KEDGE BUSINESS SCHOOL

Master Thesis (2024-25)

Title: Impact of Climate Change in France

Prepared for:

Research Proposal

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1.1 Introduction

France has achieved exceptional progress in its transition to renewable energy, spurred by the pressing need to battle climate change and meet environmental targets. Renewable energy sources, such as wind and solar power, have increased their part of France's energy mix dramatically during the last decade. Between 2010 and 2019, the country's installed wind energy capacity increased from 5,762 MW to 16,511 MW, while solar capacity increased from 878 MW to 9,567 MW. This rapid growth has been aided significantly by government subsidies aimed at increasing the adoption of clean energy and lowering reliance on fossil fuels. However, this change has created a number of operational and financial issues that jeopardize the long-term viability and profitability of renewable energy systems.

The intermittent and unpredictable characteristics of wind and solar energy pose considerable challenges for grid stability and the operations of energy markets. Given that renewable energy generation is heavily influenced by short-term weather conditions, energy providers frequently encounter difficulties in accurately forecasting their production capacity. This challenge is particularly significant within the context of France's deregulated electricity market, where producers are required to anticipate and sell their electricity in advance. Should renewable energy producers commit to supplying a specific quantity of electricity and subsequently fail to fulfill these obligations as a result of erroneous forecasts, they may incur financial penalties and find themselves dependent on expensive grid adjustments or energy imports to reconcile supply and demand. This issue is especially pronounced in coastal regions such as Aquitaine, where weather variability is exacerbated by proximity to the Atlantic Ocean. The high variability of wind, sudden fluctuations in solar radiation, and other climate-related disruptions complicate the prediction of energy output further, thereby exerting additional pressure on energy providers. Réseau de Transport d'Électricité (RTE), the French grid operator, plays a pivotal role in ensuring grid stability by forecasting energy supply and demand. Nonetheless, even with sophisticated forecasting techniques and real-time assessment systems, significant inaccuracies persist in predicting wind and solar energy generation. RTE relies on its IPES network along with meteorological information from sources such as Météo-France and the European Centre for Medium-Range Weather Forecasts (ECMWF) to project energy production. However, erratic weather patterns can still result in supply-demand mismatches. For instance, during spikes in energy consumption in winter or abrupt drops in production during summer due to heatwaves, the grid may need to implement costly adjustments, including activating fossil-fuel power facilities or importing electricity from adjacent countries. Such modifications not only inflate operational costs but also jeopardize France’s environmental objectives by increasing dependence on carbon-heavy energy sources.

Furthermore, the financial hazards tied to erroneous energy forecasting have intensified as the French administration methodically scales back subsidies for renewable energy creators. Traditionally, feed-in tariffs provided fixed pricing for renewable energy, shielding creators from market fluctuations. However, with the transition towards market-driven pricing, renewable energy creators must now vie directly in the energy sector, rendering precise forecasting even more essential. They are compelled to market their electricity on the EPEX SPOT platform, where prices vary based on supply and demand. Inaccurate forecasts of energy production expose creators to market vulnerabilities and sanctions for failing to meet expectations, jeopardizing their profitability and operational viability. Another vital factor at play is the stability of the grid. Electricity cannot be stored extensively, so supply must consistently align with demand. When the output from renewable sources falls below expectations, the grid operator needs to swiftly fill the gap by activating backup energy sources, frequently reliant on fossil fuels, or importing power. On the other hand, excess production can inundate the grid, necessitating expensive reductions like limiting energy generation or selling surplus electricity at disadvantageous rates. Both situations disturb the energy marketplace and lead to financial setbacks for energy providers, as well as increased expenses for consumers.

To tackle these obstacles, enhancing the precision of renewable energy forecasting is vital. Sophisticated predictive analytics, probabilistic forecasting models, and collective weather predictions can assist energy providers in anticipating production fluctuations more efficiently. These forecasting instruments can measure uncertainty, empowering companies to make educated choices regarding energy trading, grid management, and resource distribution. By integrating risk evaluation into their operations, energy producers can reduce financial penalties, optimize energy distribution, and bolster overall grid reliability. Allocating resources towards more precise forecasting techniques is not only advantageous for individual energy enterprises but also crucial for attaining France's overarching sustainability objectives. Accurate energy forecasts facilitate improved incorporation of renewable energy into the grid, diminish dependence on polluting supplementary energy sources, and decrease operational expenses. Furthermore, enhancing forecast reliability fortifies market competitiveness for renewable energy, driving further investment in sustainable technologies and infrastructure.

