MSc Program
Renewable Energy Systems

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Comparison of the Austrian and German renewable energy expansion laws for solar PV with an evaluation of the incentives for residential PV

A Master's Thesis submitted for the degree of
“Master of Science”

supervised by
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Affidavit

I, **MAG. FLORIAN ZEILINGER**, hereby declare

1. that I am the sole author of the present Master’s Thesis, "COMPARISON OF THE AUSTRIAN AND GERMAN RENEWABLE ENERGY EXPANSION LAWS FOR SOLAR PV WITH AN EVALUATION OF THE INCENTIVES FOR RESIDENTIAL PV", 119 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted the topic of this Master’s Thesis or parts of it in any form for assessment as an examination paper, either in Austria or abroad.

Vienna, 27.02.2023

Signature

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This master's thesis is dedicated to my parents. Thank you for always taking care of me and supporting me unconditionally.

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Abstract

To reach the targets of the Paris climate agreement, Austria and Germany need to expand their share of renewables in the energy sector. This task can only be achieved if private households back this transition to a sustainable energy system. Austria set out an ambitious plan with the new Erneuerbaren-Ausbau-Gesetz (Renewable Energy Expansion Act, “EAG”) in 2021. Austria aims to become climate neutral by 2040 with a 100% electricity supply from renewable technologies already by 2030.

This master’s thesis compares the new Austrian Renewable Energy Expansion Act with the German Erneuerbare-Energien-Gesetz (Renewable Energy Sources Act, “EEG”, the latest amendment “EEG 2023” was passed in 2022) with regards to the effects on residential solar PV from a political, economic, and legal perspective. Furthermore, a case study including NPV calculations for solar PV systems (6 kWp and 11 kWp) is conducted in three scenarios: scenario 1, whose values refer to electricity prices to the second half of 2021, scenario 2, whose values refer to electricity prices of the second half of 2022, and scenario 3, whose values refer to electricity prices to the second half of 2019. An average Austrian or German 4-person family household is selected as the operator and the subsidy schemes of the EAG and EEG are applied and compared.

As Austria and Germany are member states of the EU, both the EAG and the EEG show similarities as EU energy policies drive them. Recent EU policies oblige EU member states to introduce more market-integrating support schemes, such as market premium schemes instead of feed-in tariffs. In both countries, the operating support for solar PV has declined significantly in recent years. Nonetheless, high electricity prices and therefore higher proceeds of feed-in electricity for operators of solar PV installations have led to a boom of residential solar PV. However, it remains unclear if more private households will acquire solar PV installations when subsidies are relatively low compared to market prices – as it is currently the case in the EAG and EEG as of 2022. Therefore, it is doubtful that Austria and Germany will meet their climate targets. One significant finding of the here presented thesis is that market conditions are crucial for a feasible residential solar

PV investment. An important aspect concerning the impact of the subsidy scheme is if the operator can profit from high electricity market prices with the subsidy. As of 2022, operating a solar PV installation has become increasingly profitable in Austria and Germany. However, not due to low support schemes but due to high electricity prices.

Table Of Contents

1. Introduction

1.1. Background

With the Paris Agreement, Austria and Germany agreed to transform their electricity and energy systems into a climate-neutral system based on 100% renewables. (United Nations, 2015; EU Commission, 2016). The ambitious path to achieve this target is mainly outlined in the Austrian EAG and German EEG and their explanatory notes (Austrian Parliament, 2021a; e-control, 2022d; BMJ and BfJ, 2023). The Austrian and German climate laws ("Klimaschutzgesetz") describe other respective climate targets, such as GHG emission reduction paths (BKA, 2017; BMJ and BfJ, 2021).

