

Louvain School of Management

How to foster sustainable finance for energy transition?

Author: Marcela Raudales Diaz
Supervisor: Carlos Desmet
Academic year 2021-2022.
Dissertation for the master of Business Engineering
Master subject and focus: Philippe de Woot on Corporate Sustainable Management
Daytime schedule

Acknowledgements

I am joyful of having fulfilled this goal in my life, and I sincerely appreciate the support received in the preparation of this thesis.

First, I would like to thank my supervisor, Professor Carlos Desmet, for his constant availability and for the trust he put in me from the beginning of this work. His insights made me see things I had not seen and helped me achieve the thesis I have done. I am truly grateful for all the support from him.

My deepest love and gratitude to my family for their constant help and guidance, and specially to my husband, Rafael Reyes, for being present and willing to help whenever I needed him. Their support throughout my studies has helped me achieve the goals I have set for myself in life, and the completion of this master's degree is not an exception.

Lastly, I would like to thank all the administrative personnel of the university, for their help, for providing answers to every question one might have and for reminding us of all the milestones we had to meet as students.

Table of Contents

1	Introduction	1
2	Policies	2
2.1	Climate Law	2
2.2	Governance of the Energy Union and Climate Action.....	2
2.3	Promotion of the Use of Energy from Renewable Sources.....	3
2.4	Green Deal	3
2.4.1	Delivering the European Green Deal	3
2.4.2	Other strategies.....	5
2.5	Strategies and Mechanisms for Sustainable Finance	7
2.5.1	Framework to facilitate sustainable investment	7
2.5.2	Strategy for financing the transition	7
2.5.3	EU Taxonomy.....	9
2.5.4	EU Green Bond Standard	11
2.5.5	EU Climate Benchmarks and ESG Disclosures.....	12
2.5.6	Corporate disclosure of climate-related information	12
2.5.7	European Commission Budget	13
2.6	Progress in the implementation of policies.....	15
2.7	Analysis	17
3	Investments and energy sector data	18
3.1	Investments at European Union level	18
3.2	Energy sector data at European Union level.....	21
3.3	Legal background.....	23

3.4	Barriers to investing in renewable energy	24
3.5	Analysis	28
4	National Incentives to promote renewable sources	29
4.1	Feed-in Tariff.....	29
4.2	Quota-based system.....	32
4.3	Power purchase agreement	34
4.4	Analysis	34
5	Analysis per country.....	36
5.1	Germany	36
5.1.1	Overview of support schemes.....	36
5.1.2	Energy sector data.....	37
5.1.3	National energy and climate plan	38
5.2	France	39
5.2.1	Overview of support schemes.....	39
5.2.2	Energy sector data.....	40
5.2.3	National energy and climate plan	41
5.3	Belgium	42
5.3.1	Overview of support schemes.....	42
5.3.2	Energy sector data.....	44
5.3.3	National energy and climate plan	45
5.4	Poland	46
5.4.1	Overview of support schemes.....	46
5.4.2	Energy sector data.....	46
5.4.3	National energy and climate plan	47

5.5	Energy Security	49
5.6	Analysis	52
6	Statistical analysis of the electricity matrix per investment.....	53
6.1	Methodology	53
6.1.1	System Identification.....	53
6.1.2	Generalized Linear Models.....	55
6.1.3	Model Selection.....	56
6.2	Data description	56
6.3	Process.....	57
6.4	Results.....	58
6.4.1	Results for Selected European Countries.....	58
6.4.2	Results for Germany.....	59
6.5	Analysis	59
7	Conclusions	61
8	Limitations.....	66
9	Further development.....	67
10	Bibliography.....	68

Figure Index

Figure 1.	Trend of Investment priorities, according to outgoing loans from EIB	19
Figure 2.	Investments per type of source by the EIA, in EUR billions.....	20
Figure 3.	Investments in the distribution, transmission and heating networks, in EUR billion .	21
Figure 4.	Gross electricity production by source in GWh	21
Figure 5.	Source percentage in gross electricity production	22
Figure 6.	Share of renewable energy sources in electricity.....	22
Figure 7.	Trend of net production of electricity for Germany in GWh	37
Figure 8.	Electricity production capacities for Germany in MW.....	38
Figure 9.	Trend of net production of electricity for France in GWh	40
Figure 10.	Electricity production capacities for France in MW	41
Figure 11.	Electricity Generation by Source for Belgium in GWh	44
Figure 12.	Electricity production capacities for Belgium in MW.....	45
Figure 13.	Trend of net production of electricity for Poland in GWh	47
Figure 14.	Electricity production capacities for Poland in MW.....	47

1 Introduction

The Paris Agreement is a legally binding international treaty on climate change, which has the goal of limiting global warming to well below 2, preferably to 1.5 degrees Celsius, compared to preindustrial levels. After this treaty, the European Union has revised and elaborated policies with the main objective of developing the necessary framework to achieve climate neutrality. The purpose of this study is to review the current policies related to sustainable finance, to review the incentives used to promote the generation of electricity from renewable sources and to give some insights on how to redirect capital flows towards energy transition.

First, this work comprises a review of the policies the European Union has developed to achieve climate neutrality, more specifically policies related to energy transition and sustainable finance. It also covers the investments in renewable sources for the generation of electricity as well as the changes in the electricity mix across time and the barriers to investing in renewable energy. To analyze how renewable energies have been incentivized, this work includes a review of the support schemes used, and in addition, the review of the incentives used by four countries and its changes across time. Moreover, the quantitative analysis is focused on the Feed-in Tariff mechanism, which is a policy tool designed to promote investments in renewable sources by providing a remuneration guarantee, and European Investment Bank loans.

This study aims to study the Feed-in Tariff mechanism in order to analyze if it has had and influence in the energy mix. This study also aims to give some insights about how this mechanism, and similar structures, can be used to foster sustainable finance for the energy transition.

For the importance of the electricity sector and the concepts of digitalization and electrification, this work comprises only generation of electricity, and not energy sector as a whole.

2 Policies

2.1 Climate Law

Regulation (EU) 2021/1119

This regulation introduces some amendments to Regulation (EU) 2018/1999. It sets the objective to climate neutrality by 2050 pursuing the goals established in the Paris Agreement (European Parliament and the Council, 2021). It establishes a domestic reduction of net greenhouse gas emission (emissions after deduction of removals) by at least 55% compared to 1990 levels by 2030. This Regulation also states that a Union-wide climate target for 2040 should be introduced.

Furthermore, Parliament adopted the EU Climate Law, which makes the reduction target of emissions and climate neutrality by 2050 legally binding (European Parliament, 2022). The law introduces a process for monitoring and assessments at a Union and Member level. The Commission will assess every five years the consistency of national measures based on the national energy and climate plan, long-term strategies and biennial progress reports. If the Commission finds that Union measures are inconsistent with the objective, it will take the necessary measures according with the Treaties. If the Commission finds that a Member States's measures are inconsistent with climate-neutrality objective, it may issue publicly available recommendations to the Member State. Within six months the Member State would have to notify the Commission how it will take due account of the recommendations; the Member State has to then include the recommendations and its actions in its integrated national energy and climate progress report. (European Parliament and the Council, 2021)

2.2 Governance of the Energy Union and Climate Action

Regulation (EU) 2018/1999

This regulation established a governance mechanism for the implementation of strategies and measures in order to meet the Energy Union targets in congruence with the Paris Agreement. (European Parliament and the Council, 2018)

It provides special attention to the Integrated National Energy and Climate Plan, which is a document elaborated by countries describing their objectives, policies, current situation, barriers,

impacts of the planned measures, while considering the five dimensions of the Energy Union (Security of supply, internal energy market, energy efficiency, decarbonisation, and innovation).

2.3 Promotion of the Use of Energy from Renewable Sources

Directive (EU) 2018/2001

This directive establishes a common framework for the promotion of energy from renewable sources. It sets a Union target for the overall share of energy from renewable sources in the Union's gross final consumption of energy in 2030; this target for 2030 is at least 32%. (European Parliament and the Council, 2018)

The Directive contains the target share of energy from renewable sources for each Member State's gross final consumption. The gross final consumption includes consumption on electricity, heating and cooling and, transport. The Member States should apply support schemes as incentives for the integration of electricity from renewable sources in the electricity market. Member states should also assess the effectiveness of the support schemes and their effects on consumers and investments. Member States shall ensure that support for electricity from renewable sources is granted in an open, transparent, competitive, non-discriminatory and cost-effective manner. Member states may limit tendering procedures for specific technologies, where opening support schemes to all producers of electricity from renewable sources would lead to a suboptimal result (considering long-term potential of a technology, diversification, grid integration costs, network constraints and distortions of raw material markets). (European Parliament and the Council, 2018)

2.4 Green Deal

2.4.1 Delivering the European Green Deal

The European Commission addresses the acceleration of the reduction of greenhouse gas emission with a set of interlinked legislations. These are Renewable Energy Directive, Energy Efficiency Directive, EU Emissions Trading System, Energy Taxation Directive, Refuel EU aviation, Fuel EU maritime and Alternative Fuels Infrastructure Directive. (European Commission - Press release, 2021)

This set of proposals is called the “Fit for 55” legislative package, which aims to deliver a transformational change needed to achieve the climate targets, and contains a mix of pricing, targets, standards and support measures. The Commission acknowledges that the need to act it is a collective responsibility and recognizes that individual Member States cannot achieve the necessary targets as well as the European Union as a whole. (European Commission, 2021)

Following some of the initiatives, are briefly described:

Renewable Energy Directive

The use of energy accounts for 75% of the EU’s emissions, thus the implementation of actions is crucial. The Commission proposes to increase the current targets of use of renewable energy sources, which currently is 32% of share of renewable energy by 2030, and the proposal is to set this percentage to 40%. (European Commission, 2021)

Energy Efficiency Directive

The current EU target for 2030 for energy efficiency is 32.5%; the Commission proposes to increase this target by 9% in relation with the National Energy and Climate Plans, therefore obtaining around 36-39% by 2030. (European Commission, 2021)

The directive includes an increase in the target for primary and final consumption, involvement of all sectors in energy efficiency solutions, obligation for the public sector to reduce its energy consumption, energy efficiency requirements in public procurements, availability and provision of information towards consumers, reporting of energy efficiency investments and energy performance, and others. (European Commission, 2021)

Energy Taxation Directive

Taxation is key for sending the right message and provide investment resources for the implementation of sustainable solutions. However, taxation is not in line with EU climate and energy objectives in terms of greenhouse gas emissions reductions, energy efficiency and alternative technologies. Some of the objectives of the directive are to provide a framework that contributes to the targets for 2030, update the structure of rates, preserve the revenue capacity

generation, eliminate disadvantages for clean technologies and incorporate higher taxes for inefficient and polluting fuels, and introduce a ranking according to the environmental performance. (European Commission, 2021).

Emissions Trading System

For the EU Emissions Trading System (ETS), the proposal is to lower the cap for emissions from some economic sectors, and to link the revenues of the trading system with expenses on climate-related projects. The proposal has the following objectives: strengthening the EU ETS current scope, ensure protection for the sectors that have a significant risk of carbon leakage, address the distributional and social effects of the transition, review the monitoring and verification system of CO₂ emissions from maritime transport, and review the market stability reserve. (European Commission, 2021)

Carbon Border Adjustment Mechanism

The Commission includes a Carbon Border Adjustment Mechanism to address Greenhouse Gases (GHG) emissions that are embedded in the importation of goods. This aims to prevent the risk of carbon leakage, which occurs if a business in certain industry decides to transfer production to other countries with less strict emissions constraints or imports goods from these countries to have GHG emissions; it therefore ensures that domestic production and imports are subject to similar level of carbon pricing. The directive also aims to contribute with a policy framework for investments in low or zero carbon technologies, and encourage producers in third countries to adopt low carbon technologies. (European Commission, 2021)

2.4.2 Other strategies

Strategy for Energy System Integration

“Energy system integration is the coordinated planning and operation of the energy system as a whole, across multiple energy carriers, infrastructures, and consumption sectors”. (European Commission, 2020)

This strategy proposes the creation of legislative measures to integrate the multinational system gradually. The strategy follows three concepts: a more circular system, increase direct

electrification of end-use sectors and, use of renewable and low-carbon fuels for applications where direct heating or electrification are not feasible. (European Commission, 2020)

Strategy to harness the potential of offshore renewable energy

Europe has a tremendous advantage in terms of offshore renewable energy due to the proximity to several seas. The use of the potential of this technology makes the development of long-term plans necessary in order to ensure the coexistence with other maritime activities. (European Commission, 2020)

To develop the technology the Commission will among others, facilitate cross-border cooperation, develop pilot projects looking for risks and restoration, promote dialogues between authorities, support multi-use projects with Member States and regional organizations. Encouraging Member States to include reforms and investments for renewable projects in their national plans is important to integrate this technology across EU. (European Commission, 2020)

Hydrogen strategy

One of the main difficulties with hydrogen is that, in terms of price, hydrogen from renewable sources is not competitive yet, so it is mostly produced from fossil fuels. The strategy aims to create a roadmap to 2050 with a hydrogen ecosystem. It is a priority to develop renewable hydrogen, but in the transition period, a low-carbon hydrogen is considered necessary. Research and innovation play a huge role in the development of this technology in terms of generation, infrastructure, large-scale end-use applications and safety standards. (European Commission, 2020)

Sustainable batteries

The objective of having sustainable batteries regulation is to achieve batteries with a high-performance and with safety standards. To promote competency, the EU proposes to have mandatory requirements for all batteries, regarding the materials, carbon footprint, performance, durability and recycling. (European Commission, 2020)

2.5 Strategies and Mechanisms for Sustainable Finance

2.5.1 Framework to facilitate sustainable investment

Regulation (EU) 2020/852

The regulation establishes criteria to determine if an economic activity is environmentally sustainable, and hence if the investment is sustainable. The qualification of an investment as environmentally sustainable, analyzes the substantial contribution to one or more environmental objectives, the significant harm to any of the objectives, and the compliance with minimum safeguards and with technical screening criteria. (European Parliament and the Council, 2020)

The regulation covers the following environmental objectives to address environmental sustainability of an activity: climate change mitigation, climate change adaptation, protection of water and marine resources and sustainable use, transition to a circular economy, prevention and control of pollution, and protection and restoration of biodiversity and ecosystems. (European Parliament and the Council, 2020)

2.5.2 Strategy for financing the transition

The strategy aims to support the transition by working on four areas, which are transition finance, inclusiveness, resilience and contribution of the financial system and global ambition. (Directorate General for Financial Stability, Financial Services and Capital Markets Union, 2021)

High-Level Expert Group (HLEG)

In 2016 the EC established a HLEG, comprised by senior experts from civil society, finance sector, academia and observers. They had the mandate to give recommendations on how to accelerate the capital flow towards sustainable investments, identify actions that financial institutions and supervisors should do in order to protect the financial system from sustainable risks and, consider the elaboration of policies in a European scale. (EU High-Level Expert Group on Sustainable Finance, 2018)

This group addresses the short-termism that is present in the financial sector where it is necessary to understand the existing pressures, the regulation and current incentives for short-termism. In general, the application of the principle of “Think sustainability first” should help to clarify the

development of legislation with a sustainability mindset. (EU High-Level Expert Group on Sustainable Finance, 2018)

Action Plan

Based on the recommendations given by the HLEG, the EC developed an Action Plan for financing sustainable growth. The Action Plan aims specially to redirect capital flows towards sustainable investments, management of financial risks from climate change and its effects, and promoting transparency and long-termism in the financial sector. (European Commission, 2018)

These are the 10 actions for financing sustainable growth: (European Commission, 2018)

- Establishing an EU classification system for sustainable activities.
- Creating standards and labels for green financial products.
- Fostering investment in sustainable projects.
- Incorporating sustainability when providing financial advice.
- Developing sustainability benchmarks.
- Better integrating sustainability in rating and market research.
- Clarifying institutions investors' and asset managers' duties.
- Incorporating sustainability in prudential requirements.
- Strengthening sustainability disclosure and accounting rule-making.
- Fostering sustainable corporate governance and attenuating short-termism in capital markets.

Technical Expert Group

In 2018, the EC established the Technical Expert Group on Sustainable Finance (TEG). This group had the task of helping to establish the EU Taxonomy, an EU Green Bond Standard, the methodologies for EU climate benchmarks and, disclosures corporate disclosure of climate-related information. (European Commission, 2020)

2.5.3 EU Taxonomy

The EU Taxonomy is a classification system that establishes a list of environmental sustainable economic activities. This taxonomy aims to provide definitions for considering an activity as environmentally sustainable. Hence, it is highly important for companies, investors and policymakers, as it gives security and helps to focus investments according to the necessity. The regulatory framework for the taxonomy is established in (EU) 2020/852. (European Commission, 2022)

The TEG published the Final Report, which highlights the important role of finance in the transition. The Taxonomy sets performance thresholds for economic activities in which they have to: make a substantive contribution to one of six environmental objectives, not produce significant harm (DNSH) the other five objectives, and meet minimum safeguards. The sectors covered in the taxonomy are the ones that have the potential to make a substantial contribution to climate change mitigation or adaptation. In the report written by the TEG, it is argued that the transition to a low-carbon economy will require phase-out of some economic activities, such as unabated fossil fuel-based power generation. (EU Technical Expert Group on Sustainable Finance, 2020)

The taxonomy regulation sets three groups of users; financial market participants, large companies and the EU and Member States. (EU Technical Expert Group on Sustainable Finance, 2020)

On December 2021, the first delegated act for the objectives for climate change mitigation and adaptation was published, which was applicable from January 2022. The act details the technical screening for determining the conditions under which an economic activity qualifies as contributing substantially to climate change mitigation or climate change adaptation and, whether the activity causes no significant harm to any other environmental objectives.

The act includes activities in the following sectors: forestry, manufacturing, energy, water, transport, construction and real estate activities, information and communication. The technical screening criteria covers the description, the area where the activity takes place, a climate benefit

analysis and its criteria, when audits should be performed, guarantee of performance of the activity and the principle of do not significant harm. (Commission Delegated Regulation, 2021)

The technical screening criteria developed in the taxonomy analyses the effect of the activity on each objective. Among others, it takes into account the nature and the scale of the economic activity, ensures that the economic activity has a positive impact or reduces negative impact on the climate objective, includes best practices of the activity and standards and methodologies, and analyses if the activity avoids producing greenhouse gas emissions, or reduce or increase greenhouse gas removals. (Commission Delegated Regulation, 2021)

The taxonomy includes transitional economic activities, which are the activities that cannot yet be replaced technologically and economically for low-carbon alternatives, but can support the transition. The taxonomy states that some activities should be revised every three years to ensure a pathway for decarbonisation, i.e. manufacturing.

