence on Russia and, thus, how not diversifying energy supplies makes the region vulnerable for political influence and blackmail.
This have been looming in the background since the first gas disputes of 2006 and 2009, highlighting several MS vulnerabilities to a cut-off from Russian supplies. The subsequent energy policy development did outline energy security, however, there was a notable lack of significant initiatives aimed at diversifying fossil fuel sources and EU continued to source most of their energy supplies from Russia – and one possible explanation is that reaching climate targets was the main objective of the frameworks, undermining aspects like energy security. Another explanation might be that the perceived value of cheap Russian gas for certain MS, triumphed the deployment of RES[7].

In the period after the invasion, the EU showed significant political proactiveness in their responses as the situation critical and has acted severely faster by putting forward policy plans like the ‘Repower EU’ which communicated clear measures to bolster energy security. Firstly,

[7] Which also may demonstrate how the Energy Affordability dimension are weighted over both Energy Security and Sustainability.

by diversifying the supply of fossil fuels to multiple partners and decreasing their critical dependence on Russia, and secondly, highlighting how increased deployment of RES could enhance long-term energy security. However, these swift responses would not have been possible without the political foundation formed before the invasion. For instance, the establishment of the RED and the already binding targets from the NECP had facilitated a smoother path to updating legislative measures, underscoring how the previous period laid the fundament for the EU to ability to quickly respond to the invasion.

The literature (Khan et al., 2023; Cai & Wu,.2021) on the relationship between RES and GPR aligns in terms of the EU using RES as a strategic response to handle increased GPR. Furthermore, as energy security is threatened, the overall share of RES has increased after the invasion, which supports their findings showing that as geopolitical tensions increase, RES growth is stimulated – especially in high-income countries. (Chu et al., 2023).

The literature (Li & Lee, 2022) also notes how natural gas are crucial to aid the implementation of more intermittent RES in the power-grid, by providing grid-stabilization. Thus, by diversifying, and securing their gas supplies, one could make the argument that it may serve to facillitate more RES deployment in the future. However, in the aftermath of the Russia-Ukraine conflict, another question regarding energy security for the long-term arises:

6.1.1 Critical Minerals posing threat to Energy Security?

As Rabe et al., (2017) pointed out in their study, are the intermittent RES highly subjected to critical mineral supply risk. The EU are dependent on imports of rare earths, and particularly China, are controlling a substantial amount of the supply. This raises the question whether a future energy mix heavily reliant on RES is in fact improving energy security in the EU, as the region moves from being dependent on Russia for energy imports to be dependent on other nations for mineral supply.

The criticality of minerals is reflected in the currently, non-existent sanctions put on them, and with soaring future demand projected in the EU, dependence on critical minerals might serve to be a bottleneck to increasing RES deployment over a certain threshold – indicating a possible limit to growth due to energy security concerns. On the other hand, the EU proposed the legislative framework CRMA as a response addresses risks regarding import overdependence, reducing reliance on third parties like China and Russia, which on the surface looks to potentially pave a safer path towards increased RES deployment. Moreover, the recycling targets put forward by the CRMA highlights what Serpell et al., (2021) proposed as a currently underdeveloped aspect of the RES supply chain – again, demonstrating responsiveness from EU to create more resilient supply chains to reach the RES deployment goals set by the RePower EU.

6.2 Grid-optimizing

6.2.1 Regional Integration of grids

A reoccurring narrative within the topic of what can foster more RES deployment is improving the power-grid, and the Repower EU plan puts emphasis on rejuvenating the grid both with technological advancements, but also increased investment in storage and transport.

