Electricity price analysis and forecasting in Finland

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2023

Abstract

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Degree Bachelor of Business Administration, Business Information Technology
Report/Thesis Title Electricity price analysis and forecasting in Finland
Number of pages and appendix pages 51 + 2

The objective aims to analyze factors behind the increase in electricity prices, particularly those related to materials, weather, and government policies, and to determine how these factors contribute to the overall price of electricity. Using electricity price data, the project seeks to provide insights into the current volatility of electricity prices and develop counter plans to address rising prices.

The project aims to enhance knowledge of data analysis methods and automation tools, better understand the current state of electricity price increases in Finland and learn how to visualize data and flows using electricity data.

In this research, the author did not focus on predicting electricity prices due to the complexity of several factors involved. However, the author explains how data scientists and analysts can use machine learning and statistical methods to execute the prediction of electricity prices.

This report consists of three major parts. The first part will focus on analyzing data from multiple resources to examine the current trend of electricity price increases in Finland and other Nordic countries. This will include examining statistics on electricity generation resources, the composition of electricity prices, import dependency, and the background of price increases in Finland, providing valuable insights into the situation.

The second part will propose two solutions for solving current electricity price volatility for normal users. One of the executions is acquiring data statistics by utilizing Microsoft Power Automate Desktop, a business automation tool. The second execution is giving a comparison of electricity spot price and fixed price so that users can determine whether they can take one of the options when they create a contract with electricity providers.

Lastly, the projects will provide insights and learning points from the project’s execution, assess the usability of the outcome, and outline a plan for future implementation.

Key words
Data Analysis of Electricity price, Electricity price forecasting methods, electricity resources, Data Analysis automation, business automation methods, business intelligence tool

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1 Introduction

Data analytics is essential nowadays for any purpose in any industry. It enables us to make informed decisions from pieces of new insights from the data. Organizations can identify data set patterns, relationships, and trends that would otherwise be hidden. The data can be utilized to improve business processes and transformed into new outcomes.

One of the key actions to optimize data analysis is automation. It accelerates business professionals' needs and the productivity and speed of the data analysis process. It can say that automation is essential if Data analysts or scientists handle huge amounts of data. It also helps reduce the cost which is associated with manual work and improves the consistency and accuracy of data qualities. In today's fast-paced business environment, companies need to be able to access and analyze data immediately and effectively.

Data Analysis Automation shall be achieved when the task is repetitive, and automation saves time and reduces errors. For example, if your company must create a monthly KPI report manually, with specific data from the same source, automation should be done to reduce mistakes or speed-up business decisions. In addition, the corresponding task must bring some real value to someone or some organizations. It should impact someone's behavior or provide extra benefits and solve someone's business problem.

According to a professional, Pickell describes that Data Analysis Process consists of the 5th phase. First, defining the issue, second, collecting data, third, data cleaning, fourth, analyzing data, and, in the end, interpreting the result and applying it. (Pickell 2021).

This thesis will process all the 5th stages of the Data analysis process and is focused on how data analysts can optimize data by utilizing automation methods. The data resource is electricity prices in Finland, a hot topic for everyone in Finland. It will investigate if there is any possible way to automate electricity price prediction.

Electricity prices have dramatically increased from late 2021 to 2022. There are several factors, and it will be beneficial to know why this happened and investigate the background of the price rise. Detailed objectives will be described in the next section.

1.1 Objectives and Motivation

This report will be discussed Data Analysis of electricity prices in Finland. The motivation for this project is that this research will be beneficial from two perspectives. First, the research will be usable for all people who live in Finland. Everyone knows Russia's invasion of Ukraine affect all energy crisis around the world but is there any other factors that are hidden? In addition, it will discuss how energy is generated. It will be beneficial to analyze the data for enhancing people on how to choose an electricity company or considering the usage of electricity at home or office. The second reason, data analysis, and automation are essential in any business nowadays, the author will be able to learn how to utilize data, and how to automate data visualization techniques by utilizing Business Intelligence tools. From this research, it will be discussed; How can we automate the analyzing process by utilizing electricity data? Is it possible to accelerate people's decision-making process of selecting electricity usage or company through this research? In this project, the author will utilize open-source data and visualize it with a business intelligence tool. As outcomes, the recent trend of electricity data, comparison with other countries, prices range between Nordic countries, and prices comparison per energy.

1.2 Project Description and Scope

This thesis is a research and project-based project.

First, it will be described the research regarding the current electricity price status in Finland. The resource will be collected mainly from an online resource. For example, why has it been increasing the prices? What is the factor of the electricity price rise? How Russia's attack affects the energy crisis etc. In addition, energy generation methods in Finland, a comparison of other Nordic countries, and the characteristic of electricity consumption will be researched. Various online resources are gathered to collect appropriate data sources.

Second, there is a user story for delivering a day-ahead electricity price chart to users. Microsoft Power Automate Desktop is the key tool to generate the data and send it to users' email accounts. This will be demonstrated in section 2.

Lastly, electricity price forecasting (EPF) will not occur in this project due to the lack of appropriate resources to predict the exact price. The reason will be indicated in the later chapter: "2.1 The factors which affect electricity prices - price volatility of electricity". However, it will discuss how internal electricity generation resources will be changed until 2035 in Finland.

2 The methods to forecast electricity prices

There is a variety of methods to model electricity prices forecasting (EPF) over the last 15 years, though the accuracy may vary. According to Weron (2014), there are six models to predict EPF. Those methods are complex, and each of them has its pros and cons. This thesis will not delve deeply into the technical details of the methods, as the author's previous studies did not cover all of the technical issues involved in these solutions.

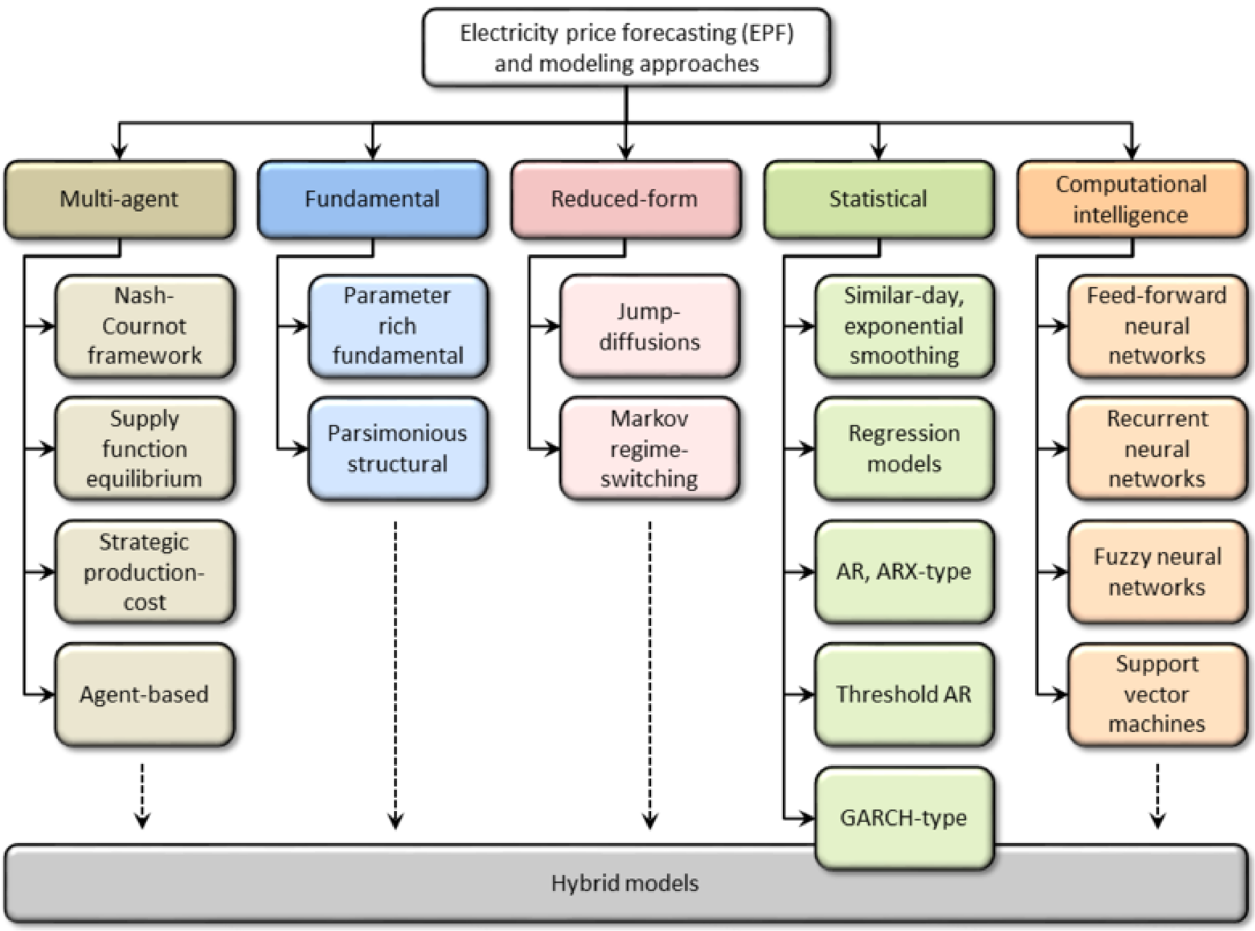

Figure 1. EPF taxonomy (adapted from Weron 2014)

Multi-agent models:

The models act as the functioning of a system composed of diverse agents (power generating units and multiple businesses) that interact with each other. It visualizes the price process by balancing the demand and supply in the market. As the compositions, there are such: cost-based models, equilibrium or game theoretic approaches, and agent-based-models. Multi-agent models normally target qualitative issues rather than quantitative outcomes. They could analyze data if the prices will get over marginal cost, and how the result affects the player's consequences. Nevertheless, some might occur some issues if more accurate electricity prices and quantitative solutions need to be executed with a high level of accuracy. (Weron 2014).

Fundamental (Structural) models:

Fundamental methods aim to identify the underlying physical and economic connections that appear in the production and trading of electricity. The correlation between fundamental drivers such as loads, weather, and system parameters is presupposed, and fundamental inputs are modeled and forecasted one by one utilizing techniques such as statistical analysis, simplified form models, or computational intelligence. There are typically two types of fundamental models: models that incorporate parameter-rich models and parsimonious structural models of supply and demand. In the implementation of fundamental models, two significant challenges appear the limited availability of data and the integration of the random variations of the underlying factors. When building the model, specific assumptions about the correlation between physical and economic factors in the market are required. Thus, those price forecasts based on the models are highly sensitive to deviations from these assumptions. (Weron 2014).

Reduced-form models:

Reduced-form (quantitative, stochastic) models are simplified, mathematical models that aim to capture the statistical properties of electricity prices over time. Their goal is not to predict prices accurately hour by hour but to replicate the important features of daily prices, such as how prices change over time and how they are related to other prices. If a reduced model does not capture these important features well, then its predictions may not be reliable. Nevertheless, if the model is too complex, it may be too challenging to utilize in real-time trading. There are two main types of reduced models: spot price models and forward pricing models. Spot price models are simpler, but they cannot be utilized to price derivatives to measure the risk premium that links spot and forward prices. Forward pricing models can be used to price derivatives, however, they have some limitations, such as a lack of data to calibrate the model and not being able to accurately predict spot prices. (Weron 2014).

Statistical models:

Statistical methods such as econometrics and technical analysis use mathematical formulas to predict the current price of something, like a stock or commodity. These methods use a combination of past prices and other outside factors, such as weather or production numbers, to make their predictions. There are two main types of models used: additive and multiplicative. Additive models add up different components to make their predictions, while multiplicative models can interpret the different components and better understand their behavior. Nevertheless, some people criticize statistical models for their inability to model the nonlinear behavior of prices and other fundamental variables. Despite this, in real-world applications, statistical models perform just as well as other methods like non-linear computational intelligence methods. For example, in a global energy forecasting competition, the top four winning entries used regression-type models. (Weron 2014).

Computational intelligence models:

Computational intelligence techniques, which are based on artificial intelligence (AI), machine learning, and non-parametric, non-linear statistics, use learning, evolution, and fuzziness to create intelligent approaches that can adjust to complicated dynamic systems. These methods, such as artificial neural networks, fuzzy systems, and support vector machines, are excellent at handling complexity and non-linearity in electricity prices. However, while they can model these features better than statistical techniques, their flexibility can also be a weakness. It does not promise improved points or probabilistic forecasts even though computational intelligence techniques can adjust to non-linear and erratic patterns. (Weron 2014).

2.1 The factors which affect electricity prices - price volatility of electricity

In the present thesis, it is not feasible to undertake the task of electricity price prediction due to the unavailability of dependable data sources that can reliably forecast electricity prices over an extended period. This is attributable to the following factors:

- Fuel price volatility: Electricity is generated by coal, natural gas, or oil, which can be highly unstable price. There are multiple participants in the fuel market which make us difficult to predict the final cost of producing electricity. In addition, if there is a disruption caused by extreme weather or significant damage to transportation and delivery infrastructure, it will result in a higher price of fuel, which eventually causes a higher cost to generate electricity. (EIA 2022).
- Power plant cost: There are always costs running to operate power plants. For instance, construction, maintenance, and operating costs. (EIA 2022).
- Transmission and distribution cost: To operate electricity transmission and distribution systems that link power plants and consumers, there are costs such as construction, operation, and maintenance costs. This aims to repair damage to the systems from incidents or extreme weather events, and improvement of cyber-security. (EIA 2022).
- Weather conditions and patterns: Weather conditions dramatically affect electricity demand, with extreme temperatures and weather circumstances

causing spikes in demand. This is also one of the reasons to make it is difficult to accurately forecast electricity prices. (Constellation 2023).

- Government policies and regulations: Government policies and regulations can also affect electricity prices since electricity is an essential infrastructure for all people. For example, globally, clean, and renewable energies are in high demand nowadays, and the adoption of those changes and energy competence standards can adjust the supply and demand dynamics of the market, which means that it affects price volatility. (EIA 2022).
- Power generation availability: If there is more demand than supply of electricity, it requires additional production of electricity to support consumption. (Constellation 2023).
- World events: International factors, such as health crises, wars or conflicts may impact energy generation and transmission. (Constellation 2023).

Overall, the complex and varied nature of the elements affecting electricity markets makes it difficult for data analysts to challenge the prediction of electricity prices with accuracy. Despite the difficulties, many experts, such as electricity companies, regulators, and traders utilize a combination of methods such as Statistical models (Weron 2014), and Computational intelligence models. (Weron 2014).

2.2 Data collection method and Tools

As a Data collection method, qualitative and quantitative data collection methods are applied. Online data are taken for creating insights and background of the price increase. Most graphs and charts are already visualized properly by online providers such as Fingrid, NordPool, etc. In addition, previous research from another thesis will be utilized to familiarize how to make a correlation between factors and technical terms.

2.3 The trend of Electricity Prices from 2010 to 2022

As everyone is aware, electricity prices have increased from 2021 to 2022. What is the trend and factors contributing to this price increase?