Nuclear and gas energy activities

The Commission approved, on February 2022, a complementary act that includes nuclear and gas energy activities in the list of economic activities covered by the EU taxonomy. The act states that the criteria for specific gas and nuclear activities are in line with EU climate and environmental objectives. (European Commission, 2022)

The taxonomy states that it is necessary to take into account and provide incentives for the ongoing and necessary transition towards a climate-neutral economy. Under the Delegated Act the technical screening criteria for evaluating the natural gas and nuclear activities are defined. The Commission established a specific process for an in-depth assessment of the DNSH aspects of nuclear energy. For natural gas, it is stated that it was included in the initial draft of the Taxonomy Climate Delegated Act (Act that was based on TEG advice and on the Platform on Sustainable Finance).

At that moment, the final conclusion was that these activities make a substantial contribution to the climate change mitigation objective and do not do significant harm to the other environmental objectives. (Commission Delegated, 2022)

This was a controversial decision, which resulted with an objection in June 2022. The members of the Environment, Public Health and Food Safety Committee and the Economic and Monetary Affairs Committee voted against the Commission's proposal with a majority of 76:62 and 4 abstentions. After this objection, the plenary session of the EU Parliament had to vote in July 2022.

The Parliament rejected the motion to oppose the inclusion of nuclear and gas as environmentally sustainable economic activities. The vote paves the way for the EU Proposal to become law and apply from 2023. Nonetheless, some countries do not agree with this decision, including Austria and Luxembourg that stated they plan to challenge the decision in court.

Financial and non-financial undertakings

The delegated commission published an act that specifies the key performance indicators for financial and non-financial undertakings and the content and presentation of the information to be disclosed by all undertakings. (European Commission, 2022)

Investors and the public should be able to assess if the investee undertakings are aligned with the taxonomy. The main key performance for credit institutions should be the Green Asset Ratio (GAR), which reflects the proportion of exposures related to activities related to the taxonomy compared to the total assets. The institution should also establish the proportion of commission income that is derived from commercial services and activities aligned with the taxonomy, and the same for underlying assets or provision of financial guarantees. (Commission Delegated Regulation, 2021)

2.5.4 EU Green Bond Standard

The European Green Bond Standard (EU-GBS) is a voluntary standard to help scale up the environmental ambitions of the green bond market. This standard is useful for issuers and investors, as they will count with a robust tool to prove that they are funding green projects and, investors buying the bonds can easily assess and understand if the investment is sustainable. (European Commission, 2022)

The four key requirements are taxonomy-alignment, transparency, external review and supervision by the European Securities Markets Authority of reviewers. (European Commission, 2022)

The key aspects of the EU-GBS include detailed guidance about the interpretation on the EU taxonomy, therefore the scope of eligible expenditures is more clearly defined; formalization of the framework of the Green Bond, specification of reporting requirements in terms of allocation and impact; and mandatory verification as well as accreditation. (EU Technical Expert Group on Sustainable Finance, 2019)

The TEG considers of high importance providing incentives for maximize the use of the EU-GBS. This might include involvement of European Central Banks, disclosure green bond holding by European institutions, encourage banks and provide financial incentives to support the market, and use the requirements of the EU-GBS for later development of financial products. (EU Technical Expert Group on Sustainable Finance, 2019)

2.5.5 EU Climate Benchmarks and ESG Disclosures

The main objectives of the climate benchmarks are to allow a significant level of comparability of climate benchmarks methodologies, provide investors with an appropriate tool aligned with the investment strategy, increase transparency and disincentivize greenwashing. (European Commission, 2022)

A climate benchmark is an investment benchmark that incorporates objectives related to GHG emissions reduction and transition to a low-carbon economy. The report first provides guidance on the methodology to follow, as minimum content, key elements and template; and secondly, on benchmark statements, as specifications of ESG factors and on methodology aligned with target of GHG emissions. (EU Technical Expert Group on Sustainable Finance, 2019)

2.5.6 Corporate disclosure of climate-related information

In terms of corporate disclosure, the guidelines propose climate-related disclosures for each of the five reporting areas listed in the Non-Financial Reporting Directive; which are business model, policies and due diligence, outcome of policies, principal risks and risk management, and key performance indicators. (European Commission, 2019)

On the business model, the disclosure should include a description of the impact of climate-related risks and opportunities on the company's business, ways the company affects the climate and the resilience of the company over different time horizons. On the disclosure on policies and due diligence processes, disclosure includes the description of any policies related to climate, any climate-related target, the board oversight of climate risks, and management role in assessing climate-related risks. In terms of the outcomes, disclosure about the results of the company's policy on climate change and the development of GHG emissions. On principal risks and their management, disclosure includes the processes for identifying and assessing climate-related risks, the principal risks identified, and its integration on the overall company management. Finally, the key performance indicators depend on the company's materiality assessment, and should reflect aspects of GHG emissions, energy, physical risks, products and services, and green finance. (European Commission, 2019)

2.5.7 European Commission Budget

To implement the policies and achieve the targets proposed, many investments need to be made. This section shows the European Union budget available to finance the transition.

The EU long-term budget for 2021–2027 is equal to €2.018 trillion. This budget is made up of two sources, the EU's long-term budget and the NextGenerationEU, the latter is a temporary instrument created to boost the recovery of the Union concerning the effects of the pandemic while also creating a more resilient economy. The budget of the long-term budget is equal to €1,210.9 billion and of the Next Generation EU is equal to €806.9 billion. (European Commission, 2021)

The EC categorizes seven heading as spending categories. The table below details the three headings containing programs that are related to climate and environment. For the purpose of this work, only the ones that can be related to expenditures for the transition are shown.

European Commission Budget related to climate change

Single Market, Innovation and Digital		
Program	EUR billion	Objectives and key areas
Horizon Europe	91.53	EU framework for research and innovation
Euratom	1.98	Research and training for improvement of nuclear safety
ITER	5.61	Scientific prove and technological feasibility of nuclear fusion
InvestEU	9.14	Investments in sustainable infrastructure, research and innovation, digitization, social investments and small and medium-sized enterprises
Cohesion, Resilience and Values		
Program	EUR billion	Objectives and key areas
European Regional Development Fund	226.05	Strengthen cohesion in the EU. Supports investments in innovation, environment, net-zero carbon economy, and focus on sustainable urban development
Cohesion Fund	48.03	Strengthen cohesion in the EU, focus on capital-intensive environmental and transport investments
Recovery and Resilience Facility	723.82	Mitigate impact of coronavirus pandemic a sustainable and resilient EU economy
Technical Support Instrument	0.86	Support member states to implement reforms to achieve recovery and resilience.
Natural Resources and Environment		
Program	EUR billion	Objectives and key areas
European Agricultural Guarantee Fund	291.09	To support farm resilience and security by common agricultural policy, address climate change and biodiversity.

European Agricultural Fund for Rural Development	95.51	Transition towards a sustainable agricultural sector and development of rural areas
European Maritime, Fisheries and Aquaculture Fund	6.1	Sustainable use and management of marine resources, development of a resilient blue economy and cooperation towards sustainable manage of oceans
Programme for environment and climate action (LIFE)	5.43	Shift towards a climate neutral resilient economy. Attain a renewable energy based economy and tackle degradation of ecosystems
Just Transition Fund	19.32	Transition towards climate neutrality. Grants to member states in line with their territorial just transition plans

Source: European Commission (European Commission, 2021)

Together with the NextGenerationEU, the funds foreseen for fighting against climate change and for achieving climate neutrality represent more than 50% of the total EU budget.

The programs mentioned above amount to approximately EUR 1,525 billion. The budget for the 2014-2020 period for sustainable growth/natural resources was EUR 420 billion. (European Commission, 2020)

2.6 Progress in the implementation of policies

The EC elaborates the State of the Union Report, which talks about the progress in the implementation of the EU energy and climate policies. The Commission reports that the EU has made important improvements with the adoption of The Climate Law and the “Delivering the European Green Deal” package. European countries are adopting steps in order to achieve EU climate goals, 20 Member States submitted in 2021 their long-term strategies and 13 members stated the goal to achieve climate neutrality by 2050. Albeit with these strategies the EU climate goals will not be achieved, henceforth it is expected that Member States enhance their ambition. (European Commission, 2021)

Additionally, the IEA mentions that even with all the policies and measures taken, the EU is not on track towards the achievement of the increase share of renewables sources, nor the energy efficiency savings by 2030. (IEA, 2020)

Availability of funds

The current availability of funds for achieving carbon neutrality is different from before, many institutions consider that the EU budget will provide significant support to implement necessary actions to advance to a low carbon economy and accelerate the European energy transition. It is considered that the European Green Deal has a big potential because of its consistency with several policies. (IEA, 2020)

Certainly, the implementation of changes requires significant investments. According to the EC, the achievement of climate and environment targets represents additional investments amounting to EUR 390 billion per year compared to average annual amounts invested over the last ten years. (European Commission, 2021)

In addition, having available budget for research is crucial to achieve carbon neutrality. The EU research budget for 2014-2020 was EUR 77 billion. The research budget for 2021-2027 is significantly larger, around EUR 100 billion. (Agora Energiewende, 2019)

Despite the policies and targets, it is worth noticing that EU's rate of public investment in clean energy technologies needed for decarbonisation is the lowest of the major economies (0.027% of GDP in 2019). (European Commission, 2021)

Sustainable finance policies

The analysis presented in a study, of the role of finance in the sustainable transition, tells us that there is a consensus among people in the financial sector that the increase of the pace of sustainability transitions is best governed by generic policies, such as taxation, subsidies and incentives on CO2 mitigation. (Nykvist & Maltais, 2022)

Specific policies that protect a niche can lower the risk and promote innovation. The current development of renewable energies it is largely due to the policies applied that can be seen as

initial niche protection, such as feed-in tariffs, CO2 taxes or tax deductions. It is not clear that changes in investments and financing patterns, such as green bonds, have played a significant role in financing the transition, but public support that lowers the risk. (Nykqvist & Maltais, 2022)

2.7 Analysis

This section aimed to briefly detail the regulation related to sustainable finance and the framework for achieving climate neutrality, with special emphasis on the regulation related to energy from renewable sources, as well as the EU funds available for the transition. Without a doubt, the budget of the EU and the recovery plan is a framework to create pathways to a resilient economy.

The regulations of the Europe Union call for prompt actions from the member states. The development of the Green Deal Package is crucial because it is an integral legislative package that considers the relationship between regulations. It is through legislation that the European Union will provide paths to climate neutrality; despite noticing that doubts have arisen as result of some regulation, as the European Taxonomy.

Nonetheless, the fact that attention is given to the harmonization of criteria is highly valuable, since this will guide societies and will permit a uniform understanding, i.e., the climate benchmarks and disclosures, and green bonds.

It is worth noticing that the regulation encourages member states to use support schemes for the integration of renewables sources in their system.

Some of the actions for financing sustainable growth are already being implemented, but most of the efforts are still to be done. Despite the measures taken by the EU and by the member states, the established goals will not be achieved with current national plans, thus further implementations and changes must be made.

3 Investments and energy sector data

This section details how the European Union's funds have been used in the electricity sector, and, as this work intends to analyze the changes in electricity generation, changes over time in the energy mix for the European Union as a whole are also shown.

3.1 Investments at European Union level

Investments of the European Investment Bank

To analyze a trend in the priorities of the European Union, the investments of the European Investment Bank (EIB) are presented.

In 2019, the EIB issued the Energy Lending Policy in order to align the activities of the bank with the European Union policies and the Paris Agreement goals. The EIB focuses its activities on four segments: unlocking energy efficiency, decarbonizing energy supply, supporting innovating technologies and new types of energy infrastructure, and securing the enabling infrastructure. It is important to add that this policy applies to all activities that involve the energy sector, thus the policy applies to direct investments but also investments through intermediaries. (European Investment Bank, 2019)

The bank states that it generally invests in the EU around EUR 10-12 billion per year, but that it will focus on booster the investment needed. The EIB established a threshold on the level of emissions, supporting projects that have emissions below 250 g of CO₂ per kWh of electricity generated. To help the transition, the bank states it will consider financing up to 75% of the eligible costs of the energy projects, increasing from its previous limit of 50%. (European Investment Bank, 2019)

The Bank's policy covers the details of the eligibility of projects, contribution, and technical and economic assessment criteria for projects regarding energy efficiency, energy supply, innovation and infrastructure. This energy policy does not support investments in natural gas, but the bank states that will review this policy in regards with the taxonomy accepted in the EU.

As of March 2022, and since early 2020, the EIB has committed USD 6.11 billion to clean energy (USD 2.56 billion to unconditional clean energy and USD 3.55 billion to conditional clean energy),

USD 1.13 billion to other energy and USD 0.65 billion to fossil fuels unconditional. (Energy Policy Tracker, 2022)

Fossil unconditional refers to production and consumption of fossil fuels without any climate targets or other requirements. Fossil conditional refers to production or consumption of fossil fuels with climate targets. Clean unconditional is the production and consumption of energy that is low-carbon and has insignificant impacts on the environment. Clean conditional refers to support the transition out of fossil fuels but is not clear the implementation of adequate environmental safeguards. (Energy Policy Tracker, 2022)

Between the sixties and the eighties, the major focus was the exploitation of resources such as coal and oil, and the use of nuclear technology. From the eighties, the investments in natural gas increased sharply, although the investments on this source had been going on since the past decade. Investments in renewables sources started around the beginning of the 2000's but only until recently one can observe an increase in the investment of these types of technologies. Investments in hydroelectric energy have been present since the 60's but the investments in this energy source have been decreasing in general. (European Investment Bank, 2022)

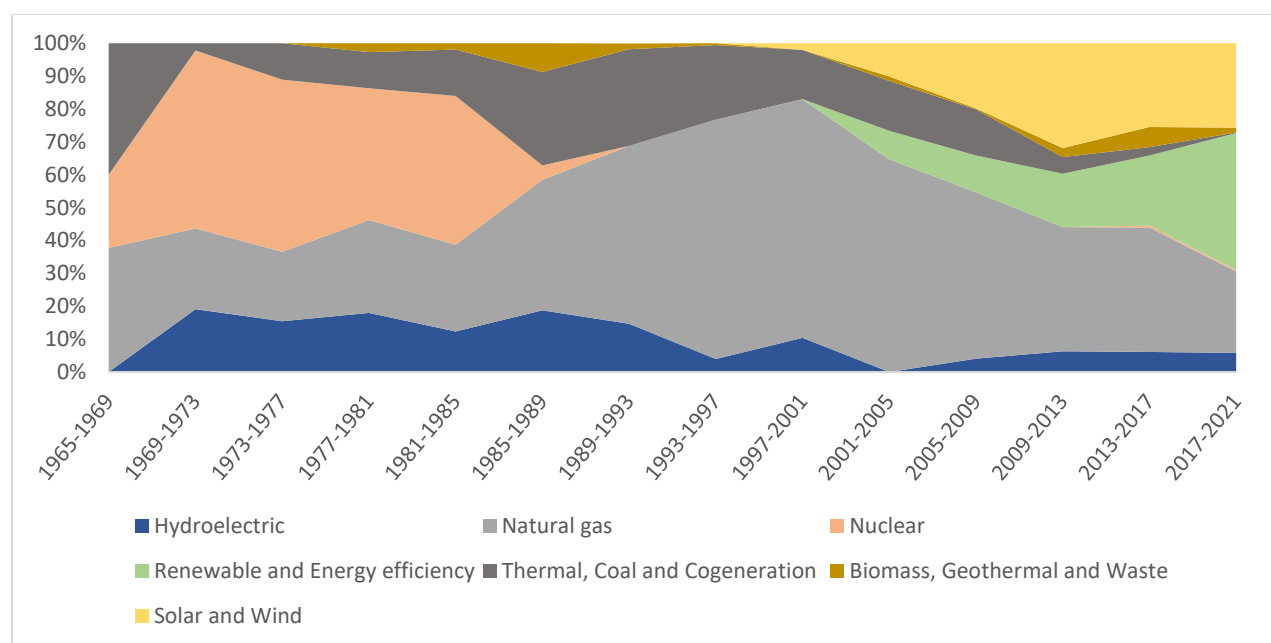


Figure 1. Trend of Investment priorities, according to outgoing loans from EIB

Source: Own elaboration with EIB data (EIB, 2022)

The amount of investments made by the EIB in the energy sector, and therefore its impact, has had a tremendous growth since the sixties. The following graph shows the investments per technology from 1965 to the end of 2020.

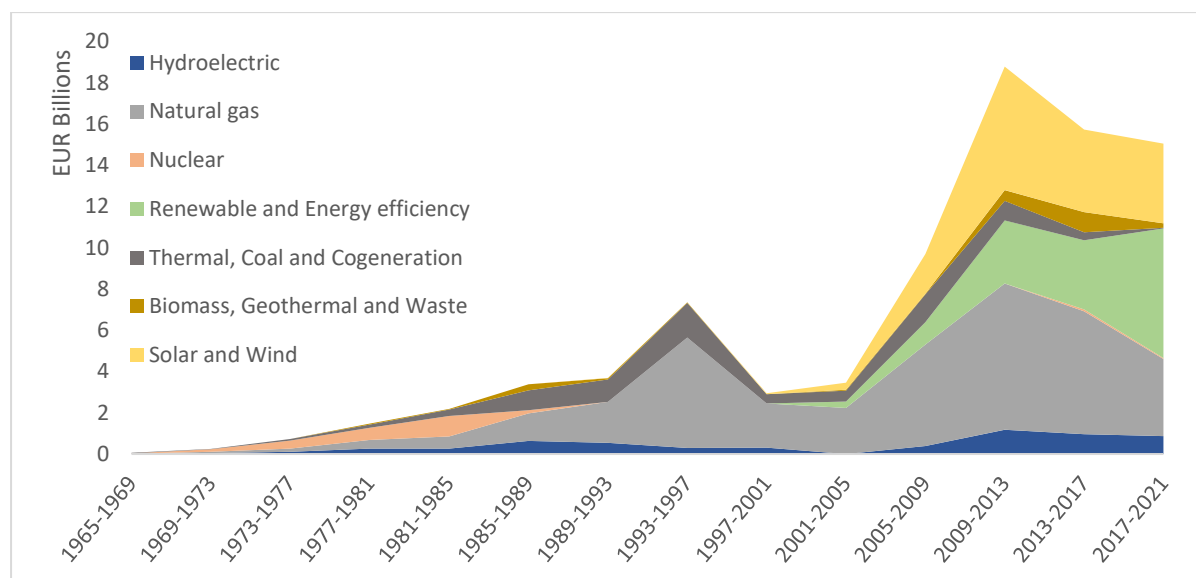


Figure 2. Investments per type of source by the EIA, in EUR billions

Source: Own elaboration with EIB data (EIB, 2022)

The category “Renewable and Energy Efficiency” includes projects financed with a wider scope than solar and wind, however it may include these two technologies. In general, certain projects have not been included because it has not been possible to categorize the investments from the original data; however, the investment trend over the years is still clearly visible.