The EU member states have set ambitious plans for the member states to become the first climate-neutral continent. The European Climate Law (Regulation 2021/1119) sets up binding goals for EU member states (EUR-Lex, 2021). Two milestones will shape EU member states in almost every business sector: Firstly, towards 2030, the EU member states shall reduce 55% of net emissions of GHG compared to 1990. Secondly, the EU shall achieve climate neutrality by 2050. After 2050, there shall only be negative emissions (EU Commission, 2022a).

As Austria and Germany are member states of the EU, both countries are subject to EU law, which has broadly influenced policies concerning the energy sector in both countries. Moreover, the EU Green Deal plays a crucial part. Especially concerning renewables, the Directive (EU) 2018/2001 (also "Renewable Energy Directive II") is highly relevant (besides the European Climate law) as it sets up the target that renewables must provide 32% of the EU's overall gross final energy consumption by 2030 (EUR-Lex, 2018a; Woerdman et al., 2021, pp. 29, 34). To achieve those targets, Austria and Germany had to transpose these EU regulations into national legislation, which, among other measures, was done by introducing the EAG and amending the EEG (EUR-Lex, 2018a; Austrian Parliament, 2021a, pp. 1-2; BMWK, 2022a, p. 1).

In 2021, the EU Commission proposed a new directive to increase the renewables target to 40%. Furthermore, in the context of current market turbulences, the EU Commission even proposed a 45% increase of renewables by 2030 with the REPowerEU Plan even (Ennser et al., 2022, pp. 20-21). Additionally, in 2022, measures to quicken the approval process in EU member states for renewable technologies, including solar PV, were passed (Council of the EU, 2022).

Austria and Germany have different “starting positions” on the path to net-zero. Austria has an advantageous position because of its high share of hydro-power due to the Alps (see Figure 1 and Figure 12). The expansion of hydro power rose after World War 1. Back then, Austria lost crown lands with a significant supply of coal and had to substitute coal with hydro power (Wagner et al., 2015, p. 306). Nevertheless, as displayed in Figure 1, Germany also has a substantial share of renewables compared to other EU countries, but also roughly ten times more inhabitants with 83.2 Mio. people than Austria with 8.9 Mio. people (Eurostat, 2022c).