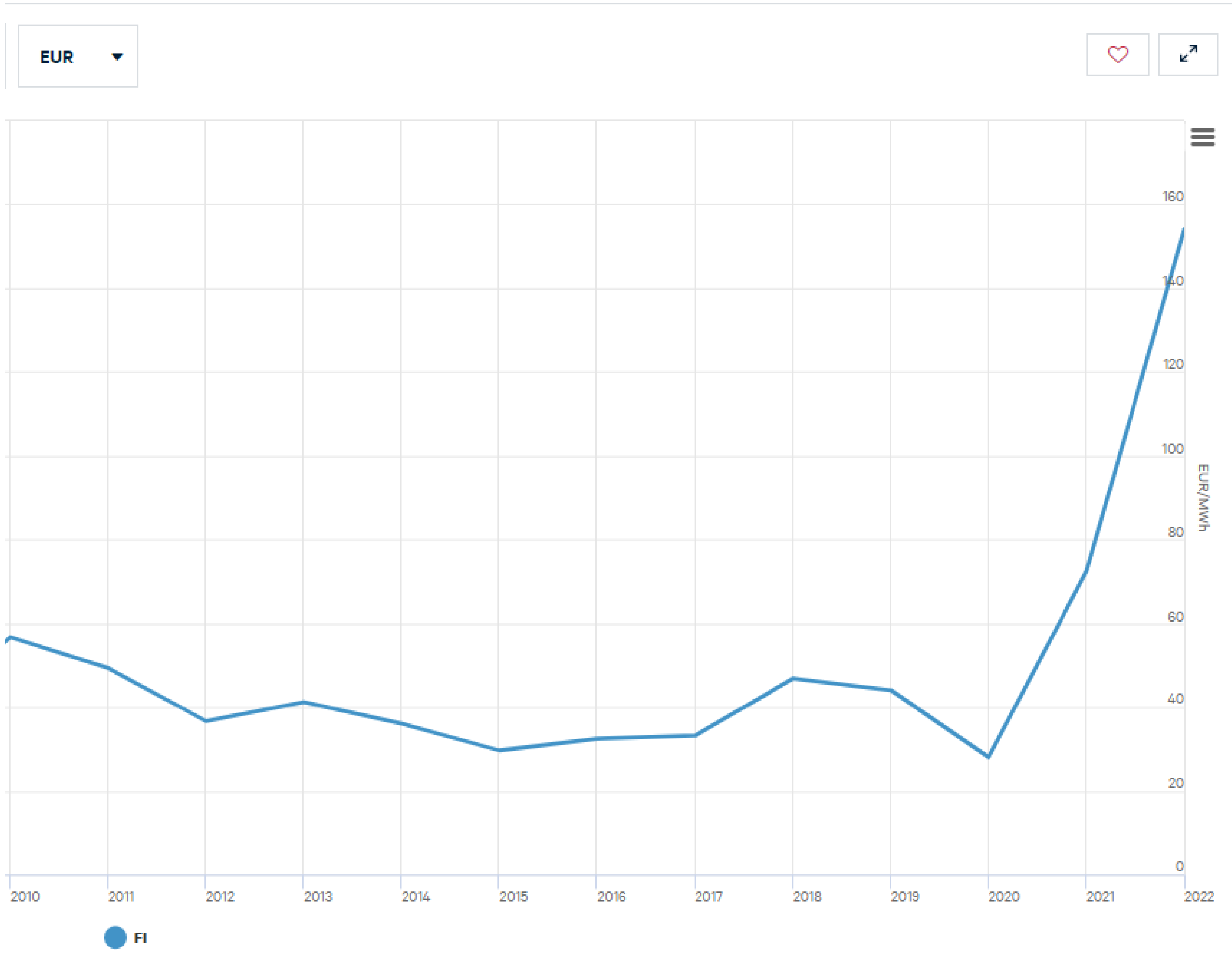

Figure 2. Average monthly electricity wholesale price in Finland from 2010 to 2022 (Nord Pool 2022)

From Figure 2, electricity prices have been dramatically increasing. In 2020, the price per megawatt-hour was 28.02. However, in 2021, it turned 72.34, which is 2.6 times bigger than the previous year. In addition, there has been a notable upswing in electricity prices towards the end of 2021. Specifically, the average monthly wholesale price for electricity was approximately 24€ / MWh (Megawatt hour) in 2020, compared to over 70€ / MWh in 2021, and almost 160€ / MWh in 2022. This represents a doubling in price from 2022.

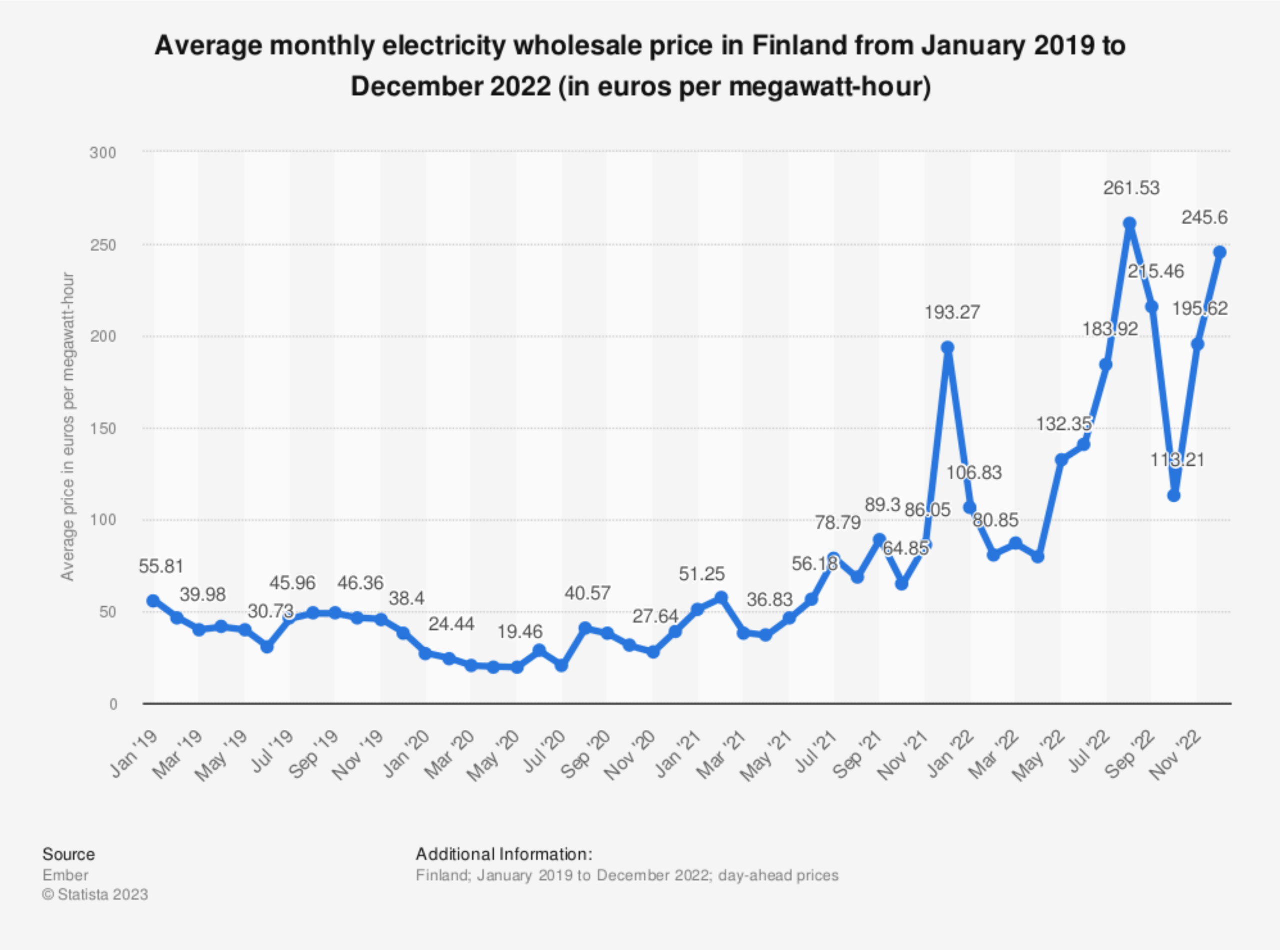

Figure 3. Average monthly electricity wholesale price in Finland (adapted from Ember 2023)

Figure 3 illustrates a sudden surge in electricity prices occurring after November 2021. It implies notable figures in the electricity prices from late 2021 to 2022, including a peak of 193€ / MWh in winter 2021, a high of 261€ / MWh in summer 2022, and another increase to 245€ / MWh in November 2022. The significant price fluctuations raise the question of what factors have contributed to this upward trend in electricity prices. Possible correlations include:

- The extreme weather and cold winter hit in December 2021. It requires a lot of electricity to keep comfortable temperatures in households or offices. (Finnish Meteorological Institute 2022).
- 2022 European heat waves impact renewable energy such as hydropower and nuclear reactors. (EIA 2022).
- Fuel costs, such as coal and natural gas to generate electricity have also risen from 2021 to 2022. (Ember 2021).
- 2022 Russian Invasion of Ukraine.

- The economic recovery after the pandemic was exceptionally fast. The supply-demand was imbalanced because of the slow supply recovery after the pandemic. (IEA 2022).
- OPEC supply restrictions. OPEC+ reduced oil production by two million barrels per day. OPEC+ claimed that the goal was to prevent price volatility, nevertheless, some analysts mentioned that it was intended to raise oil prices, which had declined in the preceding months. (Aljazeera 2022a).

Overall, the 2021-2023 global energy crisis started in the aftermath of the COVID-19 pandemic in 2021. The crisis resulted in an energy shortage and increased and increased prices in all energy resources such as oil, gas, and electricity markets in Finland. Several economic conditions and world situations that were listed before contributed to this crisis, including the rapid post-pandemic economic rebound, which left behind the energy supply. Nevertheless, the crisis escalated into a global energy crisis after the 2022 Russian invasion of Ukraine. As a result, natural gas and oil prices reached record highs, causing electricity prices to skyrocket in the market. Europe, which heavily depended on Russia for gas, suffered gas retention in 2022. Meanwhile, many emerging economies experienced fuel shortages and higher energy import bills.

The following section will provide a detailed explanation of each factor and how it contributed to the increase in electricity prices.

2.4 Factors of electricity price rise

The cold winter in 2021

There are several factors in the electricity price rise. Electricity price is determined by supply and demand, fuel costs, weather conditions, government regulation, and marketing competition.

One of the reasons is the weather condition. The extreme weather, hot summer, and cold winter hit in December 2021. It requires a lot of electricity to keep comfortable temperatures in households or offices.

The most significant deviation in temperature was recorded in June when the average temperatures for the month rose to the highest levels in the history of record-keeping in southern and central areas of the country, and parts of the north. July was also significantly warmer than average. February, September, and December were nevertheless significantly colder than usual. December 2021 was colder than normal in all parts of the country. In a few coastal stations, the month was unusually cold, with temperatures reaching once every 10 years or less. Average temperatures varied between near zero in the southwest archipelago to about -15 degrees in Utsjoki. The average temperature for the month was 2–6 degrees below the long-term average. (Finnish Meteorological Institute 2022).

Regarding climate change, other EU countries are also affected. The demand for electricity in Finland has also increased due to tight electricity demand in other countries since Finland imports electricity from other countries as well.

2022 European heat waves impact on renewable energy

From June to August 2022, constant heat waves hit parts of Europe. A lot of people evacuated, and a report says that at least 15,000 people died because of the heat in 2022. (Helsinki Times 2022). On 9th August, an expert European Commission researcher suggested the summer of 2022 is to be Europe's worst year in 500 years. (Skynews 2022). This weather condition had a serious impact on hydropower generation and power plant cooling systems. The New York Times reported that the driest summer reduced hydropower in Norway intimidated nuclear reactors in France, and disrupted coal transport in Germany. (The New York Times 2022).

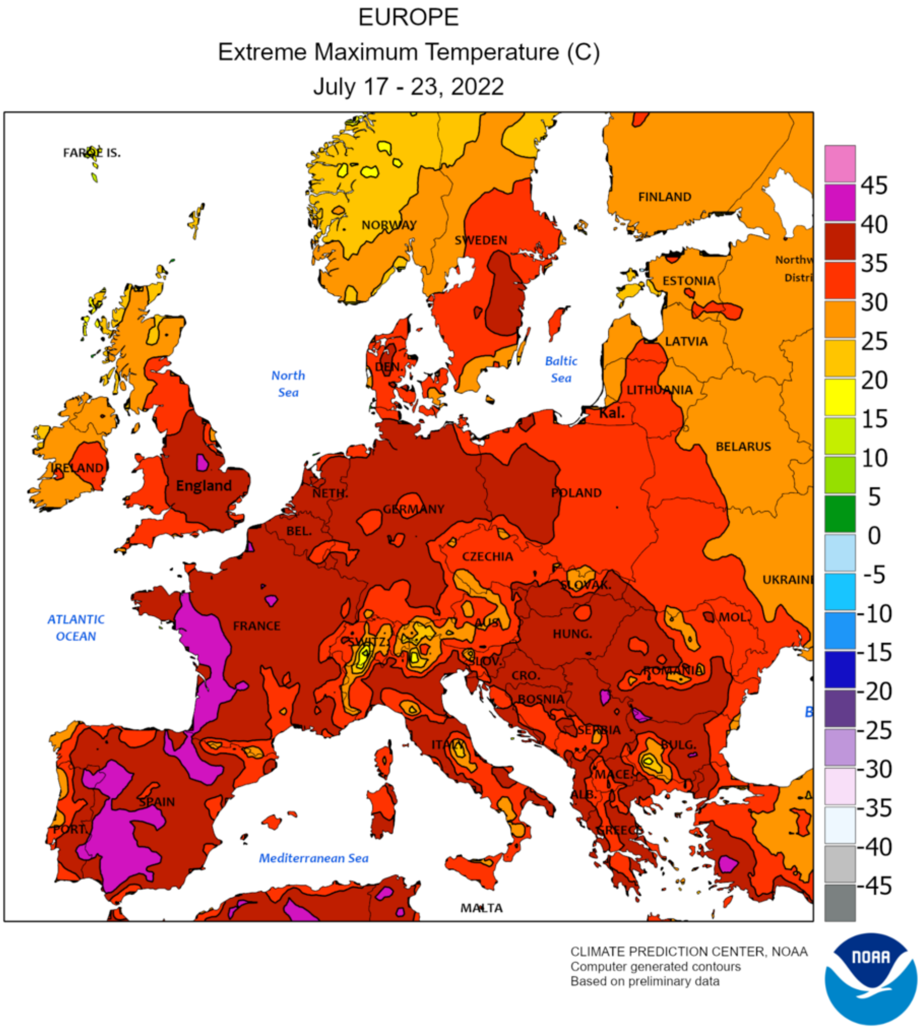

Figure 4. Extreme maximum temperature for July 17 to 23, 2022 in Europe (NOAA 2022)

Finland imports electricity from Sweden and Norway, the Figure 4 suggests that the electricity demand has increased in summer, the price increased by 47% from May 2022 to July 2022 (Ember 2023) dues to the weather condition above. (NOAA 2022). Extreme weather is one of the reasons which can increase the price of electricity for heating and cooling. (EIA 2022).

Fuel prices increased

One of the other factors is the price increase in fuel prices.

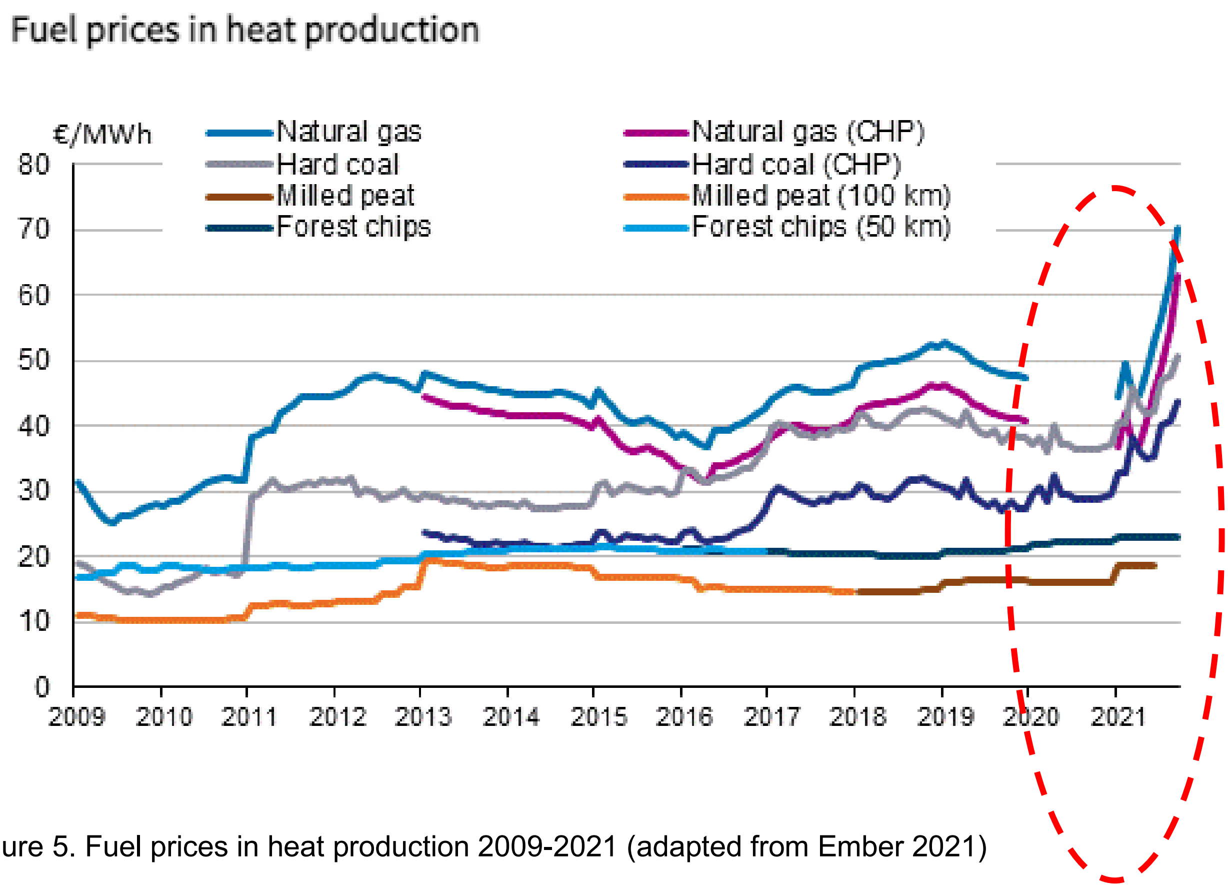

Figure 5. Fuel prices in heat production 2009-2021 (adapted from Ember 2021)

Figure 5 indicates that general fuel prices in heat production have dramatically increased.