The investments in 2021 are not reflected in the graph, however these amount to approximately EUR 5 billion, in which around 98% of the investments were directed to renewable energies.

The EIB has had a major role in financing Member States in the development of their transmission, distribution and heating networks. The following graph shows the total amount of investments made in networks and, in energy and heat supply, from 1973 to the end of 2020.

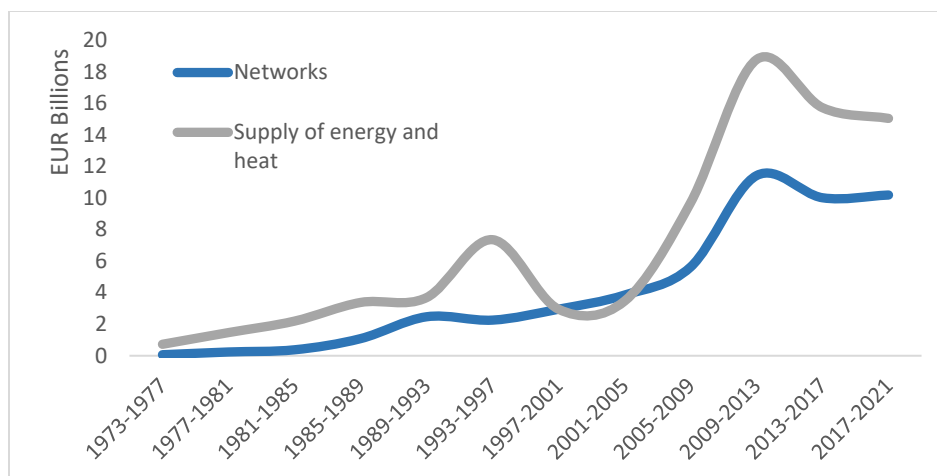


Figure 3. Investments in the distribution, transmission and heating networks, in EUR billion

Source: Own elaboration with EIB data (EIB, 2022)

3.2 Energy sector data at European Union level

In the following graph, one can see that the use of fossil fuels and oil products have been decreasing since the beginning of the 2000's, however the use of natural gas was in an increasing trend during the 2010's. The renewable source that has had major increase is wind, however the electricity production from this technology is far below that from fossil and natural gas.

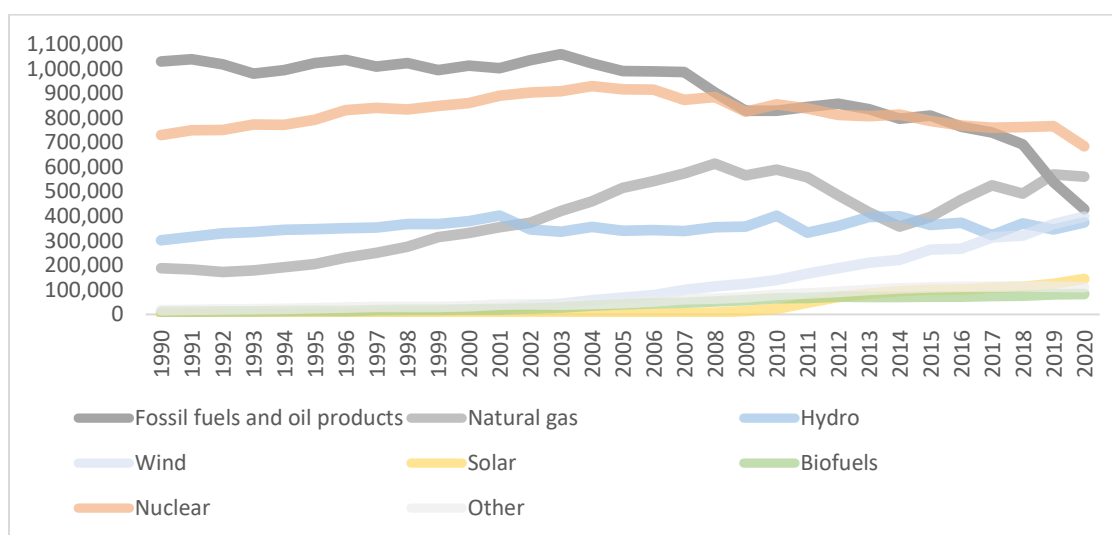


Figure 4. Gross electricity production by source in GWh

Source: Own elaboration with Eurostat data

The following graph shows the share in gross electricity production for each source. In 2020, fossil fuels (natural gas, solid fossil fuels and oil) reached 36%, nuclear was 25% and renewables were 39%. In 1990 the share of fossil fuels was 54%, 32% for nuclear and 14% for renewables.

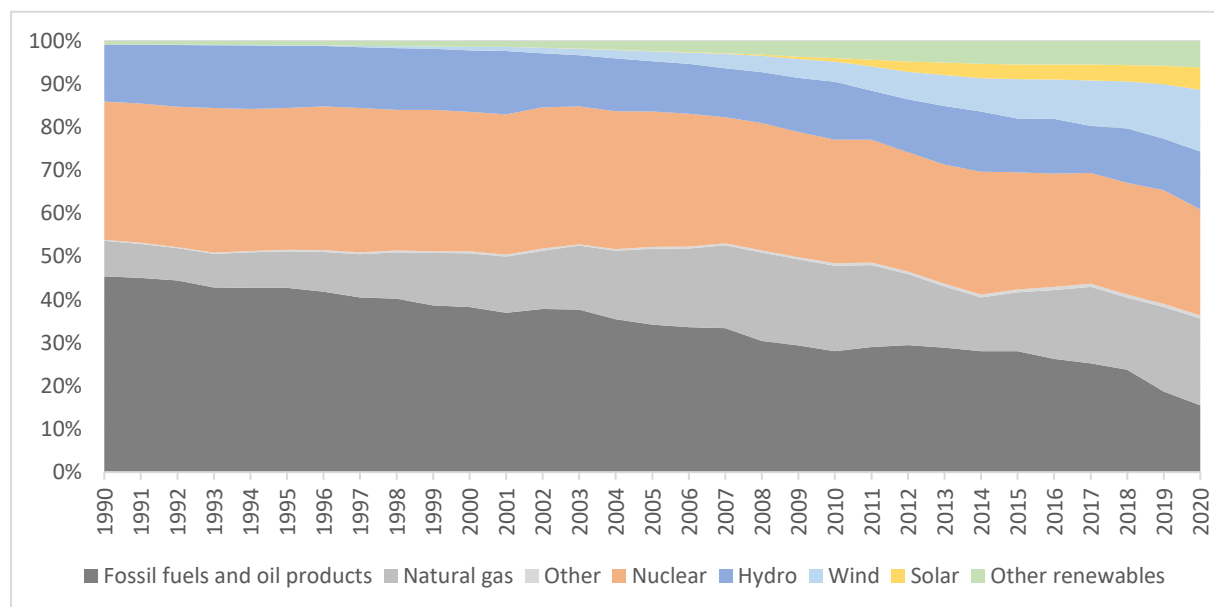


Figure 5. Source percentage in gross electricity production

Source: Own elaboration with Eurostat data

For the European Union, the share of energy from renewable sources has augmented from 9.6% in 2004 to 22% in 2020. Albeit, the share of renewable sources for the generation of electricity increased from around 15% in 2004 to 37% in 2020.

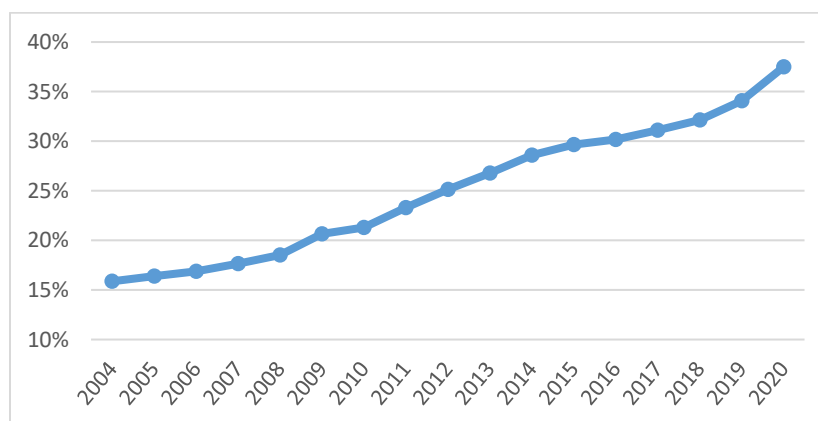


Figure 6. Share of renewable energy sources in electricity

Source: Own elaboration with Eurostat data

3.3 Legal background

As stated above, at the beginning of the 2000's we can see more investments in renewable sources, and the energy mix started to reflect some changes. From the 2000's the European Union started to promote the use of renewable sources, as result of the Kyoto Protocol. The Kyoto Protocol operationalizes the United Nations Framework Convention on Climate Change by committing industrialized countries to limit and reduce greenhouse gases emissions in accordance with agreed individual targets. (United Nations Climate Change, 2022)

In 2001, a directive was emitted for the promotion of electricity produced from renewable energy sources in the internal electricity market. This Directive laid down the framework for the integration of renewable sources in the electricity grid. (European Commission, 2009)

In 2009, the EC issued a directive to promote the use of energy from renewable sources. At that moment, the European Council endorsed a mandatory target of 20% share of energy from renewable sources in overall energy consumption by 2020. The Directive stated that each Member State should adopt a national renewable energy action plan, which should set national targets for renewable sources in transport, electricity and heating. The Directive gave freedom to Member States on the actions to take to promote the use of Renewable Energy Sources (RES). (European Commission, 2009)

The directive also stipulated that one or more Member States may cooperate with third countries on joint projects, and involve private operators. It also introduces the guarantees of origin of electricity, a tool used by the Member States to ensure that the origin of electricity from renewable sources can be guaranteed. In terms of access to the grid, transmission system operators should give priority to generation from renewable sources. (European Commission, 2009)

3.4 Barriers to investing in renewable energy

Investments and capital costs

It is expected that wind remains as the largest growing renewable power source, mostly driven by the offshore parks (IEA, 2020). However, there are many challenges to overcome to be able to increment the share of renewable sources in electricity. One challenge is related to high up-front investments costs, therefore the accessibility to EU funds is essential. Renewable energy plants have the characteristic of having high up-front investments costs and low shares of operating costs; which leads to a dominance of fixed costs. To maintain these fixed costs in a low level requires reduction of risks in terms of regulation, administration and market. (Agora Energiewende, 2019)

The cost of capital plays an important role in investments in renewable energy. It expresses the financial return, or the minimum required rate for investing in a company or a project; the cost of capital reflects the funding structure of a project, thus the cost of debt and cost of equity. (IEA, 2021)

The cost of capital can account for 20-50% of the levelized cost of electricity of solar projects. Therefore, understanding the factors that shape the costs of capital and lowering them is crucial for the transition. (IEA, 2021)

Resources

Materials to construct wind and solar farms are not renewable; the source of the energy is renewable but the materials are not. Solar photovoltaic plant, wind farms and electric vehicles generally require more minerals to build than fossil-fuel plants. A wind plant requires nine times more mineral resources than a gas-fired plant. Attaining a clean energy system will lead to a huge increase in the needs of the mineral used, which represent major challenges for the energy transition. Some vulnerabilities of the mineral market are, the high geographical concentration of production, declining resource quality, long project development times, environmental and social performance and exposure to climate risks. (IEA, 2022)

Intermittency

One characteristic of wind and solar generation is that the electricity generation is weather dependent and cannot be regulated to match electricity demand. Four strategies exist to reduce the mismatch. First, flexible supply: when electricity is generated from flexible electricity technologies. Second, demand management: demand can change over time. Third, energy storage: storing the excess amount of electricity when there is a surplus. Fourth, trade: when a country has net surplus in electricity and is exported to a country with deficit. (Golombek, Lind, Ringkjøb, & Seljom, 2021)

To boost the use of renewable sources to generate electricity, storage is highly important. Research on this technology is crucial to attain a more flexible and reliable system. The IEA mentions that EU should assess the techno-economic potential of storage, and implement policies and incentives to boost the potential. (IEA, 2020)

In addition, to decarbonize transport and heating sectors, it is considered that electrification is often the most cost-effective approach. Albeit, electrification of these sectors creates new challenges for power system planning in terms of ensuring supply security. (Agora Energiewende, 2019)

As mentioned, energy security is a challenge, and it is highly important given that some European countries decided to phase out coal in power generation and that some countries have decided to retire nuclear baseload. Some nations rely on their neighbors for baseload capacity. It is worth noticing that IEA states the EU needs to maintain financing to support nuclear power in countries where it is accepted. (IEA, 2020)

Maturity of technology

In its National Energy and Climate Plan (NECP), Poland includes as a technology risk that a large proportion of investments in generation capacity is channeled to renewable but unstable energy sources. Not enough attention is paid to manageable technologies that can have a better integration into the electricity system, such as hydrogen. (Government of Poland, 2019)

In the process of energy transition, only the energy production technologies are close to maturity, however the solutions for energy storage and other flexibility measure would stabilize the market. The market for clean energy is not fully functional without policy support, the role of the state has been crucial for the development of clean energy technologies. (Temmes, Heiskanen, Matschoss, & Lovio, 2021)

“The growth of investments in renewable power production is dependent on the growth of investments in electrification and the management of intermittency of power production”. (Temmes, Heiskanen, Matschoss, & Lovio, 2021)

Capacity factor

The capacity factor of renewable energy is a challenge. Capacity factor is the ratio of the actual energy produced in a given period, to the hypothetical maximum possible. This is an important measure to decide on new sites for further development of renewable energy sources. (Kies, Schyska, & Von Bremen, 2016)

The average annual capacity factor for Solar PV hovers between 10%-21%, for onshore wind between 23-44% and for offshore wind is between 29-52% (IEA, 2020). In 2020 the global average capacity factor for nuclear was around 80%. (World Nuclear Association, 2021).

Subsidies for fossil fuels

Non-sustainable energy subsidies are one of the main barriers to implement clean energy projects. Since these subsidies increase the demand of fossil fuels, when compared with energy from renewable sources, the latter seems to be more expensive and have a disadvantage in the market. (Qadir, Al-Motairi, Tahir, & Al-Fagih, 2021)

The EC emphasizes that these subsidies should come to an end. Ending fossil fuel subsidies would mean that national budgets will have more margin to invest in technologies that will help to achieve the energy goals and long-term goals. (European Commission, 2021, p. 29)

Total energy subsidies in the EU amounted to EUR 176 billion in 2019. Despite commitments to phase out fossil fuels they are not been reduced enough, and in some countries these subsidies

increased since 2015. The phasing out of coal power plants has been incentivized by ending subsidies in some Member States. (European Commission, 2021)

Lack of public support

Local communities are more vulnerable to the negative effects of energy plants, i.e., noise pollution, landscape changes and potential for accidents. This can be perceived as an unfair distribution of benefits and impacts, which lead to not supporting renewable projects. (Qadir, Al-Motairi, Tahir, & Al-Fagih, 2021)

Socio-economic condition of people

The people's economic capacity affects the acceptance of energy transition. The capacity of investing in clean energy is different for a wealthy household than an underprivileged family. (Qadir, Al-Motairi, Tahir, & Al-Fagih, 2021)

Unstable policies

Some financial actors interviewed in a study stated that although taxonomy and standards are important to better evaluate sustainable investments, to increase the pace of changes, it is more important to have clear market signals, as adoption of long-term policies. (Nykqvist & Maltais, 2022)

A study defined three principles that play a crucial role in designing energy policies. First, complementary, which requires to think on interlined measures. Second, transparency, which relates to uncover synergies, tradeoffs and to measure results. Third, adaptability, which requires to understand policies as a sequence of measures and plans that can be adjusted as objectives change. (Pahle, et al., 2021)

The risk perceived by market players and grid operators of changes in legislation is considered a major barrier for investments. Sometimes changes with retroactive effect, influence the level of confidence of investors. (Van Nuffel, Rademaekers, Yearwood, & Graichen, 2017)

Procedures

Other barriers to investing in the transition are related to administrative procedures, i.e., permit procedures and grid bottlenecks (European Commission, 2021, p. 29). Permitting procedures are considered a major barrier because these can cause long delays and administrative costs. (Van Nuffel, Rademaekers, Yearwood, & Graichen, 2017)

3.5 Analysis

It is a priority of the European Investment Bank to be aligned with the UE policies; this can be seen in the lending policy and in the bank's historic financing data. The EIB reflects transparency by publishing this data.

Increasing the percentage of financing up to 75% of the eligible costs of the energy projects can be beneficial for accelerating the transition, however at the same time it can raise doubts about the reach that these funds may have, due to the number of projects that can be financed. The level of uncertainty or risk that the bank accepts can certainly play a role in the transition by accepting more risk than other financial institutions.

The integration of renewable sources in the energy system has been an objective since many years ago, nonetheless not enough money was allocated to these projects. Despite watching an increment of financing renewable energies from the 2000's, these investments were not substantial when compared to natural gas investments. It was until 2009 that the investments in renewables surpassed gas. However, starting from year 2016, the value of investments have been significantly different, as the yearly investments in gas were around 30% of the investments in renewable sources.

4 National Incentives to promote renewable sources

The purpose of this section is to analyze the incentives used to promote the inclusion of renewable sources at national level. The previous section showed the trend of the changes made at European level, however to better understand those results it is necessary to comprehend the incentives at national levels. By analyzing the incentives, one aim to find insights on how to foster sustainable finance.

Several mechanisms have been established in the market, for instance feed-in tariffs, competitive auctions, quota based system or green certificates and tax exemptions are widely used. This section will cover the analysis of Feed-in Tariff and Quota based system.

4.1 Feed-in Tariff

Feed-in Tariff (FIT) is the mechanism by which renewable energy generators have the right to sell their production and obtain a fixed remuneration or alternatively obtain the price of the electricity market plus an incentive.