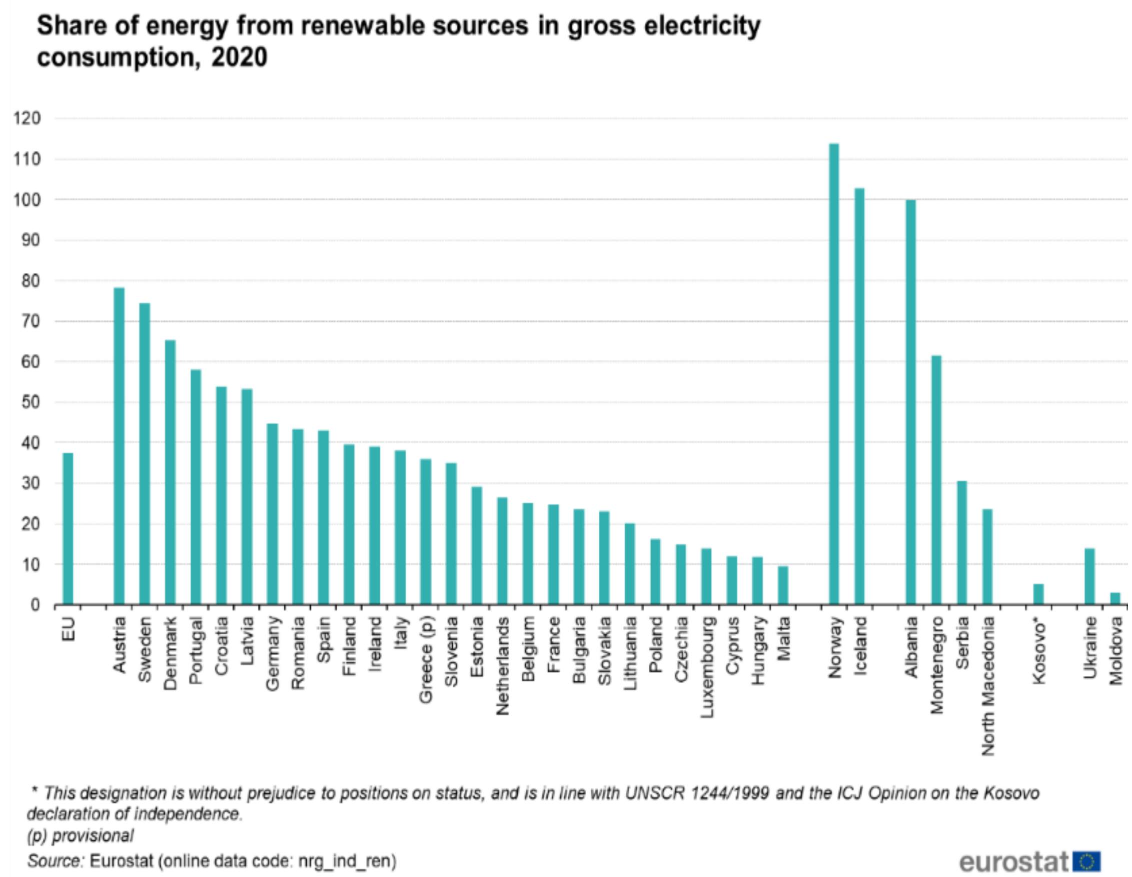

Figure 1: Share of energy from renewables in gross electricity consumption in EU countries in 2020 (Eurostat, 2022d)

Figure 2 and Figure 3 show that both, in the EU and Germany, decarbonizing the electricity sector plays a crucial part in achieving climate neutrality as this sector emits significant GHG. In the last few years, the GHG emissions of the electricity sector decreased slightly, which can be explained by the impacts of the COVID-19 crisis and the expansion of renewables in both countries. In this regard, solar PV is essential when it comes to the decarbonization of the electricity supply (Haas et al., 2023, p. 1).