> European Council (2023a) suggests that the background of the fuel price increase in 2021 was: “The rise, linked to the increase of wholesale energy prices globally, started back in 2021 in the wake of the COVID-19 pandemic and growing international demand”. (European Council 2023a).

This indicates that the economy was recovering from the Covid-19 pandemic in the summer of 2021, which affects a large demand for gas, and the supplier could not keep up with it.

2022 Russian invention of Ukraine

It is well known that Russia is one of the largest oil and gas producers and exporters in the world. It ranked third in the world for oil production in 2020, after the United States and Saudi Arabia. (Aljazeera 2022b).

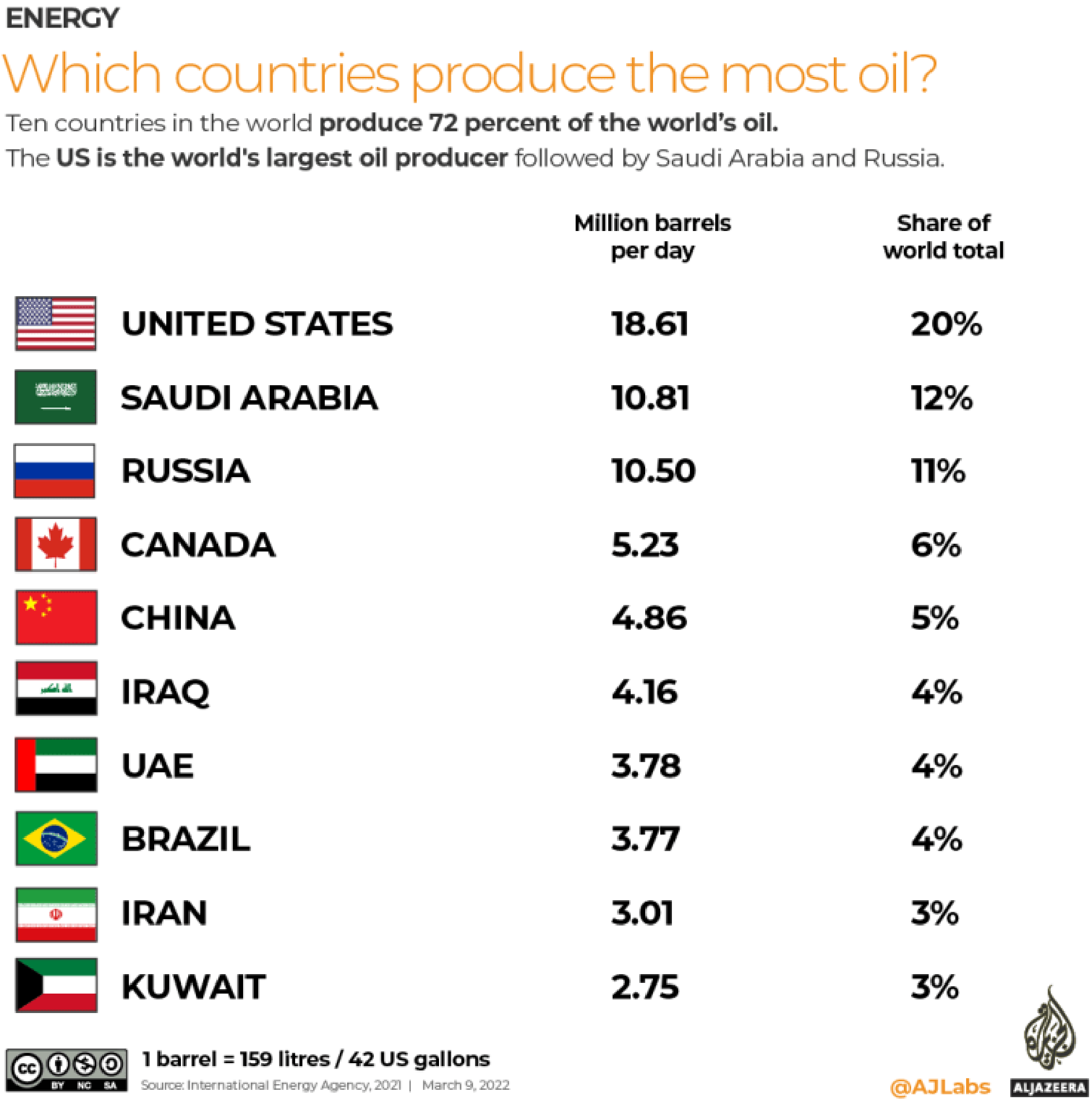

Figure 6.Top 10 Countries of producing oil 2022 (adapted from AJLabs, Aljazeera 2022b)

IEA reports that the country exports 60% of its oil to Europe. As for natural gas, Russia holds the world's largest reserves and is the largest exporter of the fuel, having produced 762 Billion cubic meters (bcm) in 2021 and exporting approximately 210 bcm via pipeline. (IEA 2022).

Nonetheless, the Russian military build-up near Ukraine and subsequent invasion have disrupted the energy supply from Russia to Europe. After the invasion, the import of Russian energy supplies by EU countries has been significantly reduced. BBC reported that in 2021, Russia exported 40% of its natural gas, which decreased by around 17% by August 2022. (BBC 2023). The EU compensated the imports from mainly the USA. (International Energy Agency 2022).

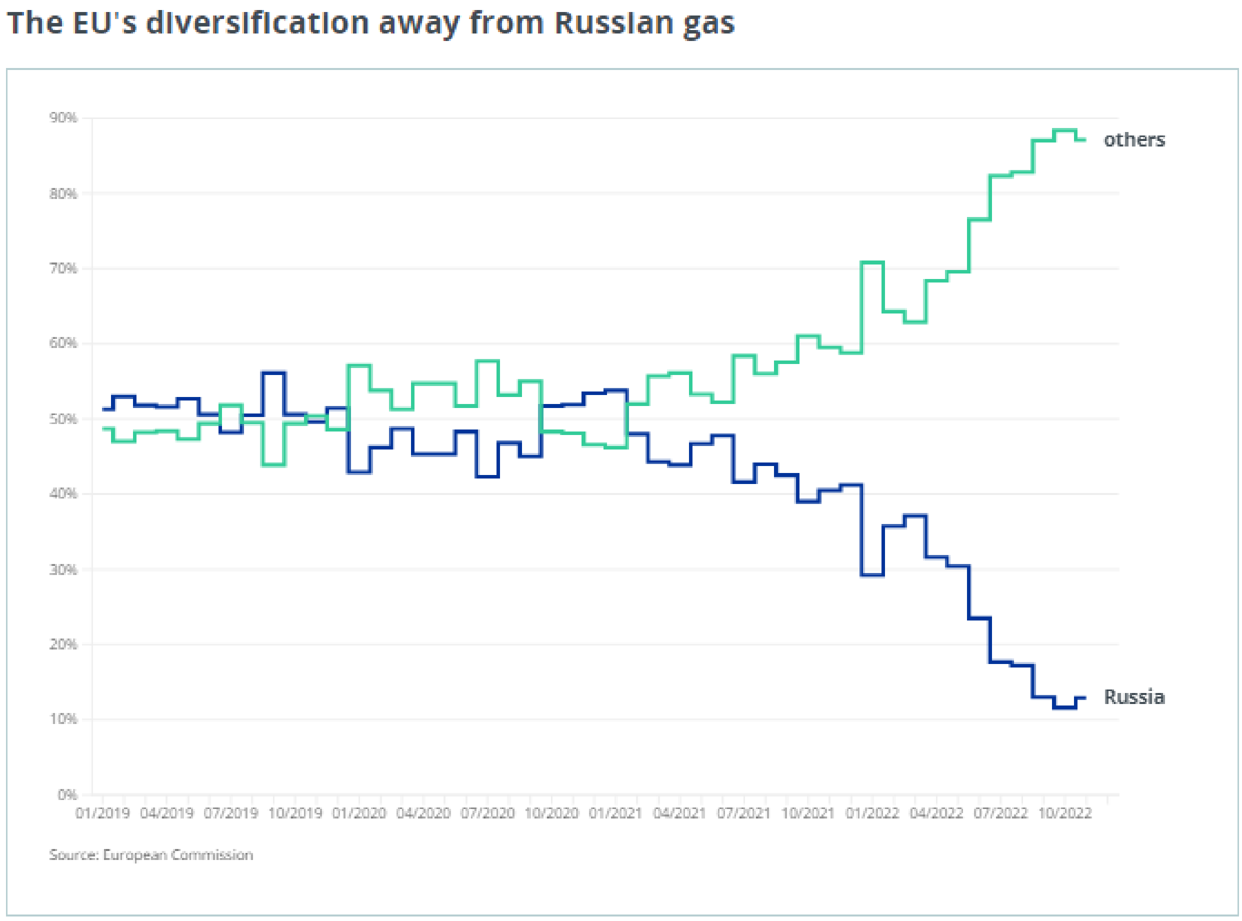

Figure 7. The EU’s diversification away from Russian gas (European Council 2023b)

Figure 7 represents the proportion of gas delivered to the EU by Russia compared every month from January 2019 to November 2022, as compared to other countries such as Norway, Algeria, etc. Up until the latter part of 2021, Russia held roughly half of the gas market share. Nevertheless, the beginning of at the same time, the percentage of Russian gas decreased significantly, and the market share of alternative suppliers began to increase. The trend accelerated notably in 2022. As of June 2022, Russia’s portion of gas imports to the EU dropped below 20%, and by November, it had fallen 12.9%. Based on European Council (2023b)’s article, from January to November 2022, the European Union’s gas imports were largely composed of sources other than Russia, which accounted for less than 25% of the total. Approximately a quarter of the imports were from Norway, while 11.6% came from Algeria. Liquefied natural gas (LNG) imports, which were excluding Russia, were mainly sourced from the US, Qatar, and Nigeria, and made up 25.7% of the total imports. (European Council 2023b).

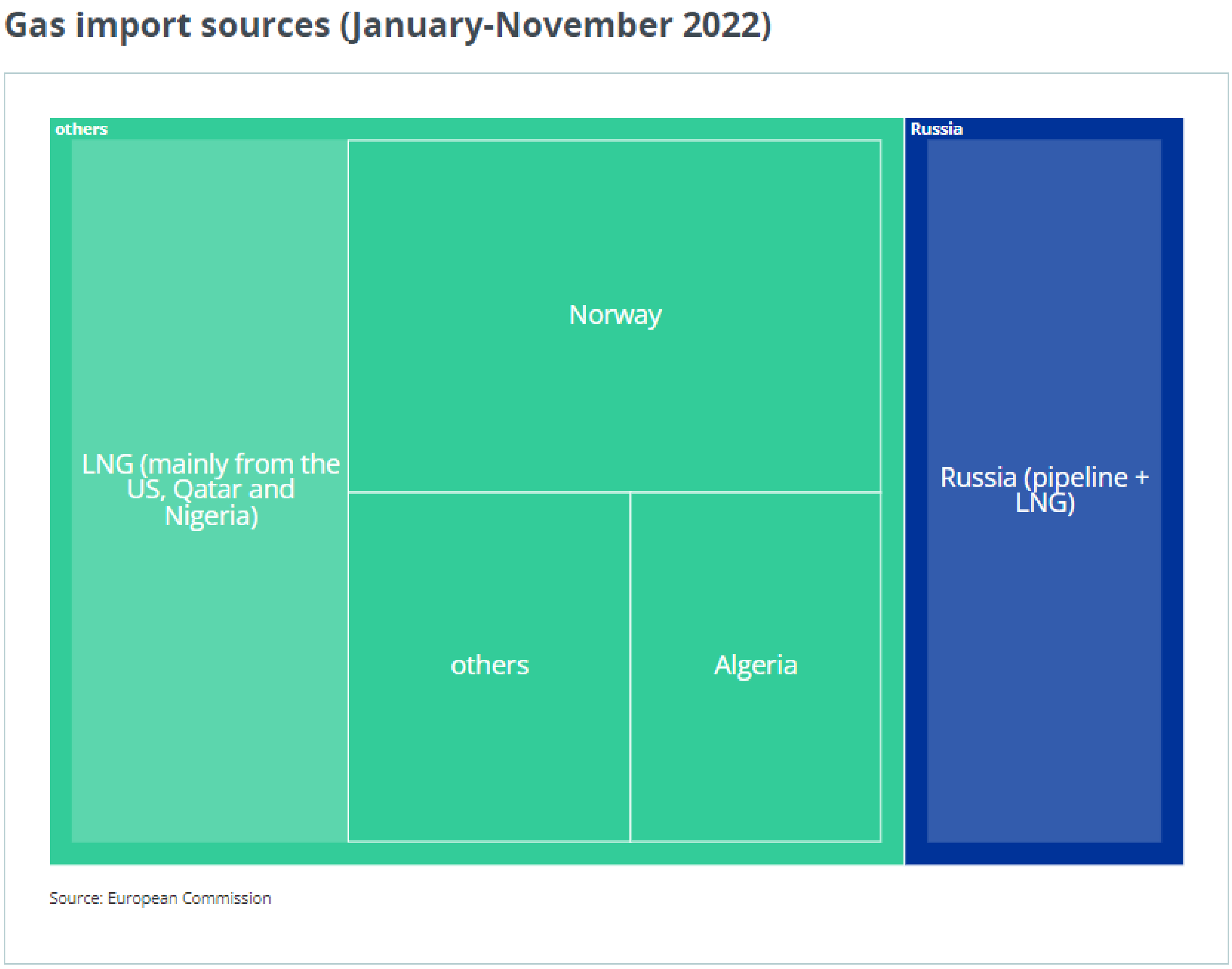

Figure 8. Gas import sources Jan to Nov 2022 (European Council 2023b)

Figure 8 describes the market shares and corresponding values of different producers of gas to the EU during the period spanning from January to November 2022.

- Russia (Pipeline + LNG): 24.65%, 803.8 Terawatt hours (TWh).
- LNG (mainly from the US, Qatar, and Nigeria): 25.7%, 838.8TWh.
- Norway: 24.9%, 812.9 TWh.
- Algeria: 11.6%, 378.8 Twh.
- Others: 13%, 426.9 Twh.

(European Council 2023b)

From January and November 2022, the amount of LNG imported from the US to the European Union was over 50 billion cubic meters (bcm), which is more than twice the amount imported in the entirety of 2021 (over 22 bcm). (European Council 2023c).

Regarding the composition of imports of gas to Finland, it will be discussed in “2.5 The breakdown of electricity resources in Finland”.

In this way, the EU imposed sanctions in response to the brutal action and invasion of Ukraine. The European Council (2023c) decided as:

- prohibits the purchase, import or transfer of seaborne crude oil and certain petroleum products from Russia to the EU. The restrictions apply from 5 December 2022 for crude oil and from 5 February 2023 for other refined petroleum products. (European Council 2023c).

The objective of these sanctions is to pressure Russia economically and diplomatically in response to actions that the EU considers unacceptable.

The fast economic recovery after the pandemic and the slow supply recovery of energy resources

Research suggests that the COVID-19 pandemic in 2019-2020 resulted in a rapid decline in energy demand, leading to a reduction in energy production.