In relation to the literature, Su et al., (2021) outlined that the relationship between energy security and RES deployment might not be straightforward, which might indicate that beneficial geographical factors interplay in which countries implement more RES – shedding light on Eastern European MS like Bulgaria and the Baltic states which previously have been deeply reliant on Russian gas for electricity. On that note, the invasion significantly influenced the fast-tracking of grid-connection projects, which has resulted in a projected future with deeper integration of grids within the EU. For instance, with the Baltic states integrated closely with new high-capacity transmission lines, it pushes towards facilitating more RES deployment in outskirt regions of the EU. The fast-tracking of cross-border transmission projects stimulates RES deployment by creating increased possibility to expand RES in countries where RES are abundant and transfer them with high-capacity transmission lines to energy-intensive areas. Furthermore, the invasion did increase energy integration of outskirt MS[8] by the construction of gas pipeline projects that removes their dependency of Russian gas, fostering more RES in the

8 Bulgaria (ref. the gas disputes) and the Baltic States.

energy mix due to increased energy security. This aligns with the observation that investments in natural gas pipelines may further incentivize RES investment and deployment (Verdolini 2018), as natural gas still is still crucial for intermittent RES deployment due to its favorable properties to provide back-up capacity.

6.2.2 Energy storage and grid-stabilization: Hydrogen & Batteries

Another key barrier to more RES deployment before the invasion was the unsatisfactory energy storage systems, which also can serve as back-up capacity for RES (Faunce et al., 2018). Despite the Repower EU plan not outlining specific strategies to incentivize increasing battery storage, the growth in large-scale battery parks in the EU after the invasion were substantial regardless, with multiple projects being commenced. On the other hand, these battery parks link back to the concerns regarding supply chain disruption risks, as these projects are highly reliant on global supply chains for minerals.

Moreover, the EU did highlight the plan to both produce and import substantial amounts of hydrogen which can be utilized both for energy transport and as back-up capacity for RES. Scholars have argued that hydrogen poses the best solution to energy storage (Leonard et,.al 2019; Ghirardi et al., 2023). However, the status quo suggests that this energy storage strategy is more ambitious than close to realization, as EU currently produces 3% of its annual 2030 target and has 1% of the electrolyzer capacity installed. On the other hand, the increased focus and investment in R&D from the Horizon Europe would likely not have been fast-tracked if Russia had not invaded Ukraine and the subsequent reduction in natural gas supplies – hydrogen is now being viewed to be the missing link to including more RES deployment in the EU power-grid, acting as a replacement for both natural gas and coal (Šefčovi, 2023., p.36).

6.3 Permitting Process

Considerably, the most evident bottleneck for more RES deployment before the invasion was the permitting process – for RES projects, but also for projects related to them e.g. battery parks, power-grid expansions. Due to the increasing legally binding target from the RED to increase RES capacity to 42,5%, the permitting process needed to be addressed. Before the war acquiring a permit for a wind project or a solar PV project could span from 4,5 to 9 years, and the respective MS also had differences in their permitting processes. The EU streamlined this process by issuing a recommendation on permitting all MS to implement, and by introducing the principle of "overriding public interest" for RES projects. Furthermore, by introducing the "go-to areas" that have a cap on 12 months for the permitting process and stating that other RES projects outside these areas should not overdue 24 months, the EU has put the wheels in motion for more RES deployment towards 2030.

Scholars have argued that public opinion and particularly "NIMBYism" (Xu & Lin, 2020; Sütterlin & Siegrist, 2017) potentially could delay future RES projects, and whilst they still can i, evidence from surveys in Europe after the war shows that public support are high and rising as a consequence of the Russian invasion of Ukraine. This might be attributed to multiple factors, like the high wholesale price for consumers, or the increased concern for energy security due to the ban on Russian fossil fuels. On the other side, scholars have argued that there is a high-willingness-to-pay among the public when it comes to RES projects (Ribeiro et al, 2023), and that support for RES implementation transcends traditional political divides (Steffen & Patt, 2023), which demonstrates growing support and attributing value to increasing RES implementation – even if it is not lowering their electricity bill initially.