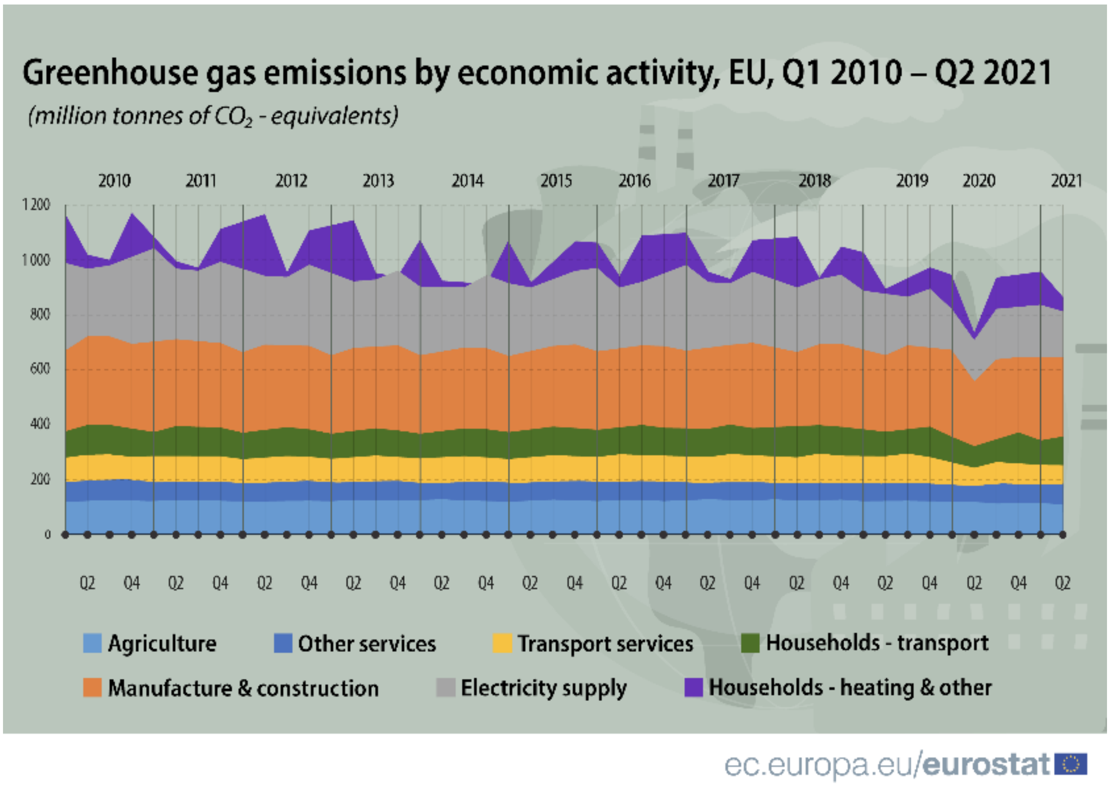

Figure 2: GHG emissions by economic activity in the EU from 2010 until Q2 2021 (Eurostat, 2021)

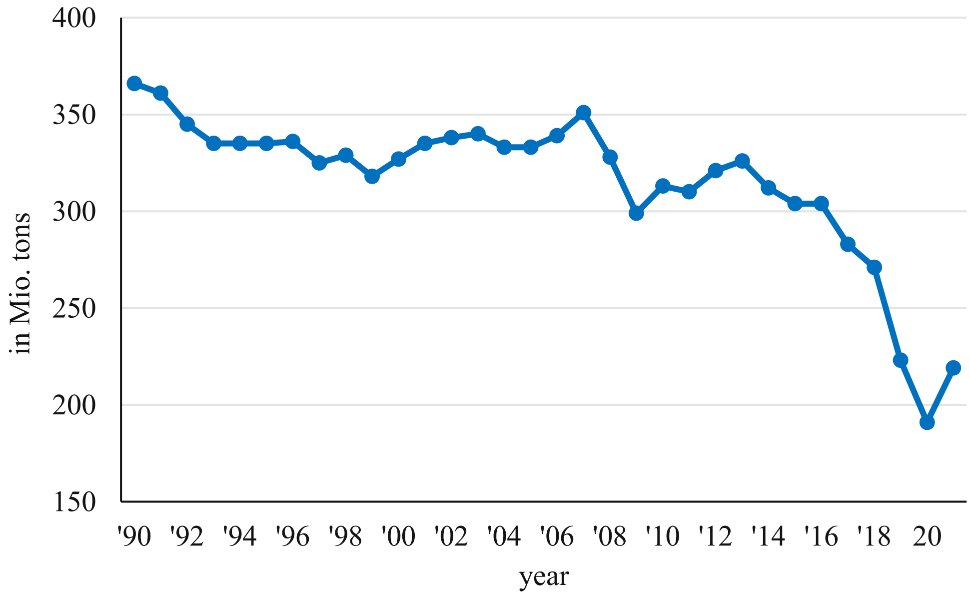

Figure 3: CO_2 emissions related to electricity generation in Germany from 1990 to 2021 in Mio. tons, based on Icha et al. (2022, pp. 10-11)

To boost renewables installation, the recent German EEG 2023 amendment increased the expansion targets for solar PV (see Figure 4). By 2026, the expansion rate for solar PV shall be increased to 22 GW p.a., in contrast to onshore wind energy, which shall “only” account for 10 GW p.a. by 2025 – less than half of the amount of solar PV. This expansion path also underlines the importance of solar PV technology. (BMWK, 2022a, pp. 23-24, 159-160; BMWK, 2022b, pp. 3-4)

