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Nuclear energy as an alternative to reduce energy prices and greenhouse gas emissions in Austria

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Abstract

Die vorliegende Masterarbeit untersucht die Möglichkeit der Einführung von Kernenergie in Österreich als Mittel zur Senkung der Energiepreise und zur Reduzierung von Treibhausgasemissionen. Angesichts der aktuellen Klimakrise und der damit verbundenen politischen Spannungen ist die Notwendigkeit alternativer und nachhaltiger Energiequellen dringlicher denn je. Diese Arbeit beleuchtet die historische und rechtliche Entwicklung der Kernenergie in Österreich, einschließlich des negativen Referendums von 1978, das zur Nichtinbetriebnahme des AKW Zwentendorf führte. Durch eine umfangreiche Literaturrecherche und eine Umfrage unter österreichischen Studierenden wird die aktuelle öffentliche Meinung zur Kernenergie ermittelt. Die Umfrage zielt darauf ab, zu verstehen, ob die Bereitstellung aktueller Informationen über die Vorteile der Kernenergie, wie geringe CO2-Emissionen und hohe Sicherheitsstandards moderner Reaktoren, die Akzeptanz in der Bevölkerung erhöhen kann. Die Ergebnisse zeigen, dass eine gut informierte Öffentlichkeit eher geneigt ist, Kernenergie als Teil der zukünftigen Energiepolitik zu unterstützen, was bedeutende Implikationen für die Gestaltung nachhaltiger Energiepolitiken in Österreich hat.

1. Introduction

Climate change and its effects, as well as both global and national difficulties associated with contested energy transitions, are the primary topics of political agendas in 2022. The energy supply issue is highly relevant at the moment, affecting us all. After the enormous price increase, controversial reports about electricity providers and quite uncertain winter forecasts, everyone should at least briefly question the economic-political energy situation. In the case of Austria - one of many EU countries facing the same difficulties outlined above – the political situation regarding this topic seems to remain very tense. Media coverage reports daily over missed climate targets and future predictions on achieving these goals are rather negative. This energy crisis clearly demands change, although it has politically not been made clear how to tackle the situation yet. There are various initiatives, obviously some more popular than others, to soothe the raging and unsatisfied population.

In contrast to the challenges posed by powerful economic interests and power dynamics, the contributions of this thesis will examine the opportunities for the development of climate and sustainable energy policies. The aim of this work is, among others, to evaluate the topicality and significance of the very outdated and socially largely rejected nuclear energy generation method. It is also intended to provide food for thought for the future, where EU countries such as Austria will not only have to struggle to meet the very ambitious climate targets, but at the same time will also have to deal with the difficult situation in the energy sector.

What is fascinating, is that nuclear decommissioning is still happening in some EU countries, regardless of the very needs for sustainable and affordable energy at the moment. The multinational energy dependencies are starting to manifest themselves stronger than ever, mainly driven by the Ukraine conflict, which clearly illustrates the impact these dependencies can have on the domestic economy and energy market. However, the deliberate separation from nuclear energy, which is to this day considered as a solid pillar for the base load supply of many EU states, is not equally supported by every European government. Other EU members follow a rather different attitude and are investing large sums of money in the expansion of their nuclear infrastructure. Given that fact, it seems that the political opinions, perhaps the publics too, differ significantly from state to state, even though their geographic vicinity is undeniable. From an outside perspective, this phenomenon raises questions on how that can be possible, given the mutual legislation system provided by the EU facilities. By taking the publics opinion under consideration, there can be many reasons for these deviations, for example cultural, economic, or even historical differences. Nevertheless, the state of knowledge as well as the initial belief system of each individual citizen could matter in the opinion formation too.

Therefore, this work will make the effort to conduct an experiment in form of a survey, which will hopefully give some answers to the underlying problem and evidence for the importance of information flow and clarity, when addressing energy challenges. The survey is intended to obtain the public's current opinion and expectations regarding nuclear energy, whereby society's view of the issue is also taken into consideration and ultimately carries decision-making power in a democratic government. Duvicic-Paoli et al. (2022) already addressed the important role of the population in relation to nuclear energy facilities. According to this affected residents should have a voting influence on decisions and there should be a fair flow of information among energy companies, trade unions and the population. The main advantage is that legislation and the nuclear power industry can better understand societal concerns, address risks, uncertainties and pursue common interests and priorities. Thus, it is hoped that this research and the conducted experiment will provide more detailed insights on possible reasons for objection of nuclear energy in Austria, and whether education is needed regarding the current state of the art in nuclear energy production and the resulting economic/environmental advantages/disadvantages. This can later be used to initiate new measures and having a better comprehension of the necessary steps for an evaluation process of that technology, of course, if ever considered.

The special incentive for the research question has been crafted after a published interview with Professor Jordan B. Peterson, who presented the simple, long since written-off nuclear energy as a solution to the energy crisis and the reduction of greenhouse gas emissions. Furthermore, the so-called "green sector", including the stakeholders of renewable energy interests, ultimately represents an economic sector in its own right, which certainly also wants to pursue its own economic goals, possibly covered under the ecological facade of the "only right solution". Common interests - such as an economic energy supply - may not always be of priority in that case. Therefore, considering and evaluating other methods is of great importance for our future, especially if climate damage starts having more negative impacts on human life than the caused harm of possible energy alternatives. Ultimately, staying open for innovation and progress has to be one of the goals for sustaining future growth and survival at last, which can be debated when looking at Austria’s current energy policy.

In consideration of the above, the following research question guides this inquiry:

"What factors hinder Austria to introduce nuclear energy into its energy policy as an alternative to reduce energy prices and greenhouse gas emissions?"

2. Review of the Literature

The following literature review is intended to synthesize and analyze the existing sources, as a way to provide an overview of the state of research on the topic. Thus, the goal of this review is to display and structure the existing knowledge and to provide an initial base for the reader, which will help to better understand the context as well as possible findings. Furthermore, the literature review will highlight the existing research's shortcomings and gaps, which will serve as justifications for developing and conducting new findings. The relevant theoretical background from the academic database will be filtered and the most important articles and journals related to the topic will be used.

Most of the admissible literature for the paper is found on Google Scholar, Wiley and Science Direct. The search process for the literature is characterized using keywords like nuclear energy in Austria, greenhouse gas emissions in Austria, energy resources in Austria, climate goals in Austria etc..

2.1 Energy industry in Austria

For the beginning of the literature review it is important to analyze the current standpoint of the main mechanisms involved in Austria's energy industry. The basic layers of energy carriers will be investigated briefly and their role in national energy policies evaluated. References between the production and consumption will be drawn and their quite significant contrast underlined. Moreover, the same procedure will be followed when analyzing Austria's energy market itself, as this presents important background, both economically and regulatory for this research work. Despite nationwide proposed energy goals, current problems, and risks for maintaining and achieving such will get featured, which provides justification for the discussion of other applicable solutions for the future. Taking into account historical data and current price development for various energy resources, first relevance for the research question will be underpinned. The value of energy will be elaborated during that process, briefly summarizing the reason and origin for current energy carriers pricing structures and possible future development for each container. Nevertheless, a sole view on Austria is not sufficient when elaborating on the energy structure and the industry's mechanisms. From a macroeconomic perspective, the term economy implies looking at other market participants too and thus, putting them into perspective to Austria's energy sector. Being one of 27 EU countries, these comparisons can provide a general position of Austria's energy industry.

2.1.1 Energy carriers

In view of the multitude of different possibilities for energy generation and energy production, it is first important to get an overview of the energy sources primarily used for energy production in Austria.

A good third of the primary energy sources come from domestic production, which is characterized by a high share of renewable energy sources. Biogenic fuels and hydropower are the two most important energy sources in domestic production. This is largely due to Austria's very advantageous topographical characteristics, which favor such types of generation (Wagner et al. 2015). Although photovoltaics, wind power and ambient heat account for a relatively small share of total energy production compared to the other energy sources, they have shown the strongest percentage growth in the past decade (BMK, 2022). Furthermore, the general decrease in the share of all fossil fuels in primary energy production and their distant use is clearly perceptible, which at around 15% for the year 2021 is only relatively small, and thus emphasizes the increasing use of renewable energy sources, as can be seen in *figure 1* below.

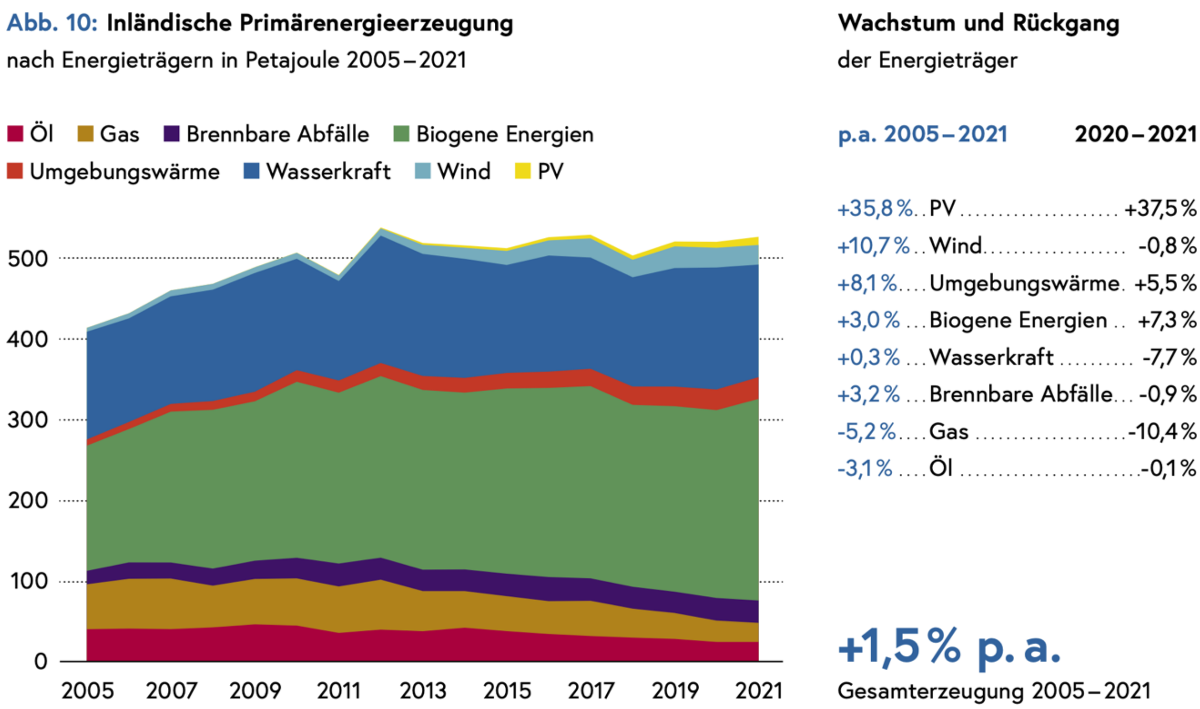

Figure 1: Domestic primary energy production in petajoule 2005 – 2021 (BMK, 2022, p.14)

In the following, the individual energy sources of domestic energy production (excluding oil, gas and combustible waste) are explained in more detail, so that their current state of development and utilization potential for future energy production become clearer:

a) Hydropower:

Hydropower is by far the most important electricity generation technology in Austria. In 2021, it covered around 61% of total electricity generation (BMK, 2022). Hydropower as an almost carbon nonpartisan, all around cutting edge and cost-effective energy source is viewed as one of the most seasoned and most settled types of sustainable power sources. However, the environmental goals of the EU Water Framework Directive may be in direct opposition to any further expansion of hydropower that is required at the national and European levels. Furthermore, a sizeable portion of Austria's hydropower potential has already been utilized, accounting for 68% (Wagner et al. 2015). The use of Austria's remaining hydropower potential is currently the subject of heated debate, as the concurrence of various interests and positions brings about pressures and lack of agreement over where, how and whether the leftover potential could be obtained (Habersack et al. 2012).

b) Biogenic energies:

At 47.5%, this type of energy generation comprises the largest share of Austria's primary energy production. On the one hand, it includes solid biogenic fuels, such as logs and other solid biomass, such as wood chips, pellets, wood briquettes, sawmill by-products, waste liquor and the biogenic part of household waste, which are used to provide heat and, in the case of CHP plants, to generate electricity and heat. On the other hand, it also includes gaseous biogenic energies as well as liquid biogenic energies such as biodiesel, bioethanol and vegetable oils that are consumed in the transport sector (BMK, 2022). In contrast to hydropower, biogenic energy is hardly used for electricity generation, but mainly for buildings and industry (Resch et al.). However, what is worth mentioning is that the combustion of biomass is only CO2-neutral if its recycling is ensured (Crasten 2017).

c) Wind power:

Although this energy source currently accounts for only 4.6% of primary energy generation, it has been greatly expanded in the last decade, already accounting for 10% of domestic electricity generation (BMK, 2022). The speed of expansion is primarily limited by the legal conditions of the Green Electricity Act, which is slowing down the commissioning of already approved wind turbines due to the long queue for contracts, including the associated subsidies (Moidl et al. 2018). Nevertheless, according to forecasts, the potential of wind power generation can be further exploited by 2030, whereby wind power plants account for a share of about 26% of Austria's total annual electricity generation. This is mainly favored by the technological progress of modern wind power plants, as these are getting larger in size and more efficient year after year, which results in greater energy production capacities per plant. Additional benefits of newly established technology improvements also include more operating hours per year, due to possibilities of wind exploitation even in less favorable weather circumstances. For 2050, the potential is even higher, at around 30 TWh total capacity (Resch et al. 2017). However, with a strong increase in energy generated with wind, the storage problem must also be solved because of the strong variability of this form of energy (Crasten 2017).

d) Photovoltaics:

The expansion of photovoltaic systems is continuously increasing and shows great potential for development. Currently, the share of this type of energy generation in Austria's annual electricity production is around 4% (BMK, 2022). In the case of photovoltaics, the potential available in the future is divided roughly equally between ground-mounted and building-integrated systems. There is a technically realizable potential of more than 20 TWh in 2050, which means that the share of Austria's annual electricity generation could already rise to 15% in 2030 (Resch et al. 2017). A clear advantage for the future expansion of this energy source is the reduction in investment costs for the plants, which are already 40% lower than in 2010 (Resch et al. 2017).

Despite the high share of renewable energies in domestic primary energy production, some difficulties stand out in the overall consideration of the Austrian energy consumption. *Figure 2* shows the gross domestic consumption of energy in Petajoule from the year 2005 to 2021. What is positive, is that consumption has remained stable for the last 15 years, which already indicates higher efficiencies.