The achievement of France's shift to renewable energy relies significantly on tackling the hurdles related to predicting wind and solar energy output. Confronting these obstacles with predictive analysis and sophisticated forecasting strategies will lessen operational uncertainties, decrease financial repercussions, and enhance grid reliability. This study seeks to investigate how improved forecasting techniques can streamline renewable energy operations in coastal France, ensuring both ecological responsibility and economic viability amid climate-induced fluctuations.

1.2 Focus and Limitations

- **Focus:** This thesis will concentrate on the study of prediction accuracy and the impact of penalties imposed by the grid on businesses, as well as financial implications and grid stability for wind and solar energy production in coastal regions of France, where climate variability is particularly pronounced. The research aims to leverage predictive analytics to address the challenges posed by the intermittent nature of renewable energy sources, thereby improving grid stability and operational efficiency.
- **Limitations:** The study will be constrained by the availability and quality of historical weather and energy production data, which may affect the precision of the forecasting models. Additionally, the research will primarily employ quantitative analysis to evaluate forecasting improvements, while selectively incorporating qualitative insights from regulatory frameworks and industry practices to provide a comprehensive understanding of the operational and financial impacts.

By tackling these challenges through advanced predictive analytics, this thesis seeks to offer actionable insights that enhance energy stability, reduce financial risks, and boost the profitability of renewable energy companies in France.

2.1 Literature Survey

The impact of climate change on energy production and consumption in France is a critical area of research, particularly in the context of renewable energy integration and the role of weather prediction in optimizing energy systems. This literature review synthesizes current research on the subject, focusing on the importance of accurate weather forecasts for wind energy production, the economic implications of forecasting accuracy, and the regulatory frameworks supporting these developments.

Accurate weather prediction is essential for optimizing wind energy production and minimizing financial risks associated with penalties for imbalances. Yan et al. (2022) highlight the significance of understanding and mitigating uncertainties in wind power forecasting, which is crucial for enhancing decision-making in power systems and electricity markets [1]. This aligns with the findings of Foley et al. (2011), who discuss the importance of advanced forecasting methods, including numerical wind prediction and ensemble forecasting, in reducing the need for additional balancing energy and reserve power [2]. These methods enable better dispatch and scheduling, thereby reducing financial and technical risks for electricity market participants.The economic benefits of accurate weather forecasting are substantial, as they allow energy producers to optimize production strategies and avoid penalties associated with imbalances. The report by Météo-France and Earth Observation (2022) underscores the critical role of refined atmospheric forecasts in steering production and markets, thus enhancing the profitability of renewable energy projects [3]. By reducing the reliance on balancing energy and reserve power, accurate forecasts contribute to more efficient energy markets and lower operational costs for producers.

The integration of renewable energy sources into the French electricity grid is supported by a robust regulatory framework that emphasizes the role of Balance Responsible Parties (BRPs) in managing energy transactions and ensuring grid stability. The French balancing model, as detailed in the RTE report, emphasizes a proactive approach to balancing, allowing for the integration of diverse balancing resources, including demand response and cross-border contributions [4]. This model supports the development and integration of new balancing resources, ensuring that renewable energy sources can effectively participate in the market. The European framework, particularly the Clean Energy For All Europeans package, aims to harmonize balancing processes across member states, ensuring that markets are open to renewable energy sources while providing incentives for investors [5].

Seasonal forecasting of wind energy resources is another critical area of research, as highlighted by Alonzo (2018). The study explores the challenges of assessing wind energy production from surface wind speed, emphasizing the need for accurate vertical extrapolation and long-term climatological data to predict wind energy potential effectively [6]. The variability of wind energy at different timescales poses significant challenges for energy producers, particularly in balancing supply and demand and ensuring network safety. Alonzo's research underscores the importance of developing robust forecasting methods to manage wind energy intermittency and optimize production strategies across various timescales [6].The Balance Responsible Party (BRP) system in France, as outlined in the Market Rules Chapter 3, plays a vital role in managing energy transactions and ensuring grid stability. The BRP mechanism involves the declaration of energy injections and extractions, allowing for precise management of imbalances in the power system. This system is crucial for integrating renewable energy sources and maintaining the balance between supply and demand [7].

3.1 Methodology

This section describes the methodology to be used in investigating how weather data and forecasting can improve renewable energy prediction, particularly for wind and solar energy in coastal regions of France. The primary focus will be on understanding the financial implications for companies and how these improved predictions can contribute to grid stability, particularly in the context of climate change and the increasing variability of renewable energy production.

3.1.1 Research Design

The research will take a descriptive and analytical approach to explore existing forecasting models and analyze the financial and operational benefits that more accurate predictions of wind and solar energy production can bring to energy companies and the electricity grid. The study will emphasize the application of forecasting models rather than the creation of new machine learning models, leveraging existing models to assess their impact on operational efficiency, risk management, and financial outcomes.