6.4 Energy Efficiency

The Repower EU plan also presented several measures to reduce energy demand during the following winter after the invasion, both short-term and long-term, which have shown to be effective. Firstly, by incentivizing consumers and businesses in MS to adopt alternative heating alternatives in the form of heat pumps, which are up to five times more efficient than natural gas. Secondly, one may argue that the price increase on marginal fuel for electricity generation caused by the invasion which consequently have increased the wholesale price of electricity in the region have furthered the energy demand reduction.

On the other side, the EU saw a historically mild winter of 2022-2023 (Ember, 2023), which raises the question if the energy demand reduction is sustainable over the long-term. However, by legally binding MS through the 'European Solar Rooftop Initiative' to install solar PV technologies on all new future buildings, and the current successful implementation, brightens the long-term outlook on reducing energy demand in the region. Firstly, this is a direct example of more RES deployment, but secondly it also aligns with Pina et al., (2011) studies on how technological energy efficiency (combined with a change in behaviors by the end-users) do stabilize the power-grid. The demand reduction will in other words, put less pressure on the power grid during peak hours, reducing the need for peak-load capacity and further incentivize more RES inclusion.

6.5 Rising costs and international competition for Wind and Solar PV

6.5.1 Input factors: Electricity Prices and Critical minerals

Our findings indicate that the EU's wind and solar PV sectors are currently facing challenges due to the invasion, and these difficulties are likely to persist in the coming years. The domino-effect from increased marginal fuel costs manifested itself in higher electricity prices.

On one side, the literature (Lagarde & Lantz, 2019; Cevik & Ninomiya, 2022; Burgos-Payan et al.,) points towards the low marginal costs of RES incentivizing more RES implementation in the power-grid during periods of high electricity prices[9], however observations in the EU does not seem to be that straightforward.

Furthermore, as underscored by Calederon et al. (2023), the critical mineral market is highly vulnerable to supply chain disruptions as those we saw during the invasion. Thus, the price level for a lot of critical minerals is still higher than pre-invasion levels. The risks associated with the supply chain combined with the explosive future demand forecasted globally (IEA, 2023), the price level might stay relatively high.

6.5.2 Wind

Especially for wind projects the soaring electricity prices are deeming to be hurtful to the industry, for instance the evidence from Germany and Sweden (Chestney & Twidale, 2023; Tigerstedt, 2023) where developers had entered long-term PPAs with fixed, pre-invasion prices leaving their current projects unprofitable, and EU is currently experiencing multiple PPA-driven bankruptcies.

Furthermore, the increased price level of input factors has also manifested itself at the production

[9] Due to the "Merit-order effect"

side as manufacturers face higher costs, consequently making development of wind farms less competitive. If these trends continue, it might hurt the wind industry's capability to attract investors, as the investment level in the European wind industry is dropping back to levels not seen since the financial crisis of 2009. On another note, this does however align with the observation that in times of increased GPR, financing in the green sector tends to go down (Dong et al., 2023). However, due to the strong emphasis from the RePower EU plan on offshore wind[10], and the EUs current marginal addition of new installments from that RES, it raises concerns regarding the immediate future of the industry.

Conversely, it should also be put in context with the historical complex permitting process[11]. Even as legislation is put in place to ease this process, it may be early to expect results this early highlighting that the coming years are crucial to determine whether the framework is speeding up deployment.

6.5.3 Solar

On the solar PV side, one may argue that high electricity prices are contributing strongly to the increased growth of capacity, as the pay-back time of installing solar panels for households and industries is decreasing with high electricity prices. The EU did experience a record growth in solar PV capacity installed in 2022, which was especially supported by rooftop installations. The RePower EU plan outlined a clear pathway for solar PV deployment and the EU has utilized the fast roll-out capabilities of solar panels, whilst providing policy support for large-scale projects.