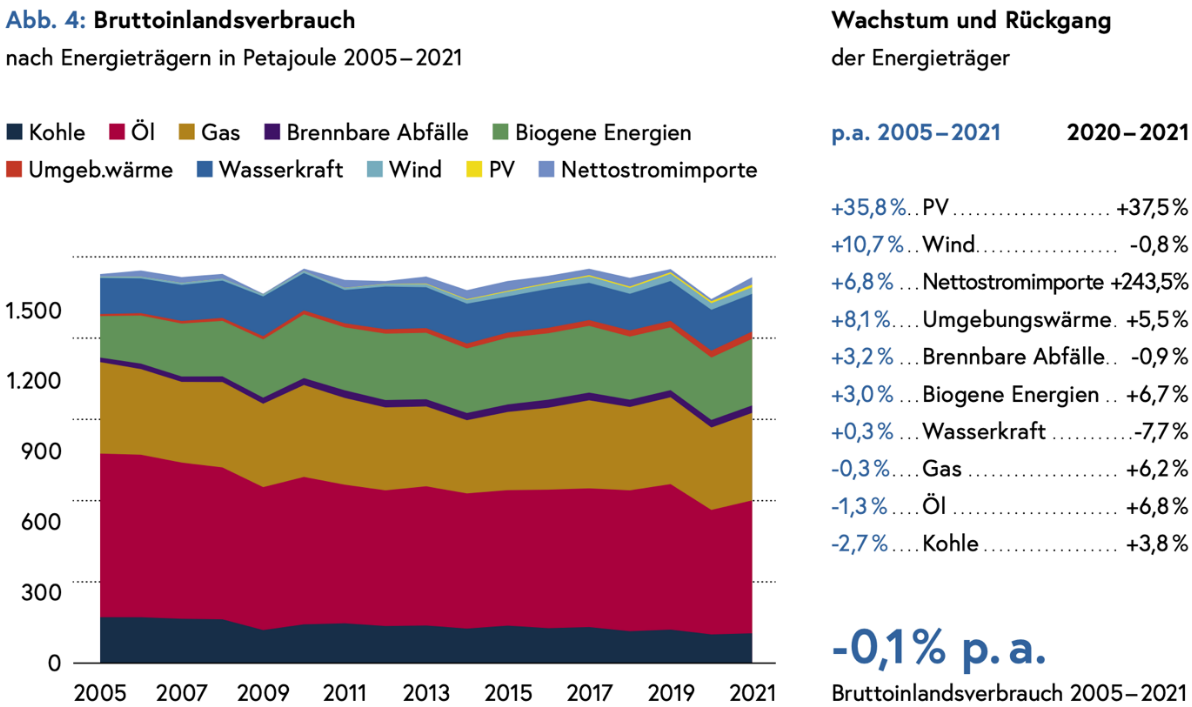

Figure 2: Gross domestic consumption by petajoule 2005-2021 (BMK, 2022, p.12)

Nevertheless, it becomes clear that the total electricity consumption is far higher than the energy generation described above. At 526 petajoules, this accounts for just over one-third of the national gross final consumption, which is 1,426 petajoules for 2021 (cf. BMK, 2022).

2.1.2 Energy Trading

Austria is engaging quite intensively in energy trading, which has multiple economic reasons. Due to a lack of sufficient domestic reserves, Austria has to import a large part of its fossil energy. Austria currently imports four times as much energy as it exports. Both imports and exports are subject to strong fluctuations due to the situation on the gas markets (BMK, 2022).

Moreover, the energy demand is not continuously equal throughout the year, as different seasons and weather conditions request divergent amounts of energy. Net electricity imports have increased significantly again due to the higher electricity demand in 2021 and the overall poorer generation conditions, especially water and wind supply in the domestic market. In order to meet the energy demand, large amounts of energy must be imported in cases like that. This significantly reduces the share of renewable energy, as shown in *figure 3*:

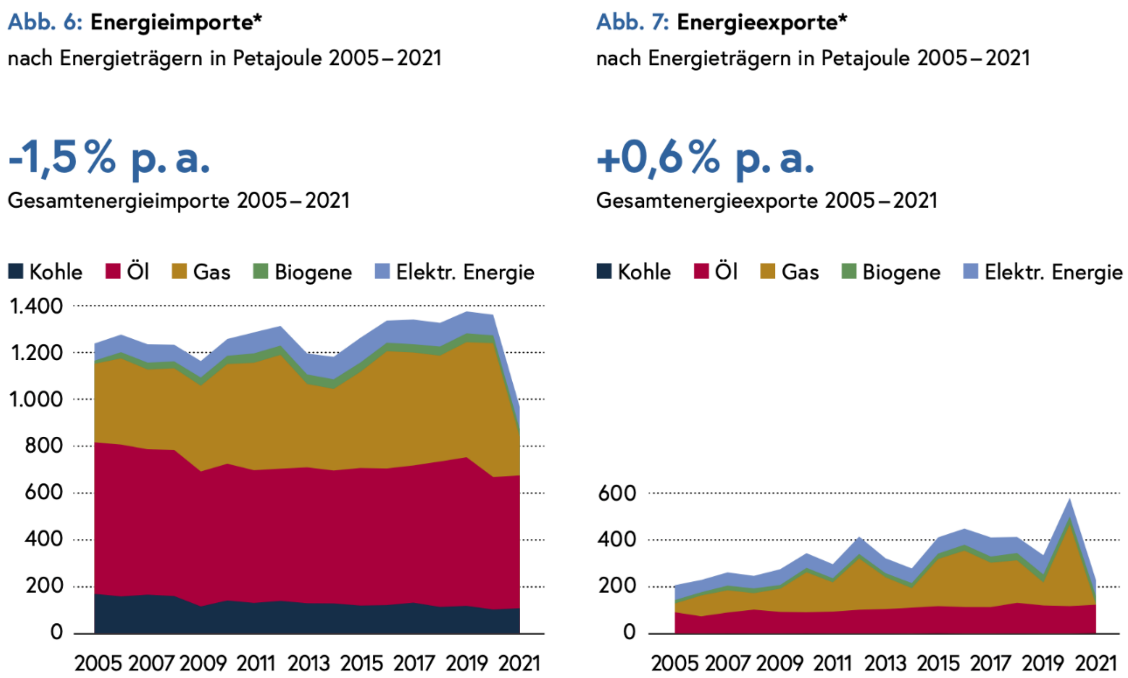

Figure 3: Energy imports / -exports in petajoule 2005 - 2021 (BMK, 2022, p.13)

2.1.3 Austria's energy market and energy legislation

Energy markets are in general highly complex and differ in scope and stage of development, as well as in their capacity and ability to implement instructions into national legislation. Additionally, regulations outline each member state's obligatory goals, that might lead to variations in how each country implements them (Biresselioglu et al. 2021). There are many different factors, such as regulatory requirements and legislative prohibitions that influence Austria's energy production structure as well as its energy trading activities. Speaking of which, the legislative aspect is of great importance for understanding market structures as well as the current range of market players, who participate in the economy and act as stakeholders in Austria's energy industry. The regulatory boundaries and legislative initiatives have been evolving intensively for more than 20 years now.

It all began on 19 February 1999 when Austria, with the enactment of the Electricity Industry and Organisation Act 1998 (ElWOG 1998), started a new era of liberalisation of the Austrian electricity market that had previously been considered impossible. Until then, the previous monopoly sector of electricity supply had been divided into the areas of generation, transmission/distribution and trading/sale of electrical energy. In this context, the areas of energy generation and energy trading are subject to the forces of the free market, while grid operation remains a monopoly area (Trattnig et al. 2022).

The declared goal of these liberalisation efforts in the European Union and thus in Austria was the gradual abolition of the existing overall energy monopoly by electricity companies, leading to free, non-discriminatory market access for all energy consumers. The aim was to abolish barriers to market access, introduce true costs and transparency, reduce bureaucracy and establish a stable energy market (Trattnig et al. 2022). This enabled all electricity customers to choose their supplier freely from October 2001 and all gas customers from October 2002 (Kretena et al.).

The laws that govern the energy market in Austria today come from both federal laws that govern the entire nation and provincial laws that govern specific regions. The Federal Act Providing New Rules for the Organization of the Electricity Sector (Electricity Act 2010) is the primary piece of electricity legislation in Austria (Biresselioglu et al. 2021). This act included arrangements for the production, transmission, dispersion, and supply of power, respecting the associative structure of the industry. In addition, it included guidelines for billing, internal organization, unbundling, and transparency in electricity companies' balance sheets. The Green Electricity Act of 2012, which regulates and provides subsidies for electricity generated from renewable sources, is another significant piece of renewable electricity legislation. The Natural Gas Sector Act of 2011 and the Federal Energy Efficiency Act are two additional significant statutes. The recent "Renewable Expansion Act" also outlined essential energy sector requirements (Biresselioglu et al. 2021). One microeconomic advantage in Austria is the legal possibility of sharing surplus electricity with neighbors and even energy suppliers. This encourages citizens to invest in own renewable energy plants, such as solar panels and wind turbines and supply private energy demand, making them both act as consumer and provider simultaneously.

2.1.4 European energy legislation

Throughout the 1990s, decentralization of the energy sector became a priority in Europe. The EU's first energy policy (Directive 96/92/EC), which was approved in 1996, included measures for the deregulation of the energy markets. The Regulation authorized both functional bundling and third-party access. Aiming to ensure the autonomy of market regulatory authorities and a competitive retail sector, the second energy package (Directive 2003/54/EC, Directive 2003/55/EC, and Regulation (EC) No 1228/2003), which was implemented in 2013, was created. The third energy package, which included Directive 2009/72/EC, Directive 2009/73/EC, Regulations (EC) No 713/2009, No 714/2009, and No 715/2009, increased the autonomy of National Regulatory Agencies, established ACER, and clarified the current laws on the dismantlement of network operators (EU Agency for the Cooperation of Energy Regulators). More lately, the Clean Energy Package, that consists of the Directives that govern energy communities (Internal Electricity Market Directive (ED 2019) 2019/944 and Renewable Energy Directive (RED II) 2018/2001/EU), granted consumers the same rights as traditional industry players in engaging in the energy markets and removed all institutional, technical, and financial impediments to creating cohesive energy initiatives (Biresselioglu et al. 2021). An important step to ensure self-participation among European citizens on the quest for a more economic and environmentally sustainable energy future in Europe.

Furthermore, authorities are looking for direction on how to enact policies and strategies in an effort to halt or reduce the consequences of climate change, for instance through the international Paris Agreement, the European Union (EU) Climate Pact, or the European Green Deal. By 2050, the latter intends for the EU to have a negative Carbon footprint (Biresselioglu et al. 2021).

2.1.5 Energy prices and market conditions

The consideration of the global energy markets is generally done according to the primary energy carriers oil, gas, coal, nuclear energy, hydropower and renewable energies. With the exception of renewable energies and hydropower, the amount of energy is always tied to a tangible primary energy source that can be transported and stored.

Therefore, structures have been developed worldwide in which these primary energy units are traded. This applies in particular to the fossil energy sources oil, gas and coal, which in the past covered around 85 % of primary energy demand (Gochermann 2021). However, an examination of oil and gas prices shows that the free forces of the market are not the only ones at work here. On the consumer side, demand is the main driver. On the one hand, this is due to the growing global traffic on land, at sea and in the air, which increasingly requires liquid energy. If the economy grows, so does the demand for oil, and the price tends to go up. Oil or natural gas exports are an enormously important source of revenue for many countries. The largest oil and gas reserves are in the Middle East, the largest coal reserves in North America, Australia, Asia and the CIS states, the most extensive gas reserves in Russia. The EU states have only 1.8% of the world's energy reserves and 2.5% of the energy resources - with a share of 15% of world energy consumption (Thoben et al. 2006). It is therefore foreseeable that in case of the slightest disruption of the gas and oil supply processes, both Austria and the EU can hardly influence gas and oil prices anymore. *Figure 3* shows the enormous quantities of these two energy resources that are imported annually in Austria. The design of numerous public functions and processes, such as the majority of public and private heating by district heating, means that the demand for these resources hardly declines despite significant price increases. Unlike the majority of the main economies in the eurozone, including Germany, France, Italy, Spain, and the Netherlands, Austria neither reduced the tax on gasoline nor actively subsidized it (Prammer and Reiss 2022).

Considering the electricity market and its price dynamics, the same conditions do not apply as for oil and gas, although there are intricate dependencies on these resources here as well, which become clear in the development of electricity prices. Electricity is a commodity, and like pretty much all resources, electricity is also traded on exchanges. On the EEX energy exchange in Leipzig, electricity is traded for the largest European electricity markets such as Germany, France and Italy. On this power exchange, the admitted trading participants buy and sell electricity for a fixed delivery period at wholesale level. Companies can exclusively trade directly at this exchange (Gochermann 2021).

Since the liberalisation of the electricity market in 2001, a steady decline in electricity prices has been observed in Austria due to increasing competition and falling energy prices, from which customers have also benefited. However, as shown in *figure 4*, this trend has changed significantly since 2017, which has several causes.

Jahr	**Preis pro kWh** **(Strompreis in Eurocent / 1 kWh)**
2023	aktuell zwischen 40 und 60 Cent, je nach Anbieter und Vertrag
2022	37,12 Cent
2021	22,85 Cent
2020	21,67 Cent
2019	20,47 Cent
2018	20,21 Cent
2017	19,78 Cent
2016	20,10 Cent
2015	19,83 Cent
2014	19,87 Cent
2013	20,18 Cent

Figure 4: Development of electricity prices in Austria from 2013 - 2023 (Energiemagazin, 2023)

First of all, On 1st October 2018, the German-Austrian electricity price zone was separated, which subsequently led to a price increase in Austrian wholesale, especially at the beginning of the price zone separation (Kratana et al.).

Secondly, the determination of the Austrian electricity price is basically based on the merit-order-system. This means that electricity is first fed into the grid by wind, hydro and solar power plants. Due to their very low marginal costs, renewable energies are always used first to generate electricity as seen in *figure 5* (Haucap, Meinhof 2022).