3.1.2 Data Collection

- Weather Data: Historical and forecasted weather data will be obtained from sources such as Météo-France, ECMWF, and other meteorological services. Key variables will include wind speed, solar radiation, temperature, and precipitation, specifically for the coastal regions of France like Aquitaine.
- Energy Production Data: Data on wind and solar energy generation will be sourced from France's grid operator, Réseau de Transport d'Électricité (RTE), and renewable energy producers to examine past production patterns, forecast accuracy, and performance.
- Financial Data: Data on energy market prices, cost structures, and revenue from renewable energy production will be gathered to analyze the financial impact of forecast improvements. This will include data on energy trading from the EPEX SPOT market and information about subsidies, penalties, and other financial incentives.

3.1.3 Weather Forecasting Models

This research will utilize existing weather forecasting models to predict variables such as wind speed and solar radiation, which are crucial for renewable energy forecasting. The focus will be on evaluating the accuracy of these models in short-term predictions (from 30 minutes to 72 hours), rather than developing new machine learning models.

3.1.4 Financial Impact Analysis

- Revenue and Cost Implications: By improving the accuracy of renewable energy forecasts, companies can better predict their energy production levels, leading to more accurate revenue forecasts. The research will examine how companies can optimize energy sales and minimize financial risks by reducing forecast errors.
    a. Market Participation: Accurate forecasts enable energy producers to participate more effectively in the energy market, minimizing the risks associated with underproduction or overproduction. This can help companies avoid penalties, optimize energy dispatch, and maximize their market share.
    b. Cost Savings: Improved forecasting can help companies reduce operational costs, such as maintenance and reserve capacity, by accurately predicting periods of low or high production.
- Risk Management: Accurate predictions will help companies manage financial risks associated with energy generation, including hedging strategies to minimize price fluctuations and improve profitability.

- Revenue Optimization: With better forecasting, companies can optimize energy sales, trading strategies, and pricing to maximize profits. The study will analyze how improved forecast accuracy contributes to more effective energy trading strategies and financial planning.

3.1.5 Scenario and Sensitivity Analysis

- Scenario Analysis: The study will conduct scenario analyses to examine different weather conditions, including extremes like heatwaves or storms, to assess their impact on renewable energy production and financial outcomes. The goal is to understand how improved forecasting can help mitigate the financial risks associated with such events.
- Sensitivity to Climate Change: The research will consider the long-term impact of climate change on weather patterns, particularly in coastal regions. By evaluating how weather patterns may shift in the future, the study will explore how forecasting can evolve to meet new challenges and contribute to grid resilience and financial stability in a changing climate.

References

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6. Alonzo, B. (2018). Seasonal Forecasting of Wind Energy Resource and Production in France, and Associated Risk. Thèse de doctorat de l'Université Paris-Saclay, École Polytechnique. Retrieved from https://hal.science/hal-01614920/file/Main_document.pdf

7. RTE. (2024). Market Rules Chapter 3. Balance Responsible Party system Version 01. Retrieved from https://www.services-rte.com/files/live/sites/services-rte/files/RM_3_BALANCE%20RESPONSIBLE%20PARTY%20_V01_20240401.pdf

Project Timeline & Action Items

Date	Task	Action Items
January 20, 2025	Upload Research Proposal	- Finalize the research proposal.- Ensure the proposal includes at least 5 academic references.- Upload the finalized version on the platform.
February 10, 2025	Finalize Research Design	- Confirm the research methodology.- Prepare any data collection plan.- Review forecasting models for weather data.
March 5, 2025	Start Data Collection	- Begin collecting historical weather data (e.g., wind speed, solar radiation).- Collect energy production data from RTE.
April 14, 2025	Upload Literature Review	- Prepare a literature review summarizing the research problem, questions, and methods.- Include a synthesis of 10 academic references.- Upload to the platform.
May 15, 2025	Data Analysis & Forecasting Models	- Analyze weather data and its impact on renewable energy production.- Review and validate forecasting models for wind and solar energy.
August 1, 2025	Mid-Term Review Preparation	- Prepare a mid-term update on progress.- Review financial impact analysis.
January 26, 2026	Upload Final Written Document	- Complete the final research paper.- Ensure the document is in PDF format.- Upload the finalized document on the platform, confirming adherence to guidelines.
February 27, 2026	Defense of Research	- Prepare for the defense presentation.- Ensure clarity on methodology, findings, and implications.- Participate in the scheduled defense session.