Due to the lockdown, social restriction, travel bans, unemployment, and work-from-home policies, many individuals were required to remain indoors. This led to a disruption in day-to-day business operations and a decrease in energy demand on providers. Industries were pressured to limit their manual operations or minimize them entirely. Businesses scaled back, and the aviation industries were severely impacted by the travel ban. Small businesses were suffering to stay afloat, while schools and universities shifted to remote teaching. The majority of other sectors adapted to work-from-home arrangements. (Madurai Elavarasan, Shafiullah, Raju, Mudgal, Arif, Jamal, Subramanian, Sriraja Ba-laguru, Reddy & Subramaniam 2020).

The Bank of Finland suggests that the Finnish economy quickly recovered from the decline caused by the COVID-19 crisis. The Finnish economy has shown an extraordinary recovery from the severe decline caused by the CoVID-19 crisis. Despite the ongoing impact of the pandemic, Finland is projected to experience a 3.5% increase in economic growth in 2021, followed by a 2.6% rise in 2022. Nevertheless, economic growth is being hindered by supply chain bottlenecks and high raw material costs, trigger inflation. The country’s aging economy is barring its potential for sustained growth, and growth rates are expected to slow to 1.3% by 2024. Moreover, the forecast for economic growth may be weaker than anticipated if global supply chain disruptions continues or the pandemic situation declines. (BANK of Finland Bulletin Articles On the Economy 2022).

The fast economic recovery after the pandemic did contribute to the slow supply recovery of energy resources, as the sudden increase in demand led to supply bottlenecks and difficulties in balancing energy needs.

Table 1. The main points of the forecast Percentage change from the previous year (adapted from BANK of Finland Bulletin Articles On the Economy 2022)

Key outcomes of the forecast						
Percentage change from the previous year						
	2019	**2020**	**2021e**	**2022e**	**2023e**	**2024e**
Excl. energy	1,0	0,8	1,3	1,7	1,7	1,8
Energy	3,0	-5,0	**9,7**	4,0	-0,1	1,3

As shown in Table 1, the Energy index saw a decline of -5.0 in 2021 but rebounded to 9.7 in 2022. This indicates that in Finland, there is a correlation between economic revival following a pandemic and a rise in energy consumption.

OPEC supply restrictions

In Oct 2022, Aljazeera reported that OPEC has reduced its oil production by 2 million barrels per day, despite pressure from the US. OPEC said that it aims to prevent price volatility. Nevertheless, some analysts believe the real objective was to boost oil prices, which have been declining in recent years due to the pandemic.

The price of oil can have an indirect impact on electricity prices; however, some oil-fired power plants could be affected since the electricity generation is oil. In some cases, power generation companies may switch to alternative fuel sources, such as natural gas or renewable energy, to prevent the higher costs of oil. (Aljazeera 2022a).

Oil is not typically considered a primary resource for generating electricity in Finland. Most electricity is generated by burning fossil fuels or renewable energies. Hence, it seems unlikely that the supply restriction imposed by OPEC was a direct cause of the electricity price rise in Finland from 2021 to 2022.

2.5 The breakdown of electricity resources in Finland

This section will discuss the sources of electricity in Finland to declare what is the breakdown of internal electricity production, and how much electricity Finland imports from overseas. First, it will break down the composition of electricity internal production and then will discuss the electricity imports from foreign countries.

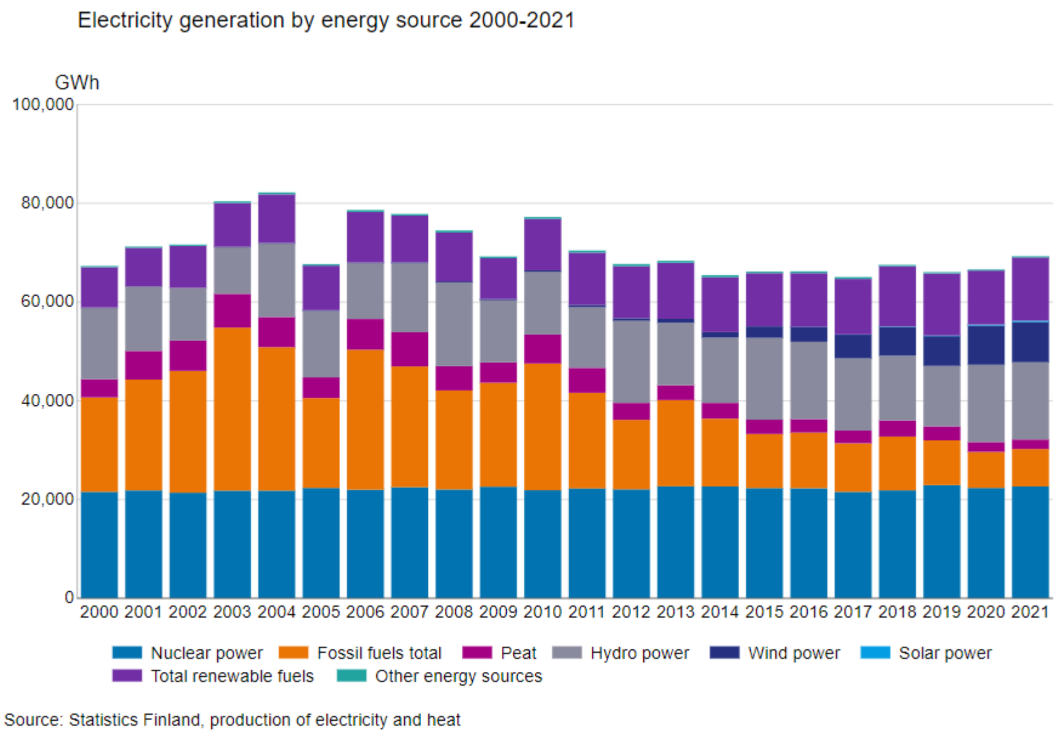

Figure 9. Electricity generation by energy source 2000-2021 (Official Statistics of Finland 2022)

From Figure 9, in 2021, electricity production in Finland amounted to 69.3 Terawatt hours (TWh), which was four percent more than the previous year. Renewable energy sources and nuclear energy fulfilled 86 percent of electricity production in 2021, which is fossil-free electricity production. 53 percent of Finland’s electricity production is renewable energy. The share of renewable energy sources in electricity production has been rising. It has increased by six percent more electricity generation with renewable energy sources than in 2020. Another point of interest is that district heat production in 2021 has increased by 16% from the previous year, due to the cold winter. (Official Statistics of Finland 2022).

Figure 9 suggests that the renewable energy production share has been increasing year by year. According to European Commission 2019, Finland has put forward several concrete targets, they will prohibit the usage of coal for energy by 2030 and promote a reduction of the usage of imported oil by 50%. (European Commission 2019).

This target indicates that Finland will increase its share of renewable energy more and more in the future and there will be more investments and efforts by the government and organizations. The background of promoting renewable energy for several reasons, one of them being the global trends. Nowadays it is clear that our resources are limited, and it is inevitable to consider the sustainability of our economic activities. Finland also set high targets for reducing fossil energy and promoting renewable energies such as wind or hydropower.

The other factor is environmental friendliness against climate change. According to the State Treasury of Republic Finland, the Finnish government aims to reduce the country's reliance on fossil fuels to reduce the carbon footprint so that it encourages the reduction of the burden on the environment. In addition, the Finnish government make a target for creating a fossil-free welfare society and be climate neutral by 2035. "Carbon neutrality" indicates that the balance between the CO2 emission and the sinks that sequester carbon are the same, which means that human activities are stabilized as greenhouse gas removals. (State Treasury of Republic Finland 2022).

Other than sustainability benefits, there is also an energy independence policy related to renewable energy production rise. In general, it is recommended that promoting energy independence helps to increase the energy security level of the country. As the Russian Attack on Ukraine happened in 2022, energy independence became more important for any country. Lastly, renewable energy development increases investments in new facilities and new job roles.

According to EY Nordics Renewables Co-Lead, she suggests as follows: "Finland ranked in the 24th Position in the renewable energy country attractiveness Index (RECAI) report" (Charpentier, EY Nordics Renewables Co-Lead 2022).

For those four reasons, the share of renewable energy will expand progressively in Finland.

Table 2. Electricity and heat production by production mode in 2021 (adapted from Statistic Finland 2021)

	Electricity generation, GWh	District heating production, GWh	Industrial heat production, GWh	Use of fuels 1), TJ
Separate production of electricity, Hydropower	15,624	data missing	data missing	data missing
Separate generation of electricity, Wind power	8,133	data missing	data missing	data missing
Separate production of electricity, Solar power	298	data missing	data missing	data missing
Separate generation of electricity, Nuclear power	22,646	data missing	data missing	data missing
Separate production of electricity, Condensing power 2)	2,848	data missing	data missing	34,106
TOTAL SEPARATE PRODUCTION OF ELECTRICITY	49,548	data missing	data missing	34,106
Combined heat and power	19,730	21,369	40,645	371,052
Separate heat production	data missing	19,429	11,577	107,221
TOTAL PRODUCTION	69,277	40,798	52,222	512,378
Net imports of electricity	17,768	data missing	data missing	data missing
TOTAL PRODUCTION AND NET IMPORTS	87,046	40,798	52,222	512,378

From Table 2, Finland imports electricity 17,768 Gigawatt hours (GWh) in 2021. The net import percentage is 20% of the total production and net imports.

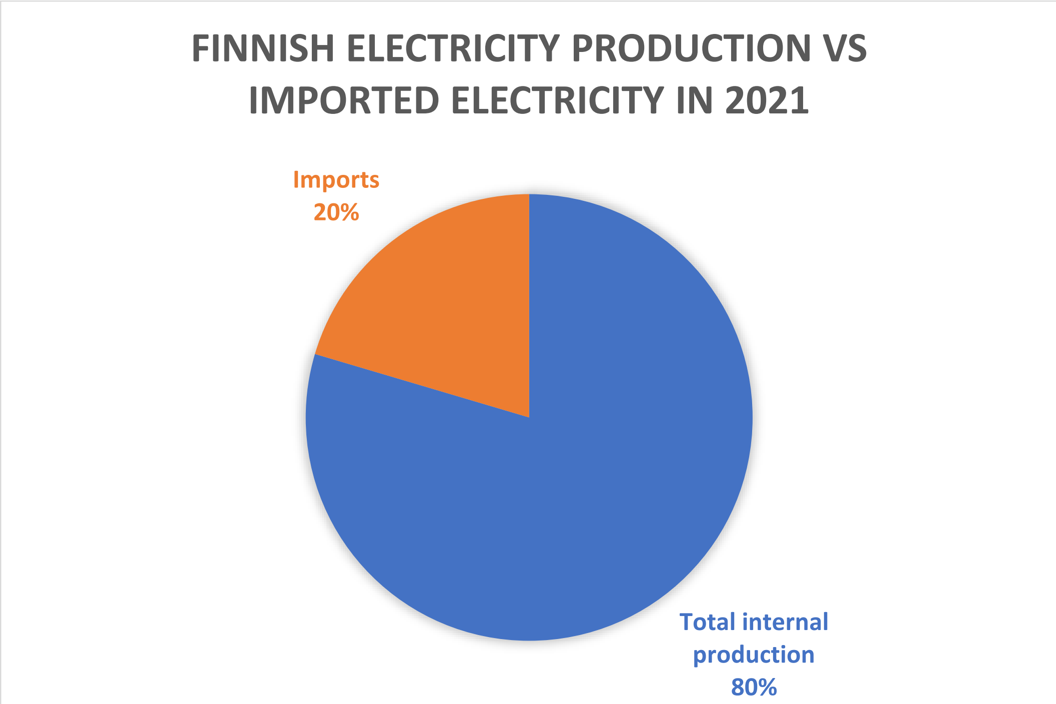

Figure 10. Finnish electricity production vs imported electricity in 2021. (Adapted from Statistic Finland 2021)

From Figure 10, Finland imported 20% of the electricity it consumed in 2021. This suggests that Finland has a significant degree of domestic capacity for generating its electricity, although it remains reliant to some extent on imports from foreign nations.

2.5.1 Finnish electricity market import status and the level of dependence

How much does Finland depend on Russia for energy? According to Statistic Finland (2022), it described that "share of energy imported from Russia was 34 percent of total energy consumption in 2021". (Statistic Finland 2022).

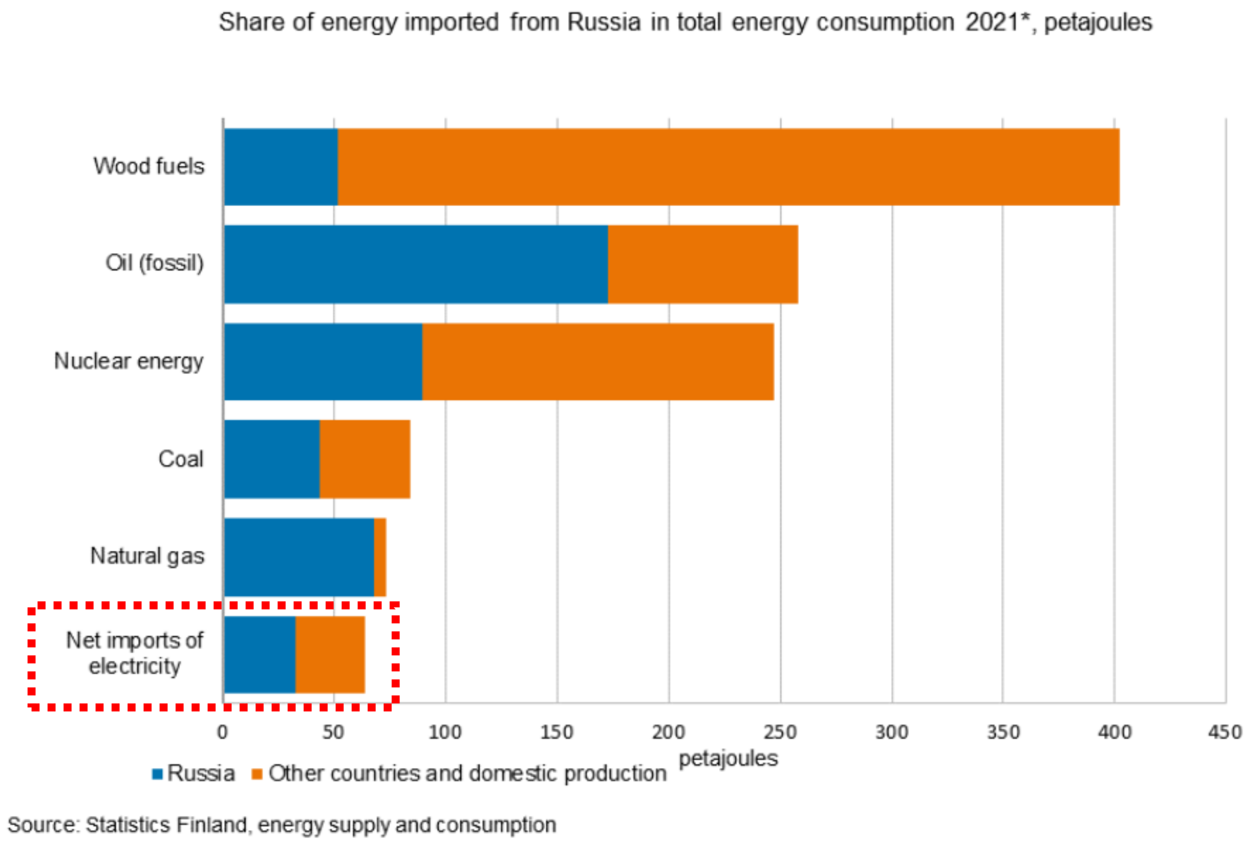

Figure 11. Share of energy imported from Russia in total energy consumption in 2021. (Adapted from Statistic Finland 2022)

Figure 11 indicates that Finland imported approximately half of the electricity import from Russia in 2021.

Table 3. Energy import and export, quantity by Country, Information, Quarter, Energy product and Flow (Adapted from Tilastokeskus 2023)

Import Quantity			
Electricity, GWh	2022Q1	2022Q2	2022Q3
TOTAL	6303.9	4515.4	4442.4
Sweden	3580.8	3393.1	4309.7
Russia	2647.8	988.9	0.0
Norway	74.0	115.4	131.0
Estonia	1.3	18.0	1.7

Table 3 suggests that Finland was dependent on Russian electricity for around 42% of the total net import in Q1 2022. The amount is not too large if it is compared to other EU countries. Finland shut down most of its electricity imports after the Russian invasion of Ukraine, and most of the gas imports had been replaced by Baltic countries and Nordic counties. (Yle 2022a). According to Table 3, in Q3 2022, all of electricity from Russia have been completely shut down.