Hence our findings portray a rather nuanced situation, with the electricity price driving the growth of solar whilst hurting the wind industry. The critical mineral price is raising concerns for both industries - however the literature (Rabe et al., 2017) does underline that the solar PV market is more resilient to supply disruption compared to the wind industry.

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10 which only accounted for 13% of new installments in 2022 (WindEurope, 2023)

11 Permitting process, as previously mentioned span up to 9 years pre-invasion. Legislation have been put in place to speed it up to 12-24 months depending on location.

6.5.4 International competition in manufacturing

Our findings indicate that domestic EU manufacturers in both the wind and solar industry might encounter a somber outlook.
Firstly, the domestic solar PV manufacturers are currently facing challenges in competitiveness, and the expanding Chinese solar PV manufacturers and excess supply in the market, are exacerbating this. Thus, raising questions regarding the viability of the target of re-shoring 30GW annually from the EU solar strategy.

Secondly, whilst the solar PV industry faces challenges in reshoring, the case is the opposite for the domestic wind turbine manufacturers. Turbines that historically, have been produced within the EU now faces substantial price risk from particularly Chinese manufacturers as costs of input factors have risen. Thirdly, the US policy response after the Russian invasion, IRA, have provided incentives for EU manufacturers to relocate. Integrating the and ensuring the resilience of the supply chain for RES would help strengthen energy security in a high-RES energy mix, and the way towards the 42,5% RES target. Thus, to address these forces, the EU has recently responded by attempting to mirror the incentives provided by other regions, whilst also implementing a CBAM to protect the manufacturers domestically – the effects of which remain to be observed.

6.6 Interest rate – the black horse?

The Russian invasion initiated an energy crisis, which are a main factor driver of the rising inflation globally. Thus, to manage inflation, central banks have raised interest rates worsening the investment climate for RES.
Historically, scholars have argued that the growth seen throughout the decade have been driven by technological advancements (Khan et al., 2022), an whilst this serve to be true, there is also evidence in the literature that the technological advancements have gotten too much attention regarding RES deployment growth (Egli et al. 2022). This raises the question about RES deployment in the EU under increased interest rates, as interest rates historically have remained low during the last two decades.

For example, Jonathan Stern (J. Psaropoulos, 2022; as cited in J. Stern), professor at Oxford Institute for Energy Studies raises concerns regarding future solvency of EU governments:

"Renewable energy will remain attractive, but there will not be enough money to scale it up because European governments have committed $500bn[12] to subsidize industry and consumers "

And thus, the rising interest rates may pose to slow down, or threaten, the possibility for the RFF to give loan guarantees to companies or entities for developing renewable energy projects.
This raises the question to what degree the speeding up of new, especially large-scale, RES capacity which were installed in the post-invasion period were driven by RES projects that were already in the pipeline[13].
Observing how RES deployment during conditions of high interest rates poses an interesting area for future research, as it could provide valuable insights into the resilience and adaptability of RES projects during periods of financial constraint in the EU.

7.0 Limitations

7.1 Broad research question leading to multi-finality.

We recognize that there are several limitations within this thesis. Firstly, due to performing qualitative research it is hard to assess causality between the impact of the Russian Invasion on RES deployment in the EU. Furthermore, the factors, policies, and developments we evaluated to assess whether the Russian invasion "pushed" or "pulled" the deployment of RES are not mutually exclusive. In the context of our qualitative thesis, it means that even when researchers start with similar data, theoretical frameworks, or methodologies, they might arrive at different conclusions or interpretations, thus demonstrating multi-finality. (Hinnant, 2021)

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[12] Here he is including the UK governments spending

[13] This theory could receive support by considering the permitting process before the invasion.

7.2 Equifinality

Secondly, for the sake of scope did we limit the RES we looked at to solar and wind (and a bit towards hydrogen), disregarding how other RES like Biofuels and Hydropower were impacted even though they fell under the RES umbrella. Additionally, there is growing support for increasing nuclear power generation for baseload capacity in the power-grid in the EU to address energy security for the EU (IEA, 2022). Furthermore, in regard to Energy Security, we did not cover the looming cybersecurity threats with expanding RES and developing smart grids (DNV, 2023).