Many countries around the world have used this mechanism to promote renewable energy generation. FIT can significantly reduce the risks of investing in renewable energy and create conditions for changes in the sector. The design of FIT policy has an important effect in the development of new investments in renewable energy as it influences the confidence of the investors. One challenge of FIT policy is to ensure that the payments are adequate to recover project costs over the life of a project and at the same time allow a reasonable return. (Couture & Gagnon, 2010)

The remuneration to the producer may be dependent or independent from the electricity market price. Independence of the market means that a fixed price or a minimum price is offered. Market dependence means that a premium is paid above the market price. One study about FIT mechanisms explains several options in which this model can be implemented, this will be covered briefly. (Couture & Gagnon, 2010)

Market-independent

When the price is independent of the market, the fixed price model is not related to variables like inflation or fossil fuels price. This fixed price generally is established for the duration of the contract term, which can create stable and reliable environment to invest in renewable sources. (Couture & Gagnon, 2010)

Another option is to design a policy based on fixed price model with full or partial inflation adjustments. The methodology to adjust inflation can vary according to the country.

Front-loaded model is another design of FIT policy, a higher price is paid at the beginning of the project, and then in later years the price is reduced. This type of incentive can be very helpful for the investor at the initial years of a project, which is when it is mostly needed. Another model is the spot-market gap model, designed to cover the gap between the spot market and the required price. (Couture & Gagnon, 2010)

Market-dependent

Premium price model is a method that gives a constant premium or bonus above the average retail price. On this model, there is a risk that the remuneration to the investor be too high that affects consumers, or too low that affects the investors. (Couture & Gagnon, 2010)

Variable premium is another design of a market-dependent policy, where the remuneration paid to the investor has a cap and a floor. If the market price reaches a level, the premium declines to zero. The percentage of the retail price model establishes a remuneration according to a percentage of the retail price. (Couture & Gagnon, 2010)

Feed in premiums

Premium systems are an evolved version of feed in tariffs, in which there is several degrees of market exposure for producers. They can provide a more predictable revenue stream for investment in new technologies that are not fully developed. The feed in premium can ignore electricity price movements, or can be adjusted automatically according to electricity prices changes. (European Commission, 2013)

Advantages and disadvantages

The main advantage associated with this mechanism is the reduction of risk. A fixed price removes completely the risk associated with the volatility of electricity price.

Additionally, support policies have an impact on the cost of financing, by affecting the perceived risk of the renewable projects. Hence, the interest in the project due to the reduction of risks is visible not only by the shareholders but also by credit institutions. (Fagiani, Barquín, & Hakvoort, 2012)

Some authors have found that the low risk environment that the FIT policy produces can be much more effective than certificate trading. (Krogh Boomsma, Meade, & Fleten, 2012)

A disadvantage related to this policy is that electricity prices are distorted. Additionally, it does not consider the time of day when the electricity is supplied.

FIT policy might result in very high public costs, which cause social burden and puts in debate if the country should support renewable energy (Yang, Jing, Wang, Nie, & Sun, 2021)

Another disadvantage is that if the investments exceed the need and the government target, there could be an over installation and this might be a burden for customers in terms of electricity prices.

Implementation in countries

From 1991 to 2000, Germany used a percentage of the retail price model, however later Germany opted for a fixed-price model based on project costs. Germany's renewable electricity contribution to the energy matrix has grown due to the security provided by the FIT policies. The main regulation to promote the use of renewable sources is the Renewable Energy Sources Act (EEG). The main mechanism implemented has been the use of fixed feed-in tariffs, which are guaranteed for a period of 20 years. (Leepa & Unfried, 2013)

This support scheme needs to be continuously revised and updated according to the market changes and technology improvements. Germany updated its FIT policy several times, as its design has trade-offs in terms of long-term and short-term goals, like the search for technical

innovation or the search for a rapid expansion of renewable sources. (Drechsler, Meyerhoff, & Ohl, 2012)

Spain have had important results in the implementation of RES, a premium tariff applied is supposed to have a significant effect in the electricity mix. In the first law applied, the government paid a range from 80%-90% of the average electricity price. The application of this incentive began with a decree emitted in 1998, but later the country made reforms in terms of the application, index and mechanism. (Del Río González, 2008)

Several authors have studied Germany and Spain to analyze the establishment of feed-in tariff system, one study argues that the development of RES entails environmental protection, increase of employment, contribution to GDP, and the development of research and innovation. (García & Mariz, 2012)

In France, the mechanism was applied on periodical bases, in which the FIT is adjusted by 2% every year. (Leepa & Unfried, 2013)

All in all, although there are some risks in the implementation of this strategy, FIT policy has influenced the expansion of renewable energy projects, and will continuously to be a support scheme in the transition to a neutral economy.

The time when the policy is introduced needs to consider the maturity of the technology it will support. Some authors have concluded that FIT is suitable at an early stage of the development of the renewable energy industry. Once the industry is mature, governments can introduce support schemes like the quota-based to ensure a sustainable development. (Yang, Jing, Wang, Nie, & Sun, 2021)

4.2 Quota-based system

A quota-based system establish the obligation of the distributors to acquire certain percentage of the supply from renewable sources.

The quota system is a regulatory quantity-driven strategy, which governments used to achieve a desired level of generation from renewable sources. (Haas, et al., 2011)

Demand for certificates is created by mandating one of the parties involved in the supply chain of electricity, to acquire these certificates in proportion to the electricity they acquire. Thus the renewable energy producers, are sure to have sufficient demand for the electricity they generate.

Generally, the certificates from a Tradable Certificate Scheme, can be obtained by certifying the own generation of renewable electricity , by the purchase of renewable electricity from a generator, or by the purchase of the certificates without purchasing the power from the generator. (Haas, et al., 2011)

An important idea behind this scheme is that the competition created in a trade market system is an optimal way to allocate resources, which then results in a market that includes renewable sources but at the same time with low costs for the customers. Some studies have found that the quota-based system does not impact generation as much as governments intend, and that FIT scheme has shown significantly better results (Kilinc-Ata, 2016) (Haas, et al., 2011).

It might be useful to know other common names that apply the same concept. These are Renewable Portfolio Standard, Renewable Electricity Standard, and Renewables Obligation/Certificates. (Kilinc-Ata, 2016)

Implementation in countries

Quota-based systems have been used in several countries, i.e. in UK, Sweden, Italy, Belgium, Poland and France. In addition, a study about the Tradable Green Certificate scheme in UK tell us that even though the main idea of this scheme is that competition will drive the prices down, it can create higher cost of capital because of higher perceived risk due to the price uncertainty. (Butler & Neuhoff, 2008)

Whilst the producers are exposed to market prices, there is no revenue certainty. Although this risk can be considered normal and encourage competition, the rise in revenue risk can increase the cost of capital, and in some cases can result in not available debt financing. (European Commission, 2013)

However, the price risk for investments under this scheme can be reduced with a floor price for the tradable certificate. (European Commission, 2013)

4.3 Power purchase agreement

A PPA is an agreement between a producer (generator) and a buyer (consumer) for exchanging electricity over a defined period and under certain conditions. It defines an agreed tariff over a determined time, generally between 10-20 years. (Jain, 2021)

The seller is the entity that owns the project and is key to obtaining financing for the project. The PPA represents a reduction of market price risks through fixed price agreement, as well as individual contract design.

The long-term nature of these types of contracts can be a disadvantage if the final price ends up being negative for one party. If the provider does not achieve to deliver the amount of electricity agreed, the generator has to provide financial or physical compensation, or outsource to a third party.

New forms of PPA are surging where real-time on-demand variable renewable energy is considered, in which the generator has to meet annual energy delivery and hourly power obligations. Nonetheless, these types of contracts are introducing challenges for buyers and sellers. (Jain, 2021)

The Corporate power purchase agreement is also being used by industries in order to reduce its environmental footprint. (Mendicino, Menniti, Pinnarelli, & Sorrentino, 2019)

4.4 Analysis

Certainly, the replacement of old power plants with newer plants can put pressures on the electricity price, as the amount of investments to be made for infrastructure replacement will influence the price. However, that is the reason why investments in research and innovation are a key aspect, to open up the possibility of reducing the costs of the new technologies needed.

The intervention of governments is very important, and will be necessary to introduce mechanisms that reduce the burden on consumers to achieve the established goals and subsequently achieve climate neutrality. Just as subsidies for fossil fuels have existed for years, subsidies for renewable sources must also be established as a permanent relief mechanism for consumers. This will be necessary for the achievement of sustainable goals.

The literature tells us that there is no perfect incentive scheme. Instead, adapting the mechanism according to the results of the implemented incentive, the technological improvements, the investors' interest, and the technical operation of the sector, may be the key aspects to follow to maintain a sustainable scheme.

To promote renewable energy, reducing the perception of risk seems to be one of the most important things to do since this certainly will increase the attention of investors and financial institutions. The FIT scheme has been effective in reducing project risks.

5 Analysis per country

This section will briefly cover the incentives used by some countries of the European Union, with the intention to analyze to what extent the incentives mentioned in the previous section have impacted the energy mix across time.

As an introduction, a brief summary of the National Energy and Climate Plan of each country is included.

5.1 Germany

5.1.1 Overview of support schemes

The main incentive used by the German Government has been the Feed-in tariff. The amount of incentive depends of the renewable energy source, the size and the site.

In 2000, the government launched the Renewable Energy Sources Act (EEG). The aim of the EEG was to enable young technologies such as wind and solar to enter the market through fixed remuneration as well as through the guaranteed purchase and priority feed-in electricity. With this Act, the operators were entitled to a remuneration for 20 years.

Recently, the country also has made use of auctions to expand wind power and photovoltaics. From 2017 the state does not determine the remuneration level for renewable energy, with it being instead determined by tenders. (Federal Ministry for Economics and Climate Protection, 2022)

In 1990, Germany issued the Electricity Feed-in Act, which regulated the purchase of electricity generated with renewable sources by public electricity supply companies. The Feed-in Act obliged electricity supply companies to pay premium prices for the electricity supplied from renewable energy power plants. (Federal Ministry for Economics and Climate Protection, 2022)

Germany's feed in tariff differentiated the incentive by source and by size of plant, and the year the installation was put into operation. The extra cost caused by the mechanism is paid by the end consumers by the EEG surcharge. However, Germany has decided to abolish the surcharge on July 2022 due to the energy crisis; the Energy and Climate Fund will therein finance the promotion of renewables.

In 2001 there were also other measures introduced such as tax reforms, tax exemption for biofuels. The country made several amendments in accordance with the development of the scheme, the sector and the technology.

5.1.2 Energy sector data

The production of electricity from coal went from 58% in 1990 down to 25% in 2020. The opposite trend is seen with natural gas, which was around 7% in 1990 and 17% in 2020. The production of electricity from renewable sources has grown sharply, from 4% in 1990 to 43% in 2020. The production of wind is the one that has shown larger increase, from 2% in 2000 to 23% in 2020.

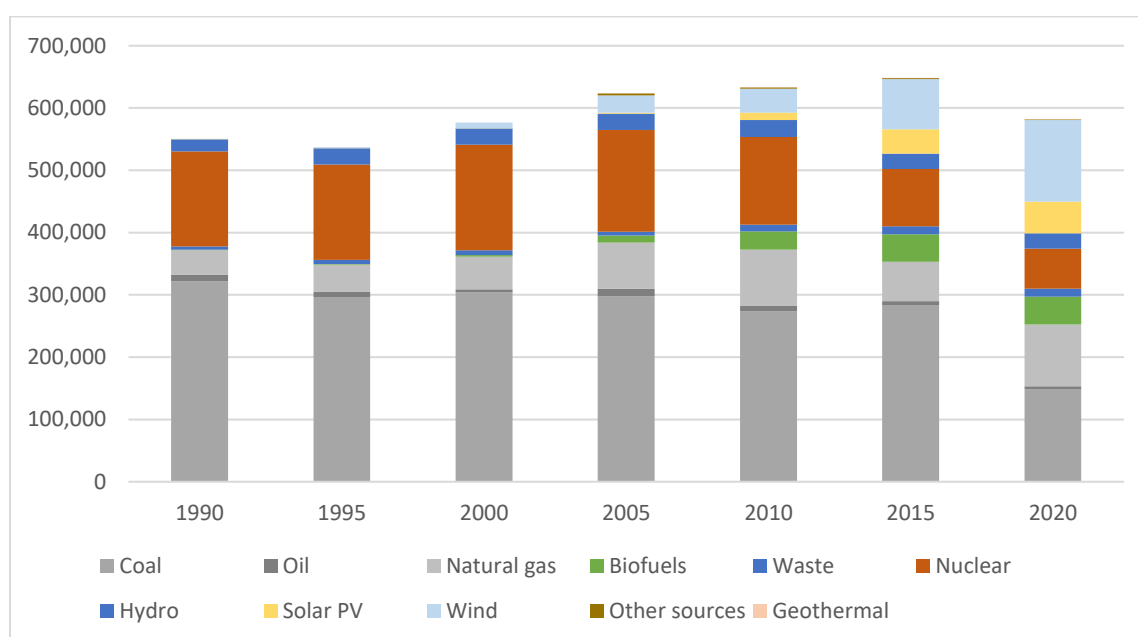


Figure 7. Trend of net production of electricity for Germany in GWh

Source: Own elaboration with IEA data

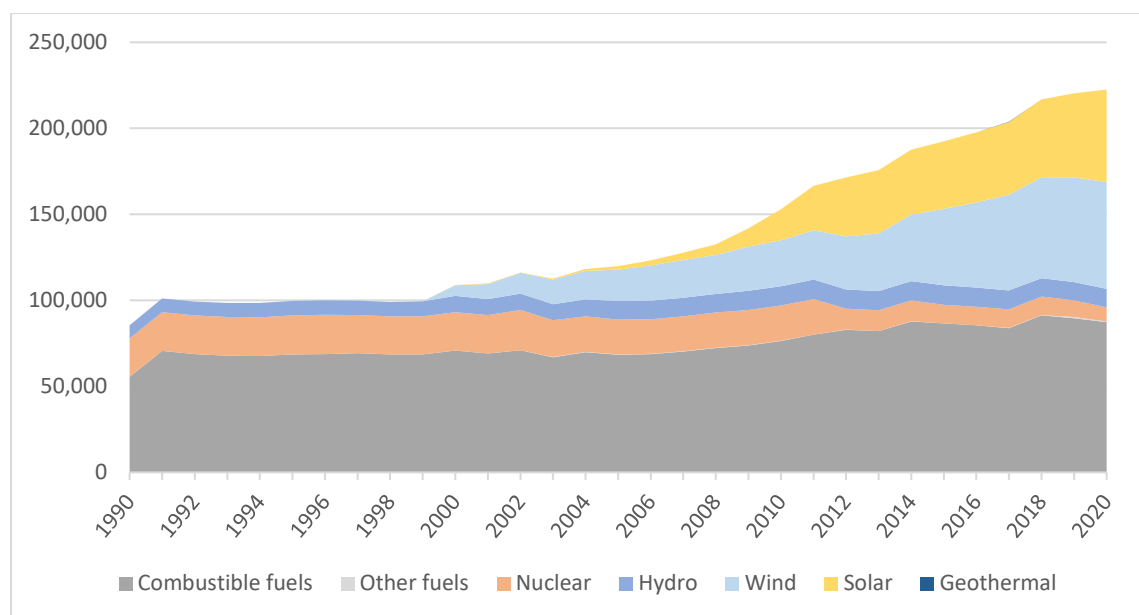


Figure 8. Electricity production capacities for Germany in MW

Source: Own elaboration with Eurostat data

5.1.3 National energy and climate plan

The target share of renewable energies in gross final energy consumption is 30% by 2030.

The country highlights the significant importance of regional cooperation, making emphasis that the energy transition and climate protection can only succeed if they are managed and enshrined at an EU level.

The government plans to implement the Renewable Energy Sources Act and the Offshore Wind Energy Act, as well as to have a closer synchronization between expansion of renewable energy and grid expansions, and to further develop cogeneration field and to be a location for battery cell production.

In electricity, Germany plans to replace coal cogeneration with gas cogeneration, and to reduce coal-fired power generation in line with the expansion of renewables sources of energy. The target for 2030 is to achieve 65% share of renewable energies in gross electricity consumption. The measures to increase the share of renewables include calls for tenders, remove obstacles in planning and approval processes, and availability of land.

In energy security, it is worth noticing that natural gas will continue to represent a significant portion of the energy supply in Germany. The country intends to have gas power plants and storage reservoirs to respond flexibly to the availability of wind and solar power generation. In addition, load management is important to minimize peak loads of electricity.

The gas industry will undertake significant efforts to expand the natural gas infrastructure. The LNG terminals will expand and strengthen the diversification of sources of supply and pipeline transport routes.

In terms of research and innovation, the Federal Government has the Seventh Energy Research Programme, which focuses on the alignment of energy research with the needs of the energy transition. Some of its goals are to develop innovative and holistic solutions to energy transition challenges, to strengthen the reputation as an industrial country, and to develop potential technologies.

Investment needs

The additional investments that result from the planned policies and measures add up to EUR 95.2 billion in the period 2021–2030 (as EUR 2016). In the final sectors, the figure is EUR 184 billion in the period 2021-2030. The total additional investments are then expected to be EUR 279.2 billion up to 2030.

5.2 France

5.2.1 Overview of support schemes

Electricity from renewable sources is promoted through the feed-in tariff mechanism, premium fees and tax benefits. The country established the feed in tariff mechanism around the year 2000, from 2010 the government has been lowering the tariffs because the return on capital was considered too high.

Tenders may be used by the State when the development of production capacities in the market is not meeting the target of the energy multi-annual programme. France has developed a tender in the form of competitive dialogue, in which the Minister has a dialogue with some candidates

prior to the elaboration of tender guidelines , which helps to open up markets by encouraging bidders to discuss possible solutions.

Corporate Power Purchase Agreements are also developed in France mainly within groups of companies or within State-owned entities that are interested in fixed prices. Crowdfunding is also being used to finance energy projects; until 2014 a form of participative funding in renewable projects was not possible. France has focused its efforts in the development of offshore wind energy, by developing a legal framework and calling for projects. Additionally, the state provides several trainings to support the installation of renewable energies.

France aims to develop nuclear power plants, specifically in Small Modular Reactors, and Clean Hydrogen. The country has decided to gradually close coal power-plants generation.

5.2.2 Energy sector data

France produces its electricity mainly by nuclear power with a contribution of 66% in 2020. The production of electricity with renewable sources went from 14% in 1990 to 23% in 2020. The main renewable energy is hydroelectric, followed by wind and solar. Hydroelectric energy has sustained its percentage of contribution, hovering between 12% and 15%. The development of wind electricity started around 2010, at the end of 2020 wind generation accounted for 8%.