Although Finland has imported half of the total import of electricity (Figure 11), Fingrid (2022a) mentioned that Finland will be able to handle the situation without the import from Russia by 2024 (Fingrid 2022a).

> – Finland will become self-sufficient in electricity in 2023 or 2024 at the latest. Thanks to the Olkiluoto 3 nuclear power plant, which will be completed this year, and the increasing volume of wind power generation, Finland generates as much electricity on an annualized basis as it consumes. This change is a significant one, as until now, Finland has imported up to 20 percent of the electricity consumed in the country. (Fingrid 2022a)

In addition, yle reported that the Finnish Minister of Economic Affairs, Lintila commented that Finland will be able to depend on other countries in terms of electricity.

> – There's no going back to the old situation. We know that Finland will be self-sufficient in electricity within two years. We have investments in domestic electricity production to thank for that. (Lintila, Minister of Economic Affair, Yle b 2022)

Based on this, Finland may be able to reduce its dependence on electricity from Russia in the future. Additionally, the widespread adoption of nuclear power and renewable energy could lower the country's dependence on imported electricity from other nations.

2.5.2 The historical trend Imports and exports of electricity 2018-2022

Has Finland depended on external resources historically? The below graph shows the trend of electricity supply in Finland.

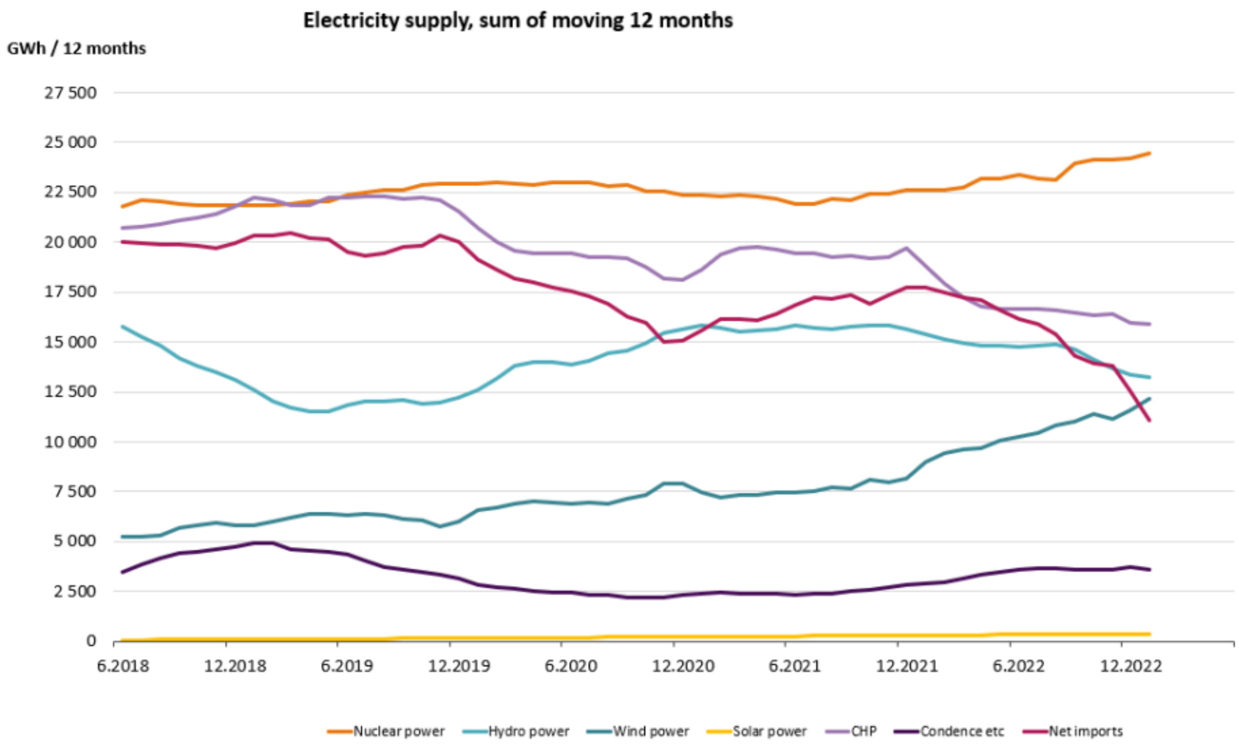

Figure 12. Electricity Supply, the sum of moving 12 months (Finnish Energy 2023)

As can be seen from Figure 12, there is a notable decline in net imports of electricity from other countries, indicating a shift towards greater self-sufficiency in the domestic energy sector. On the other hand, Figure 12 reveals a significant increase in the generation of electricity from renewable and low-carbon sources, such as hydro power, and wind power. Additionally, nuclear power generation has also increased, as a low-carbon source.

The upcoming section will delve into the countries from which Finland imports electricity, as well as provide context regarding these imports.

2.6 The current trend of electricity price comparison in Nordics

Here is the comparison of electricity prices in Nordic countries:

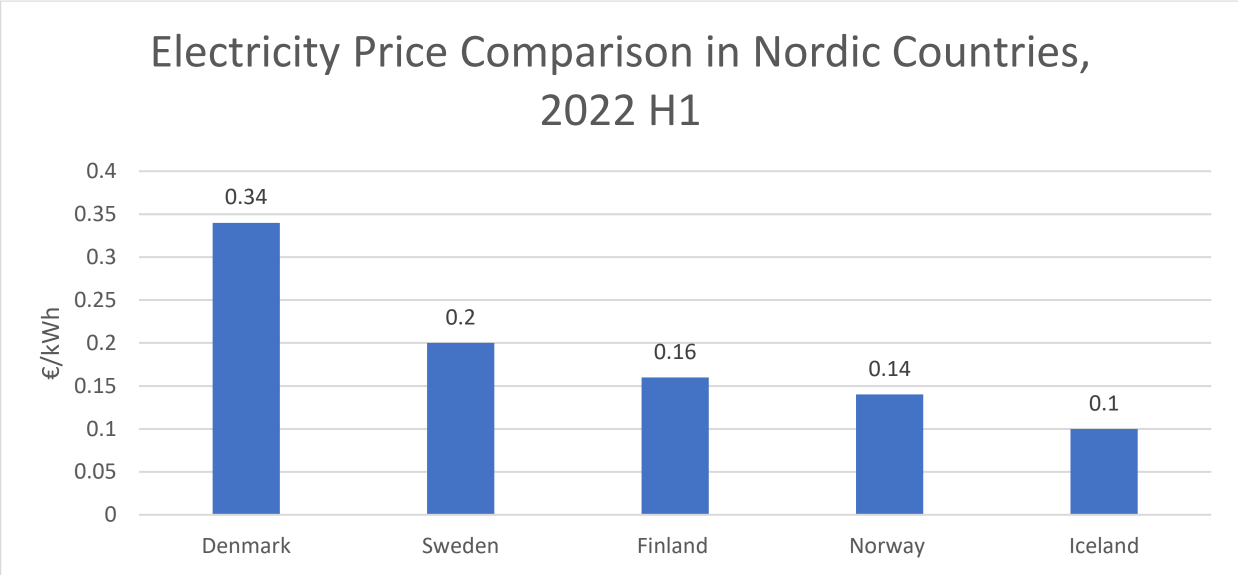

Figure 13. Electricity Price Comparison in Nordic Countries, in the first half of 2022 (adapted from Statistic Iceland 2022)

Based on the data presented in Figure 13, Denmark has the highest electricity prices among the other Nordic countries. Finland ranks third in terms of prices. Notably, the figure illustrates that Finland does not have the highest electricity prices in the Nordic region, with Iceland boasting the lowest prices among the five countries compared.

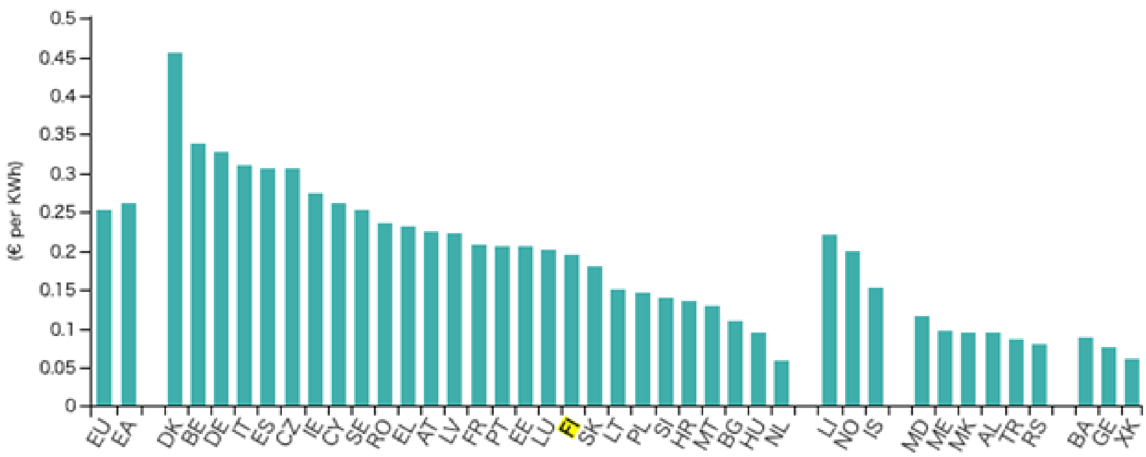

Figure 14. Electricity prices (including taxes) for household consumers, in the first half of 2022 (adapted from Eurostat 2022)

Based on the information presented in Figure 14, it can be inferred that the price of electricity in Finland remains relatively moderate in comparison to other European nations.

What is the background of the Finnish electricity market status among the EU? Professor in Energy Markets and Energy Systems at LUT University describes this in an article.

Finland has more flexible power consumption than most European countries. The reason is that after the Invasion of Ukraine, Finland has replaced most of the imports from Nordic or Baltic electricity (Figure 13). In addition, there are significant differences between Germany's situation, since natural gas is not utilized as the main method of house heating systems in Finland. (MunFin 2022). As Professor Honkapuro describes:

- "Where Finns once decided to build district heating networks, Germans chose natural gas Finland uses gas mainly for industrial purposes, and those amounts are relatively small too". (Honkapuro, Professor in Energy Markets and Energy Systems in LUT University, School of Energy Systems 2022).

Green power also helps avoid price pressures. As last, Finland has been increasing the amount of wind power. For example, in 2021, it broke the record with 141 new wind turbines, but in 2022, it has been broken in less than six months. Those factors reflect the Finnish electricity price is not high as Germany, France, etc. The fact that the increase in wind power and other renewable energy source and no longer dependent on natural gas imports from Russia helped to keep domestic electricity prices low in the end. The relatively low electricity prices in Finland compared to countries like Germany and France can be attributed to factors such as the increased use of wind power and other renewable energy sources, as well as reduced dependence on natural gas imports from Russia. (MunFin 2022).

2.7 Historical electricity price data view in the Nordic

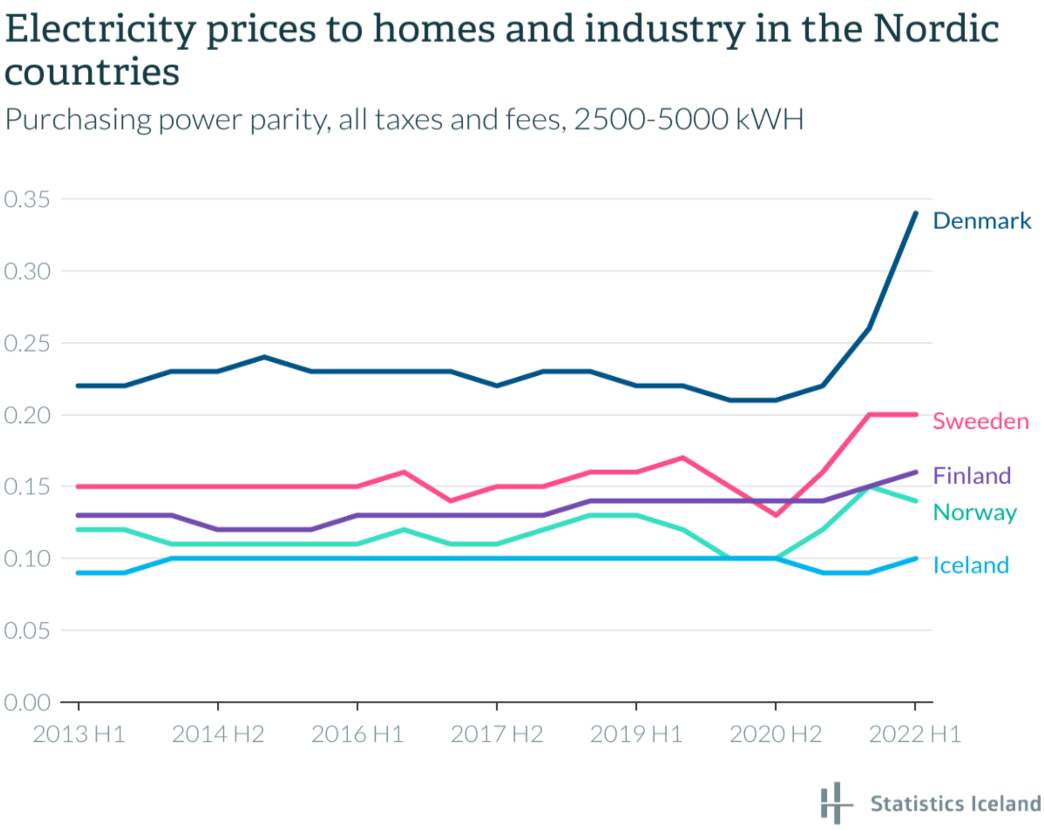

Figure 15. Electricity prices for homes and industry in the Nordic countries (Statistics Iceland 2022)

Figure 15 illustrates that historically Denmark is the highest electricity price among those five Nordic countries. In general, the orders are similar in all seven years. Sweden and Norway have similar graph movements, especially from 2014 to 2022. There are a lot of similarities in electricity policies and patterns in the Nordic. After the Attack on Ukraine by Russia, the demand and supply balance changed, so prices in the whole Nordic have risen as well as can be seen in Figure 15.

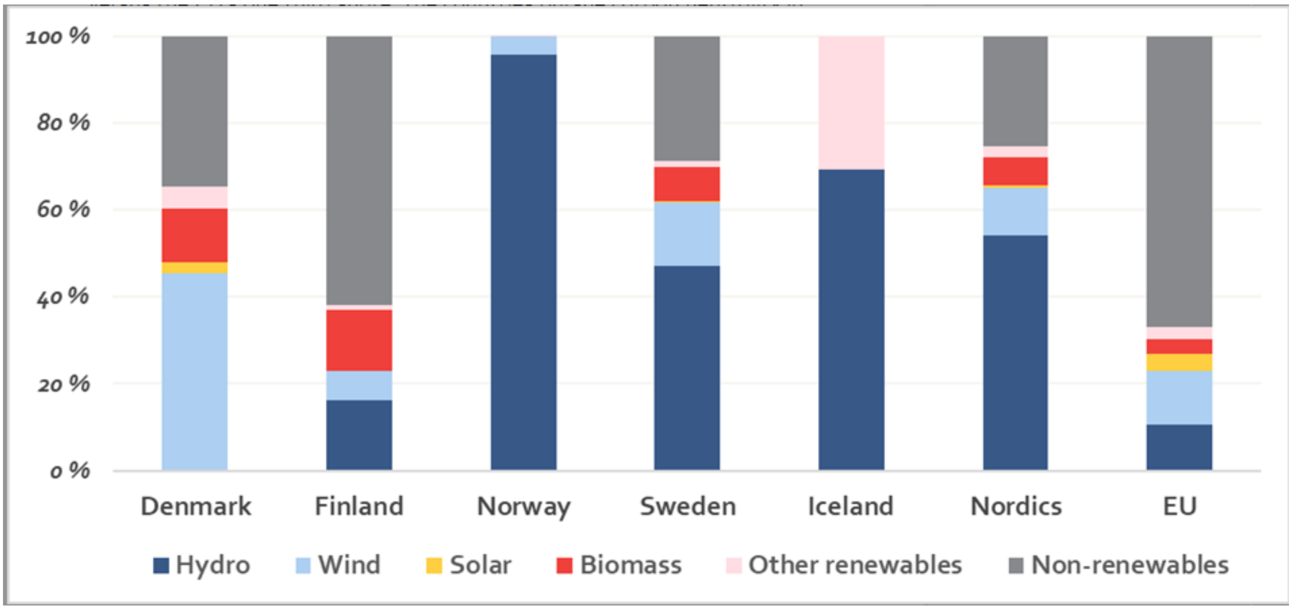

Figure 16. Renewables in the Nordic and EU electricity mix 2019 (% of consumption) (Nordic Energy Research 2022)

As Figure 16 indicates, the Nordic countries have a unique market characterized by high electricity prices if we compare it to other continents or countries. The historical data provide us insights into several trends and patterns, including:

Seasonal fluctuation

The prices in the Nordic region tend to be higher in the winter due to high demands for heating households or economic activities. (Figure 16).