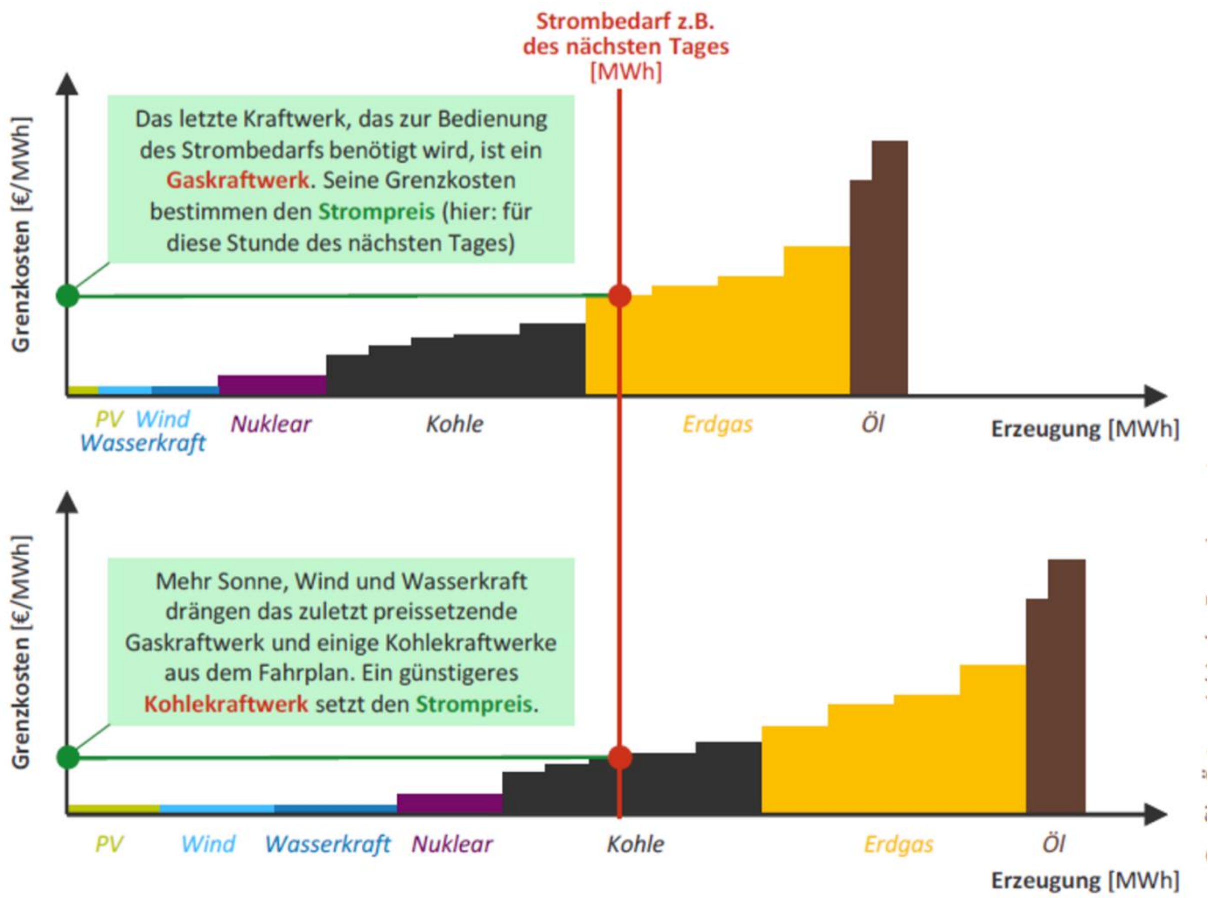

Figure 5: Operating principle of price determination in European wholesale - "the merit order curve" (Austrian Energy Agency, 2023)

As soon as they feed electricity into the grid, they drive forms of generation with higher marginal costs, such as gas, out of the market. After that, more expensive power plants are added until the electricity demand is covered. The price of the last power plant to feed in, which in Austria are gas-fired power plants, then determines the electricity price (Haucap, Meinhof 2022).

As a result of the Russian war against Ukraine, there has been an additional increase in electricity prices, which have risen sharply in this context. At an average of 37.12 cents per kWh in 2022, the price in Austria has risen by 62% compared to the previous year. The war in Ukraine has driven up prices on the electricity exchange primarily because natural gas has become more expensive. But the increased CO2 prices aimed at reducing CO2 emissions also continue to have a price-driving influence (Haucap, Meinhof 2022). Nevertheless, many of the current energy providers in Austria have collected massive profits over the last months, despite the political conflict in Ukraine. In reaction to that, several member states have imposed specific taxes on windfall profits from energy producers, who have been profiting from high energy prices, in order to avoid overtaxing the budget. Romania skims off 80% of surplus revenues above a predetermined reference point, Italy and the UK have temporary tax rates of 25% on energy (oil producing) enterprises, and Hungary has distinct tax rates for those who make petroleum products (25%) and those who make electricity (65%). Greece charges a 90% windfall profit tax on electricity producers, with certain exemptions for specific businesses that solely use renewable energy sources (Prammer and Reiss 2022). On the contrary, despite all these examples, Austria has not followed the steps of these Member states and has not imposed taxes on such windfall profits yet, which certainly is not going to effectively reduce the burden Austria's citizens have to take while struggling financially to pay these high prices.

From this, it can be concluded that there will be favorable electricity prices as long as renewable energies can cover the electricity demand. However, if citizens and the economy consume so much that further energy has to be supplied from gas-fired power plants, the electricity price increases. This raises the general question of whether the basic demand should not be produced to some extent from nuclear energy, whereby the merit order system would use the relatively cheap nuclear power as the baseline for the electricity price.

2.1.6 Problems and risks

In the discussions about the right way forward in climate protection, more and more people are prioritizing the environmental value over the material values of the economy. The demand to shut down coal-fired power plants "immediately" does not ignore their economic consequences. Rather, it places the value of the impact for climate protection above the short-term economic value of this type of energy production. The desire for renewables involves some technical, as well as financial, hurdles that are often not given sufficient attention and, in difficult economic times such as these of the post-pandemic and Ukraine conflict, lead to a less surprising increase in energy prices. As shown on the above, Austria takes hardly any initiatives to reduce these energy prices, which partly profit equity holders of liberalized energy firms charging these prices. The demand for more transparency and clearer actions in this regard seems to be necessary for maintaining any future consent of the citizens towards the Austrian energy policy.

Although renewable energy produces fewer waste products and is generally considered sustainable and environmentally sound, one of the main problems with this type of energy production is that it cannot be called upon at all times. Because of the volatility and fluctuating availability of renewables, the distribution stage must also take on the task of organising availability. New value-added elements are emerging here, and numerous companies have already specialised in them. Intelligent technological solutions, virtual power plants, smart grids and other services must coordinate and regulate supply and demand in real time. In the end, it is the user who converts the electricity or gas into the desired form of energy (Gochermann 2021).

2.2 Climate Situation in Austria

Just as most of the countries in this world, Austria has already been experiencing first climate effects in forms of weather disruptions for the last couple of years, most probably due to enhancing climate change. Numerous studies show that trend is expected to continue, if not get worse unless the human species does not actively tackle some of the possible perpetrators more effectively.

2.2.1 Climate impact of energy industry

The energy industry has a major influence on the development of the global climate and contributes significantly to a variety of climate-related impacts. In order to curb the emission of pollutants into the nuclear sphere and the resulting climate change, alternatives have always been sought that are politically as well as technically and economically feasible. In this context, so-called decarbonisation is considered the fundamental driver of the energy and mobility transition. The complete abandonment of fossil energy sources is an important step in achieving any environmental goals. In addition to the high share of imports, fossil fuels have a negative impact on our climate and the environment in general. Ecological aspects are therefore the main drivers of the mobility, heat and energy transition. This change is additionally promoted by a strong increase and high volatility of energy prices (Jacobsen et al. 2022). The most important greenhouse gas is CO_2, which contributes to 77% of the greenhouse effect. The CO_2

concentration in the atmosphere already reached 380 ppm (parts per million) in 2014, 36% higher than pre-industrial levels (280 ppm, virtually unchanged over the last 10,000 years). It is increasing by 1.5-2 ppm per year. Scientific simulations for the year 2100, assuming a doubling of the pre-industrial concentration, show an increase in mean temperature of 2 to 6 °C depending on the scenario. The probability is 66 % that the increase will be between 2.4 and 4.1 °C (Crasten 2017).

In this sense, energy prices have a directional effect. Additional measures, such as the pricing of CO2, lead to investments in alternative energy sources. One way to decarbonise energy demand locally is to rely on electrical energy. Focusing on electrical energy has several advantages. On the one hand, it is possible to provide large amounts of electrical energy in a renewable way by using solar and wind energy. Furthermore, with electrical energy it is possible to decouple the place of energy provision from the place of energy demand (Jacobsen et al. 2022).

Probably the greatest and most significant advantage of using electrical energy is that it can be used universally. With the current state of technology, it can easily be converted into any other form of energy, such as heat, power or light. In the context of environmental protection, the decisive advantage is that the use itself is free of greenhouse gas emissions in the narrower sense. Only the provision of electrical energy from fossil fuels produces greenhouse gas emissions (Jacobsen et al. 2022). With increasing electrification, however, there is also an increased demand on the infrastructure and an increase in the importance of supply reliability. To make matters worse, electricity demand is expected to increase by around 50% globally from 2019 to 2030 (Crasten 2017). With regard to this expansive growth, there are some problems and difficulties in making these amounts of electricity available on demand. These obstacles demand political tactics and strategies to being able to enjoy an economic and environmentally sustainable energy supply in Austria, which will be discussed in more detail.

2.2.2 EU and national regulations of energy policies

Even after a brief consideration of European energy policy, it quickly becomes clear that national regulations and approaches, especially on issues such as climate change mitigation, often vary widely among individual EU member states. From a legal point of view, energy policy is largely defined as the organization of the energy sector in the respective economic area in such a way that the current and foreseeable energy demand is met at the lowest overall economic cost (Schulenberg 2009). The goals of economic efficiency, security of supply and environmental compatibility or sustainability are given priority and have a decisive influence on decision-making at the legislative level, as well as on the strategic design of a country's energy industry (Schulenberg 2009).

In the case of security of supply, not only the necessary technical facilities but also an energy mix are essential to ensure stable and uninterrupted satisfaction of energy needs. This energy mix is fundamentally dependent on geographical conditions and is additionally overshadowed by the political sovereignty of the individual member states. Which energy sources are included in the energy mix is decided solely at the national level (Schulenberg 2009). The EU has been unable to create a unified nuclear energy strategy due to the severe variations in national nuclear energy laws, despite the fact that nuclear power generates around one-third of all the electricity produced in Europe. There are many different perspectives on whether nuclear power is acceptable within the EU, since it is left to each member state to decide whether to integrate it into its energy mix. In a similar vein, nuclear regulation falls within national jurisdiction (Kanellakis et al. 2013). As this is a very sensitive area, any restrictions or specifications are immediately perceived as an encroachment on political sovereignty (Schulenberg 2009).

In terms of nuclear energy and its high safety standards, both national and EU wide regulations have to work in harmony. The goal of EU nuclear policy is to create a European framework for nuclear safety by requiring Member States to adopt a legal and regulatory guideline that assures the establishment of national safety precautions, including a system of licenses, inspection and assessment of nuclear facilities, management and storage of radioactive waste, crisis management mechanisms, and damage reparation guarantees in the event of an accident (Kanellakis et al. 2013).

2.3 Nuclear power in Austria

In order to be able to pursue the purpose of proper research and not to disregard geopolitical aspects, this section explains the events that were decisive in the background and explains Austria's relationship to nuclear power in more detail. In the process, historical key data are summarised and the resulting influences on the country's energy policy are substantiated. In addition, legal aspects and interpretations that were sometimes adopted by the Austrian government in the course of the development of energy policy should not be disregarded, as these ultimately continue to have an effect to a large extent up to the present day and form the legal framework for any implementation measures and changes to the structural energy supply carriers.

2.3.1 History and legislation in Austria

Energy production in Austria was a government monopoly until the late 1980s. On the one hand, it was organised via the central Verbundgesellschaft (Österreichische Elektrizitätswirtschafts-Aktiengesellschaft), which was controlled by the federal government, and on the other hand via the provincial companies, which were subordinate to the respective provincial governments. At the beginning of the 1960s, when first research reactors were built, energy generation from nuclear fission was still considered too expensive compared to hydroelectric or thermal power plants based on oil or coal. Even the prediction in 1956 that the demand for energy would double within a decade, from the mid-1950s to the 1960s, did not lead to a change of opinion (Forstner 2019).

Austria's dependence on energy imports must not be disregarded. Austria has had to import primary energy since 1955. In 1970, this already accounted for more than 50 percent. However, dependence on imports was subject to seasonal fluctuations. While electricity consumption was particularly high in winter, run-of-river power plants reached their highest output in summer. The existing storage power plants were not sufficient to cover the additional consumption in winter and consumption peaks in general, so that these consumption peaks had to be covered by additional imports of coal and oil. Nuclear energy appeared to be a possible way out of Austria's growing dependence on primary energy imports from the Eastern Bloc and the OPEC countries (Forstner 2019).

At the end of the 1960s, the time had come to realise nuclear energy production. Under the sole government of the Österreichische Volkspartei (ÖVP) (1966-1970), the Federal Ministry of Transport and Nationalised Enterprises took the initiative and organised an enquiry on nuclear energy in Austria in October 1967. The result of the enquiry was the foundation of the "Kernkraftwerksplanungsgesellschaft m.b.H." (KKWP) in April 1968. The Austrian federal government's energy plan of 1969 envisaged the construction of two run-of-river power plants and one nuclear power plant over the next ten years (Forstner 2019).

After further approval procedures, the construction of the first and only nuclear power plant in Austria was started in 1972. It took a full 6 years before the plant, known as "AKW Zwentendorf", was largely completed in 1978. Quite a few tests were run on the operational safety of the plant, but the question of the final disposal of the waste materials made the technical approval of the plant difficult (Forstner 2019). At the same time, protests and increasing headwinds had been felt by the population for years. This was also the reason for the negative referendum in 1978, as a result of which the nuclear power plant "AKW Zwentendorf" was never put into operation until today.

2.3.2 Austria's referendum

The Austrian referendum and the question it raised about the future of nuclear power in Austria was not originally intended by the government to be a direct decision by the population. The final decision on the medium of the referendum had a long road behind it, which involved some political events. A discussion meeting in Linz in April 1975, attended by more than 3500 people, represented a first high point in the development of the Austrian anti-nuclear movement, which was also attended by the Federal Chancellor Bruno Kreisky. The discussion was turbulent and was broadcast by ORF throughout Austria. The issue of nuclear energy was thus no longer a local problem, but occupied the entire federal territory. Throughout the country, working and action groups were founded with the goal of raising awareness about the dangers of nuclear energy (Forstner 2019).

When the federal government attempted to go on the offensive in the fall of 1976 by means of the "Nuclear Energy Information Campaign," this proved to be another engine for expanding the movement (Forstner 2019). The campaign's management thought that inaccurate information constituted the sole source of skepticism. It was believed that expressing different points of view and enabling experts to publicly address the issues would lead to consensus and allay public fear (Felt 2015). The events in the fall of 1976 and spring of 1977, respectively, were attended almost exclusively by opponents of nuclear power, providing opportunities to mobilize the movement in the respective provincial capitals, and securing Austria-wide media coverage (Bayer 2014). Thus, the actual goal of this campaign, to bring nuclear power closer to Austrian society through transparent information flow and education, was largely missed and the civilian headwind only strengthened. After a joint parliamentary resolution for the commissioning of the power plant could no longer be reached by the SPÖ and ÖVP in the first half of 1978, Kreisky settled on a decision of the Zwentendorf issue by referendum (Bayer 2014).

The result of the referendum on the commissioning of the Zwentendorf nuclear power plant must be described as both close and surprising. While opinion polls had predicted a clear majority for the proponents, 50.5% of voters voted against the commissioning of Zwentendorf in a turnout of 64.1%, while 49.5% supported it (Forstner 2019). Especially the SPÖ, which had been in power with Kreisky, could not mobilize many of its voters to vote, which explains a strong decline in the final proponent numbers. A look at the regional results shows that especially in the eastern and southern provinces (Burgenland 59.8%, Vienna 55.4%, Carinthia 54.1% and Styria 52.8% yes-votes) the majority voted in favor of nuclear power, while in the west (Vorarlberg 84.4%, Tyrol 65.8% and Salzburg 56.7% no-votes) the critics clearly prevailed (Bayer 2014). The strong differences in voting behavior in western and eastern Austria can be explained on the one hand by the history of the anti-nuclear movement, which already had a long tradition, especially in Vorarlberg (Forstner 2019).

Kreisky remained chancellor and initiated the law under the name "Federal Law of December 15, 1978, on the Prohibition of the Use of Nuclear Fission for Energy Supply in Austria" (Forstner 2019). It included two paragraphs:

- §1 Plants with which electrical energy is to be generated by nuclear fission for the purpose of energy supply may not be erected in Austria. However, if such plants already exist, they may not be put into operation.
- §2 The enforcement of this federal law shall be the responsibility of the Federal Government.