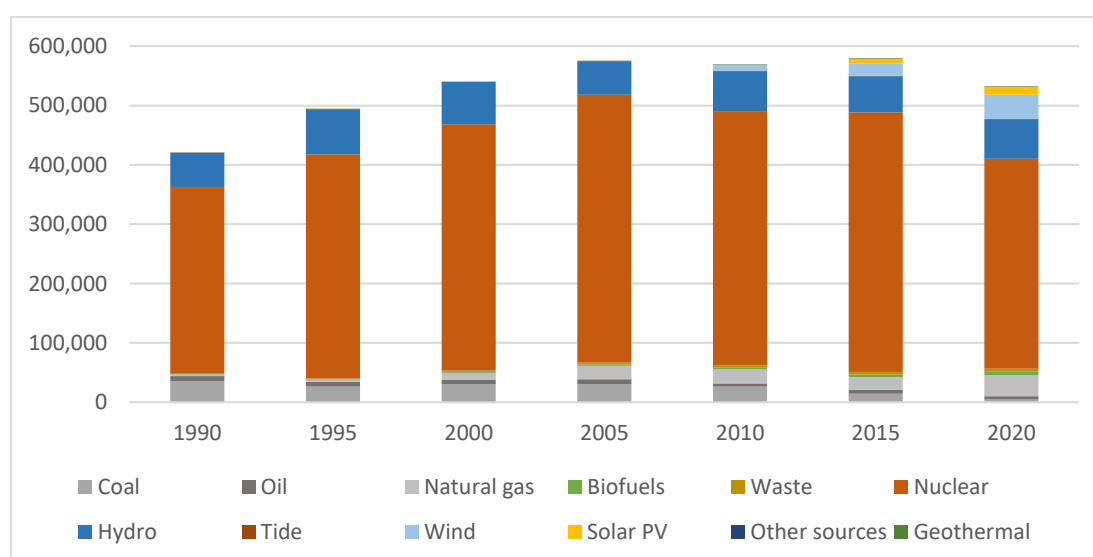


Figure 9. Trend of net production of electricity for France in GWh

Source: Own elaboration with IEA data

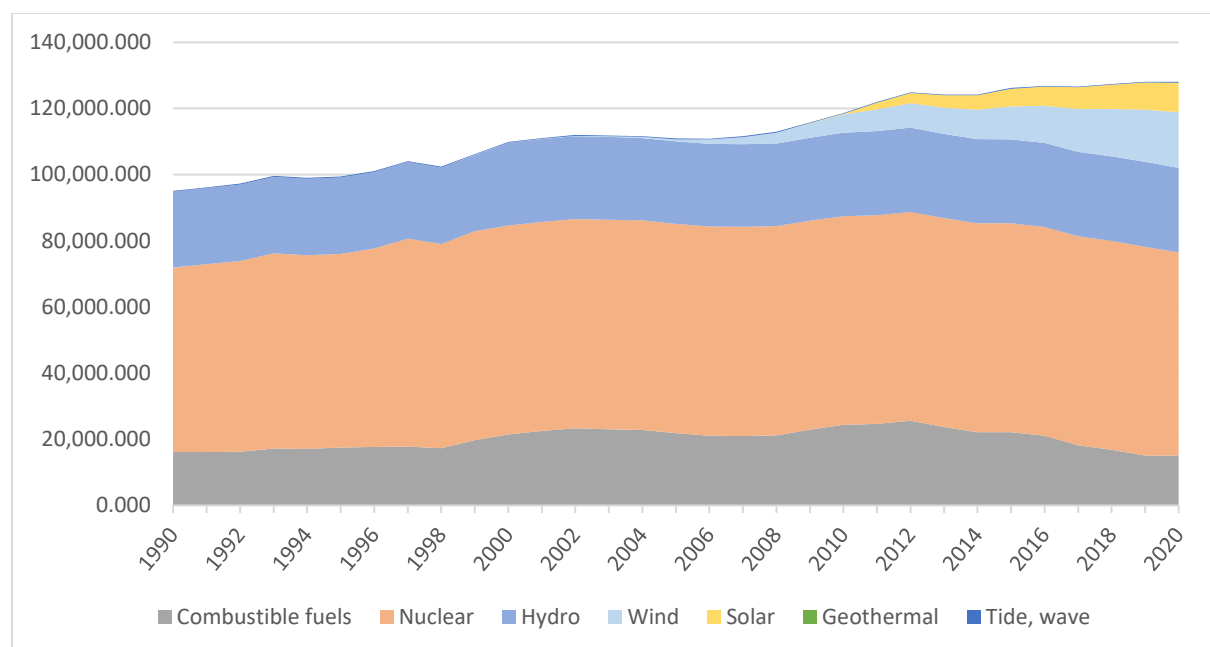


Figure 10. Electricity production capacities for France in MW

Source: Own elaboration with Eurostat data

5.2.3 National energy and climate plan

The target share of renewable energy of the gross final energy consumption is 33%.

The country states that the measures considered in the NECP will not be sufficient to achieve all the relevant targets by 2030, especially with the reduction in final energy consumption.

By 2030 the share of renewable energy should be 33%, and for this it is necessary that the share of renewable sources are 40% for electricity, 38% for final heat, 15% for final fuel consumption and 10% for gas.

Some cross-sector measures to increase capacity to generate electricity from renewable sources are: provide visibility for tender schedules, simplify administrative measures, support development of crowdfunding investments and prepare large-scale recycling of end-of-life installations.

According to some studies, the supply of electricity is flexible enough to manage the inclusion of renewable energy capacity, over 100 GW by 2035. France will conduct studies on the technical feasibility of an electrical system with a significant level of variable renewable energies.

Imports from France are almost all the gas, oil and coal that is necessary for their energy system. The main energy produced is electricity; to ensure security of electricity supply, the country is paying attention to handling consumption peaks and managing rapid fluctuations in supply and demand. France introduced the Law on New Structure of the Electricity Market where a capacity obligation mechanism is included; in which each electricity supplier has the obligation to cover with enough capacity guarantees the consumption of their customers.

Investment needs

The average annual investments needed for the transition hovers between EUR 45 billion and EUR 85 billion, until 2032. From this, EUR 10 billion are necessary for energy and electricity grids, and additional costs represent around EUR 7 billion per year.

5.3 Belgium

5.3.1 Overview of support schemes

The Federal State is responsible for: supply security, studies concerning future of electricity and gas, nuclear, offshore wind power, hydropower, big infrastructure for production and transport of energy and tariffs. The regions are responsible for electricity distribution, transport of electricity with a nominal voltage equal or less than 70,000 volts, public gas distribution, remotely produced heat distribution networks, new sources of energy except nuclear, energy recover by industries and rational use of energy. (Federal Public Service Economy, 2022)

Electricity from renewable sources is promoted mainly through a quota system based on the trade of certificates. Electricity suppliers are required to present green certificates to prove that a certain proportion (quota) of the electricity was generated from renewable sources.

Renewable electricity producers receive one green certificate for each MWh they generate. The certificates can be sold energy suppliers, intermediaries and the transmission operator.

Net metering is also part of the support schemes applied in Belgium. With this scheme small auto-producers are entitled to benefit from a compensation mechanism for the difference between the amount of electricity taken from the grid and the amount fed into the grid. Electricity from renewable sources has priority in the connection and use of the grid.

In Brussels, there are several policies that aim at promoting the development, installation and usage of RES-installations. The production of electricity is promoted through the federal system of green certificates and through regional support schemes, such as energy subsidies, investments assistance for companies and net-metering.

In Flanders, electricity from renewable sources is promoted by quota system, an ecological premium and a net-metering scheme. A decree emitted in 2001 regarding the green certificate scheme, stated that every electricity supplier had the obligation to buy a certain amount of green certificates from green electricity producers. This amount gradually increased until 20.15% in 2020. (Climate Policy Database, 2022)

Flanders established the Flemish Energy and Climate Agency (VEKA), which is an independent agency of the Environment policy area and implements sustainable energy and climate policy. This agency calls for the action of individual people in several ways; by buying electricity from suppliers that offer green energy, becoming a cooperative or support crowdfunding, making own green energy, and giving a change to new large projects. (Flemish Energy and Climate Agency, 2020)

In Walloon region, the generation of renewable electricity is promoted through the federal system of green certificates. In addition, regional support schemes, as energy subsidies, investment assistance and net-metering. The access is regulated by the Walloon grid code and by the regional electricity market decree.

The Walloon government implemented a decree in 2002, where it established targets of electricity demand to be met from renewable sources, which was 3% by 2003 with an annual increase reaching 12% by 2012. (Climate Policy Database, 2002)

Some studies have analyzed the experience of the implementation of green certificates in Belgium, in which some flaws in the implementation and adaptation of the support scheme are shown. The scheme and the massive adoption implied substantial and increasing financial costs to society. The sales of solar panels boomed when the price dropped but the incentive was high. The adoption rate of solar panels grew during 2009-2012, period when the return of the investments reached the highest levels. This was translated into a burden for small consumers

who do not have the opportunity to invest in solar panels. Contrary to the wealthiest citizens who can invest and obtain returns. This highlights the importance of continuous monitoring of the support mechanism as well as the segmentation of support schemes. (Verbruggen & Laes, 2021) (De Groote, Gautier, & Verboven, 2022)

5.3.2 Energy sector data

Electricity production in 2020 was 88.91 TWh, of which nuclear represented 39% and natural gas represented 30%. Belgium has been reducing the consumption of coal to produce electricity, from 28% in 1990 to 2% in 2020.

The generation of electricity from renewable sources was 26% in 2020. The major electricity production from renewable sources is wind with 14%, which increased from 8% in 2015 to 14% in 2020. (Eurostat, 2022)

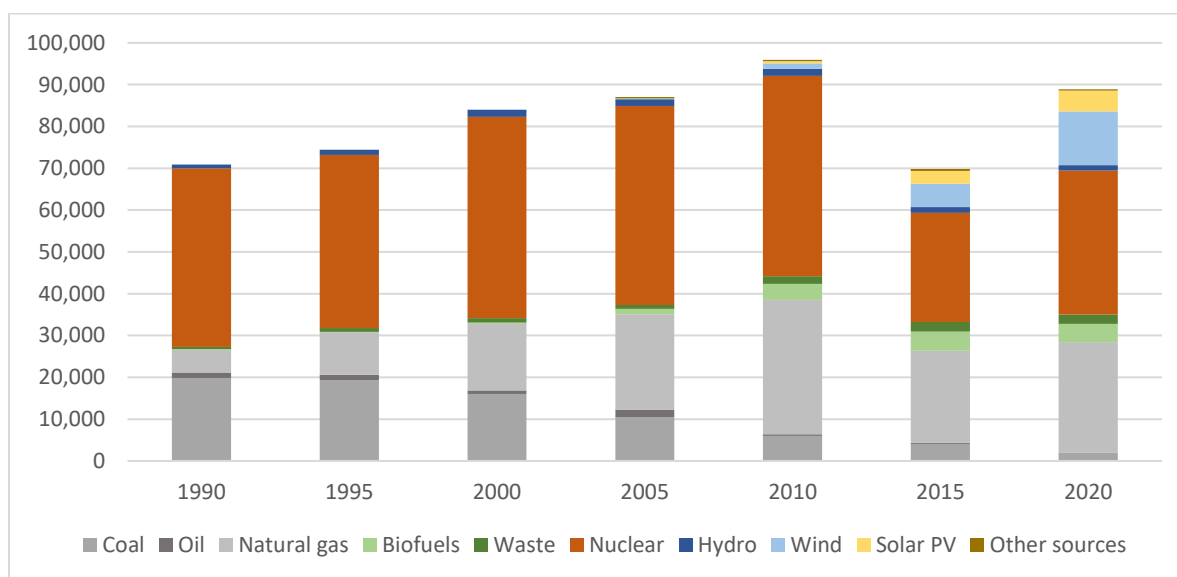


Figure 11. Electricity Generation by Source for Belgium in GWh

Source: Own elaboration with IEA data

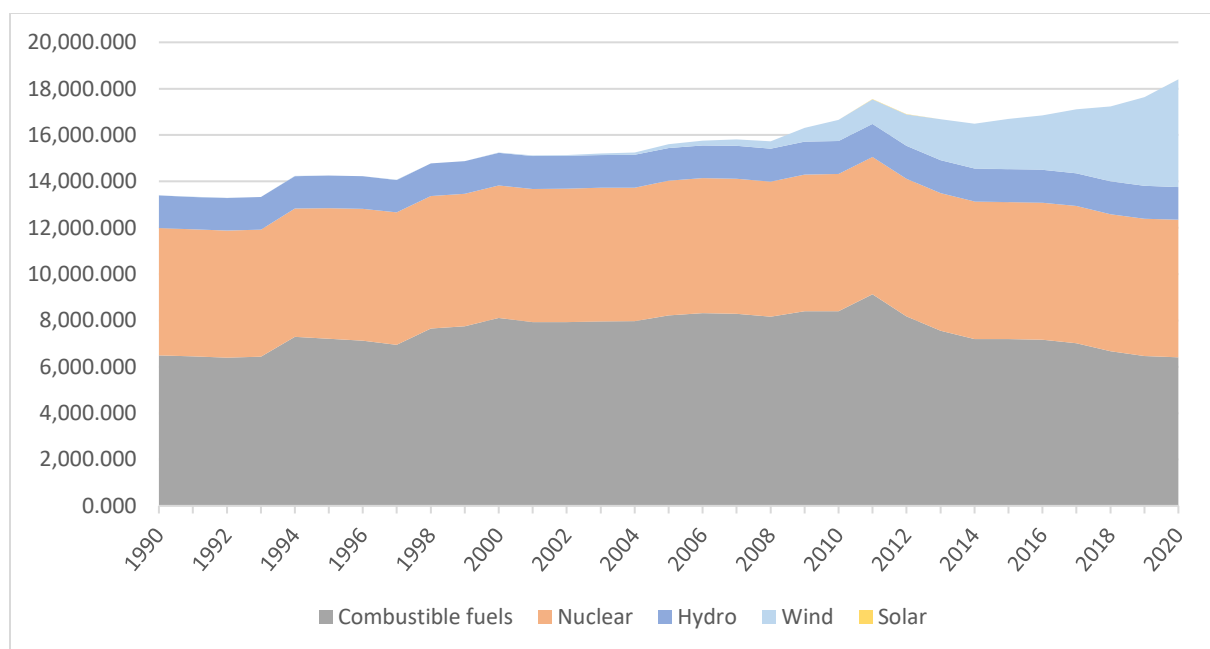


Figure 12. Electricity production capacities for Belgium in MW

Source: Own elaboration with Eurostat data

Approximately 66% of the capacity production in the country comes from Engie/Electrabel SA, with 10.8 GW in 2021, which results in 75% of the electricity produced with 59.1 TWh for the year 2021. (CREG, 2021)

5.3.3 National energy and climate plan

According to the plans of the different regions, Belgium will generate 17.5% of its gross final energy consumption from renewable energy sources by 2030. Belgium is committed to spend at least 3% of GDP on research and development.

Some of the challenges for the energy transition mentioned in the plan are that according to European rules, Belgium has to reduce its public debt, and that there is a lack of knowledge in terms of how to use the European funding. In regards with public-private partnerships, there is a lack of technical expertise and additionally difficult and time-consuming administrative and legal procedures.

Investment needs

For the Flemish Region, the total estimation of investment needs for 2021-2030 period is EUR 7.5 billion. For green electricity the estimation is around EUR 530 million per year, and for green heat the estimation is around EUR 200 per year.

For the Walloon region, the investment needs for renewable electricity production to 2030 amount to EUR 5,702 million and, in renewable heat amount to EUR 4,404 million.

For the Brussels region, the investment needed is EUR 28.7 billion up to 2050.

5.4 Poland

5.4.1 Overview of support schemes

Poland encourages RES mainly by certificates of origin and auction system. The country has been focusing its efforts in the auction system, in which projects are granted to the lowest price. The green certificate system is being gradually phased out and replaced by the auction system, which was introduced by the Renewable Energy Sources Act in 2016.

The Polish government requires to electricity trading companies to buy energy from renewable sources. Renewable energy producers have priority access to the transmission grid and, the grid connection fee is reduced by 50% for small installations (<5MW). (Polish Investment & Trade Agency, 2020)

It is considered that one of the obstacles for the development of onshore wind energy is a regulation that stipulates that wind turbines cannot be built within 2km of other buildings or forests. The government plans to make changes to the regulation in order to increase the development of wind energy. (International Trade Administration, 2022)

5.4.2 Energy sector data

The coal electricity production went from 96% in 1990 to around 69% in 2020. From 2010 the country started to develop wind energy, in 2020 this energy represented 10% of the total. The production of hydroelectricity has remained stable since the 90s.