Renewable energy

Figure 16 shows that the Nordic countries have a large share of renewable energy resources in their energy productions in 2019, which affects the price when sometimes the generation amount is low or high. (Nordic Energy Research 2022).

Market integration

The Nordic countries are supporting each other regarding electricity transmission, which could affect electricity prices because of the trade between the countries. According to Fingrid, (2023b),

Bidding zones within the Nordic countries are established based on the physical transmission capacity of the Nordic power system, leading to uniform pricing within each zone. Nevertheless, when electricity transmitted to different zones, it will be delivered though transmission lines. Sometimes these lines get busy, which can result in different prices in different parts of the market. (Fingrid 2023b).

Market liberalization

The Nordic electricity market has had more liberalization in recent years. (Ministry of Economic Affairs and Employment of Finland s.a.). This could increase competition and price volatility.

2.8 The factor of rising prices in the EU

Several factors affect the current energy crisis. First, the origin started the COVID-19 outbreak in 2020. the consumption of global energy dramatically decreased. However, with a fast roll-out of vaccines and monetary policy delivery, the energy demand has recovered in 2021. In the meantime, it leads to prices of fossil fuels, especially of gas. Energy supply could not always serve the demand. Therefore, all fossil fuels, such as oil, gas, and coal significantly increased the price. Secondly, after the invasion of Ukraine by Russia in February 2022, all of them skyrocketed for a short time. Russia is one of the largest global energy suppliers. EU depended on Russian fossils, especially gas for a long time. After shutting down Russia's energy, the prices accelerated dramatically.

World Economic Forum indicates that oil prices approached over $100 per barrel after the military invasion of Ukraine. (World Economic Forum 2022).

2.9 The cost composition of electricity price in Finland

How much taxes do consumers pay for electricity in Finland? This section will discuss the cost composition of Finnish electricity prices, to understand information on what kind of costs are included in electricity prices in the Finnish market.

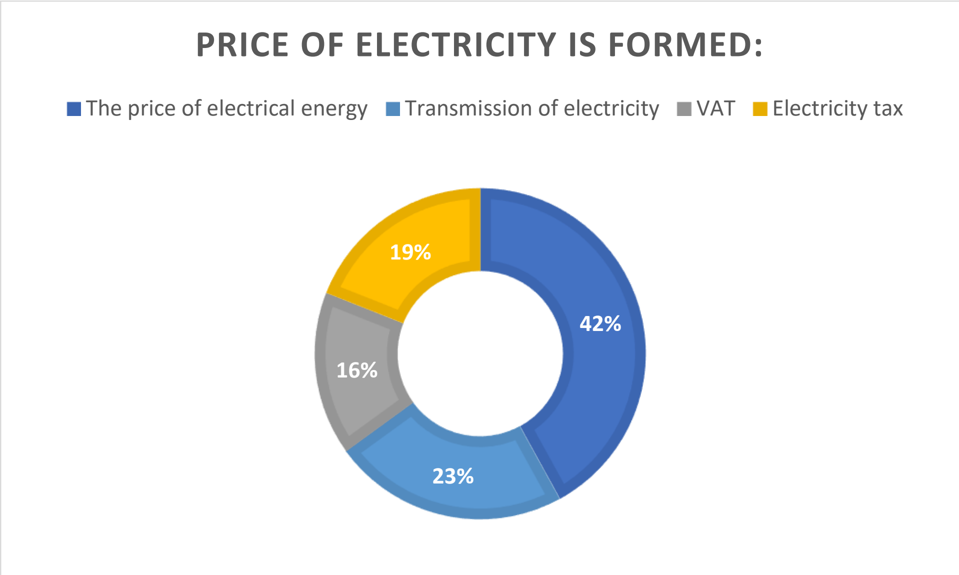

Figure 17. Electricity price composition (adapted from Keravan energia s.a.)

Figure 17 indicates the composition of electricity wholesale price if the household consumed 5,000 kWh. 42% of the price is purely from electricity generation price, 23% is electricity transmission fee, 19% is value-added tax and 16% is electricity tax. The condition is both the energy and transmission piece of electricity consist of a fixed monthly basis fee (€ per month), and a fee according to the energy consumed (cent per Kilowatt hour (kWh)). This fact implies that 35% of the electricity wholesale price consists of tax. 23% is the transmission fee. The actual generation price is less than half of the total price. Overall, the cost composition of electricity in Finland is influenced by not only the cost of generation, but also the cost of delivering it to end-users, and government policies for taxes. (Keravan Energia s.a.).

3 Electricity price data visualization

3.1 How to visualize electricity prices

How can we predict our electricity prices? As a data source, the daily basis of electricity prices from the Nord pool will be utilized to visualize electricity prices. As explained in the introduction, Microsoft Power Automate Desktop and Excel are the main tools to demonstrate the outcome.

User story

User stories are prepared based on the needs of the author and the family and friends about electricity prices.

- As a consumer, I would like to see the price if I use the sauna three times per week since the electricity price is high these days.
- As a consumer of electricity, I would like to decide whether I should make a contract with a fixed price or a spot price. What would be the “good” fixed price for the consumer in 2023 or 2024?

3.1.1 Requirement Analyst and data source

After analyzing user stories, the requirements are transformed into a list. A chart will be used to visualize the business flow of implementation1 once the requirement analysis has been completed.

As data sources, statista.com, Fingrid Oyj, Statistics Finland, Eurostat, and Nord Pool are the data origin place. All of them are free resources to acquire the necessary information to proceed with these experiments.

3.2 Implementation of User Story 1

Implementation1 will develop by utilizing Microsoft Power Automate Desktop.

User story 1. Automate sending price range every day:

- As a consumer, I would like to see the day-ahead price since the electricity price is high these days. For example, I can decide whether I should take a sauna or not since it requires a lot of electricity Approximately 5–7 kWh within the first hour. (Harvia 2023).

3.2.1 Method and tools, Microsoft Power Automate

As a development tool, Microsoft Power Automate will be utilized to achieve the below user story 1.

Microsoft Power Automate is an automation tool, which is a cloud-based platform for automating and streamlining various workflows and business processes. Users can automate repetitive tasks, streamline data and information flows, and adapt to different systems and applications. It allows users to build custom workflows and automate tasks, which generally require manual work and effort. It helps users to concentrate on valuable tasks and save time and resources. As a few examples, Microsoft Power Automate can operate the following tasks. (Microsoft 2023a):

- Send automatic email reminders.
- Migrate business data between systems on a schedule.
- Connect to more than 500 data sources or any open API sources.

(Microsoft 2023a)

Power Automate is one of the Microsoft products, that can be integrated with a wide range of Microsoft or non-Microsoft products and services, such as SharePoint, OneDrive, Dynamics 365, and other well-known cloud-based applications such as Google Drive, Google Sheets, Trello, Twitter, and so on. It allows users to demonstrate a variety of workflow types, including automated workflows, human workflows, and business workflows and can be connected to a web browser or the Power Automate mobile app. (Microsoft 2023a).

Microsoft Power Automate Desktop version is included in Windows 10 and 11. Windows 10 or 11 users can utilize it for free. (Microsoft 2023a). Multiple price ranges depend on the subscription type. As a Modern Workplace M365/SharePoint Consultant, Celis explains the differences between Power Automate Desktop and Cloud.

Power Automate Desktop is an ideal tool for handling complicated automation tasks that necessitate the utilization of local resources and applications. On the other hand, Power Automate Cloud is more applicable for workflows that operates in the cloud. (Celis, Modern Workplace M365/SharePoint Consultant 2023)

To utilize Cloud flows, it starts from $15 per month. (Microsoft 2023b).

In this project, Microsoft Power Automate Desktop functions will visualize user story 1: “Sending Nordpool’s price trend to an email account at a specific time for a user, so that he or she can know how much it cost”.

3.2.2 Requirement Analysis

Table 4. Requirement list for sending automation email. (Created by the author 2023)

Id	Requirement	Category	Priority	Traceability	Notes
RE1	Send automatic price emails from the Email list	Functional	High		Use Microsoft Power Automate Desktop
RE2	Recipients can view the electricity price daily	Functional	High	RE1	
RE3	The data must be visible	Functional	High	RE1	The data is from NordPool

3.2.3 Create workflows on Microsoft Power Automate

The process is composed of each phase based on the requirement list.

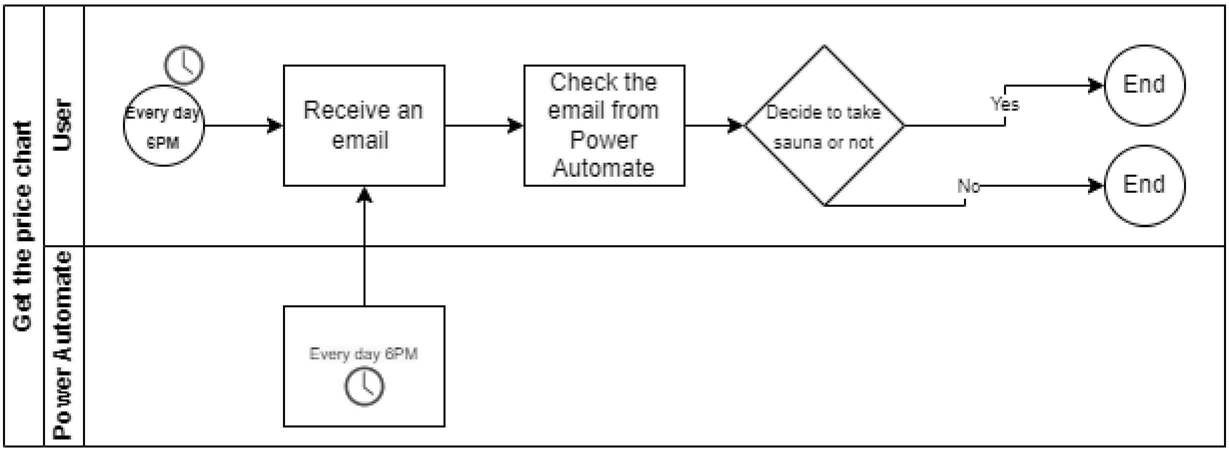

Figure 18. Process of receiving day-ahead electricity price by Microsoft Power Automate Desktop (Created by the author 2023)

From Figure 18, the user receives an automated email. Microsoft Power Automate Desktop automatically sends an email to the user at a specific time and date. After receiving it, the user checks the price of electricity at the time he/she will take a sauna, he/she can decide whether it should turn on or not.

The process is simple and clear. Regarding sending an email process from Power Automate, the procedure of sending an email is discussed in the next section.

3.2.4 Automate the process of sending an email of the captured page

In Microsoft Power Automate Desktop's application, there is a button for "Actions" on the left side.

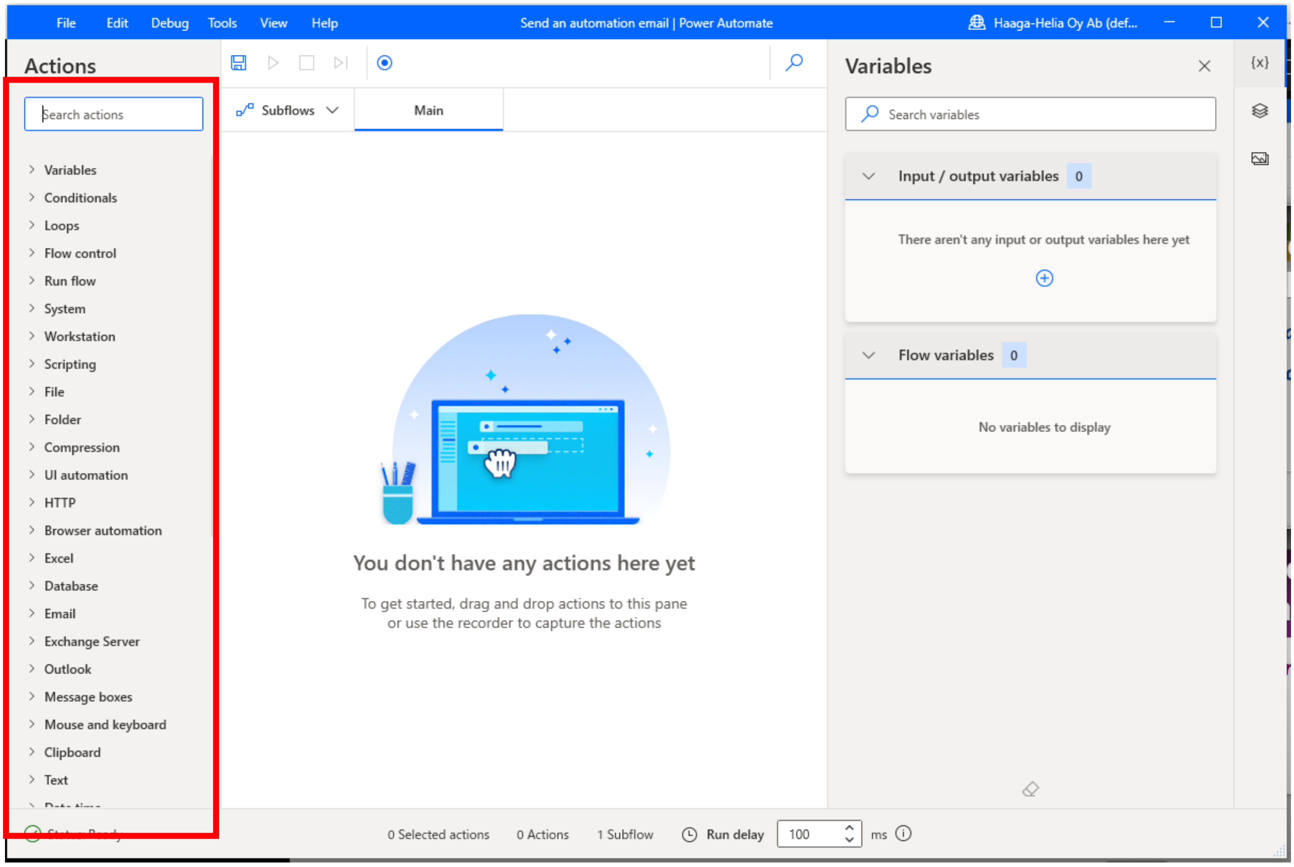

Figure 19. Microsoft Power Automate Desktop overview

As a whole process, each stage is described as follows:

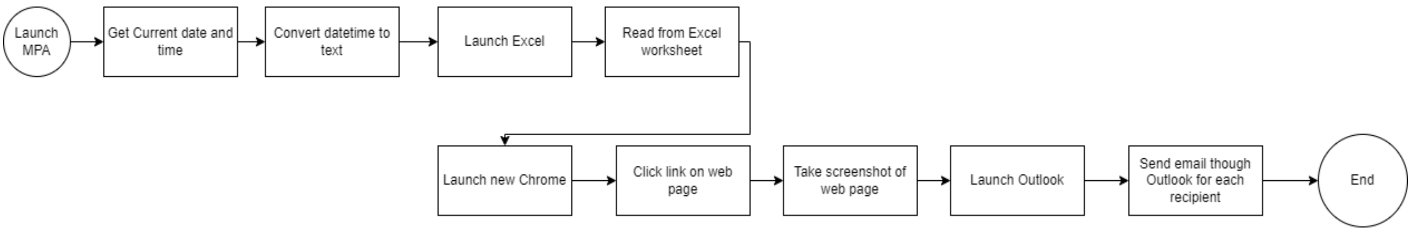

Figure 20. Process of automated email notifications with data charts by Microsoft Power Automate Desktop (Created by the author 2023)

1. First, it needs to get today's date and time to receive today's data.

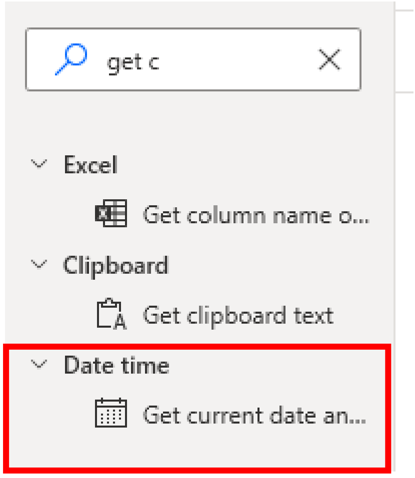

Figure 21. Select Date time from Actions

2. After selecting" Get select date and time", it can drag and drop the Flow

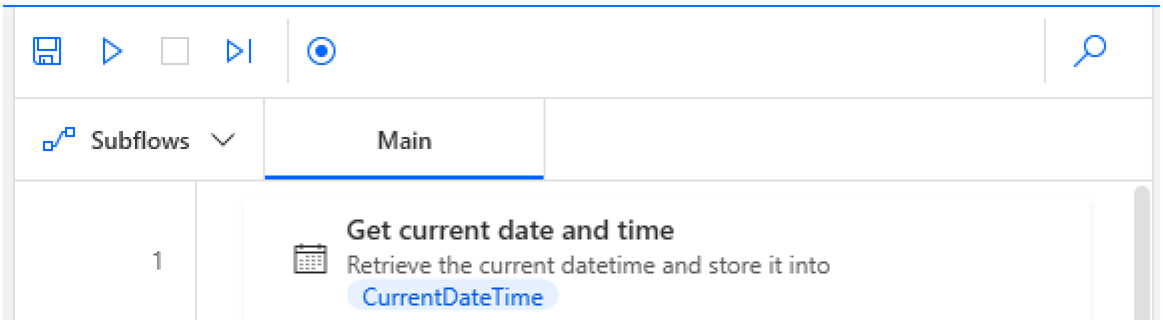

Figure 22. Line 1 in the RPA system

In Appendix 2, there are overall procedures for this process.