7.3 Secondary data

In our thesis, we acknowledge several limitations associated with the use of secondary data. Firstly, the relevance and currency of this data may not precisely align with our specific research aims, potentially leading to inaccuracies. Additionally, we have limited control over the quality and scope of the data, which was collected and interpreted by others, introducing potential biases. These factors necessitate careful analysis and interpretation on our part to ensure that our conclusions are as reliable and valid as possible within these constraints.

7.4 Hard to assess the magnitude of effect from the areas we identified

Due to the qualitative approach, it is hard to assess the magnitude of which specific key areas are “Pulling” or “Pushing”. Hence, it is hard to reach a definitive conclusion to our research question.

8.0 Conclusions

If we consider the key areas and bottlenecks, we have identified:

- Creating resilient, supply chains for key RES technologies
- Optimizing energy grid infrastructure and increasing storage solutions
- Efficiency permitting process to accelerate the development of renewables
- Improving energy efficiency

- **Improving energy security**

The EU's responses have indeed addressed all key areas and factors.

Firstly, the Russian invasion presented immediate risks to the energy security of EU member states. Although earlier energy policies presented after the gas disputes like the 'Third Energy Package' focused on enhancing regional connectivity through interconnected energy grids and gas pipelines, the EU still possessed a notable lack of diversifying their energy supplies. The EUs decision to ban imports of fossil fuels created urgency to ensure energy security for MS. Through fast-tracking projects that connected regions that previously had been dependent on Russian fossil fuels for energy, and by constructing LNG-terminals and forming new trade agreements for imports of energy, the EU was ensuring the regions security in energy supply. The effectiveness in diversifying their supplies was demonstrated in the EU reaching its annual gas storage targets of 90%, by early September 2023.
Due to the necessity of using natural gas to stabilize power-grids to act as back-up capacity for intermittent RES, the fast responses by the EU to build infrastructure and diversifying supply points towards "pushing" the feasibility of more RES deployment, or at least not "pulling" it.

Moreover, the 'Repower EU' plan addresses bottlenecks in the current power-grid by fast-tracking multiple projects that are enhancing grid-connectivity, to transfer power between regions with High-RES generation to areas with high electricity demand, whilst also enhancing cross-border grid-connections between MS. The unsatisfactory energy storage solutions were highlighted by the literature, and the responses in the EU have addressed it. 2022 saw a record growth in battery parks, and the Repower EU also outlined an ambitious plan to both import and produce Hydrogen. Although, the latter has seen moderate growth, the increased investment in R&D, infrastructure, and production may serve as the missing link to provide a zero-emission back-up capacity for intermittent RES.

One of the most promising aspects of the Repower EU was addressing the major bottleneck to permitting process of RES projects. By aiming to streamline the permitting process in MS by presenting recommendations and limiting the handling time may strictly accelerate the growth of RES deployment. The principle of "overriding public interest" and the introduction of "go-to areas" combined with the seemingly growing public support for RES deployment despite their potential impact on price and nature points in a positive direction for RES deployment.

Furthermore, reduced pressure on the power grid through demand-reduction do allow for more intermittent RES. The 'European Solar Rooftop Initiative' is allowing for record growth of solar panel deployment, whilst the Repower EU's incentivizing of heat pump installations have led to record demand reduction. Hence, regardless of the mild weather conditions in the winter of 2022-2023, the future outlook for demand reduction appears promising.

Lastly, the CRMA are addressing the supply chain concerns regarding the sourcing of critical minerals, whilst also shedding light on the untapped potential of increasing recycling policies. As these minerals are crucial for the production of RES equipment, the targeted legislative response from the EU is crucial.