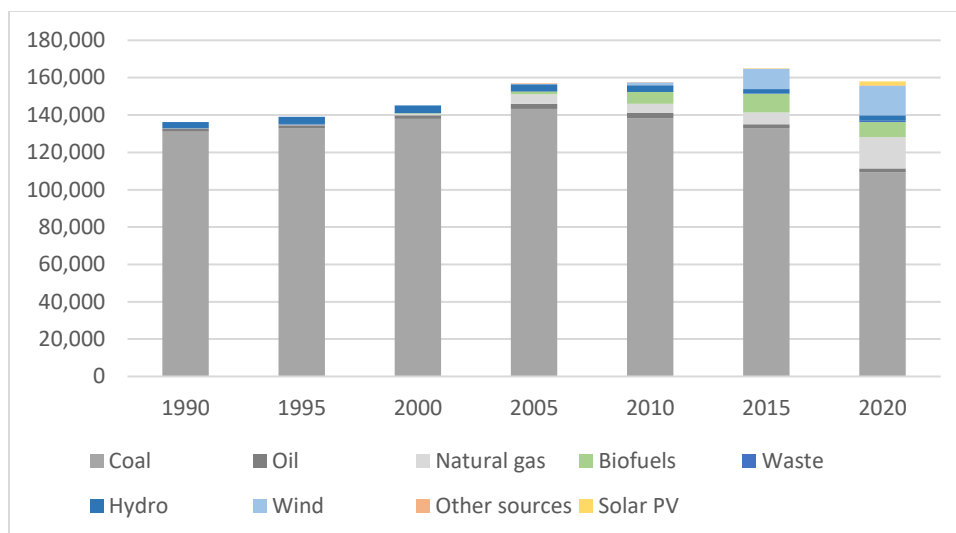


Figure 13. Trend of net production of electricity for Poland in GWh

Source: Own elaboration with IEA data

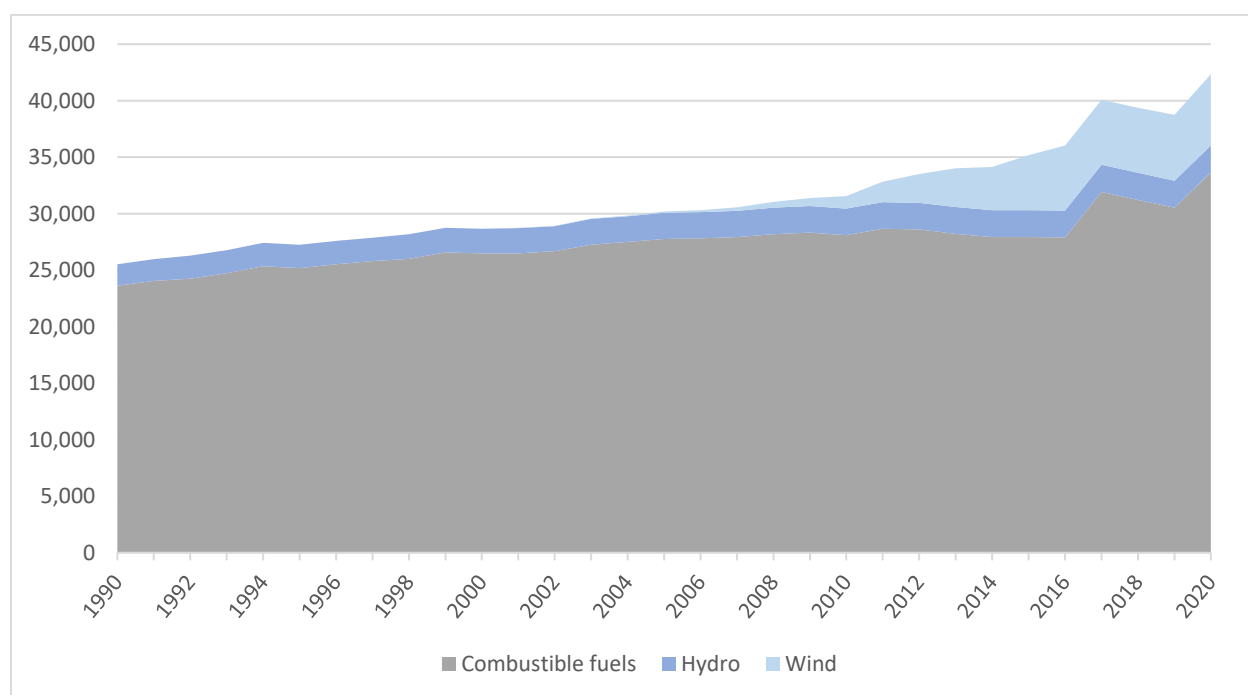


Figure 14. Electricity production capacities for Poland in MW

Source: Own elaboration with Eurostat data

5.4.3 National energy and climate plan

The target share of renewable energy in gross final energy consumption is 21-23%.

The European Commission recommended an increase in the share of renewable energy in final gross energy consumption to 25% in 2030; however, Poland assessed this target as too ambitious, taking into account national circumstances and the development of energy transition and social aspects. Poland makes emphasis that the target of 21-23% for RES, will be possible if the country is granted additional EU funds, including the ones addressed to a Just Transformation. The scale of the use of renewable sources will depend on the technological progress in terms of generation methods and storage technologies.

In terms of generation of electricity, the share of renewable energy sources is expected to increase from 14% to 32%. It is needed to expand the transmission network to allow the use of renewable sources. Support will vary according to the source; this support includes priority access to the network, auctions, feed-in tariff, feed-in premium and guarantees of origin.

Energy security is a priority for the country, the government states that given the domestic hard coal and lignite deposits, it is expected that coal generation will be key to guarantee a stable supply. In addition, Poland plans to put its first nuclear power plant in place for 2033. The country analyzed the national uranium deposits, which concluded that Poland does not have industrial quantities of uranium in conventional deposits, but there is unconventional deposit potential.

Poland plans to maintain coal with a leading role in the energy structure. However, it intends to reduce gradually the percentage share of this fuel in the energy mix, down to approximately 56–60% in 2030, in 2018 the production with coal/lignite share was 77%. The demand for coal will be met by domestic resources, however imported coal can be used as supplementary source. To maintain energy independence, the country will diversify the energy mix and diversify suppliers of imported fuel, which means that, it will to develop infrastructure for crude oil and natural gas.

Poland plans to increase the expenditure on research and innovation from 0.75% of GDP to 2.5% in 2030. The direction for research and development related to climate issues are focused on new energy technologies, modern materials technologies and natural environment, agriculture and forestry.

Minimizing the social costs that go in line with a low-carbon economy is essential. The pace of the energy transition must be adapted to the economic and financial capacities of mining regions.

Poland emphasizes that it is crucial to increase the EU funds to the regions dedicated to coal and lignite production, in order to minimize socio-economic effects. The Government will develop, along with the EU, financial instruments that support the energy transition, to ensure that funds are directed to the regions that depend on mining employment.

Investment needs

The Energy related Capex in the National Economy, is around EUR 452 billion to 2040. In the electricity sector, expenses include the construction and modernization of the generation sector, and the transmission and distribution network; forecast includes heating, gas, liquid and mining sectors. The forecast requires around EUR 50 billion per 5-year periods, and amounts to a total of EUR 245 billion by 2040.

5.5 Energy Security

The Russian invasion of Ukraine has brought concerns about Europe's energy security on the short and long-term. The invasion also raises concerns about Europe's environmental goals and achievements, and how Member States will be affected giving its reliance on Russian resources.

The IEA defines energy security as the uninterrupted availability of energy sources at an affordable price. Long-term energy security mainly deals with timely investments to supply energy according to the environmental and economic needs. Short-term energy security refers to the ability of the energy system to react promptly to changes in the supply-demand balance. (IEA, 2022)

One can expect that this will affect the national energy and climate plans in the short and long term. Some countries are more affected according to the dependence they may have on Russian sources. For this reason as of June 2022, the actions taken by the countries analyzed in this work, in terms of energy security, are briefly shown.

Germany

Some countries of the European Union announced they are weaning themselves off Russian fossil fuel supplies, and Germany is one of them.

Germany is heavily dependent on Russian natural gas and currently has no LNG terminal of its own. Germany was in favor of the Nord Stream 2 project, an underwater pipeline that aimed to transport natural gas directly from Russia to Germany. However, after the invasion, Germany suspended the certification process of the natural gas pipeline Nord Stream 2.

Russia started to cut supplies to European countries. Gazprom, the Russian gas company, reduced the supplies via the Nord Stream 1 pipeline that runs from Russia to Germany under the Baltic Sea. This has affected Germany's energy security. Germany's government announced that they would return to coal-fired power plant to prevent shortages in the winter.

After approximately one month after the Russia's invasion on Ukraine, Germany declared the first phase of its Emergency Plan, follows EU Regulation No 2017/1938.

In June 2022, Germany announced that it will move to stage two of its three-stage emergency plan. This alert phase is triggered "where a disruption of gas supply or exceptionally high gas demand which results in significant deterioration of the gas supply situation occurs but the market is still able to manage that disruption or demand without the need to resort to non-market-based measures". (Federal Ministry for Economic Affairs and Energy, 2019)

The Emergency Plan for Gas defines three crisis levels: early warning level, alert level and emergency level. The emergency level is triggered when all relevant market-based measures have been implemented but the gas supply is insufficient to meet the gas demand. (Federal Ministry for Economic Affairs and Energy, 2019)

In the early warning and alert level, the market players act on their own responsibility to overcome the supply bottlenecks. Whereas in the emergency level, there is a need to resort to state intervention.

France

On June 2022, France states that is no longer receiving any natural gas from Russia, due to the reduction of gas supplies via Nord Stream 1 pipeline.

Previously, France considered to expand its gas infrastructure through new gas pipelines between Spain and France. Currently this plan has gained momentum in order to strengthen Europe's energy security, and to seek independence from Russia.

Belgium

Belgium is a 100% importer of natural gas. However, Belgium's strength is that it is very well connected with neighboring networks. In addition, it has the advantage that it is not very dependent on Russian gas. To transport gas, Belgium has border interconnection points with the Netherlands, Norway, the UK, Germany, France and Luxembourg, as well as the port of Zeebrugge through which liquefied natural gas (LNG) is imported.

As of May 2022, the government stated that there were no elements to announce the first 'Early Warning' phase of the national Emergency Plan for Natural Gas in Belgium. However, in April Belgium updated the emergency plan considering the input of companies that will further refine the concrete measures.

Belgium was committed to phase out from nuclear electricity generation by 2025, however in light of the goals to reduce fossil fuel dependency due to the invasion, the Federal Government decided to extend 2 GW of nuclear energy by ten years, and introduced a 1.2 billion package to accelerate energy transition and protect consumer from high energy prices. (IEA, 2022)

Poland

In April 2022, Gazprom halted gas supplies to Poland for the refusal to pay for gas in rubles, which is the currency unit of Russia. However, the government announced that it did not represent a threat of shortages for the country because they have sought alternative sources.

Poland terminated the agreement on the Yamal gas pipeline, which was a gas pipeline system for the transit of Russian gas through Poland. Russia violated the agreement by cutting off supplies, therefore the government decided that due to the violation, the agreement ceased to apply. (Ministry of Climate and Environment, 2022)

The government stated that Russia's invasion has affected various aspects of its energy policy, and results in the need of changing the approach to guarantee energy security, in terms of greater diversification and independence. On March 2022, the Council of Ministers adopted the principles to update the Energy Policy, with the aim of strengthening energy security and independence (Ministry of Climate and Environment, 2022). For the short term, Poland is enhancing its energy security, by improving its capacity to import natural gas from Norway through Baltic, importing Liquefied Natural Gas, and expanding their gas storage capacity. The country states that moving away from Russia is possible, but it will have significant impact on costs and prices.

5.6 Analysis

Germany aims to keep including renewable energy in its electricity matrix. The country has already experienced the challenges of the intermittency observe with renewable sources, therefore they put emphasis on the integration of the EU market.

France has used several financial mechanisms to promote capital flows in the electricity sector. The use of Competitive Dialogue and Crowdfunding are interesting mechanisms that can bring changes to the sector.

In Belgium, 75% of the electricity is generated by the same organization; this raises doubts about the existence of real competition in the sector and about the incentives implemented.

Poland's vision is different from the other countries analyzed, the country pays special attention to minimizing social costs due to the transition. Being a country with non-renewable sources gives a different perspective, given that the economic dependence on the management of fossil resources makes the transition more difficult as increases the financial burden on people. However, from around 2010 the country started to show increments in wind generation and aims to lower its emissions as stated in the NECP.

The challenges that the war in Ukraine has brought in terms of energy security may seem to reduce the importance of the energy transition. However, this is another reason to push renewable technologies in order to reduce dependency on non-renewable sources.

6 Statistical analysis of the electricity matrix per investment

To evaluate the existence of influence on the installed capacity for energy generation from the incentive structures described in this work, a statistical analysis for the Feed-In-Tariff and EIB Financing is developed. While several statistical analyses can be found in a per-country basis in other studies, this study is developed for several countries in the European Union at once, including the countries selected and explained in the previous section.

For the statistical tests to develop, the null hypothesis is that none of the variables used as input (except the existing capacity for previous years) have a relationship to the production capacity of a given year. The alternative hypothesis to be evaluated is whether inputs, and especially for our purposes, the Feed-in Tariff and EIB financing of previous years, have an effect on present installed capacity from renewable sources.

6.1 Methodology

6.1.1 System Identification

While System Identification theory is used for problems with large input-output sequences, like mechanical and electrical systems, their methods can be applied to social and economic systems as well. For this analysis, the structure for a Linear Time Invariant (LTI) model is defined, where the response of a system using a linear combination of inputs and state variables, with response functions that are not affected by time shifts, for a discrete time system, as:

$$\begin{aligned} x(t+1) &= A X(t) + B U(t) \\ y(t) &= C X(t) + D U(t) \end{aligned}$$

Where t is time, $y(k)$ represents the output at time k , variables $x_1(k), x_2(k), \dots \in X(k)$ describe the state of the system at time k , and variables $U_1(k), U_2(k), \dots \in U(k)$ describe the inputs of the system. Matrixes A, B, C , and D represent the parameters that define the linear relationships between inputs, states and outputs. For this study, we assume a system with one output and several inputs.

As all functions are linear, this model can be expressed as a convolution (where the effects of previous inputs are transferred directly to the output, instead of to state variables). If $G(q)$ is a function of the backward shift operator $q^{-1}u(t) = u(t - 1)$, the model can be expressed as:

$$y(t) = G(q) U(t) = \sum_{k=0}^t g(k) U(t - k)$$

$$y(t) = g(0)U(t) + g(1)U(t - 1) + g(2)U(t - 2) + \dots$$

Where $g(0), g(1), \dots$ are the coefficients of the shifted (or lagged) inputs, corresponding to the elements of $G(q)$.

In these models, the output is exactly modelled by a linear combination of inputs. If a Gaussian noise term $e(t)$ is included, to account for the misfit between output measurements and model output, three types of basic LTI models for dynamic system identification can be described:

- The Autoregressive model (AR), where a function of the backward shift operator, $A(q)$ affects the output, to represent that a linear combination of the current and previous outputs can be modelled via a noise or error variable. The main assumption is that the previous state of the output will explain part of its present state:

$$A(q)y(t) = e(t) \rightarrow y(t) = e(t)/A(q)$$

- The Convolution, or Finite Impulse Response model (FIR), where the output is a function of a set of inputs modified by a backward shift operator function $B(q)$, and the error term. In this model, the output is a function of the input and previous inputs:

$$y(t) = B(q)u(t) + e(t)$$

- The Autoregressive exogenous model (ARX), where we combine the definition of the AR and FIR models, and the convolution of the output is a function of a convolution of inputs and the error term:

$$A(q)y(t) = B(q)u(t) + e(t) \rightarrow y(t) = \frac{B(q)}{A(q)}U(t) + \frac{e(t)}{A(q)}$$

$$y(t) + a_1y(t - 1) + a_2y(t - 2) + \dots = b_0U(t) + b_1U(t - 1) + \dots + e(t)$$

This last model will be used for the analysis in this study. Note that each b_t variable represents a vector, as several inputs are present in the analysis for each moment in time. (Keesman, 2011) (Ljung, 1999)

6.1.2 Generalized Linear Models

In a generalized linear model, it is assumed that a response variable belongs to an exponential family, and hence can be modelled through (McCullagh & Nelder, 1989):

$$f(x_i, \theta_i, \phi) = \exp \left(\frac{x_i \theta_i - b(\theta_i)}{a(\phi)} + c(x_i, \phi) \right)$$

In this analysis, it is assumed that the error term is normally distributed, implying a generalized linear model of the Gaussian family can be used (equivalent to a linear regression with square residual penalty) to describe the behavior of the output. Combining this description with the ARX model described in the previous section, the model can be represented as:

$$a_1 y(t-1) + a_2 y(t-2) + \dots + b_0 U(t) + b_1 U(t-1) + \dots = y(t) - e(t)$$

Assuming that 100 datapoints are used to input data into the model, that a convolution function for the output of $n = 3$ terms is used, and that a convolution function for the inputs of $m = 4$ terms is used, while not allowing current inputs to immediately affect the output ($l = 1$), the matrix representation of the formulation, where time is shown as a subscript ($y(t) = y_t$), becomes:

$$\begin{bmatrix} y_3 & y_2 & y_1 & U_3 & U_2 & U_1 & U_0 \\ y_4 & y_3 & y_2 & U_4 & U_3 & U_2 & U_1 \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ y_{99} & y_{98} & y_{97} & U_{99} & U_{98} & U_{97} & U_{96} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ b_0 \\ b_1 \\ b_2 \\ b_3 \end{bmatrix} = \begin{bmatrix} y_4 \\ y_5 \\ \dots \\ y_{100} \end{bmatrix} - \begin{bmatrix} e_4 \\ e_5 \\ \dots \\ e_{100} \end{bmatrix}$$

$\begin{matrix} A & & & & & & \\ & x & & & & & \end{matrix}$

Where the solution for the parameters $a_1, a_2, a_3, b_0, b_1, b_2, b_3$ can be obtained via Least Squares, optimizing for a minimization of the squared error terms.

6.1.3 Model Selection

As several possible combinations of inputs, lagged inputs and lagged outputs are considered for the full model, it becomes relevant to have a tool to compare the resulting models to choose one in which the variables used to describe the behavior of the output are sufficiently relevant.

This sufficiency is evaluated using Aikake's Information Criterion (AIC), in which the likelihood that a model generated the observed data is added to a penalty for the amount of variables used, to prevent model overfitting. This formulation results in a balance between a good fit (high loglikelihood), and complexity (as more complex models are penalized more than simple ones). The model with the lowest AIC value will be selected.

6.2 Data description

The variable of interest for the analysis, equivalent to the output of the model (y_k) will be the Production Capacity (Power, in MW) for each energy source for selected countries. The countries included in the study are Belgium, France, Germany and Poland (analyzed in the previous section), and Italy, The Netherlands, Greece and Denmark (added to provide consistency to the statistical results); the latter group was chosen as they had relevant historic behavior for the Feed-in-Tariff mechanism. For the autoregressive component of the model, the two previous periods of Production Capacity will be considered. Capacity for each country is obtained from Eurostat (Electricity production capacities by main fuel groups and operators). (European Commission, 2022)

Data is separated in records per country, energy source, and year. The energy sources considered are Hydro, Solar (Solar Photovoltaic and Thermal are combined), Wind, and Tide/Wave/Ocean, as defined by the Standard international energy product classification (SIEC). The analysis is performed with yearly data from 2003 to 2020.

Several inputs are included for the model; all of them being shifted at least one period. Data on the Feed-in-Tariff and the total loans from the EIB are added to confirm that they produce a statistically significant effect in Production Capacity; market prices for Coal, Crude Oil and Natural Gas are added as control variables:

- Average Feed-In-Tariff (USD/kWh): FITs values across countries, years and renewable energy sub-sector, obtained from the Organization for Economic Co-operation and Development (OECD, 2020), $m = 5$ lagged terms are used.
- Total EIB Loans (EUR): Projects financed by the EIB for the energy sector, obtained from the European Investment Bank (EIB, 2022), $m = 6$ lagged terms are used.
- Average Coal Price (\$ per Metric Ton): Australian coal (index mundi, 2022), $m = 2$ lagged terms are used.
- Average Crude Oil Price (\$ per barrel): Basket price obtained from the Organization of the Petroleum Exporting Countries (OPEC, 2022), $m = 2$ lagged terms are used.
- Average Natural Gas Price (\$): Henry Hub natural gas prices obtained from macrotrends (macrotrends, 2022), $m = 2$ lagged terms are used.
- Year: While the year describes the source of the data, it is also added as an input variable, in case a trend can be explained directly by time.