The Atomic Cut-off Act put an end to all plans for the development and expansion of nuclear energy in Austria. The individual companies drew their consequences from this. Thus, the "zentrale Kernkraftwerk-Planungsgesellschaft m.b.H." decided in November 1978 to dissolve and to initiate liquidation as of January 1979. Regarding the utilization of the nuclear power plant facility, it was decided in February 1979 to commission a conversion study to settle whether a conversion into a conventional fossil-fired thermal power plant was possible. However, plans in this direction were never implemented (Forstner 2019). Today, the facility, which never went into operation, proves several uses, including hosting various events there. Energy is very much generated on the property itself, but from a photovoltaic array installed on the site.

All attempts to reverse the Atomic Cut-off Act have also failed. The last attempt to revise the result of the referendum was made in 1985. Here, SPÖ Federal Chancellor Fred Sinowatz, Bruno Kreisky's successor, initiated an SPÖ motion to hold a referendum on the peaceful use of nuclear energy. In the event of a majority in favor of nuclear energy, the Atomic Cut-off Act would automatically have been repealed. However, this motion did not find the required majority in either the parliamentary committee or the National Council (Forstner 2019). This was shortly followed by the nuclear power accident in Chernobyl, which strengthened the debate on nuclear power both politically and socially to the point of antipathy.

With the "No" to Zwentendorf and the final decommissioning, a transformation process began that resulted in the narrative "Austria is free of nuclear energy" that is fundamental to Austrian identity today (Forstner 2019). However, the analysis of the further handling of nuclear energy in the Austrian parliament between 1978 and 1986 shows that the origins of the current rejection of nuclear energy were strongly shaped by the party-political debate and less by a critical public or the anti-nuclear movement (Bayer 2014).

Immediately after the referendum, nuclear power was given a largely negative connotation and was consensually removed from day-to-day politics and thus from the coming election campaign by means of the Atomic Cut-off Act. A few years later, the commissioning of the Zwentendorf nuclear power plant once again appeared to be a real option for the SPÖ, and the chance of reaching an agreement with the ÖVP was seen as existing, with good reason. This phase of renegotiating the nuclear issue was accompanied by a reinterpretation of nuclear power as a safe and progressive technology of the future. Central demands of the anti-nuclear movement and moments of today's anti-nuclear consensus, such as the thematization of nuclear power plants close to the border, served again at this time as a reference for the commissioning of the Zwentendorf nuclear power plant (Bayer 2014).

2.3.3 The narrative of Nuclear Free Austria

Considering the evolving technological aspects of this energy generation method, as well as ever growing global difficulties such as climate change, the implementation of nuclear energy is still not being considered in Austrian politics whatsoever. Moreover, the country itself is following a unique trend of rejecting any forms of nuclear energy production and consumption for many decades now. This rather unusual position towards this topic is uncommon in the EU and has multiple factors which contributed towards it over time. Of course, during the time of the referendum in the 1970's, Austria's nuclear energy opposition won the so-called battle about the initial implementation of this energy technology. What is even more interesting, is that since then Austria's opinion was shaped through multiple ways and happenings of that time, which resulted in a stronger opposition. A sociotechnical idea that endorsed a particular kind of new national identity slowly took shape by certain types of memory techniques, such as iconic images, taglines, or narratives, practiced on major events and demonstrating Austria's freedom from specific nuclear threats. This opened up space for unconventional visions while also nurturing opposition to a nuclear future (Felt 2015). Boosted by tragic events as Chernobyl or even Fukushima, the initial decision of a nuclear free Austria many years ago seemed more and more correct. As a result, Austria developed a new sense of itself as a little country with the ability to adopt a distinct sociotechnical course unlike its more modern counterparts. This conveyed the idea that a citizen's perspectives can influence their technological decision-making, and it also gave rise to a specific type of ideal society: Austrians as people who are against nuclear power generation, rejecting specific interventions into nature, and willing to make "the right" value-based decisions (Felt 2015). The problem with this approach, is the possible ignorance for any further scientific findings and state of the art technological evolutions regarding nuclear energy. When decisions, and in Austria’s case rejections, become based on historical or even emotional components, technological innovation can have difficulties taking place.

2.3.4 Technical aspects of nuclear power plants

The technical aspects of nuclear power plants and their life cycles have been constantly evolving since their first installations decades ago. For evaluating future applications, a further understanding of this technologies’ concepts is important. Electricity generation in a nuclear reactor works in a very simplified way like this: Fuel rods made of fissile material form the reactor core, which is enclosed in a pressure vessel and generates heat by means of nuclear fission. This generates superheated steam in a heat exchanger, which produces electricity through a turbine generator as in a conventional power plant (Nötzold 2011).

After use in the NPP, the spent fuel elements are first temporarily stored in water in the reactor building for approximately 1 year and cooled until the residual heat has decayed, and then fed to reprocessing or prepared for final disposal. If no reprocessing is planned, the spent fuel assemblies are temporarily stored centrally for a longer period and finally conditioned. Conditioning includes vitrification and confinement of the waste in steel containers (Crastan 2021). In reprocessing, reusable material, such as uranium and plutonium, is separated and returned to enrichment or fuel fabrication. Non-usable waste is conditioned and put into final storage. Low- and intermediate-level waste from power plant operations, along with that from medicine, research and industry, is also conditioned (using other processes) and finally placed in suitable repositories. Reprocessing has the advantage of requiring less natural uranium and allows the plutonium to be recycled, reducing the amount of high-level waste (Crastan 2021).

2.3.4.1 Reactor Types

Generally speaking, second generation nuclear power stations are the most common forms of currently existing plants. The European Pressurised Reactor, also known as EPR, is currently experiencing a boom and new facilities are now under fabrication in France, UK and Finland, which are categorized as third generation power plants (Lynas 2021). These reactors of the so-called 3rd generation have significantly better characteristics in terms of safety. The efficiency is also said to be better, at 36 % (Crastan 2021).

However, interest in smaller nuclear power reactors, generally known as Small Modular Reactors (SMRs), is growing (Abousahl et al. 2021). These types of fourth generation plants include more recent designs, even for gas-cooled and liquid metal reactors, that do not require water in the reaction chamber. Instead of being manually put together on-site, they are constructed to be modular and adaptable, being manufactured in facilities and transported to locations afterwards (Lynas 2021). In the high-temperature reactor (HTR), graphite and silicon are used as fuel cladding material and helium as a coolant. This allows coolant temperatures of 700-950 °C to be achieved, enabling the operation of both steam cycles with superheating and gas turbines or combined cycle plants. Accordingly, power plant efficiencies can reach 40-48%. Despite the great advantages of this reactor line, including passive safety, its development to industrial maturity in the European area is currently blocked. The development of this reactor line, which belongs to the so-called 4th generation reactors, is being pursued mainly in China, Japan and South Africa. It also allows thorium, which is about three times more abundant on Earth than uranium, to be used as fuel (Crastan 2021).

Considering the whole nuclear life cycle, several steps and processes have to be taken into account, which are partly location-dependent and partly location-independent. The latter are mainly related to the raw material extraction of the required natural resources, which in most cases takes place in a country other than that of the energy production plants.

2.3.4.2 Safety and risks

Regarding the safety of nuclear power plants, there are multiple aspects and processes, which have to be taken care of in order to meet the safety standards accustomed by national and EU legislation. The fission products produced in the reactor are kept away from the environment by a staggered barrier system. A first barrier is formed by the pressure-resistant and gas-tight cladding of the fuel elements. A second barrier is the likewise pressure-resistant steel shell of the reactor or primary system. Finally, the reactor systems are located in the aforementioned reactor protection building made of steel and concrete, which forms the third barrier. This triple barrier system is intended to provide protection against internal and external impacts. External impacts include aircraft crashes and earthquakes. The internal effects include radioactive radiation generated during operation, which must be absorbed, and the pressure increase or heat buildup that occurs during accidents, which in the worst case can lead to a core meltdown if the multiple control and shutdown devices fail (Crastan 2021).

Modern nuclear power plants designed according to Western standards offer the highest level of safety, as proven by the years of operation of the more than 430 power plants installed and producing energy worldwide, with an experience of more than 10,000 man-years. The additional level of radioactivity during normal operation in the vicinity of a nuclear power plant is far below that of natural radioactivity (Crastan 2021). Nevertheless, if there should occur any incident where the environment gets polluted, the consequences would be devastating. Whether such damage or risk is reasonable (and insurable) or not is the subject of socio-political discussion. The ecological benefit of nuclear energy in view of the climate problem must be taken into account, and the possible damage must be put in relation to that caused annually by other technical facilities e.g. road and air traffic or chemicals (Crastan 2021).

Furthermore, highly enriched uranium is needed for nuclear weapons production too. It is feared that the plutonium present in small quantities in the spent fuel rods could be misused for this purpose. The dangers posed by this are real and are prevented by political measures and appropriate monitoring, such as the non-proliferation agreement. However, the threats posed by the peaceful use of nuclear energy in facilities with low-enriched uranium are comparatively small (Crastan 2021).

2.3.5 Nuclear energy in Europe

Nuclear energy is still a large part of the energy industry in many areas of Europe, despite controversial attitudes. *Figure 6* shows that the share of CO2-free electricity produced by the 28 EU Member States is 40% for nuclear power generation.

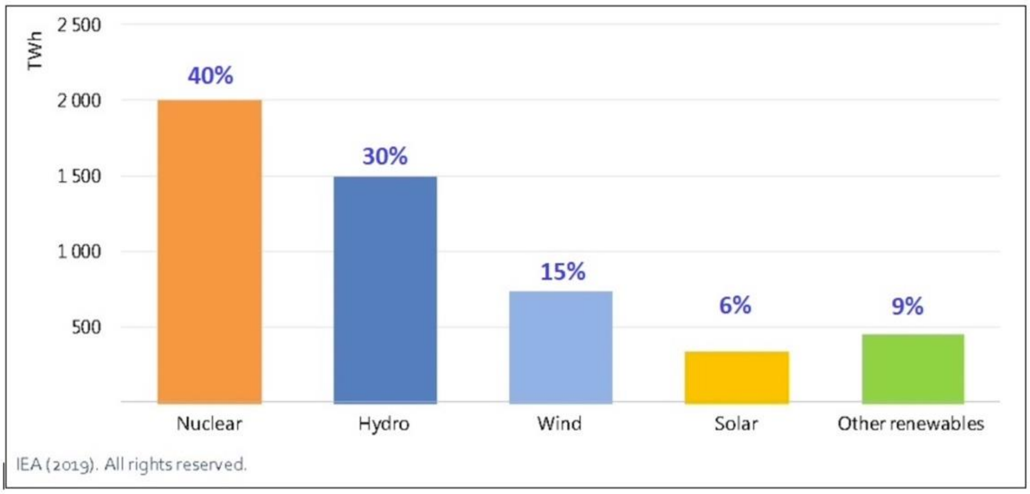

Figure 6: Low carbon electricity generation in advanced economies by source in 2018 (Abousahl et al. 2021, p.32)

Thus, this type of energy production is considered the most important low-carbon energy production method, with a total of 2000 TWh produced for the year 2018, followed by hydropower in second place and, with considerably smaller shares, wind and solar, in third and fourth place (Abousahl et al. 2021).

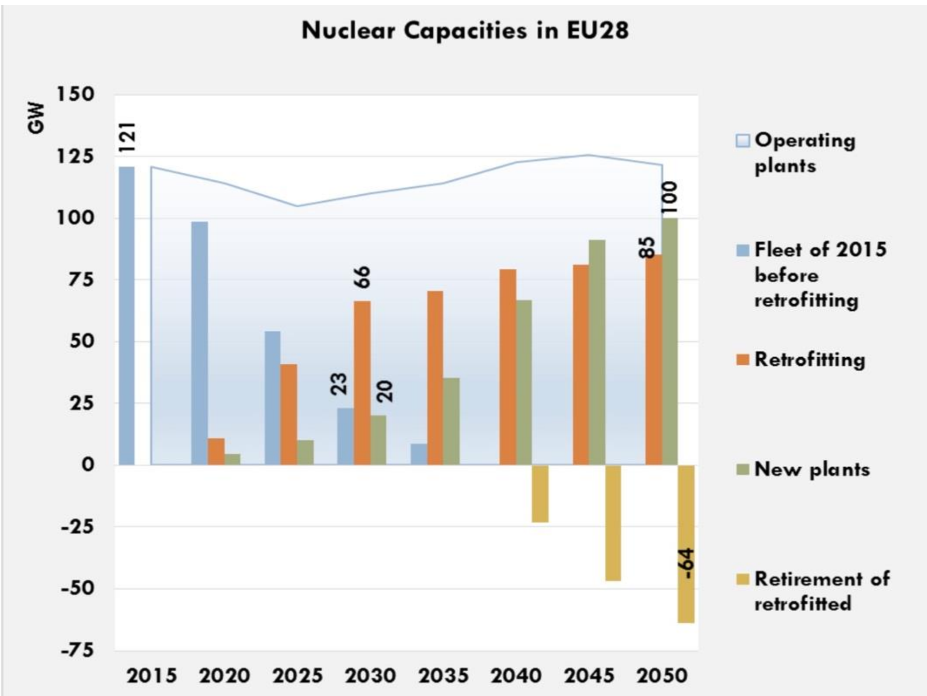

Figure 7: Evolution of the nuclear installed capacity in the EU (Abousahl et al. 2021, p.34)

The installation of new nuclear power plants is considered as the most capital-demanding baseload technology and thus, as displayed in the chart above (*figure 7*), retrofitting of the armada of plants is often the more convenient option in the mid-term. In order to meet higher safety standards and fulfill all regulatory expectations, lengthening the lifespan of existing nuclear generation capacities frequently necessitates significant renovations and work, to replace worn-out parts and enhance safety overall. Nevertheless, lifespan extension of existing plants continues to be an economically more appealing alternative and a strategy that is currently applied or anticipated in some EU Countries, despite these additional expenses (Abousahl et al. 2021). This trend is expected to continue for the next decade at least, until the increasing numbers of newly constructed power plants is going to dominate the refitting of older ones.

In terms of new installation, Member Countries have either begun or are intending to develop new, sizable nuclear power plant projects, as nuclear energy is starting to return to prominence. While Poland is turning to nuclear as a tool to repower its coal plants in a carbon-free manner, the Czech Republic is aiming to utilize nuclear energy to achieve its climate targets. To urge the incorporation of nuclear in the EU taxonomy, governments from both nations testified to the EU Commission in 2020 (Lynas 2021).