3. Then, the data and time need to get converted to a usable format.

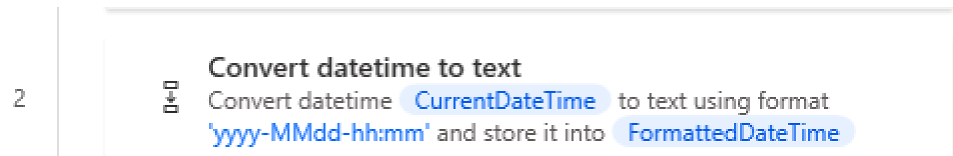

Figure 23. Convert datetime to text

4. Launch Excel to take the values of the email receiver to get the Electricity Price List.

Name	Email
Jane Doe	Jane_Doe@haaga-helia.fi

Figure 24. Email recipient list on Excel (Created by the author 2023)

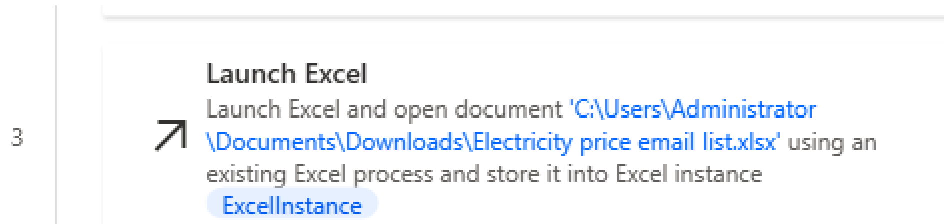

Figure 25. Set Launch Excel Action

5. After setting it, it needs to read the email receiver's information as follows.

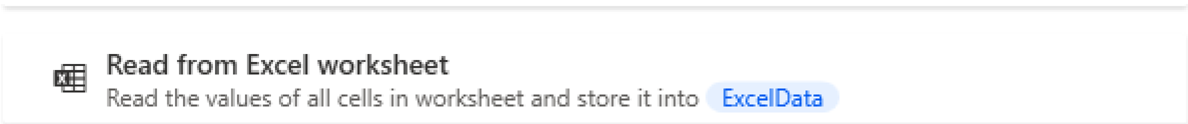

Figure 26. Set the Read function of Excel data

It reads data from Excel and sends an email automatically.

6. After setting Excel functions, it should open a web browser. In Microsoft Power Automate, there are multiple options to open a web browser such as Chrome, Safari, Firefox, etc. In this process, Google Chrome will launch and get the data source of electricity prices.

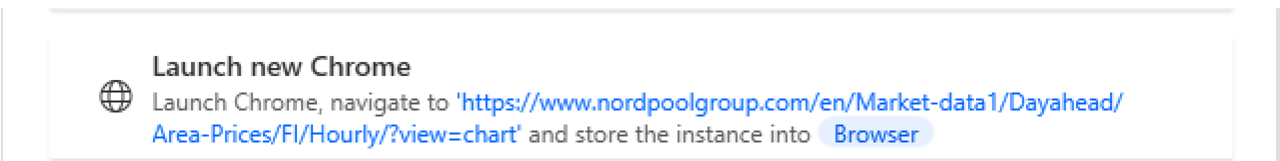

Figure 27. Set Launch new Chrome

In the setting, it can choose the launch mode and needs to paste the corresponding URL.

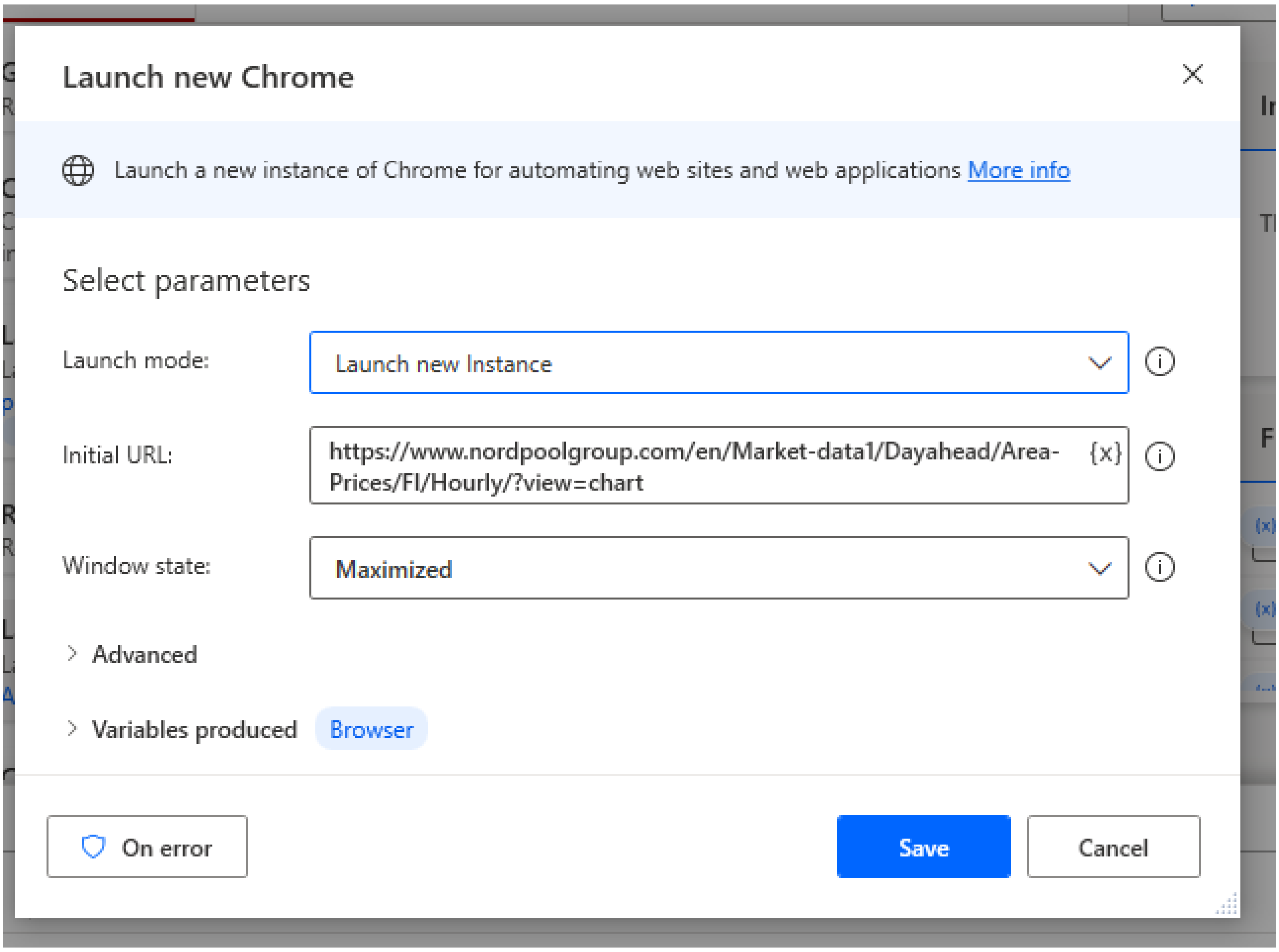

Figure 28. The setting of Launch New Chrome

7. After 6, it needs to set “Click the link on the web page”

Figure 29. Set Click link on the web page

In this setting, the user can choose the corresponding web browser instance, UI elements that need to be clicked, and type of click. Choosing “UI elements” means that users could specify the UI components from the web browser, for example, in this case, if it is required to capture the chart, it can select the components of the graph.

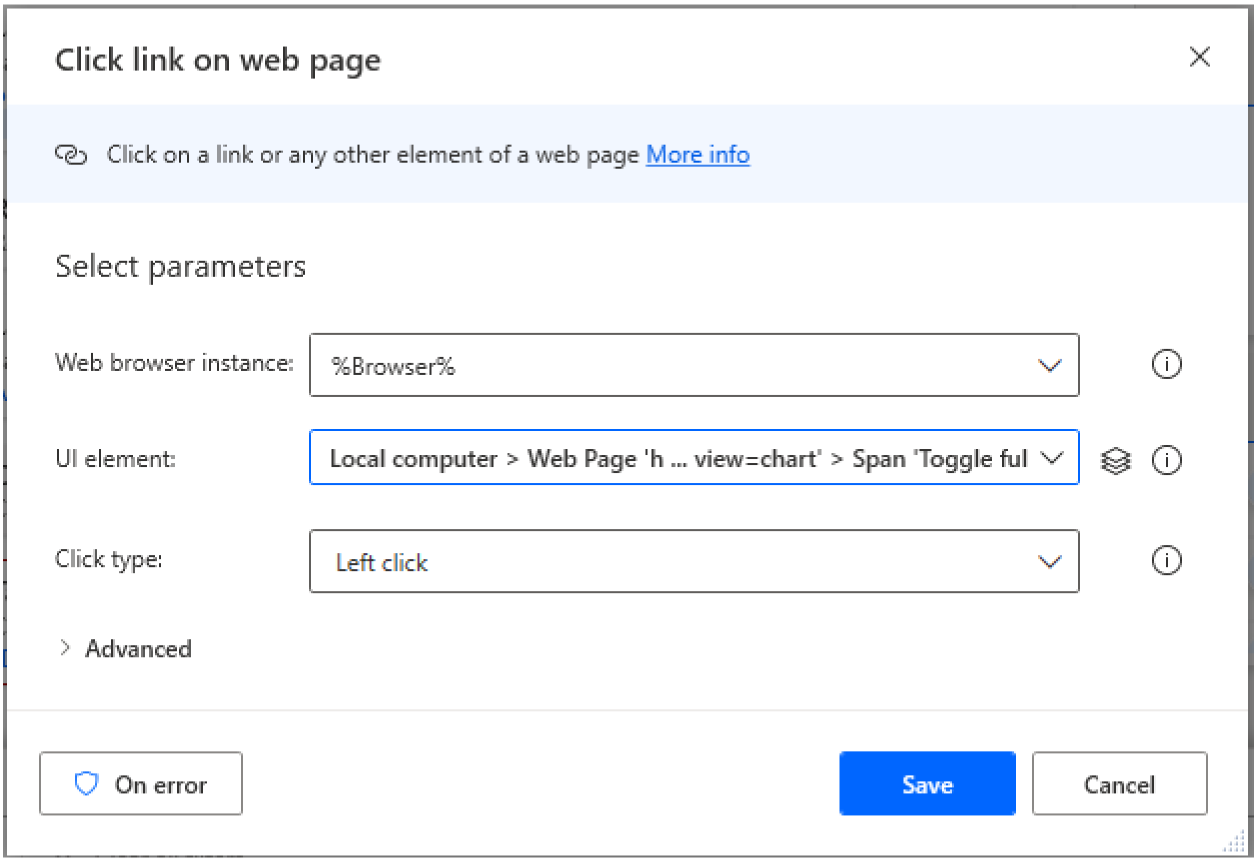

Figure 30. The setting of Click the link on the web page

It requires a selection of corresponding UI elements on the web page. In this case, it should select "Span Toggle fullscreen".

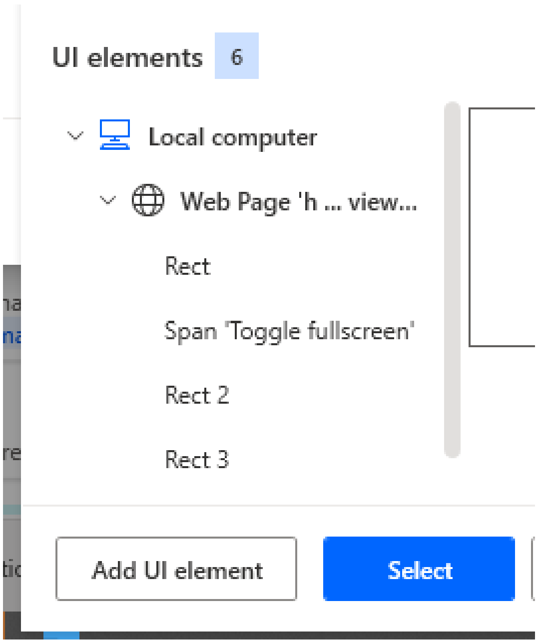

Figure 31. Select UI elements on the web page

8. Take a screenshot of the web page

After 7, it finally takes a screenshot of the graph.

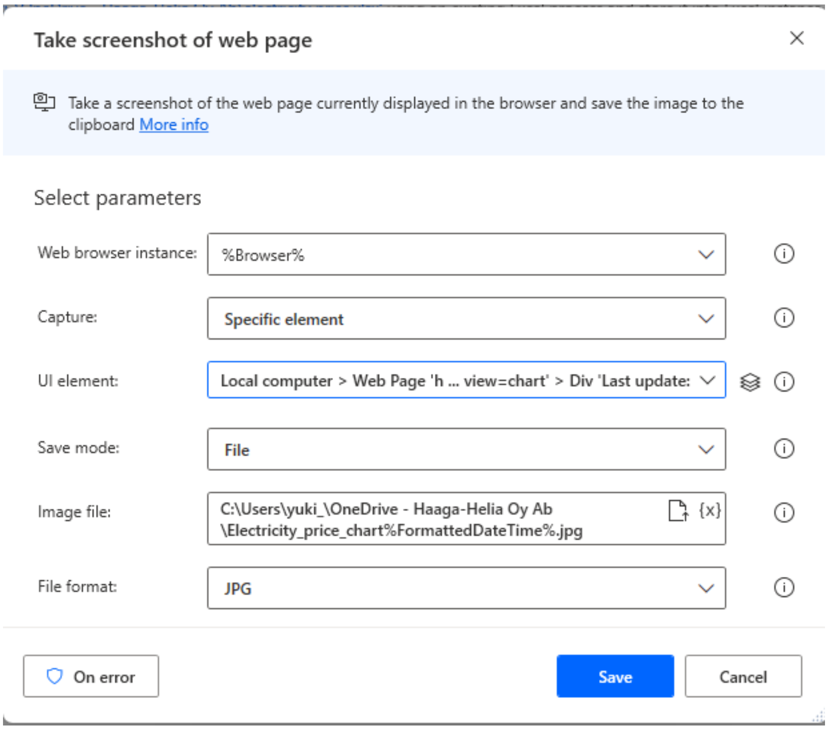

Figure 32. The setting of Take a screenshot of the web page

Take a screenshot and save the file to the corresponding destination. This time, the previous "%FormatDateTime%" is used to indicate the current date and time information in the file. One important thing when we take a screenshot is that we need to select the right UI element from the webpage. Otherwise, the robot will not capture the correct element from the web browser. In this case, we need to choose "Div" from the web element:

9. After 8 is successful, it opens Outlook to send the image which the robot automation has saved in the location.

Figure 33. Set Launch Outlook

10. Finally, drag and drop the “send an email message through Outlook” so that Microsoft Power Automate can send a notification email with the attachment of the electricity price graph.