6.3 Process

The lagged variables are processed and added to a dataset with the Production Capacity for each country, energy source, and year in the study. Using Statistical Software, two extreme models are generated: a constant model (where the mean is used as a prediction function), and a full generalized linear model of the Gaussian family, including all the lagged terms for all variables described in the previous subsection. These models are fed into a step function, which iterates over different combinations of variables to identify the option with the lowest AIC value, optimizing for good fit and simplicity.

Country information and energy source were not used as input variables for the generalized linear model, expecting that Production Capacity can be calculated without using this information. The model selection procedure ensures that variables which produce a penalty that is larger than the additional predictive capacity they provide are not included, leaving only relevant variables in the resulting model.

6.4 Results

6.4.1 Results for Selected European Countries

At the level of the 8 countries studied, the Generalized Linear Model with the lowest AIC results in:

$$\begin{aligned} Capacity_k \sim & Int + a_1 Capacity_{k-1} + a_2 Capacity_{k-2} + b_2^F FIT_{k-2} + b_1^L Loans_{k-1} \\ & + b_2^L Loans_{k-2} + b_2^O Crude_{k-2} \end{aligned}$$

The coefficients a_t, b_t^U , the intercept and their statistical significance are shown in the following table:

Variable	Coefficient	Estimate	Std. Error	t-Value	P-Value	Significance
<i>Intercept</i>	<i>Int</i>	71.07	57.45	1.237	0.2165	
<i>Capacity_{k-1}</i>	<i>a₁</i>	1.741	$2.86 \cdot 10^{-2}$	60.85	$< 2 \cdot 10^{-16}$	***
<i>Capacity_{k-2}</i>	<i>a₂</i>	-0.736	$3.01 \cdot 10^{-2}$	-24.50	$< 2 \cdot 10^{-16}$	***
<i>FIT_{k-2}</i>	<i>b₂^F</i>	802.8	160.6	4.998	$7.72 \cdot 10^{-7}$	***
<i>Loans_{k-1}</i>	<i>b₁^L</i>	$1.168 \cdot 10^{-6}$	$3.292 \cdot 10^{-7}$	3.549	$4.18 \cdot 10^{-4}$	***
<i>Loans_{k-2}</i>	<i>b₂^L</i>	$7.081 \cdot 10^{-7}$	$3.357 \cdot 10^{-7}$	2.110	0.0353	*
<i>Crude_{k-2}</i>	<i>b₂^O</i>	-1.453	0.837	-1.735	0.0832	.

Statistical Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The adjusted R-squared values for this model are 0.9970, implying a highly predictive capacity. Most of the predictive capacity arises from the autoregressive component of the model, but an increase in AIC and adjusted R-squared values when including lagged FIT values, lagged Total Loans and Crude Oil prices are observed.

Of the input variables in the table above, only Crude Oil prices cannot be concluded to be significant according to a significance level of 5%. Feed-In-Tariffs and EIB Loans are shown to provide positive influence in future production capacity, as reflected by their coefficients' positive estimated values.

6.4.2 Results for Germany

Following (Leepa & Unfried, 2013), a similar study is performed using only data corresponding to Germany, which analyzed the FIT system for photovoltaic power.

The Generalized Linear Model with the lowest AIC is:

$$\begin{aligned} Capacity_k \sim & Int + a_1 Capacity_{k-1} + a_2 Capacity_{k-2} + b_3^L Loans_{k-3} + b_4^F Fit_{k-4} \\ & + b_4^L Loans_{k-4} + b_2^O Crude_{k-2} + b_1^C Coal_{k-1} \end{aligned}$$

Variable	Coefficient	Estimate	Std. Error	t-Value	P-Value	Significance
<i>Intercept</i>	<i>Int</i>	184.1	312.8	0.589	0.5582	
<i>Capacity_{k-1}</i>	<i>a₁</i>	1.626	$8.96 \cdot 10^{-2}$	18.16	$< 2 \cdot 10^{-16}$	***
<i>Capacity_{k-2}</i>	<i>a₂</i>	-0.623	$9.27 \cdot 10^{-2}$	-6.72	$5.88 \cdot 10^{-9}$	***
<i>Loans_{k-3}</i>	<i>b₃^L</i>	$8.330 \cdot 10^{-6}$	$1.453 \cdot 10^{-6}$	5.734	$2.88 \cdot 10^{-7}$	***
<i>FIT_{k-4}</i>	<i>b₄^F</i>	3,177	878.7	3.615	$5.92 \cdot 10^{-4}$	***
<i>Loans_{k-4}</i>	<i>b₄^L</i>	$-4.590 \cdot 10^{-6}$	$1.614 \cdot 10^{-6}$	-2.844	$5.98 \cdot 10^{-3}$	**
<i>Crude_{k-2}</i>	<i>b₂^O</i>	-11.74	4.334	-2.709	$8.65 \cdot 10^{-3}$	**
<i>Coal_{k-1}</i>	<i>b₁^C</i>	7.443	4.185	1.778	0.0800	.

Statistical Significance codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

The Adjusted R-squared for this model is 0.9977. Similar to the analysis for the selected countries in the EU, the lagged values for FIT and EIB Loans are shown to be significant to describe the production capacity in Germany. The Price of Crude Oil also appears to have significance, while the price for Coal is present in the model, but cannot be concluded to be significant for the model.

6.5 Analysis

The results imply that the null hypothesis is to be rejected. The study provides a clear conclusion that there is a statistical relationship between changes in capacity for renewable energy sources and the analyzed incentives: Feed In Tariffs, and EIB Loans; the amount of productive capacity for a given country can be predicted with higher accuracy when using these data (and the existing capacity) than without considering it.

This analysis does not ensure the efficacy of the measures studied, as their influence on production capacity can be related to a different underlying variable that was not included as an input, but is a good indicator that countries that prioritize incentives for renewable energies are shown to increase their production capacity in these energy sources.

For example, the higher estimate for the coefficient related to lagged FIT can be assimilated to a higher efficiency of the mechanism for Germany; if the models shown in this study are assumed to adequately reflect reality, the results imply that for each 1.00 USD Tariff added in the selected countries in Europe, 802.8MW of Production Capacity were added, while this value for Germany is 3,177MW. However, this result can be a limitation of the additive model, as incentives are expected to produce capacity changes in relation to a country's size (in electricity supply or demand); a model in which inputs affect multiplicatively could be better suited for this type of analysis.

7 Conclusions

Decision-making process for investing in the electricity sector

It is expected that the private sector will lead most of the investments to be done in the electricity sector. The need for private capital draws attention to how to make energy projects more attractive to private investors.

The final decision-making for investing in a project is the result of a cost-benefit analysis; this is dependent on the project risk and on its projected profit. As detailed on previous chapters, many factors affect the overall risk of an electric power project.

One of the biggest risks investors face is regulatory risk. The harmonization of national policies is important to give confidence to investors, as this allows for the understanding of the rules and avoids the analysis and cost of changing rules. Certainly, no incentive is sufficient if the permitting processes are confusing and full of bottlenecks, resulting in stranded costs and making the project even more expensive, or resulting in the potential producer avoiding projects in the sector. As mentioned previously, the principles of complementary, transparency and adaptability play a crucial role in the energy policies.

The technology risks are as well one of the main challenges investors face. The maturity of a technology dictates the level of confidence an investor can have in certain technologies. However, to reach certain level of maturity, the implementation of projects is required to attain experience and identify possible improvements, hence this implementation needs to be incentivized.

Financial and market risk, including the revenue risk, level of competition and high up-front investments, certainly are other factors that play a huge role in the decision-making process. All of these aspects have a significant influence on the final cost of capital and impact the Net Present Value of the analyzed project.

Energy transition and energy security

The energy transition has to be guided by the governments in order to attract investments according to the energy national plans. The European Union budget and the national budgets for research and innovation are important tools to promote and guide later private investments.

The targets regarding renewable energy penetration in the electricity system has brought concerns about energy security. Several aspects are important in terms of energy security with intermittent generation such as, storage, diversification of the electricity mix, integration of Europe Market and flexible plants available for back-up generation. These aspects need to be considered in the national plans to attain a reliable system and a successful transition.

Diversification of suppliers is as well important to maintain a secure system; this problem has become present with the Russia's invasion over Ukraine. Reducing the dependence on fossil resources from Russia is now a priority and it will influence the NECP of some countries of the European Union, as they will stop importing resources from Russia. Poland already stated that it will adapt its national plan as a result of the current crisis, and Germany's energy national plan will certainly be adapted as they are highly dependent on Russia's resources.

The plans related to the energy transition differ for the four countries analyzed. Poland pays special attention to the economic capacity of the country given that it is an economy that is highly dependent on coal, and it will replace annual coal production at a very small percentage. In addition, it emphasizes that it depends on EU funding to integrate RES in its system.

Germany aims to keep increasing the share of RES in its power system and plans to back-up the intermittent generation with gas facilities, however these plans may change due to the current situation with Russia. Germany is facing important challenges as result of their dependency on Russia's resources. The country depends on European integration in terms of energy security.

France aims to continue developing nuclear power by developing small nuclear reactors. In terms of energy security, the country has a flexible system that can manage the integration of RES.

Belgium states that it is necessary to have technical expertise in the structuration of public-private partnerships and additionally states that there is a lack of knowledge on how to use European funding, which can be an important barrier for the transition.

Sustainable finance policies

Through the review of the policies emitted by the European Union and the actions recommended by the designated technical groups promoting sustainable finance, it can be seen that there is a great interest in including opinions from different sectors to have a holistic view of the actions needed.

Clarifying institutions investors' and assets managers' duties can be helpful to open up the opportunity for investment institutions to participate in projects regarding the energy transition, and therefore increase capital flows towards electric power projects. However, this is highly dependent on the risk of the projects and on the policies of the investment institutions.

The taxonomy is elaborated with an interesting approach since it considers and compares the effect that an activity produces on the different established environmental objectives. Currently it is highly debated if the current activities accepted as sustainable activities will help or hinder the energy transition.

Other actions to foster sustainable finance proposed by the EU are more focused on standards and labeling, and disclosures and benchmarks, however it can be argued if this will influence the energy transition as prompt as it is required. Nonetheless, promoting transparency and long-termism in the financial sector is crucial to implement gradual changes for the energy transition.

To incentivize capital flows towards sustainable projects in the power sector, the implementation of specific support schemes are definitely necessary.

Support schemes

To boost investments for the energy transition it is necessary to reduce the risks of the private investors. The adoption of mechanisms that guarantee a level of income for a period of time, reduce the cost of capital, certainty of existence of buyers, simplify permit procedures are some ways of reducing the risk.

The effectiveness of a support scheme is highly dependent on the adoption of the appropriate scheme according to the maturity of the technology, competition will only exist when the technology is mature enough. The experience tells us that monitoring the development of the technologies is important to be able to adapt the support scheme at an appropriate time in order to avoid that certain actors gain exaggerated profits at the expense of the people. The effectiveness of a support scheme is also related to not treating the technologies equally since this will not promote diversification.

Quantitative analysis Feed-in Tariff and European Investment Bank Funding

The quantitative analysis conducted in this work tell us that changes in installed capacity of renewable energy sources can be explained as a function of the analyzed incentives: Feed In Tariffs, and EIB Loans; these incentives can be used to better predict the changes in the installed capacity of a country.

As the analysis concluded that EIB loans are significant to explain the changes in capacity for renewable sources, the involvement of the European Union in the energy transition is key to achieving the established goals at the right time. This also implies that lowering costs of financing and improving access to credit (the main advantages provided by the EIB) are adequate tools to ease a transition towards sustainability.

How to foster sustainable finance for the energy transition

As the sustainable finance actions and policies stand today, they are not enough to incentivize capital flows sufficiently towards energy transition projects, as these do not attack the barriers to invest in energy transition. The defined actions do not considered many aspects of the energy sector, hence they will not have a significant impact in promoting the transition.

The path each country take will be in line with its national characteristics regarding some of the following subjects:

- Economy: the affordability to implement changes for energy transition.
- National resources: renewable and non-renewable resources of a country will take part of the cost-benefit analysis of implementing changes.
- Grid: the capacity of the grid of include renewable energies and the investments needed.
- Interconnection: how well connected is the country from the rest of the member states.
- Permits and procedures: how simplified are the permits and procedures for the implementation of energy projects.

Guidelines at EU-level on how to attack the barriers of the energy sector according to the national characteristics are necessary for the implementation of national policies and support schemes.

Certainly, wealthier countries are the ones who should guide the implementation of changes towards a clean energy system since they can bear the costs of learning, as well as the investments in research and innovation, in which coordination between Member States is necessary. The public sector has to invest on the riskiest projects to lead the changes on the expected paths, in the cases where private sector is not willing. Exaggerated incentives for the private sector will not bring a proper transition, since it will cause these investors to gain increased profits for the risk they are taking; therefore, a direct participation of public sector has to be implemented.

As mentioned previously, making energy transition investments attractive to private investors requires reduction of risk. The use of financial tools that address these risks will have an impact, i.e. implementation of guarantees, co-financing by the state, implementation of technical assistance, use of grants for the more risky projects, and use of support schemes. Transaction costs, facilities to obtain land permits, facilities dedicated to the use of EU funds, standardization of processes wherever possible, and guidance for the coordination of inter-nations projects, are as well important for the promotion of energy projects.

The Feed-in Tariff scheme can be used for the energy transition by encouraging generation technologies that are not mature enough, as well as encouraging aspects related to energy security. Because of the attained maturity of solar and onshore technology, it would be recommended to use other schemes as tenders and PPAs.

The use of quota-based scheme for photovoltaic systems should go in line with gradual predefined targets for this technology. Reliance on too widely distributed generation by installation of solar panels can bring challenges for the management of the system and may hinder people with less income if the payment scheme is not well designed.

As seen throughout this work, a proper energy transition requires much more than just focusing on support schemes to promote generation of energy from renewable sources; to foster sustainable finance for energy transition requires the alignment of the different aspects that are involved in the sector.

8 Limitations

For the quantitative analysis, obtaining historical information was an important limitation to analyze other support schemes; for example, quota-based systems could not be analyzed as their information is limited and their implementation differs for distinct countries.

The study done does not explain the effectiveness of the support mechanism. It does not tell either if the mechanism analyzed is the cause of the effects seen in installed capacity, as there can be other variables in parallel, not analyzed in this study, which influenced the changes in the energy mix. The positive effects in present installed capacity may be the results of all the efforts done by the countries to promote renewable energy, including feed-in tariff scheme and EIB loans. A more detailed analysis is required if an accurate predictive function for production capacity is intended.

This work does not include interviews to representatives of the energy and finance sectors, which could bring important updated insights about challenges and opportunities to foster sustainable finance for the energy transition.

9 Further development

This thesis highlights the need for further development for several researches, since many aspects can have an influence in the transition.

An interesting study could be related to the appropriate design of the support schemes, how the countries have modified the applied schemes in accordance with technology improvements and resulting costs.

Given the importance of Research and Innovation, studying how the funds for this purpose have been used and the results obtained, can bring awareness of the challenges and the opportunities for improvement. Other technical studies are also needed to analyze in more detail some key aspects of the sector, such as the grid and the interconnection between countries of the European Union, and additional improvements in technology regarding production of electricity and storage could be studied.

Another relevant study could be a meta-analysis of the impact of policies from years prior to those analyzed in this work, with the aim of evaluating the policies emitted and actions developed to promote previous energy transitions throughout history.

Finally, a study of private investments in different sectors to analyze the flows of capital towards projects, analyzing the opportunities seen by investors, available incentives, the risks that private investors are taking, and how this can be carried over into the energy sector, could improve the understanding of sustainable finance policies.

10 Bibliography

- ADEME. (2022). *The French Agency for Ecological Transition*. Retrieved from ademe.fr: <https://www.ademe.fr/en/our-missions/support-and-mobilise/>
- Agora Energiewende. (2019). *European Energy Transition 2030: The Big Picture*.
- Butler, L., & Neuhoﬀ, K. (2008). Comparison of feed-in tariff, quota and auction mechanisms to support wind power development. *Elsevier. ScienceDirect*, 1854-1867.
- Climate Policy Database. (2002). *Green certificates scheme (Wallonia)*. Retrieved from climatepolicydatabase: <https://climatepolicydatabase.org/policies/green-certificates-scheme-wallonia>
- Climate Policy Database. (2022). *Green Certificates Scheme (Flanders)*. Retrieved from climatepolicydatabase: <https://climatepolicydatabase.org/policies/green-certificates-scheme-flanders>
- CMS. (2022). *Electricity Law and Regulation in Poland*. Retrieved from cms.law: <https://cms.law/en/int/expert-guides/cms-expert-guide-to-electricity/poland>
- Commission de Régulation de l'Électricité et du Gaz. (2018). *Comment devenir Producteur?* Retrieved from creg.be: <https://www.creg.be/fr/professionnels/production/comment-devenir-producteur>
- Commission Delegated. (2022). Amending Delegated Regulation (EU) 2021/2139 as regards economic activities in certain energy sectors and Delegated Regulation 2021/2178 as regards specific public disclosures for those economic activities.
- Commission Delegated Regulation. (2021, 12 09). Supplementing Regulation (EU) 2020/852 of the Parliament and Council by establishing the technical screening criteria for determining conditions under which an activity qualifies as contributing substantially to climate change mitigation or adaptation. *Official Journal of the European Union*, L 442/1.
- Commission Delegated Regulation. (2021). Supplementing Regulation EU 2020/852 of the European Parliament and the Council by specifying the content and the presentation of information to be disclosed by undertakings. 2021/2178. *Official Journal of the European Union*, L 443/9.
- Couture, T., & Gagnon, Y. (2010). An analysis of feed-in tariff remuneration models: Implications for renewable energy investment. *Energy Policy*, 955-965.
- CREG. (2021). *Annual Report 2021*.
- De Groote, O., Gautier, A., & Verboven, F. (2022). *The political economy of financing climate policy - Evidence from the solar PV subsidy programs*. Toulouse.