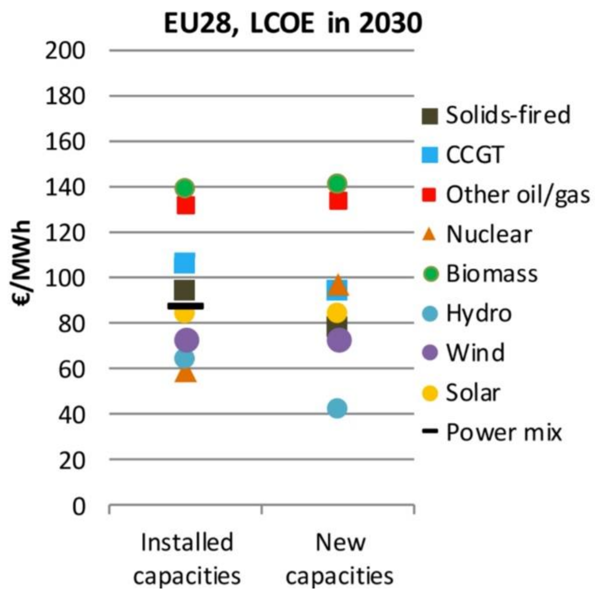

Figure 8: Levelised cost of electricity in the EU (Abousahl et al. 2021, p.35)

The production expenses of various technologies are displayed in *figure 8*. Nuclear energy will have the least production cost in 2030 considering the current facilities. Even if the expenses rise when additional installed facilities are taken into account, nuclear power is still competitive and comparable to levelized costs of the present energy mix. Nevertheless, the building of new, giant nuclear power plants, which has grown increasingly difficult for investors over the last 30 years as energy markets have been liberalised, is further made more challenging by the fact that construction of nuclear power plants is very capital-intensive. Given the challenges, the IAEA claims that various funding and support methods are being sought, such as partial government participation or loan guarantees, to promote nuclear development (Abousahl et al. 2021). This presents a crucial part of the process, as the governmental and financial support are necessary for the costly investments to take place and further develop in future.

2.3.6 Contribution to climate change mitigation

The Technical Expert Group (TEG) acknowledged in its Taxonomy Report Technical Annex that nuclear energy has almost no carbon dioxide emissions during the power production process and that nuclear energy can significantly contribute to reducing global warming, which is among the six sustainability goals of the Taxonomy Regulation. It is also important to contrast the lifecycle greenhouse gas emissions of nuclear energy to those of other alternatives, which can be seen in *figure 9* (Abousahl et al. 2021).

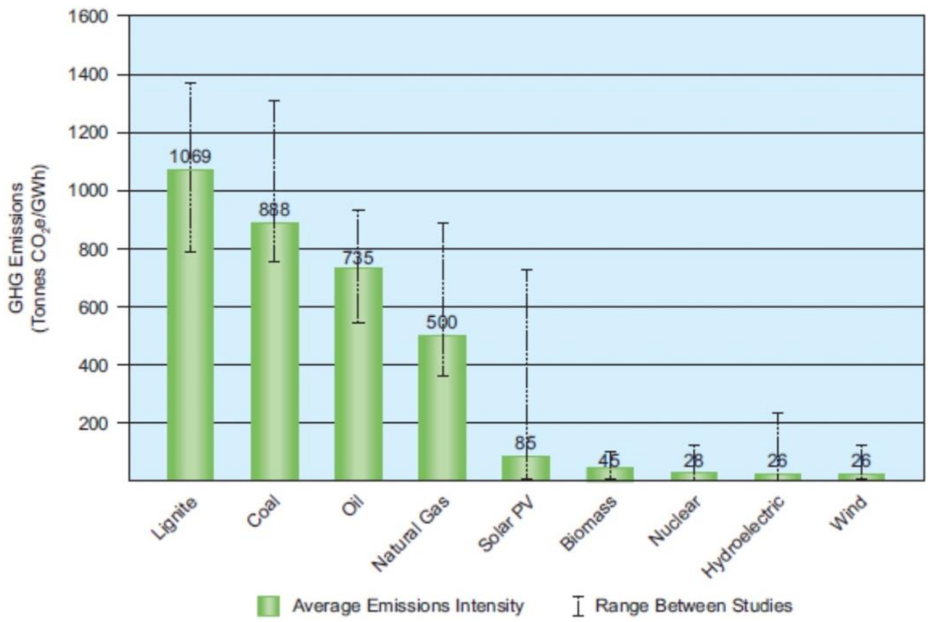

Figure 9: Lifecycle GHG emissions intensity of electricity generation technologies (Abousahl et al. 2021, p.36)

The graph demonstrates that nuclear energy has some of the least lifespan greenhouse gas emissions of any technology, equivalent to (or slightly higher than) renewables like wind and hydropower, and even fewer emissions than solar photovoltaic systems. The findings of this study indicate that nuclear electricity generation's lifecycle greenhouse gas emissions are conveniently below the 100 gCO2-eq/kWh emissions amplitude limit suggested by the TEG for electricity production and will stay below it for the next 50 years, meeting the required TEG's interpretation of a major contribution to climate change mitigation (Abousahl et al. 2021). Utilized as baseload supply, this offers a flexible production process to support inconsistent renewable energy sources. Hence, wind and solar are utilized more effectively. This prevents the usage of very carbon-intensive production methods, which are usually employed as a backup. On the contrary, by reducing temporary disturbances, this implementation as well as the electricity storage strengthen the power network (Abousahl et al. 2021). With the reactors serving as a backup alternative, Gigafactories of Small Modular Reactors might be used to manufacture hydrogen too. Furthermore, energy security challenges can be readily addressed by storing nuclear fuel (Lynas 2021).

2.3.7 EU Taxonomy

The EU Taxonomy is a categorization scheme for economically sustainable environmental practices. It may have a significant impact on how the EU scales up sustainable investment and puts the European Green Deal into practice. Companies, investors, and regulators would have access to proper definitions of whether economic activities qualify as ecologically sustainable thanks to the EU taxonomy. This should provide safety for investors, safeguard private investors from greenwashing, assist businesses in growing more environmentally friendly, lessen market segmentation, and assist in directing expenditures to areas which are most necessary (European Commission 2022). There is, nevertheless, constant discussion over what it ought to and ought not to contain. The categorization must include renewable energy sources since there is widespread public support for them. Unabated gas has been considered as highly improbable to be incorporated as it presents a fossil fuel, and although if it emits fewer greenhouse gas emissions than coal, its continued exploitation after the zero-carbon deadline of 2050 would hinder Europe reaching its climate goals (Lynas 2021).

As there are many nuclear detractors, nuclear energy was also not included in the EU Taxonomy, although it provided scientific evidence of being sustainable. Anti-nuclear claims have existed since the 1970s, when the Green Movement first gained popularity, and are frequently ideological instead of factual (Lynas 2021). Nevertheless, following the political agreement between the co-legislators on the Taxonomy Regulation, the Commission began a thorough investigation to determine whether nuclear energy should be included in the EU Taxonomy of ecologically sustainable activities in 2020. The Joint Research Center, which is the in-house science and knowledge center of the Commission conducted the report (European Commission 2022). For a successful implementation of nuclear energy into the Taxonomy, four different criteria had to be met:

- Making a substantial contribution to at least one environmental objective

  This criterion makes sure that the economic activity either significantly improves the environment or significantly lessens adverse environmental effects, such as significantly lower levels of greenhouse gas emissions (European Commission 2022).

- Doing no significant harm to any other environmental objective;

  It makes sure that the economic activity does not significantly harm the other environmental goals or prevent them from being achieved (European Commission 2022).

- Complying with minimum social safeguards (European Commission 2022).

- And complying with the technical screening criteria (European Commission 2022).

After the successfully completed report, two other groups of experts have further examined the study: The Scientific Committee on Health, Environmental and Emerging *RisksSearch* on environmental consequences and the Group of Experts on Radiation Protection and Waste Management under Article 31 of the Euratom *TreatySearch*. Taking into aspect all three scientific instances, the Commission passed a complementary climate delegated act that, with certain restrictions, added specified nuclear and gas energy operations to the list of commercial activities covered by the EU taxonomy on March 9, 2022. It will be effective as of January 2023 after being published in the Official Journal on July 15, 2022. The requirements for nuclear and gas operations are in accordance with EU environmental and climatic goals, and they will hasten the transition away from solid or liquid fossil fuels like coal in favor of a future without global warming (European Commission 2022). This important step serves as a milestone regarding European CO2 mitigation, as regulatory structure, that welcomes new investments in nuclear power plants is being provided on EU basis. That initiative presents a more convenient ground for the implementation of nuclear energy power plants among the EU member states. Furthermore, the recent study mentioned above, which was obviously reviewed multiple times by experts and qualified scientific instances, serves as proof for an urgent reevaluation of Austria’s national legislation regarding nuclear energy. The outdated views and regulatory laws, which were decided three decades ago, have to get revised in order to meet climate objectives and reduce climate risks that could have fatal consequences in future.

2.3.8 Nuclear waste and challenges

Notwithstanding that there are some advantages associated with this technology, some of which have already been discussed, this method of energy generation also has complicating characteristics and challenges that must be considered. Directly related to the use of fissile material in reactors is a disadvantage of nuclear power. Both the facilities for the necessary enrichment of natural uranium and breeder reactors can produce nuclear enriched material that can find military use in nuclear warheads in addition to civilian uses. Therefore, nuclear power is accompanied by the risk of proliferation of nuclear material, nuclear technology, and know-how to support a nuclear weapons program (Nötzold 2011).

Another challenge accompanied by nuclear energy, is its waste management as well as the disposal of an average of 30 tons of spent fuel per year per nuclear power plant (Nötzold 2011). If the levels of radioactivity are dangerous, radioactive wastes must be kept segregated from the environment since they are made up of things that are no longer usable (Jimenez-Reyes et al. 2021). Various nations may decide to describe their radioactive waste management plans in various ways. Some nations may create the requirements and place the responsibility of waste management on the waste generators, while others may define the plan at the national level and assign an organization or body the task of implementing it (Aboushal et al. 2021). Practical problems arise in democratic, federally organized countries due to the initial mostly lack of regional acceptance of repositories, which must be achieved through arduous educational work or centralization of competencies by political means (Crastan 2021).

The final disposal of low- and intermediate-level waste must be distinguished from that of high-level waste. The first problem is not unique to nuclear reactors and thus must be addressed whether electricity is produced by nuclear power (Crastan 2021). Nuclear fuel cycle operations, nuclear power plants, decontamination of nuclear facilities, usage of isotopes in medicine, scientific research, and agriculture, as well as uranium and thorium ores are some of the causes of radioactive waste. Due to its huge quantities and intricate chemical and radiochemical makeup, liquid radioactive waste poses a significant concern (Jiménez-Reyes et al., 2021). The waste must be processed to lower the volume and concentration of radioactive compounds and other harmful solutes in the effluent in order to meet the criteria outlined in national and international laws. Liquid radioactive waste may be treated using a variety of techniques, namely evaporation, precipitation, ion exchange, and adsorption (Jiménez-Reyes et al., 2021).

The environmental aim "Transition to a circular economy, waste avoidance and recycling" is pertinent to the primary goals of "closing" the nuclear fuel cycle (Abousahl et al. 2021). These goals are as follows: The percentage of spent nuclear fuel that can be recycled in nuclear reactors should be increased. Furthermore, the long-term radiotoxicity of HLW (high-level radioactive waste) that will be disposed of in a geological deposit should be reduced or optimized. By chemically dissolving used fuel and segregating reusable and/or burnable species, these goals are accomplished. Nuclear fast reactors use the partitioned reusable/burnable species as part of specific fuel components and irradiate them to recycle the fuel component and eradicate long-lived radiotoxic species (transmutation) (Abousahl et al. 2021).

Emphasizing the distinction between radioactive waste storage and disposal is also crucial. Both phases of managing radioactive waste are essential and each has its own function in the nuclear fuel cycle. Storage might be defined as the deposit of waste in a nuclear facility with active human control over isolation, management, and safeguarding of people and the environment. The garbage is often meant to be removed from storage at a later date for further treatment. While storage is an essential interim step, it cannot take the place of the necessity for long-lived waste forms, such as HLW, to be disposed of in a geologic repository (Abousahl et al. 2021). Long-lived waste and HLW must thus be gathered and delivered to the disposal site after storage. The process of disposing radioactive waste involves arranging the waste material in a way that assures that no major harm, as defined by the applicable legislation, is done to the environment or to people's lives (Abousahl et al. 2021).

Geological disposal has been extensively studied in Europe over the past five decades as a reference method for the long-term management of HLW and spent fuel. Given that there is widespread agreement, based on the results of decades of concentrated research and development, that the deep geological disposal idea is secure and developed technologically (Abousahl et al. 2021). Nevertheless, such disposals are not present yet and their construction has not been started for most of the nuclear energy using countries. Germany for example, is planning to finish the construction of their geological disposal at the year 2050.

Further disadvantages of the use of nuclear energy are mainly the effects of a possible accident with reference to historical examples. With regard to technological development in the field of nuclear power utilization, the reduction of the risk of a general accident is at the center of research. In the medium to long term, improvements with regard to sustainable use of resources, economic efficiency, counteracting proliferation and reducing radioactive waste are being sought within the framework of newer reactor technologies (Nötzold 2011). Both international and domestic efforts to create third generation nuclear power facilities were concentrated after the Chernobyl disaster. These facilities provide the capacity to offset the effects of a significant deterioration of the reactor core, should such an accident ever occur, since they were built in accordance with enhanced standards relating to severe accident avoidance and mitigation. The core purpose was to guarantee that, even in the most severe case scenario, the environmental impact of any radioactive emissions would be contained to a few kilometers outside the site border. Internationally, the adoption of several third generation plant designs just recently began, and today, almost only Gen III nuclear plants are being built and put into service (Abousahl et al. 2021).

3. Methodology

The literature analysis has revealed some interesting points regarding Austria's general energy policy and its economic and political basis. The energy policy crisis, which is clearly having a noticeable effect on the economy and ultimately the end consumer, requires urgent action and further evaluation of various measures. The scientific method investigated in this paper is related to nuclear power generation, argued by the associated described advantages for the energy price and various environmental concerns in Austria. The basis of interpretation of the law was also described, and the resulting power of the people in decisions of this magnitude was explained. Since past measures with regard to the provision of energy through nuclear energy have largely failed and were met with rejection by the population entitled to vote, the initiative of this work is to establish new points of contact on this basis and to obtain a new evaluation of social opinion with the current state of research, technology and law enforcement at the EU level.

3.1 Data

In addition, a quantitative research method will be used in the form of a questionnaire in order to provide some new findings to the existing research. In the course of this work, Austrian students are to be questioned about their opinion on the topic described above. The choice of students is justified by the fact that the scope of this work is not exceeded in the course of the research. The additional findings and results are relevant for further political investigation and could provide new proof for necessity for political initiatives regarding the topic of nuclear energy in Austria.

To best answer the research question, a scientific model will be established. The questionnaire will provide enough data to fill the model, which will structure the new findings and provide the basis for the statistical data evaluation.
The survey is expected to register about 250 participants (more if possible), of which the majority will be students. The survey will be conducted virtually, by sending the questionnaire to student's email addresses and providing it to collective WhatsApp group chats. The collected data will be cross-sectional, as the survey will be conducted only once and during a total period of 2 weeks, starting from January 10th, 2023. This will present enough time, as each questionnaire will aim 5 to a maximum of 10 minutes, depending on the included type of information set, in order to be fulfilled. The brief summary of the given information and the short questions are purposely designed to motivate the participants action to start and most

importantly, complete the full questionnaire. The choice of a longitudinal time horizon would have been surely interesting too, as the current energy and economy crisis are further evolving and possible changes in people's behavior and opinions could be captured and documented. However, this form of data collection would exceed the time limits of this master's thesis.