However, this dependency on critical minerals is potentially limiting RES deployment. Firstly, even though the CRMA are likely to be implemented in 2024, the EU is still highly dependent on China for sourcing rare earths, potentially threatening energy security in a future high-RES scenario. Secondly, the surge in mineral prices due to heightened demand and supply chain disruptions has escalated the costs of RES equipment. This, combined with the rising electricity prices, has further increased the costs of RES projects, impacting the financial outlook for RES equipment manufacturers.

Furthermore, the price increase of input factors has hurt EU manufacturers' competitiveness, which now are seeing stronger competition from intercontinental competitors. Although the CBAM are addressing some of these predicaments, the communicated targets of reshoring solar are looking quite ambitious at this point in time. Conversely, the domestic wind turbine manufacturers are experiencing elevated competition from Chinese manufacturers.

Lastly, we have denoted how the rising interest rates to curtail inflation are posing risks to the financing of future RES projects. Observations are limited regarding the response of RES deployment to higher interest rates, yet this situation is prompting concerns about investment trends. Notably, the current downturn in new wind capacity investment, dropping to lows not

seen since the financial crisis of 2009, is particularly alarming. The combination of rising interest rates, increased costs, and dependency on third parties like China for minerals, raises questions surrounding if there is a limit to growth for RES deployment in the EU under these conditions. As they are potential threats both to the ‘Energy security’ and ‘Energy affordability’ dimensions of the Energy trilemma.
However, a critical observation from the aftermath of the invasion is that governments, when concerned about their people's energy security, are prepared to escalate their spending to unprecedented levels.

One may argue that the pre-invasion years energy policy was largely addressing the ‘Energy Sustainability’ dimension of the trilemma, whilst the post-invasion policies had an increased focus on ‘Energy Security’, in conjunction with the other two dimensions. The Repower EU plan certainly has facilitated for more RES deployment, specifically targeting it with policy and legislative acts. And the record growth in capacity installed and the increased binding targets from the updated NECPs (solar PV and wind power increased by 64% and 49% respectively) points in the direction that RES deployment is indeed “pushed” by the Russia-Ukraine conflict. However, the sector is facing new hurdles that potentially are going to “pull” deployment in the future, hence, the long-term effect of the consequences of the invasion for RES deployment are still open-ended.

To summarize, our post-invasion findings point towards a sunnier outlook for solar PV through clear strategies and incentives, whilst the situation in the wind industry is more nuanced. Hydrogen is outlined in the Repower EU as crucial to replace coal and gas in power-generation, however current adoption is modest at best and way below set targets.

However, we want to emphasize that the streamlining of the permitting process in its infancy period and that large-scale projects are being delayed due to unsatisfactory transmission lines, storage capacity and connectivity. Hence, the level of grid-enhancements and the success in streamlining permitting process will be decisive to assess RES deployment over the next years.

8.1 Recommendations to further studies

As we focused on the EU as a whole, we want to underline that the RES deployment varies greatly among MS. Thus, an avenue for future research would be to examine specific areas, or countries, within the EU to assess how the Russia-Ukraine invasion have impacted RES deployment in locally within the region.

Secondly, assessing the impact of increased interest rates on RES projects in the EU can be a critical area to be further explored to assess their financial resilience.

On a final note, the Russian invasion of Ukraine impacted directly the 'Energy Security' and 'Energy Affordability' pillar of the energy trilemma; however, one might argue that the Energy sustainability aspect of the trilemma is a in the background of multiple of the responses by the EU. A major trend observed on the policy side, during the pre-invasion years was an overarching climate aspect, thus analyzing how the 'Energy Sustainability' pillar has been affected by the Russia-Ukraine conflict, both in the EU, but also globally, and serves to be an interesting topic for further research. Coal-consumption reached an all-time high in 2022 globally (IEA, 2023b), posing a threat to the climate goals set by the Paris Agreement, hence the assessment of how other regions have responded may prove valuable insights

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