- Del Río González, P. (2008). Ten years of renewable electricity policies in Spain: An analysis of successive feed-in tariff reforms. *Elsevier, Energy Policy*, 2917 - 2929.
- Directorate General for Financial Stability, Financial Services and Capital Markets Union. (2021, 07 06). *Strategy for financing the transition to a sustainable economy*. Retrieved from ec.europa.eu: https://ec.europa.eu/info/publications/210706-sustainable-finance-strategy_en
- Drechsler, M., Meyerhoff, J., & Ohl, C. (2012). The effect of feed-in tariffs on the production cost and the landscape externalities of wind power generation in West Saxony, Germany. *Elsevier. Energy Policy*, 730-736.
- EIB. (2022). *Financed projects*. Retrieved from eib.org: <https://www.eib.org/en/projects/loans/index.htm?q=&sortColumn=loanParts.loanPartStatus.statusDate&sortDir=desc&pageNumber=0&itemPerPage=25&pageable=true&language=EN&defaultLanguage=EN&loanPartYearFrom=1959&loanPartYearTo=2019&countries.region=1&orCountry>
- Energy Policy Tracker. (2022). *Energy Policy Tracker Methodology*. Retrieved from Energypolicytracker.org: <https://www.energypolicytracker.org/methodology/>
- Energy Policy Tracker. (2022, 03 30). *European Investment Bank (EIB)*. Retrieved from Energypolicytracker.org: <https://www.energypolicytracker.org/institution/european-investment-bank-eib/>
- EU High-Level Expert Group on Sustainable Finance. (2018). *Financing a Sustainable European Economy*.
- EU Technical Expert Group on Sustainable Finance. (2019). *Report on Benchmarks*.
- EU Technical Expert Group on Sustainable Finance. (2019). *Report on EU Green Bond Standard*. .
- EU Technical Expert Group on Sustainable Finance. (2020). *Technical Report. Taxonomy: Final report of the Technical Expert Group on Sustainable Finance*. Brussels.
- European Commission - Press release. (2021). *European Green Deal: Commission proposes transformation of EU economy*.
- European Commission. (2009, 04 23). Directive 2009/28/EC of The European Parliament and of The Council . *Promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC*. Brussels: Official Journal of the European Union.
- European Commission. (2013). *European Commission guidance for the design of renewables support schemes*. Brussels.
- European Commission. (2018, 03 08). Commuincation from the Commission to the European Parliament, The European Council, The Council, The European Central Bank, The European Economic and Social Committee COM(2018) 97 final. *Action Plan: Financing Sustainable Growth*. Brussels.

European Commission. (2019). Guidelines on non-financial reporting: Supplement on reporting climate-related information. *Official Journal of the European Union*, C 209/1.

European Commission. (2020, 07 08). Communication from the Commission to The European Parliament, The Council, The European Economic and Social Committee and The Committee of the Regions. COM (2020) 301 final. . *A hydrogen strategy for a climate-neutral Europe*. Brussels.

European Commission. (2020, 11 19). Communication from the Commission to The European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions. COM(2020) 741 final. SWD (2020) 273 final. *An EU strategy to harness the potential of offshore renewable energy for a climate neutral future*. Brussels.

European Commission. (2020, 07 08). Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee and The Committee of the regions. COM (2020) 299 final. . *Powering a climate-neutral economy: An EU Strategy for Energy System Integration*. Brussels.

European Commission. (2020). *EU funding programmes 2014-2020*. Retrieved from ec.europa.eu: https://ec.europa.eu/info/strategy/eu-budget/long-term-eu-budget/2014-2020/funding-programmes_en

European Commission. (2020). European Commission - Press release. *Green Deal: Sustainable batteries for a circular and climate neutral economy*. Brussels.

European Commission. (2020). <https://ec.europa.eu/>. Retrieved from Technical expert group on sustainable finance (TEG): https://ec.europa.eu/info/publications/sustainable-finance-technical-expert-group_en

European Commission. (2021, 07 14). Amendment to the Renewable Energy Directive as regard the promotion of energy from energy sources, COM(2021) 557 final, 2021/0218 (COD). *Proposal for a Directive of the European Parliament and the Council amending Directive (EU) 2018/2001 of the European Parliament and of the Council, Regulation (EU) 2018/1999 of the European Parliament and of the Council and Directive 98/70/EC* . Brussels.

European Commission. (2021, 07 14). Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions. *'Fit for 55': delivering the EU's 2030 Climate Target on the way to climate neutrality*. COM(2021) 550 final. Brussels.

European Commission. (2021). *Decarbonising our energy system to meet out climate goals*. Brussels.

European Commission. (2021). *European Commission. Headings: spending categories*. Retrieved from ec.europa.eu: https://ec.europa.eu/info/strategy/eu-budget/long-term-eu-budget/2021-2027/spending/headings_en

European Commission. (2021, 07 14). Proposal for a Directive of the European Parliament and of the Council on energy efficiency. COM(2021) 558 final, 2021/0203 (COD). *Proposal on Energy Efficiency*. Brussels.

European Commission. (2021, 07 14). Proposal for a Directive of the European Parliament and of the Council, COM(2021) 551 final, 2021/0211 (COD). *Amending Directive 2003/87/ED establishing a system for greenhouse gas emission allowance trading within the Union, Decision 2015/1814 for the establishment of a market stability reserve for the emission trading scheme and Regulation 2015/757*. Brussels.

European Commission. (2021, 07 14). Proposal for a Regulation of the European Parliament and of the Council, COM(2021) 564 final, 2021/0214 (COD). *Establishing a carbon border adjustment mechanism*. Brussels.

European Commission. (2021, 10 26). Report from the Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions. COM(2021) 950 final. *State of the Energy Union 2021*. Brussels.

European Commission. (2021, 07 14). Revision of the Energy Tax Directive, COM(2021) 563 final, 2021/0213 (CNS). *Proposal for a COUNCIL DIRECTIVE restructuring the Union framework for the taxation of energy products and electricity (recast)*. Brussels.

European Commission. (2021, 10 26). State of the Energy Union 2021 - Contributing to the European Green Deal and the Union's recovery. *Report from the Commission to the European Parliament, The Council, The European Economic and Social Committee and the Committee of the Regions*. Brussels.

European Commission. (2021). *The EU's 2021-2027 long-term Budget and NextGenerationEU Facts and Figures*. Luxembourg.

European Commission. (2022). *Corporate disclosure of climate-related information*. Retrieved from ec.europa.eu: https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/corporate-disclosure-climate-related-information_en

European Commission. (2022). *Electricity production capacities by main fuel groups and operator*. Retrieved from eurostat: https://ec.europa.eu/eurostat/databrowser/view/NRG_INF_EPC__custom_3009775/default/table?lang=en

European Commission. (2022). *EU labels for benchmarks and benchmarks' ESG disclosures*. Retrieved from ec.europa.eu: https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/eu-climate-benchmarks-and-benchmarks-esg-disclosures_en

- European Commission. (2022). *EU taxonomy for sustainable activities*. Retrieved from ec.europa.eu: https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/eu-taxonomy-sustainable-activities_en
- European Commission. (2022). *European green bond standard*. Retrieved from ec.europa.eu: https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/european-green-bond-standard_en
- European Investment Bank. (2019). *EIB energy lending policy*. Luxembourg.
- European Investment Bank. (2022, 04 01). *Financed Projects*. Retrieved from eib.org: <https://www.eib.org/en/projects/loans/index.htm?q=&sortColumn=loanParts.loanPartStatus.statusDate&sortDir=desc&pageNumber=0&itemPerPage=25&pageable=true&language=EN&defaultLanguage=EN&loanPartYearFrom=1959&loanPartYearTo=2022&countries.region=1&orCountry>
- European Parliament. (2022). *News European Parliament*. Retrieved from europarl: <https://www.europarl.europa.eu/news/en/headlines/priorities/climate-change/20200618STO81513/green-deal-key-to-a-climate-neutral-and-sustainable-eu>
- European Parliament and the Council. (2018). Directive (EU) 2018/2001 of the European Parliament and the Council on the promotion of the use of energy from renewable sources. *Official Journal of the European Union*, L 328/82 - L 328/209.
- European Parliament and the Council. (2018). Regulation (EU) 2018/1999 of the European Parliament and of the Council on the Governance of the Energy Union and Climate Action. *Official Journal of the European Union*, L 328/1 - L 328/77.
- European Parliament and the Council. (2020). Regulation (EU) 2020/852 of the European Parliament and of the Council on the establishment of a framework to facilitate sustainable investment and amending Regulation (EU) 2019/2088. *Official Journal of the European Union*, L 198/13 - L 198/43.
- European Parliament and the Council. (2021). Regulation (EU) 2021/1119 of the European Parliament and of the Council establishing the framework for achieving climate neutrality and amending regulations. *Official Journal of the European Union*, L 243/1 - L 243/17.
- Eurostat. (2022). *Electricity production capacities by main fuel groups and operator*. Retrieved from eurostat: https://ec.europa.eu/eurostat/databrowser/view/NRG_INF_EPC__custom_2929618/default/table?lang=en

- Fagiani, R., Barquín, J., & Hakvoort, R. (2012). Risk-based assessment of the cost-efficiency and the effectivity of renewable energy support schemes: Certificate markets versus feed-in tariffs. *Elsevier. Energy Policy*, 648 - 661.
- Federal Ministry for Economic Affairs and Energy. (2019, 09). Emergency Plan for Gas for the Federal Republic of Germany. Germany.
- Federal Ministry for Economics and Climate Protection. (2022). *EEG 2017: Competitive remuneration*. Retrieved from [erneuerbare-energien.de: https://www.erneuerbare-energien.de/EE/Navigation/DE/Recht-Politik/EEG-Ausschreibungen/eeg-2017-wettbewerbliche-foerderung.html](https://www.erneuerbare-energien.de/EE/Navigation/DE/Recht-Politik/EEG-Ausschreibungen/eeg-2017-wettbewerbliche-foerderung.html)
- Federal Ministry for Economics and Climate Protection. (2022). *The Renewable Energy Sources Act*. Retrieved from [erneuerbare-energien.de: https://www.erneuerbare-energien.de/EE/Redaktion/DE/Dossier/eeg.html?cms_docId=72462](https://www.erneuerbare-energien.de/EE/Redaktion/DE/Dossier/eeg.html?cms_docId=72462)
- Federal Public Service Economy. (2022). *Politique énergétique de la Belgique*. Retrieved from [economie.fgov.be: https://economie.fgov.be/fr/themes/energie/politique-energetique/politique-energetique-de-la](https://economie.fgov.be/fr/themes/energie/politique-energetique/politique-energetique-de-la)
- Flemish Energy and Climate Agency. (2020). *Green energy and CHP*. Retrieved from [energiesparen.be: https://www.energiesparen.be/groene-energie-en-wkk](https://www.energiesparen.be/groene-energie-en-wkk)
- France Government. (2020). *Integrated National Energy and Climate Plan for France*.
- García, M. T., & Mariz, R. M. (2012). Analysis of the success of feed'in tariff for renewable energy promotion mechanism in the EU: lessons from Germany and Spain. *Elsevier. Procedia - Social and Behavioral Sciences*, 52 - 57.
- Golombek, R., Lind, A., Ringkjøb, H.-K., & Seljom, P. (2021). The role of transmission and energy storage in European decarbonization towards 2050. *Elsevier. Energy*, 239 (2022) 122159.
- Government of Poland. (2019). Annex 2 to the National Energy and Climate Plan for 2021 - 2030. *Energy and Climate Policy (ECP) Scenario. Impact assessment of policies and measures*.
- Haas, R., Resch, G., Panzer, C., Busch, S., Ragwitz, M., & Held, A. (2011). Efficiency and effectiveness of promotion systems for electricity generation from renewable energy sources - Lessons from EU countries. *Elsevier. Energy*, 2186-2193.
- IEA. (2020). *Average annual capacity factors by technology, 2018*. Retrieved from [iea.org: https://www.iea.org/data-and-statistics/charts/average-annual-capacity-factors-by-technology-2018](https://www.iea.org/data-and-statistics/charts/average-annual-capacity-factors-by-technology-2018)
- IEA. (2020). *European Union 2020*.

- IEA. (2021, 12 17). *The cost of capital in clean energy transitions*. Retrieved from [iea.org: https://www.iea.org/articles/the-cost-of-capital-in-clean-energy-transitions](https://www.iea.org/articles/the-cost-of-capital-in-clean-energy-transitions)
- IEA. (2022). *Belgium 2022 Energy Policy Review*.
- IEA. (2022). *Energy Security*. Retrieved from [iea.org: https://www.iea.org/topics/energy-security](https://www.iea.org/topics/energy-security)
- IEA. (2022). *IEA Data Services*. Retrieved from [IEA.org: https://www.iea.org/data-and-statistics/data-products](https://www.iea.org/data-and-statistics/data-products)
- IEA. (2022). *IEA Greenhouse Gas Emissions from Energy*. Retrieved from [IEA.org: https://www.iea.org/data-and-statistics/data-product/co2-emissions-from-fuel-combustion](https://www.iea.org/data-and-statistics/data-product/co2-emissions-from-fuel-combustion)
- IEA. (2022). *The Role of Critical Minerals in Clean Energy Transitions*.
- Index mundi. (2022). *Coal, Australian Thermal Coal*. Retrieved from [indexmundi: https://www.indexmundi.com/commodities/?commodity=coal-australian&months=60](https://www.indexmundi.com/commodities/?commodity=coal-australian&months=60)
- International Trade Administration. (2022). *Energy Resource Guide - Poland Renewable Energy*. Retrieved from [trade.gov: https://www.trade.gov/energy-resource-guide-poland-renewable-energy](https://www.trade.gov/energy-resource-guide-poland-renewable-energy)
- IRENA. (2021). *Energy Profile Belgium*. Masdar City.
- Jain, S. (2021). Exploring structures of power purchase agreements towards supplying 24x7 variable renewable electricity. *Elsevier. Energy*, 244 (2022) 122609.
- Keesman, K. (2011). *System Identification - An Introduction*. Springer.
- Kies, A., Schyska, B., & Von Bremen, L. (2016). Curtailment in a Highly Renewable Power System and its effect on Capacity Factors. *MDPI*.
- Kilinc-Ata, N. (2016). The evaluation of renewable energy policies across EU countries and US states: An econometric approach. *Elsevier. Energy for Sustainable Development*, 83-90.
- Krogh Boomsma, T., Meade, N., & Fleten, S. E. (2012). Renewable energy investments under different support schemes: A real options approach. *Elsevier. European Journal of Operational Research*, 225 - 237.
- Leepa, C., & Unfried, M. (2013). Effects of a cut-off in feed-in tariffs on photovoltaic capacity: Evidence from Germany. *Energy Policy*, 536-542.
- Ljung, L. (1999). *System Identification - Theory for the User*. New Jersey: Prentice-Hall.
- Macrotrends. (2022, 07 12). *Natural Gas Prices - Historical Chart*. Retrieved from [macrotrends.net: https://www.macrotrends.net/2478/natural-gas-prices-historical-chart](https://www.macrotrends.net/2478/natural-gas-prices-historical-chart)
- McCullagh, P., & Nelder, J. (1989). *Generalized Linear Models* (Second ed.). London - New York: Chapman and Hall.

- Mendicino, L., Menniti, D., Pinnarelli, A., & Sorrentino, N. (2019). Corporate power purchase agreement: Formulation of the related levelized cost of energy and its application to a real life case study. *Elsevier. Applied Energy*, 253 (2019) 113577.
- Ministry of Climate and Environment. (2022). *Energy Policy of Poland until 2040 (EPP2040)*. Retrieved from gov.pl: <https://www.gov.pl/web/climate>
- Ministry of Climate and Environment. (2022, 05 27). *Poland terminated the gas agreement on the Yamal gas pipeline*. Retrieved from gov.pl: <https://www.gov.pl/web/climate/poland-terminated-the-gas-agreement-on-the-yamal-gas-pipeline>
- Nykqvist, B., & Maltais, A. (2022). Too risky - The role of finance as a driver of sustainability transitions. *Elsevier. Environmental Innovation and Societal Transitions*, 42 (2022) 219-231.
- OECD. (2020, 04 01). *OECD.Stat*. Retrieved from stats.oecd.org: https://stats.oecd.org/Index.aspx?DataSetCode=RE_FIT
- OPEC. (2022). *OPEC Basket price*. Retrieved from opec.org: https://www.opec.org/opec_web/en/data_graphs/40.htm
- Pahle, M., Schaeffer, R., Pachauri, S., Eom, J., Awasthy, A., Chen, W., . . . Verdolini, E. (2021). The crucial role of complementarity, transparency and adaptability for designing energy policies for sustainable development. *Elsevier. Energy Policy*, 159 (2021) 112662.
- Platform on Sustainable Finance. (2021). *Transition finance report*.
- Platform on Sustainable Finance. (2022). Retrieved from ec.europa.eu: https://ec.europa.eu/info/business-economy-euro/banking-and-finance/sustainable-finance/overview-sustainable-finance/platform-sustainable-finance_en
- Polish Investment & Trade Agency. (2020). *Renewable energy*. Retrieved from paih.gov.pl: https://www.paih.gov.pl/sectors/renewable_energy#
- Qadir, S. A., Al-Motairi, H., Tahir, F., & Al-Fagih, L. (2021). Incentives and strategies for financing the renewable energy transition: A review. *Elsevir. Energy Reports*, 7 (2021) pp. 3590-3606.
- REEEP. (2014). *Belgium*. Retrieved from reeep.org: <https://www.reeep.org/belgium-2013>
- RTE. (2018). *Rationalising the way in which the grid is operated*. Retrieved from rte-france: <https://www.rte-france.com/en/accelerate-energy-transition/rationalised-use-grid>
- SPF Economie. (2022). *economie*. Retrieved from economie.fgov.be: <https://economie.fgov.be/fr/themes/energie/sources-denergie/electricite/autorisation-de-construction>

- Temmes, A., Heiskanen, E., Matschoss, K., & Lovio, R. (2021). Mobilising mainstream finance for a future clean energy transition: The case of Finland. *Elsevier. Journal of Cleanear Production*, 319 (2021) 128797.
- United Nations Climate Change. (2022). *What is the Kyoto Protocol?* Retrieved from unfccc: https://unfccc.int/kyoto_protocol
- Van Nuffel, L., Rademaekers, K., Yearwood, J., & Graichen, V. (2017). Directorate General for Internal Policies. Policy department A: Economic and Scientific Policy. *European Energy Industry Investments*. Brussels.
- Verbruggen, A., & Laes, E. (2021). Early European experience with tradable green certificates neglected by EU ETS architects. *Elsevier. Environmetal Science and Policy*, 119 (2021) 66-71.
- World Nuclear Association. (2021). *World Nuclear Performance Report*.
- Yang, D.-x., Jing, Y.-q., Wang, C., Nie, P.-y., & Sun, P. (2021). Analysis of renewable energy subsidy in China under uncertainty: Feed-in tariff vs. renewable portfolio standard. *Elsevier. Energy Strategy Reviews*.

UNIVERSITÉ CATHOLIQUE DE LOUVAIN
Louvain School of Management

Place des Doyens, 1 bte L2.01.01, 1348 Louvain-la-Neuve
Boulevard Emile Devreux 6, 6000 Charleroi, Belgique
Chaussée de Binche 151, 7000 Mons, Belgique

www.uclouvain.be/lsm