Additionally, the data collection will be supported with an experiment, which is intended to be conducted. This proves to be the best way to provide new findings and further be able to answer the research question. Furthermore, the questionnaire allows to distribute different sets of information to certain groups of the sample, thereby creating the base layer for the experiment. Each information set will be tested on its impact on the supportiveness for nuclear energy in Austria. With that diversification, new evidence will be collected, and new conclusions will be possible. Further research can profit from this approach too, as the general reasons for specific opinion formation will be extracted and thus, serve for future research and provide discussion points for energy politics.

In part of the experiment, the Information given to the participants of the conducted survey differs significantly. For more and better observation of the participant's opinion leading and decision driving arguments, the experiment will be classified in three diverse group settings, each provided with a different combination of the following information sets. The information sets have been chosen according to the best representation of the research question and for future research purposes.

The first set of provided information, the impact of climate change, provides a brief information summary of latest scientific evidence on the environmental contribution and effect on climate change regarding the use of nuclear energy. The scientific evidence is delivered by the JRC Report, which was conducted by the European commission itself. This source has been mainly chosen as the reference point of the questionnaire's information as it's reliability and accuracy was proven from other, autonomous and highly recognized scientific institutions as well.

Information set 1:

- Impact on Climate Change:
  The Technical Expert Group (TEG) - which is the European Commission's in-house research team - acknowledged in a detailed report in 2021 that Nuclear energy has

almost no carbon dioxide emissions during the power production process and can significantly contribute to reducing global warming (Abousahl et al. 2021).
Average lifecycle Greenhouse Gas emissions determined for electricity production from nuclear energy are comparable to the values characteristic to hydropower and wind (Abousahl et al. 2021).

The second set of information is considering the safety standards, with respect to the possibility of negative health impacts, which is also covered in a brief, explanatory way. Again, the source for the scientific arguments is taken from the same JRC Report, which next to its scientific acceptancy also scores with recent and up-to date information, having been conducted only less than two years ago.

Information set 2:

- Safety standards:
  Some 30 or 40 years ago, the currently operating NPPs (Nuclear Power Plants) were constructed according to standards that were considerably different from standards of today. During the last 15 years, 3rd Generation Reactors were designed according to extended requirements related to severe accident prevention and mitigation (Abousahl et al. 2021).
  Practically only Gen III reactors are constructed and commissioned today, and the fatality rates characterizing state-of-the-art Gen III NPPs are the lowest of all the electricity generation technologies (Abousahl et al. 2021).
- Health risks:
  According to the LCIA (Life Cycle Impact Analysis) studies analysed the total impact on human health of both the radiological and non-radiological emissions from the nuclear energy chain are comparable with the human health impact from offshore wind energy (Abousahl et al. 2021).

The first of the three sample groups will receive the whole information about the most important and notable factors of nuclear energy, which is equivalent to both information sets of the above, each being provided to the participant. This group will be classified as “full information” and the questionnaire’s sample size, containing this set, will amount to approximately one third of the whole conducted sample.

The second of the three groups will receive only part of the whole information. Information set 1 “The impact on climate change” will be presented to the participant, leaving the second information set of information “Safety standards and health risks” out. This group will be classified as “Climate information only” and the goal of this approach is to be able to compare the impact of the thoughts on climate change mitigation considering nuclear energy with the opinion held on nuclear energy in Austria. The questionnaire’s sample size, containing this set, will also amount to approximately one third of the whole conducted sample.
The third and last group will receive no included information at all. This mainly simulates the participant’s existing knowledge on the topic of nuclear energy and its effects on various standpoints. Again, this too will give an insight on the current willingness to support nuclear energy in Austria and through comparison to the other groups, indicate the effects of the amount of information given to each participant and thus, identify the core drivers of information for the advocacy of nuclear energy in Austria. Again, the aim is to achieve an equal distribution of participants for this questionnaire, which amounts to one third of the total sample size.

The questionnaire itself will contain 19 different questions altogether, which cover four different topics. All questions will be presented in form of closed-ended questions, as this type of measurement seems best for the following statistical analysis. The order of the questions follows a strict logical flow, starting with more simple questions first and later ending with more sensitive and perhaps challanging questions. Even though this might have negative effects on the validity of this research, the proper structure of the questionnaire seems all but relevant for the participant’s rational decision process, especially because information is continuously distributed during the survey and not just at the beginning. The first topic, including 2 questions, is surveying the opinion on the currently ongoing climate change and other climate related questions in terms of goals and the likeability of achieving those. The second topic contains 7 questions and asks about the individual perception and opinion on nuclear energy. A psychometric scale known as the Likert scale is frequently used in studies that use questionnaires to examine social attitudes, which is why a great share of these questions will be asked through such scale (Roopa et al. 2012). The third topic is concerning Austria nuclear policy. The participants are being asked 5 questions about their opinion on the legislative acts underheld in Austria and the general awareness of the current energy situation the country is facing. This topic also contains the question about the future support of nuclear energy in Austria. What is notable here, is that further information is being provided to all questionnaire groups. This takes place through a brief historical overview of Austria’s last referendum, including the date and the overall outcome in percentage points. The reason for that has mainly to do with the fact, that not all participants are expected to know about the legislation on nuclear energy in Austria, especially if participants come from a different country. Furthermore, that knowledge is necessary to answer the topic's related questions, especially the one about the advocacy for nuclear energy. Finally, the last section asks about the participant's sociodemographic data, such as age, gender, net income, highest level of education, and domestic country. This will help to identify the samples characteristics and provide further data which can be compared in the statistical analysis.

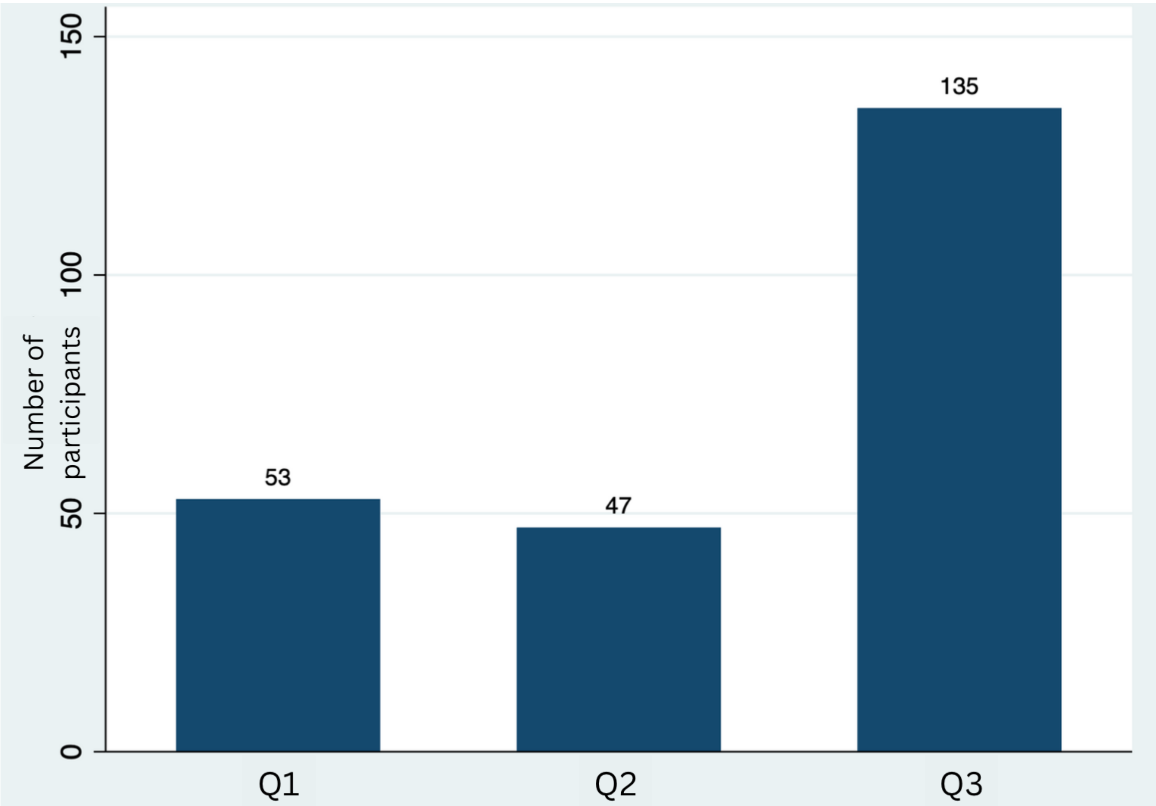

Figure 10: Distribution of participants for all questionnaires (own elaboration)

3.2 Model

The research model of this work will include one dependent variable, namely the support for the expansion of nuclear power plants in Austria. For simplistic reasons and the intended closed end question with answer options of "Yes" or "No", this variable will be binary.

The first independent variable will be the perceived safety of nuclear power plants, which will be measured on a Likert scale.

The second independent variable will be the perceived impact of nuclear power plants on greenhouse gas reduction in Austria. The perceived impact is measured on a Likert scale and classifies as the ability to help mitigating climate change and reaching climate targets for 2035. In retrospect to the perceived safety, a moderating variable will be included in the model as well. The moderator will be the awareness of Austria’s neighboring power plants and their short distance to the Austrian border (70 km or less). This variable will be measured on a binary scale from 0 to 1, as the question itself options for a close ended answer of “Yes” or “No”.
A control variable will be introduced to the model as well, which will be the support for a new referendum. It is assumed that people who would support the execution of a new referendum for nuclear energy in Austria, are more likely to support the technology itself in Austria.
Lastly, the mentioned experiment will be statically evaluated as well. The treatment group, which receives the set of full information will be tested against the control group, which will receive no information. Therefore, a dummy variable will be generated, in order to test the general surplus of information regarding the support for nuclear energy. The first information set with full information will have the number 1 of this binary variable, the last information set with no information the number 0. This dummy variable will then get tested with the dependent variable on correlation, after which the effects of additionally provided information can be measured. In order to ensure the validity of the treatment effect, the groups need to be as homogenous as possible. The sociodemographic data will help tackling this matter.

These results will then be statistically analyzed, allowing correlations to be established between advocacy and the other variables. The program which will be used is STATA, as this one provides precise statistic measures, graphs, and other tools. It was covered briefly in previous lectures too, which will certainly be of help while reviewing the collected data.

The consideration of safety of any energy generation method should have great matters and thus, this challenge when facing nuclear power plants needs to be evaluated. Even though the safety, as described before, is constantly growing, and boosted by new technological and security standards, its perception may still be relatively low or has remained unchanged. Moreover, Austria’s specific case regarding nuclear energy has experienced both political and sociotechnical denial in the past. New technical standards present new opportunities for Austria’s energy policy, which is why this matter is of evaluation need. Therefore, the first hypothesis is proposed as follows:

H1a: Austrian Students with higher safety perceptions are more likely to support nuclear energy in Austria.

Regardless of the opinion on nuclear energy, the awareness of Austrian students of the country's nearby nuclear power plants is certainly not always high, as this topic is seldomly discussed in media and politics, for reasons that were mentioned in the literature review. Thus, the moderator variable for the awareness of these neighboring power plants comes in place. The second hypothesis is proposed as follows:

H1b: Austrian Students with higher safety perceptions are more likely to support nuclear energy in Austria, more so if they are aware of the country's neighboring power plants and their short distance to the Austrian border (70 km or less).

The ever-growing climate crisis is forcing alternative thinking when facing its multifaceted problems. Targeted climate goals are distinct in future and reaching these is often considered with difficulties and great challenges for economies and citizens, who must adapt accordingly. These adaptations differ in all sorts of form, even though their main goal, which is mitigating climate change, stays the same. Countries individual strategy plans differ as well, even in close political unions such as the EU. Some EU states have initialized the further exploitation of nuclear energy as opportunities for reaching greenhouse gas emission targets in future and fighting climate change. For that reason, this matter presents an important motivation for a countries' engagement in nuclear energy. Therefore, the third hypothesis is posed as follows:

H2: Austrian Students with higher climate change mitigation perceptions are more likely to support nuclear energy in Austria.

Nevertheless, it seems of great matter that the knowledge on both safety and environmental effects of nuclear energy is given. The information distribution is not equal and the coverage of it on media or even schools differ for each individual. Thus, providing the information to participants is assumed to boost their support for nuclear energy in Austria. Hence, the fourth hypothesis is posed as follows:

H3: After receiving the information on safety, health and climate matters of nuclear energy, people are more likely to support this technology in Austria.

To ensure a proper and correct scientific approach, this research must get tested for certain measures. The degree to which a measurement of an event yields a steady and consistent result is what reliability refers to (Taherdoost 2016). Repeatability is another aspect of reliability, which is of great importance for this topic, considering that the purpose of this research is providing latest findings with possible evidence alongside the public's opinion for a future evaluation of nuclear energy in Austria. Reliability is ensured by keeping the questions very clear, specific, and short. Proper and easy comprehendible language is used as well, in order to prevent any misinterpretations of the context of the questions. However, the questionnaire is following a specific structure and the sequence of the questions could possibly influence the answers and thus, the outcomes of the study, which takes influence on its repeatability for future research.

Both the questionnaire and its pretest have to be examined on validity. Validity reveals how well the data is representative of the subject under examination (Taherdoost 2016). The extent by which a measure appears to be connected to a certain concept in the eyes of non-experts, including test-takers, is known as face validity. In other terms, a test has face validity if the information only seems relevant to the test-taker (Taherdoost 2016). All questions are specific and fulfill a certain purpose, which is strongly connected to this work's research question and no unnecessary information is given in order to ensure validity. Nevertheless, there are certainly some limitations to this research and there is still room for improvement. Other factors, which would probably influence the decision-making process and the support for nuclear energy were not included in the questionnaire and model, as the scope of this thesis would be exceeded.

4. Results and conclusion

This section will focus on the presentation of the statistically evaluated data, with special care to this works main topic as well as the answering of the hypothesis and, ultimately, the research question. After the elaborated findings, which stem from the conducted questionnaire, conclusions for the Research Question will be drawn. In addition, this process will also identify recommendations and opportunities for future research that can link to this topic and this state of research to advance societal progress in its struggle with climate change and other factors both economic and environmental.

The scope of the survey was ultimately able to provide a total of 235 valid results over the period of 6 weeks. Of course, a higher number of answered questionnaires would provide clearer and more valid results, but due to the short time frame and the scope of the work, it was not possible to collect a larger sample. In total, the 19 different questions were prepared for statistical analysis and went through the Stata program. In the process, interesting findings were made, which entail some conclusions. The effects of the individual information allocation of the three questionnaire groups were also analyzed and this form of experiment was statistically tested.

In order to test *H1a: "Austrian Students with higher safety perceptions are more likely to support nuclear energy in Austria."* generalized linear model with probit regression was used as the statistical measurement element. Here, the results of all 235 respondents were first analyzed and evaluated together in a data table.