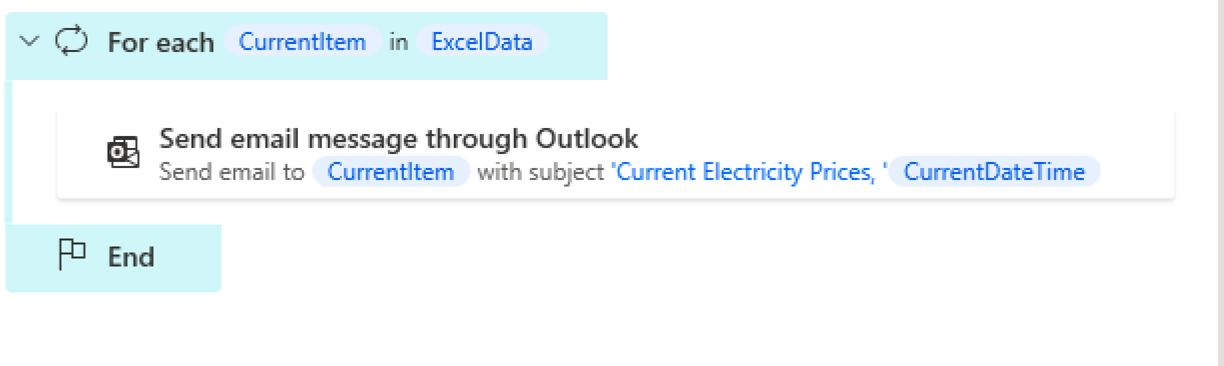

Figure 34. Set For each function

In this case, the “For each” function is applied to repeat the same action for each email recipient in Excel.

The whole automation process is captured in Appendix 2.

As above, Microsoft Power Automate Desktop enables users to visualize the process automatically. It is flexible to utilize the function so that it is easily integrated into different applications such as Google Chrome, Excel, Outlook, and so on. One important reminder when users use Chrome, the browser extension should turn on to take screenshots. Microsoft Power Automate Desktop is free to use if the user signs into Microsoft Office 265. However, one of the limitations of the free plan of Power Automate Desktop is that a single desktop flow can execute only 10,000 actions (Microsoft 2023d). The paid plan allows users to automate cloud apps, services, and data with digital process automation (DPA). With the paid version, users can create and execute an unrestricted number of workflows.

3.2.5 Testing

The author conducted a test case to ensure that all requirements were met. The test case report can be found in the appendix for reference. Overall, the results of the test were successful, with one minor concern. The header element of the UI appeared to distract from the image of the electricity price data, which could be due to the size of the window. To improve this, the author could select a more appropriate web element when choosing the UI selection part on the power automate side.

3.2.6 Summary

Microsoft Power Automate enables us to create automated workflows between different apps and services. With Power Automate, it is possible to monitor and analyze the daily data sets, which helps us to identify issues or problems. Users can generate custom workflows adapted to specific business needs, without hard coding. It can be utilized for a wide range of projects and tasks across different industries and business functions. For example, streamlining document approval, collecting, and analyzing data, automating customer service requests, managing inventory and supply chain, automating HR processes, etc. Microsoft Power Automate supports getting rid of our daily repetitive tasks and concentrates on complex, high-value tasks, to give extra value to our business.

3.3 Implementation 2: Spot prices or fixed price

Implementation 2 is to find a solution for user story 2.

User story 2. Find a solution for choosing a spot price or fixed price:

- As a consumer of electricity, I would like to decide whether I should make a contract with a fixed price or a spot price. What would be the “good” fixed price for the consumer in 2023 or 2024?

Electricity prices are determined by various factors, such as supply and demand, weather conditions, government policy, or such elements, as the author mentioned earlier. Overall, one question arises: Spot price or Fixed price, which is better? In this section, the comparison between a spot price or a fixed price, the pros and cons, and the conclusion of whether people should sign up and which types of contracts they should sign for electricity.

3.3.1 Definition of spot prices and fixed prices

The electricity spot price is determined by supply and demand on electricity changes, such as Nordpool in the Nordic region. This price fluctuates on an hourly basis.

As previously stated by the author, the Nordic region is highly dependent on renewable energy such as wind, hydro, etc. Therefore, the price of electricity exchange depends on weather conditions. There are mainly three benefits of spot price:

- It reflects the real-time supply and demand of the electricity market. It can fluctuate based on multiple elements, such as weather, demand, and so on.
- Spot price provides transparency and encourages competition in the energy market. It encourages consumers to compare the wholesale price of electricity

so that electricity providers try to sell it at the best prices, which helps to offer the best service and efficient operation for their customers.

- Spot prices can be beneficial for customers who are willing to take on more risk. Some energy providers promote low energy prices to acquire customers who would like to take advantage of low spot prices. However, the spot prices have price volatility which may lead to higher energy bills in some instances. Customers should be aware of risk tolerance and appropriate energy usage patterns before having a spot prices contract.

On the other hand, with a fixed price electricity price, the cost of each kilowatt-hour (kWh) remains constant throughout the duration of the contract. As a result, any fluctuation in market prices will not impact on the rate. The benefits of a fixed-rate electricity plan are the following:

- Easy to predict the bill: It can be beneficial for consumers who would like to plan their monthly energy expenses more accurately and avoid price volatility in their electricity bills.
- Prevention against price volatility: Electricity prices can be changed all the time and are subject to sudden increases due to multiple factors. If the price is locked, there is no need to monitor the prices at all.
- Cost saving in the long-term: a fixed-rate electricity plan may provide long-term savings compared to a spot-price plan. The reason is that fixed prices are usually paid to include a buffer against potential future price increases.

Below is the summary of both pros and cons.

Table 5. Spot-price vs Fixed-price (Created by the author 2023).

Spot-price	Fixed-price
Price volatility may increase the electricity bill	Price is predictable, no surprise bills
The bill can be saved if the consumer uses electricity when market prices are low.	Prices are fixed, which means that will not affect the market prices even if the prices are less.
Difficult to monitor prices all the time	No need to monitor since prices are locked

3.3.2 Conclusion and Summary

Overall, the choice between the spot price and fixed price depends on whether the consumer can monitor electricity prices, and if they are willing to take the risk of price volatility. Opting for a spot price could result in lower electricity bills if the consumer can take advantage of price fluctuation. Nevertheless, the market situation is still unpredictable due to Russia’s attack on Ukraine, and weather conditions. If consumers prefer a predictable electricity bill, selecting a fixed plan would be a wise decision as it eliminates the concern of unexpected price fluctuations.

4 Conclusion

In this project, the first attempt was to create an electricity forecast tool in Excel. Nevertheless, the direction should be changed due to the technical challenge and complexity of electricity predictions. In general, various factors, such as weather conditions, supply, and demand, and market status determine market electricity prices. In addition, the cost of transmission and distribution, government regulation and taxes, and market forces also affect the price. So, the author changed the topic to a different perspective, Electricity price analysis and forecasting in Finland during 2020-2022, which is focused on the analysis of electricity price rise during 2020-2022. The research concluded with a combination of qualitative analysis and practical implementations.

The factors of 2021 - 2022's energy crisis was caused by multiple circumstances. The main root factors are as followed:

- After the COVID-19 pandemic, a rapid economic recovery caught energy providers unprepared, as they were unable to expect a swift rebound in electricity demand.
- Cold winter from 2021-2022. It requires a significant amount of natural gas to generate electricity for heating homes. This increased demand for gas placed additional pressure on the energy market.
- The Russian invasion of Ukraine. It prompted Finland to eliminate importing natural gas from Russia. This decision not only led to a rise in electricity prices but also required the search for alternative sources of natural gas from other countries.

The complex interplay of these root factors and the imbalance between supply and demand around the world have brought about the crisis. The occurrence of an energy crisis due to the market's inability to keep up with rapid economic recovery after the pandemic highlights the prediction of controlling the fluctuation of the energy supply. Considering the impacts of global warming on rising energy costs, each government must consider the need to enable a sustainable energy supply using renewable energy sources in the future. The Russian invasion of Ukraine clarified the extent to which countries had been dependent on Russia for energy. Considering this electricity crisis, the importance of nationalizing energy production has been re-emphasized as not only politically advantageous but also crucial for stabilizing the energy supply.

In finding the data related to a price rise of electricity from 2020-2022, many factors affect electricity prices. The author was able to acquire the consequences of electricity price volatility and the complexities, the difficulties of price predictions, factors that make electricity prices makes expensive, the Nordic region's electricity price comparison and resources, the recent Finnish government's policy against energy consumption, and generations and the goal of electricity generation methods by 2030. Finland is currently promoting renewable energy initiatives on a national level to decarbonize its energy sector by 2030 (European Commission 2019). This effort is anticipated to enhance the stability of the energy supply and foster economic development by advancing the adoption of renewable energy technologies.

In Implementation 1, the author implemented delivering day-ahead electricity prices for users who would like to know the price of electricity daily. This is a process of capturing electricity prices on Nordpool's webpage and sending them to the user at a specific time every day. The automation process using Microsoft Power Automate Desktop looks simple and easy, although there are multiple complex settings required to achieve the expected result. Microsoft Power Automate desktop is low-code development so allows us to construct existing applications and integrate a flow into one platform. Nevertheless, it was challenging to visualize the whole data execution process using the robot. It always requires translating each action into the flow, which the robot can read and execute it. To demonstrate desired flow, users need to know a detailed understanding of each function and workflow of the operation. In addition, basic programming knowledge, such as conditional logic and loops, so that users can visualize the workflow logically.

Overall, Implementation 1 succeeded. It fulfilled the user story and the requirements. Sending an automatic email by capturing day-ahead electricity prices looks simple but requires a lot of skills to demonstrate as the author mentioned above. It is essential to try it first, no need to be perfect from the start. Handling errors and issues gives us new insights into visualizing workflows. Thus, understanding basic functionalities and knowledge boosts effective workflows and saves time and cost. There are multiple possibilities for using this automation robot tool for data analysis purposes. For example, automating the data collection process, data visualization, reporting data, data transformation, and so on. It can be usable with tools such as Excel, Outlook, Power BI, and SQL servers. (Microsoft 2023c).

In Implementation 2, the author conducted a comparison of the benefits of choosing fixed-price and spot-price of electricity by providers. This purpose is to choose the best methods for users who are trying to renew his/her electricity contract. As a result, here is a comparison table that describes both pros and cons of choosing two methods. Users can select whether they would like to get by the parameter they would like to choose such as price transparency, time availability for monitoring prices daily, and price predictability. In the end, the choice differs depending on choosing pricing options for consumers. This implementation successfully fulfilled the user story. Nevertheless, it could have been improved if the author had conducted interviews with real users who take spot-price or fixed-price options, allowing the author to work with actual price data from those users. For future implementation, the author could collect possible electricity price data from fixed-price and spot-price users. This would enable the modeling of a price comparison dashboard, which would support the data and visualize meaningful conclusions.

Regarding the analysis process, the research was occasionally challenging due to the initial focus on advanced data analysis skills. Conducting preliminary research on the electricity price prediction could have allowed the author to adjust the topic direction at the earlier phase. The author's thesis advisor, Tapola, has provided valuable advice, enabling a smooth transition to a new research direction. Electricity is a fundamental infrastructure for everyone, but its pricing is influenced by multiple factors. It makes it difficult for data analysts or scientists difficult to create accurate price predictions and requires a lot of technical skills such as machine learning, and statistical mathematics. In this research, the analysis of electricity price volatility was successful, but the price prediction aspect was not comprehensive enough to benefit a wide audience. insufficient to solve many people. The two implementations were achieved, but the scope of issues addressed did not have a significant impact on many people. Therefore, in the next chapter, the selection of the data topic and the resources must be considered to provide benefits for people who need the analysis. In this data analysis, the complexity of electricity prices makes the author difficult to continue the research. For the next project, it is important to define a clear research question and objectives, understand the type of data that should be collected (e.g., quantitative, or qualitative), review relevant previous research in the related field, and consult with a supervisor well. Technical skills require learning statistics, programming languages such as Python or R databases knowledge such MySQL, and Data Visualization tools such as Power BI, and Excel to create a visual presentation.

Although the initial goal has changed, investing in the reasons behind the electricity price rise during 2021-2022 was valuable and stimulating. Through this process, the author learned how to collect relevant electricity data from multiple sources and find two solutions as countermeasures for electricity price volatility based on two user stories. In addition, learning Microsoft Power Automate Desktop introduced a new perspective on visualizing business processes. By implementing the capture day-ahead electricity prices and sending automatic emails, the author gained experience in visualizing process flows reflecting on their functionality in the context of robotic automation. Microsoft Power Automate Desktop potentially handles repetitive automatic data collection tasks in the future, replacing human effort. This tool helped the author answer the question and achieve the user stories' goals.

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6 Appendices

Appendix 1. Test case for sending day-ahead electricity prices (Created by the author, 2023)

Test Case

Test Case #	**1**	Test Case Name:	**Send automatic emails from an Excel list**
System:	Microsoft Power Autoamte	Subsystem	Outlook, Excel, Google Chrome
Designed by:	Yuki Sugiyama	Design Date:	28 Feb 2023
Executed by:	Yuki Sugiyama	Execution Date:	9 March 2023
Short Description	Open Power Automate and press execute button, and the expected flow will operate successfully.	Time:	15:00

Pre-condition:

The user has already login to the Microsoft Account

Step	**Action**	**Expected System Response**	**Pass/Fail**	**Comment**
1	Open Microsoft Power automate	Open Microsoft Power Automate	Pass	
2	Click Start button	Execute the flow by the robot	Pass	
3	The robot will execute the whole flow	Open the corresponding Excel, open the URL, capture the data, and send it to the email list.	Pass	
4	Open the user's email account	The email has been received	Pass	
5	Check if the daily electricity price data attached to the email	Everyday electricity price has been captured successfully.	Pass	The data was captured but some destruction appeared on the image.

Appendix 2. Process Overview in Microsoft Power Automate Desktop

1 **Get current date and time**
Retrieve the current datetime and store it into CurrentDateTime

2 **Convert datetime to text**
Convert datetime CurrentDateTime to text using format 'yyyyMMdd-hhmm' and store it into FormattedDateTime

3 **Launch Excel**
Launch Excel and open document 'C:\Users\yuki_\OneDrive - Haaga-Helia Oy Ab\electricity price.xlsx' using an existing Excel process and store it into Excel instance ExcelInstance

4 **Read from Excel worksheet**
Read the values of all cells in worksheet and store it into ExcelData

5 **Launch new Chrome**
Launch Chrome, navigate to 'https://www.nordpoolgroup.com/en/Market-data1/Dayahead/Area-Prices/FI/Hourly/?view=chart' and store the instance into Browser

6 **Click link on web page**
Click on Span 'Toggle fullscreen' of web page

7 **Take screenshot of web page**
Capture Div 'Last update: . ... 22-02-2023' and store the captured image in file 'C:\Users\yuki_\OneDrive - Haaga-Helia Oy Ab\Electricity_price_chart' FormattedDateTime '.jpg'

8 **Close web browser**
Close web browser Browser

9 **Launch Outlook**
Launch Outlook and store the instance created in OutlookInstance

10 **For each** CurrentItem in ExcelData

11 **Send email message through Outlook**
Send email to CurrentItem ['Email'] with subject 'Current Electricity Prices, ' CurrentDateTime

12 **End**

13 **Close Excel**
Close the Excel instance stored into ExcelInstance