The advocacy of nuclear power (A suppo = binary; 0=no; 1=yes) for the purpose of energy production in Austria was chosen as the dependent variable. All remaining independent variables are described as following:

- **NEsafe** = the perceived safety of nuclear energy plants (1 – 5; 1=lowest; 5=highest)
- **NEredgg** = the perceived ability of nuclear energy reducing greenhouse gas emissions (1 – 5; 1=lowest; 5=highest)
- **NElowp** = the perceived ability of nuclear energy reducing energy prices for consumer (1 – 5; 1=lowest; 5=highest)
- **NErelia** = the perceived reliability of nuclear energy (1 – 5; 1=lowest; 5=highest)
- **NEfures** = the support for future research of nuclear energy (1 – 5; 1=lowest; 5=highest)

- **NEmitcc** = the perceived ability of nuclear energy mitigating climate change (1 – 5; 1=lowest; 5=highest)
- **NEwogdif** = the perceived ability of reaching climate goals for 2035 without the supply of nuclear energy (1 – 5; 1=lowest; 5=highest)
- **Aappro** = the perceived approach of Austria regarding nuclear energy (1 – 5; 1 = scientific; 5 = idealistic)
- **Arefe** = the support for a new Austrian referendum regarding the decision on this topic (1 – 5; 1=lowest; 5=highest)
- **Aaware** = the awareness of other nuclear facilities close to Austria's border (1 – 5; 1=lowest; 5=highest)
- **Adepre** = the support for a revision of Austrias energy policy because of growing import dependencies (1 – 5; 1=lowest; 5=highest)
- **CCbeliv** = the individual belief in climate change (1 - 5; 1 = no belief; 5 = full belief)
- **CCgoal35** = the belief in austrias ability of reaching its climate goals in 2035 (1 - 5; 1 = no belief; 5 = full belief)
- **Gender** = the gender of the participant (1=male; 2=female; 3=binary)
- **Age** = the participants age (4 groups: 1=15-19yrs; 2=20-24yrs; 3=25-29yrs; 4=30+)
- **Country** = the participants current residential country (5 groups: 1=Germany, 2=Austria, 3=Switzerland, 4=Other EU country, 5=Non EU country)
- **Education** = education listed in many groups from 1=lowest to 8=highest
- **Netinc** = net income of participant listed in 10 income groups: 1=no income, 10=highest income

All of these variables were tested for significant relevance.

Variables	Support of nuclear energy in Austria
Questionaire 1 (full information)	0 (.)
Questionaire 2 (half information)	-1.158406** (.5189825)
Questionaire 3 (no information)	-.4060062 (.3649118)
NE safety	.568163*** (.1680202)
NE reduction GG	.1985498 (.1875612)
NE lower prices	.1252453 (.1613873)
NE reliability	.3992071** (.1921694)
NE future research	.2641456 (.177203)
NE mitigate climate change	.0836781 (.2099801)
NE climate goals difficulty	.1548789 (.1656755)
Austrian approach	.5032285** (.1955674)
Support Austrian referendum	.6810083*** (.157258)
Awareness NE facilities nearby	.4361306 (.3078114)
Revision Austrian energy policy	-.1334434 (.1731751)
Belief in climate change	-.3179508 (.223219)
Belief reaching climate goals 2035	.2578521* (.1485702)
Gender	.1758419 (.2904626)
Age	-.0298125 (.2111878)
Residential country	.6620865* (.3443505)
Level of education	.1987671** (.0901627)
Net income	-.0138949 (.0595803)
Constant	-11.666 (2.131604)

*** p<0.01. ** p<0.05, * p<0.1

N 235

Figure 11: Result table of probit regression (own elaboration)

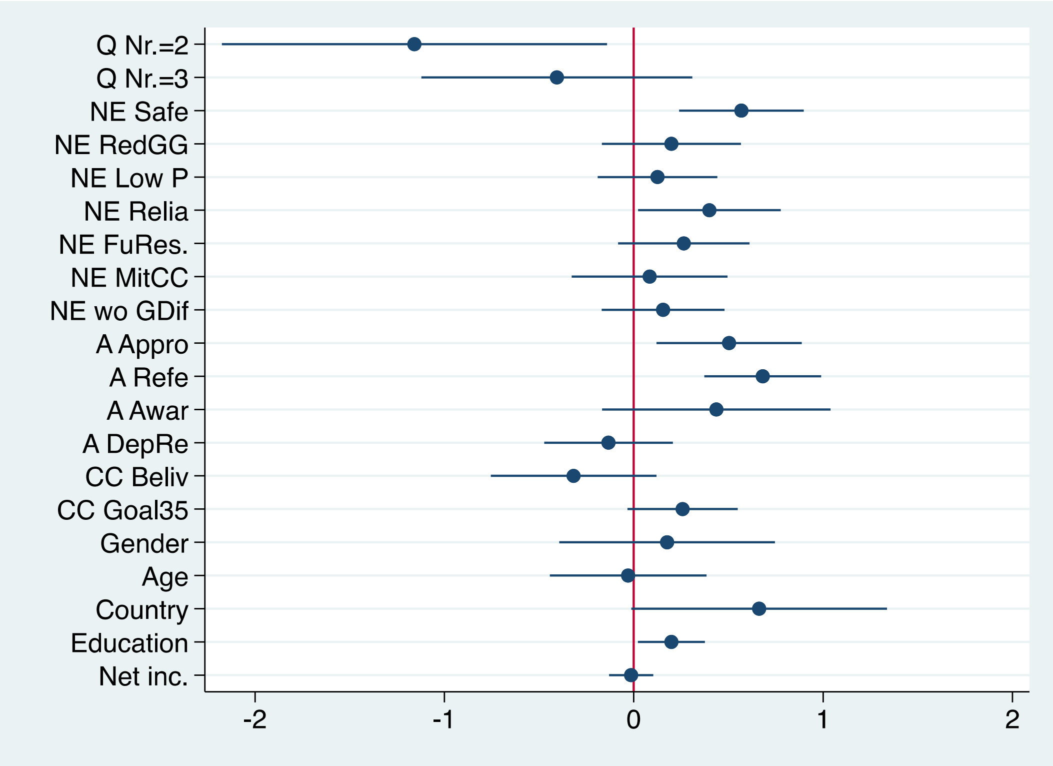

Figure 12: Result graphics probit regression (own elaboration)

Given the results from above, the following equation can be estimated:

Support of NE in Austria = -11,666 + 0,568406*NE Safe + 0,1985498*NE RedGG + 0,1252453*NE Low P + 0,3992071*NE Relia + 0,2641456*NE FuRes. + 0,0836781*NE MitCC + 0,1548789*NE wo GDif + 0,5032285*A Appro + 0,6810083*A Refe + 0,4361306*A Awar – 0,1334434*A DepRe – 0,3179508*CC Beliv + 0,2578521*CC Goal35 + 0,1758419*Gender – 0,0298125*Age + 0,6620865*Country + 0,1987671*Education – 0,0138949*Net inc. + ε

The results from *figure 11* raise that the variable "NE Safety" - i.e. the generally assumed safety perception of the respondent - significantly influences the dependent variable of advocacy, which is true even in the 1% confidence interval. Nuclear energy's reliability plays a significant role in this aspect too, as its perception is positively correlated as well at a significance level of 5%. Thus, *H1a* cannot be rejected since an increased perception of safety contributes positively to the endorsement of nuclear power in Austria.

In this model, the variable "Aaware" describes the perception and prior knowledge of the adjacent nuclear power plants within a distance of < 70 km from Austria of the respective respondent. Although this variable is positively correlated with the support of NE in Austria, it is not significant in this model, whereby *H1b: "Austrian Students with higher safety perceptions are more likely to support nuclear energy in Austria, more so if they are aware of the country's neighboring power plants and their short distance to the Austrian border (70 km or less)."* can be discarded.

To answer the third hypothesis *H2: "Austrian Students with higher climate change mitigation perceptions are more likely to support nuclear energy in Austria."* The independent variable "NEmitCC" provides more detailed information. This variable describes the respondent's individual belief about climate change. Even though a positive correlation exists again, the p-value is not significant enough. Accordingly, H2 can be rejected in its entirety.

In this context, the independent variable "NEwogdiff5" was also recorded and evaluated in the regression. This variable tests the support for the declaration that nuclear power generation would help Austria to achieve the climate targets for the year 2035. With a coefficient of 0,1548789, this variable is positive but not significantly influential on the advocacy of nuclear power in Austria.
Thus, both variables "NEbeliev" and "NEwogdiff" do not appear significant in this test, but because of the high t values, they could also be examined in further research as part of a more detailed information assignment on the impact of nuclear power on the environment.

Another observation that can be made after considering the results is the general data regarding the support for nuclear energy in the Austrian national area of all 235 respondents. Here, the average advocacy makes up a total of 45.5% of all respondents. Accordingly, the remaining 54.5 % of the 235 subjects voted against nuclear energy.

Overall, this indicates a relatively narrow but clear majority of respondents who oppose nuclear power and its future existence in Austria.
Since this proportion of supporters of nuclear power comes from the total number of respondents, regardless of which of the three questionnaires was submitted in each case, it was of great relevance to evaluate the questionnaires independently of each other. The comparison of these results does not show any major deviations in the support for nuclear power among the respondents, however, notable differences can be identified:

- Questionnaire 1, which contains the full information on nuclear energy provided by this experiment, has the highest approval rate in the comparison. At 47.2%, the proportion of supporters is not yet a majority, but this figure is close enough to the 50% mark to warrant further attention and clarification.

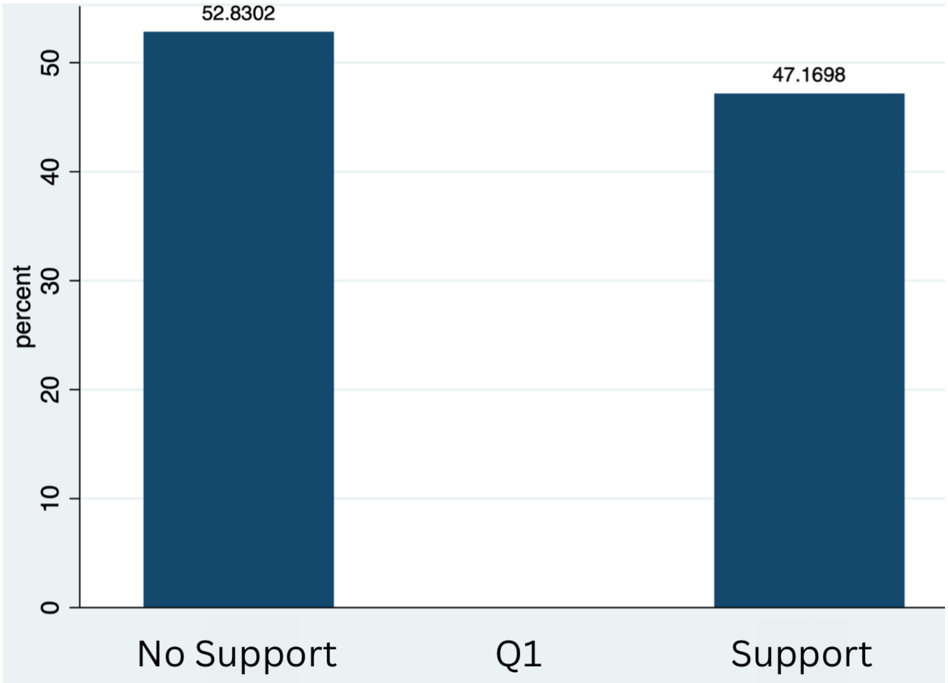

Figure 13: Summary statistics for questionnaire 1 (full information) (own elaboration)

- Questionnaire 2, which presents only half the information bundle - the impact on nature and the environment associated with the use of nuclear power for energy production - achieves an endorsement rate of 46.8% among the subjects despite the lack of safety information.

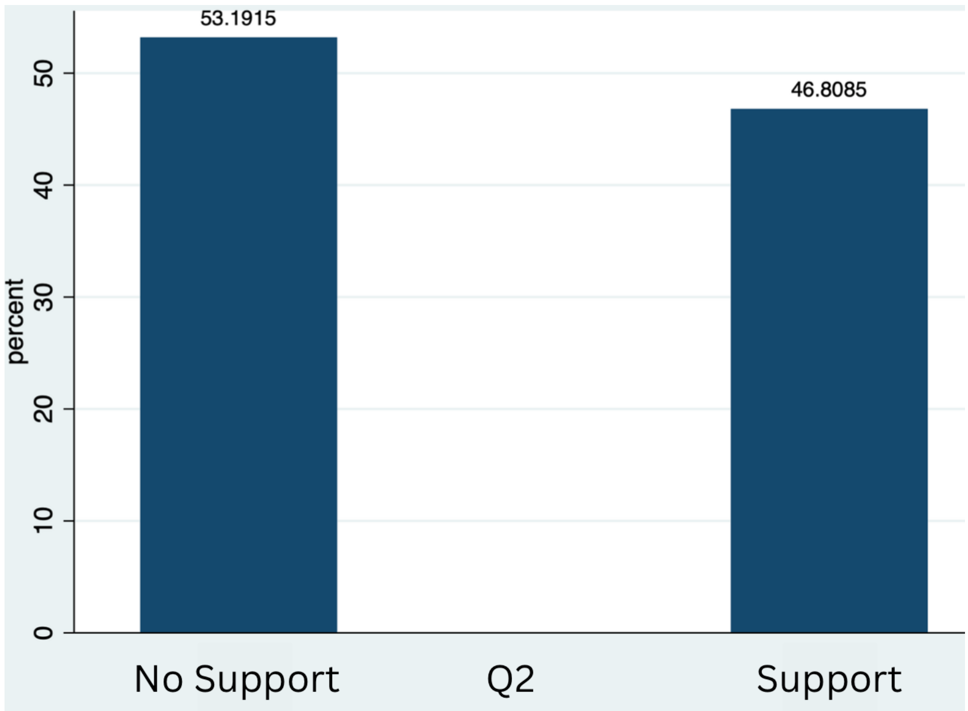

Figure 14: Summary statistics for questionnaire 2 (half information) (own elaboration)

- Questionnaire 3, which provides neither any information on the operational safety of nuclear power plants nor any information on related impacts on nature and the environment, achieves an advocacy rate of 44.4%. This, thus, represents the lowest ratio among the 3 test groups.

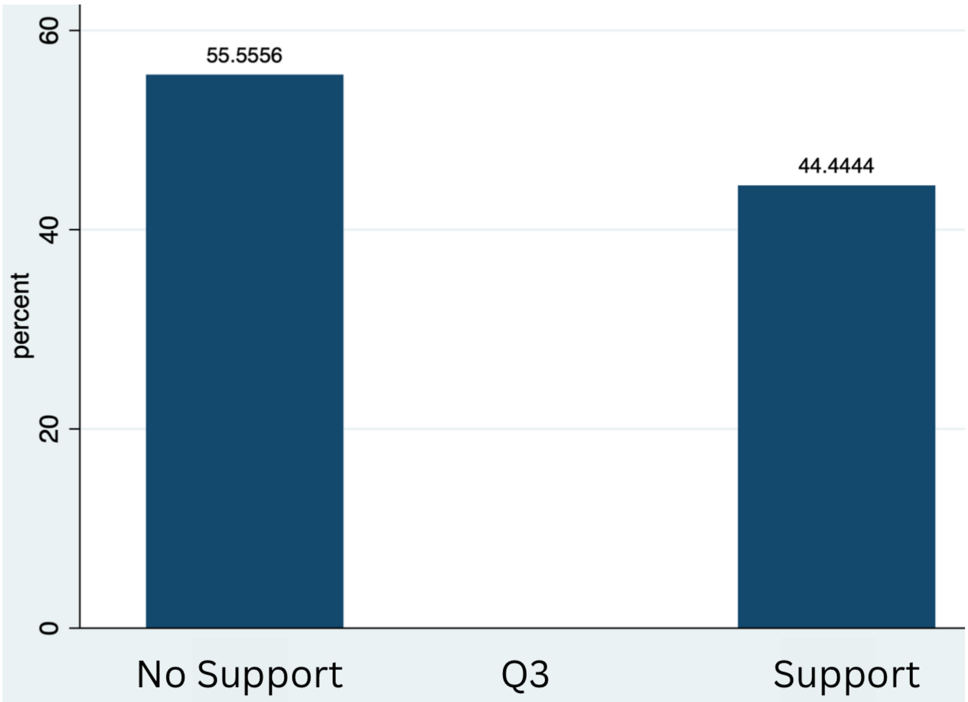

Figure 15: Summary statistics for questionnaire 3 (no information) (own elaboration)

Even if the scope of these sample deviations is rather minor, the influence of the provided information flow is nevertheless evident and already plays an important role in this experiment, despite its smaller extent and sample size.

Accordingly, the hypothesis *H3: "After receiving the information on safety, health and climate matters of nuclear energy, people are more likely to support this technology in Austria"*, cannot be rejected, since in fact the questionnaire with the most information achieves the highest level of support and the coefficients for questionnaire nr. 2 (half information) and questionnaire nr. 3 (no information) are both negative, nr. 2 even significantly on the 95% level.

Considering the control variables, it can be stated for the time being that the gender share is almost equally distributed for both sexes. The average age of all respondents is between 22 and 26 years, which clearly reflects the age of the desired target group of students. The country of origin of the respondents is considered to be the only one of the tested control variables of the survey with a significant influence on the dependent variable. Here, a clear deviation in the support for nuclear power in Austria can be seen on the side of the foreign students - i.e. those who do not originate from Austria. Namely, they show a clearly positive view of nuclear power and also represent an 86% majority in favor of nuclear power in Austria. Although the cause of this deviation could be of various reasons, for example the difference in basic knowledge on the subject or the fact that nuclear power plants are actively in operation in the respondent's country of origin, it is nevertheless relevant for future research to investigate this divergence further. What sticks out, is the positive correlation of the level of education of each participant. It clearly shows that education matters when addressing this topic, stating a higher likelihood of support for nuclear energy in Austria with higher levels of education, even at a 95% significance level. This fact combined with the conclusions drawn on the differences of the test groups really emphasize the importance of informed knowledge and challenge future research and perhaps political action to ensure a brief understanding of certain viewpoints which indeed matter for making a fundamental decision that can shape Austria's energy policy in future.

Furthermore, the number of scientific facts provided in the questionnaires with information was kept very low in order to facilitate an actual answering of the questionnaires by the participants. The influence of significantly more extensive information and knowledge provision could possibly bring about even more substantial differences compared to opinion collection without information and could entirely change the results in the context of the question on the advocacy of nuclear energy.

Further research could pick up on this point and explore in more detail in an expanded framework. One factor that would need to be considered, however, is the choice of one's primary channel of information. In the age of digital media and social media, it may well be relevant who conveys the factual information to respondents. A growing distrust in politics as well as an increasingly significant influence from a specific group of outsiders such as influencers and celebrities could strongly shape a very sensitive question such as this one in Austria, which is why the path of information supply can distort the validity of the results.
Similarly, more detailed audience segmentation may potentially reveal further contrasts, both in terms of the age and social standing of the respondents. Finally, the question on the introduction of nuclear power plants and their commissioning for energy production is of nationwide relevance, where all eligible voters may have a say and not just primarily students.

Considering the leading research question "What factors hinder Austria to introduce nuclear energy into its energy policy as an alternative to reduce energy prices and greenhouse gas emissions?" the following conclusions can be drawn:

A certainly influential aspect and possibly preventive factor of the development and commissioning of new nuclear power plants in Austria is the high-cost issue, especially of the initial investment. As the literature review shows, enormous costs and capital in the form of billions of Euros are necessary for the construction of modern nuclear power plants, which therefore fundamentally requires a well-thought-out strategic plan for the future with regard to the energy policy of the Austrian state, as the example of France shows.
In order to make such an investment in one or more facilities possible, however, sufficient political agreement and consent of the people is required in advance, which already represents the second preventive factor of the nuclear power issue in Austria. From the research of this thesis, it became apparent that the information distribution on the current state of knowledge of nuclear energy production definitely influences the opinion on this issue. Accordingly, the bias of Austrian citizens has just as much influence on their decision-making, which is why it would be fundamentally important to replace such with scientifically reliable information.

In addition, more frequent discussion by policymakers about the environmental impacts resulting from the literature review in relation to nuclear power would make sense, especially on open issues such as nuclear waste processing. Making room for consideration of alternative energies would be a positive start in this regard, rather than facing the subject with a closed curtain and focusing on far less effective methods of $CO2$ mitigation. After all, a solution is needed in the race to meet climate goals, which is still undefined at this point.

In summary, the research in this paper provided a comprehensive view of the current state of nuclear power generation in Austria from both an economic and an environmental perspective. Furthermore, the different approach and handling of the countries in the EU area only makes the controversial nature of this topic clearer and provides approaches for future research, which should not disregard this aspect of energy production during the current energy crisis. This reflects especially on Austria and its energy policy, which is politically very averse to nuclear power in comparison to other countries. The results of the survey confirm this approach and provide clues that can be examined and questioned more closely. Also, the importance of nuclear power in the social context plays an essential role in a decision that can only be made democratically and on the basis of scientifically precise baseline knowledge. Ultimately, the current energy crisis calls for solution-oriented action and thinking, and possibly a somewhat broader perspective when considering alternative energy production methods.

Table of figures

Bibliography:

Rokicki, T., & Perkowska, A. (2021). Diversity and changes in the energy balance in EU countries. *Energies*, *14*(4), 1098.

Haas, R., Mez, L., & Ajanovic, A. (2019). *The technological and economic future of nuclear power* (p. 385). Springer Nature.

Simionescu, M., & Schneider, N. (2022). Revisiting the nuclear energy-income nexus in Europe: An application of the JKS panel causality test with cross-sectional dependence and heterogeneity. *International Journal of Energy Research*, *46*(6), 8328-8351.

Thoben, C., Elsässer, R. F., Oesterwind, D., & Hennicke, P. (2006). Security of supply-how should future energy policy be shaped?. *ifo Schnelldienst*, *59*(03), 3-18.

Heselhaus, S. (2022). The quest for the future energy mix in the EU and in Switzerland. In *Swiss energy governance* (pp. 49-66). Springer, Cham.

Lynas, M. (2021). EU Taxonomy and Nuclear Energy: How to Fix Europe's Energy Crisis while also Achieving Climate Neutrality. *Antonios Nestoras*, 211.

Narula, K., Ploiner, C., Getzinger, G., & Patel, M. K. (2022). Impact of energy efficiency and decarbonisation policies for buildings: A comparative assessment of Austria and Switzerland. *Energy and Buildings*, 112175.

Duvic-Paoli, L. A., & Lueger, P. (2022). A democratic nuclear energy transition? Public participation in nuclear activities. *Review of European, Comparative & International Environmental Law*.

Zawalińska, K., Kinnunen, J., Gradziuk, P., & Celińska-Janowicz, D. (2020). To whom should we grant a power plant? Economic effects of investment in nuclear energy in Poland. *Energies*, *13*(11), 2687.

Kirchengast, G., Kromp-Kolb, H., Steininger, K., Stagl, S., Kirchner, M., Ambach, C., ... & Strunk, B. (2020). Referenzplan als Grundlage für einen wissenschaftlich fundierten und mit den Pariser Klimazielen in Einklang stehenden Nationalen Energie-und Klimaplan für Österreich (Ref-NEKP) Vision 2050 und Umsetzungspfade: Österreich im Einklang mit den Pariser Klimazielen und der Weg dorthin.

Forstner, C. (2019). Österreich nach 1945. In *Kernphysik, Forschungsreaktoren und Atomenergie* (pp. 123-232). Springer Spektrum, Wiesbaden.

Steininger, K. W., König, M., Bednar-Friedl, B., Kranzl, L., Loibl, W., & Prettenthaler, F. (Hrsg.). (2015). Economic evaluation of climate change impacts: development of a cross-sectoral framework and results for Austria. Cham: *Springer Verlag.*

Schleicher, S. P., & Steininger, K. W. (2017). Wirtschaft stärken und Klimaziele erreichen: Wege zu einem nahezu treibhausgas-emissionsfreien Österreich. *Scientific Report*, (73– 2017).

Steininger, K. W., Bednar-Friedl, B., Knittel, N., Kirchengast, G., Nabernegg, S., Williges, K., ... & Kenner, L. (2020). Klimapolitik in Österreich: Innovationschance Coronakrise und die Kosten des Nicht-Handelns. *Wegener Center Research Briefs*, *1*.

Horvath, P., & Gutschick, R. (2009). Aktuelle Positionen zur österreichischen Energiepolitik. *SWS-Rundschau*, *49*(4), 519-524.

Berthold-Besagin, N. (2017). *Die Zukunft der Atomkraft in Europa-rechtliche Rahmenbedingungen/eingereicht von Nicole Berthold-Besagin* (Doctoral dissertation, Universität Linz).

https://www.bmk.gv.at/themen/energie/publikationen/zahlen.html (2022). Energie in Österreich.

Bayer, F. 2013. "Political culture, national identity and nuclear energy; Politische Kultur, nationale Identität und Atomenergie." Austria.

Wagner, B., Hauer, C., Schoder, A., & Habersack, H. (2015). A review of hydropower in Austria: Past, present and future development. *Renewable and Sustainable Energy Reviews*, *50*, 304-314.

Habersack, H., Wagner, B., Hauer, C., & Jäger, E. (2012). Wasserkraft in Österreich—aktueller Bestand und decision support system (DSS WASSERKRAFT). *Österreichische Wasser-und Abfallwirtschaft*, *64*(5), 336-343.

Moidl, M. S., & Winkelmeier, M. H. (2018). Neubewertung des Potentials zur Nutzung der Windkraft in Österreich bis zum Jahr 2030.

Resch, G., Burgholzer, B., Totschnig, G., Lettner, G., Auer, H., Geipel, J., ... & Windkraft, I. G. (2017). Stromzukunft Österreich 2030. *Technische Universität Wien, Wien*.

Gochermann, J. (2021). The Value of Energy–Der Wert der Energie. In *Halbzeit der Energiewende?* (pp. 165-205). Springer, Berlin, Heidelberg.

Biresselioglu, M. E., Limoncuoglu, S. A., Demir, M. H., Reichl, J., Burgstaller, K., Sciullo, A., & Ferrero, E. (2021). Legal provisions and market conditions for energy communities in Austria, Germany, Greece, Italy, Spain, and Turkey: A comparative assessment. *Sustainability*, *13*(20), 11212.

Jacobsen, B., Liebmann, R., & Elbers, M. (2022). Dekarbonisierung durch Elektrifizierung mit begrenzten Netzkapazitäten. *Zeitschrift für Energiewirtschaft*, 1-10.

Crastan, V. (2017). Energiewirtschaft und Klimaschutz. In *Elektrische Energieversorgung 2* (pp. 3-63). Springer Vieweg, Berlin, Heidelberg.

Crastan, V. (2021). Power Generation. *Springer Handbook of Power Systems*, 45-130.

Crastan, V., & Höckel, M. (2022). Thermische Kraftwerke. In *Elektrische Energieversorgung 2: Energiewirtschaft und Klimaschutz, Elektrizitätswirtschaft und Liberalisierung, Kraftwerktechnik und alternative Stromversorgung, chemische Energiespeicherung* (pp. 341-403). Berlin, Heidelberg: Springer Berlin Heidelberg.

Haucap, J., & Meinhof, J. (2022). Die Strompreise der Zukunft. *Wirtschaftsdienst*, *102*(1), 53-60.

Trattnig, U., Haubenhofer, R., Möltner, L., & Hauser, R. (2022). 2001 bis 2021–20 Jahre Strommarktliberalisierung in Österreich: Bestandsaufnahme und Ausblick. In *Zukunft verantwortungsvoll gestalten* (pp. 63-76). Springer Gabler, Wiesbaden.

Kratena, K., Knaus, K., Schwarzmaier, C., Scharner, A., & der Elektrizitäts, R. Volkswirtschaftliche Effekte der Energiemarktliberalisierung.

Abousahl, S., Carbol, P., Farrar, B., Gerbelova, H., Konings, R., Lubomirova, K., ... & Wastin, F. (2021). Technical Assessment of Nuclear Energy with Respect to the 'Do No Significant Harm'Criteria of Regulation (EU) 2020/852 ('Taxonomy Regulation'). *doi*, *10*, 665806.

European Commission (2022), 'EU taxonomy for sustainable activities'. https:// ec.europa.eu/info/business-economy-euro/banking-and-finance/ sustainable-finance/eu-taxonomy-sustainable-activities_en.

European Commission (2022), 'FAQ: What is the EU Taxonomy and how will it work in practice?'. https://finance.ec.europa.eu/system/files/2021-04/sustainable-finance-taxonomy-faq_en.pdf

Bayer, F. (2014). Die Ablehnung der Kernenergie in Österreich: Ein Anti-Atom-Konsens als Errungenschaft einer sozialen Bewegung?. *Momentum Quarterly-Zeitschrift für sozialen Fortschritt*, *3*(2), 170-187.

Felt, U. (2015). Keeping technologies out: Sociotechnical imaginaries and the formation of Austria's technopolitical identity. *Dreamscapes of modernity: Sociotechnical imaginaries and the fabrication of power*, 103-125.

Jiménez-Reyes, M., Almazán-Sánchez, P. T., & Solache-Ríos, M. (2021). Radioactive waste treatments by using zeolites. A short review. *Journal of Environmental Radioactivity*, *233*, 106610.
Roopa, S., & Rani, M. S. (2012). Questionnaire designing for a survey. *Journal of Indian Orthodontic Society*, *46*(4_suppl1), 273-277.

Taherdoost, H. (2016). Validity and reliability of the research instrument; how to test the validation of a questionnaire/survey in a research. *How to test the validation of a questionnaire/survey in a research (August 10, 2016)*.

Schulenberg, S. (2009). *Die Energiepolitik der Europäischen Union*. Nomos Verlagsgesellschaft mbH & Co. KG.

Nötzold, A. (2011). Die Energiepolitik der Europäischen Union. In *Die Energiepolitik der EU und der VR China* (pp. 187-308). VS Verlag für Sozialwissenschaften.

Kanellakis, M., Martinopoulos, G., & Zachariadis, T. (2013). European energy policy—A review. *Energy Policy*, *62*, 1020-1030.

Prammer, D., & Reiss, L. (2022). Fighting (the effects of) inflation: government measures in Austria and the EU. *Erscheint in Monetary Policy & the Economy Q*, *4*.