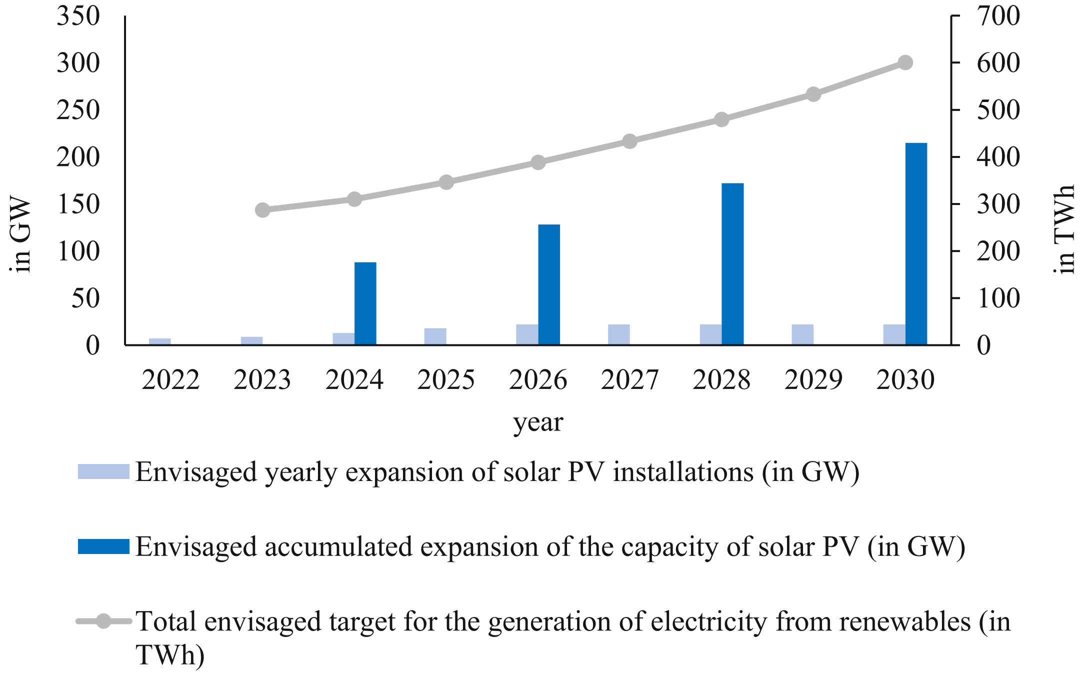

Figure 4: Envisaged expansion of solar PV capacity in Germany in GW p.a. according to the EEG and total envisaged targets for the generation of electricity from renewables in Germany, based on BMWK (2022a, pp. 23-24, 159) and Offene Gesetze (2022, p. 1248)[1]

Figure 4 also shows the total envisaged target for generating electricity from renewables. By 2030, 600 TWh shall be provided by renewable technologies in the electricity sector. In comparison, Germany’s net public electricity generation in 2021 amounted to 495.05 TWh, of which renewable technologies provided 225.58 TWh, which equals 45.6% (Energy-Charts, 2022).

Also, for Austria, a significant expansion of solar PV is equally essential when establishing an electricity system based solely on renewables. According to the explanatory notes in the EAG, Austria shall increase its additional renewable capacities by 27 TWh until 2030, of which solar PV shall provide 11 TWh (corresponds to more than 40%), wind energy 10 TWh, hydropower 5 TWh, and

[1] The values for the yearly expansion of solar PV (blue values) derive from the values according to explanatory notes to the EEG 2023. The accumulated values in dark blue derive from the legal text of the EEG 2023 amendment (Sect. 4 EEG).

biomass 1 TWh. Solar PV is one of Austria's main pillars and a key technology of the energy transition. Figure 5 shows the projected increase of renewables until 2030. (Austrian Parliament, 2021a, pp. 1-6) Figure 6 shows the expansion targets for all relevant renewables according to the EAG. (Austrian Parliament, 2021a, p. 6)

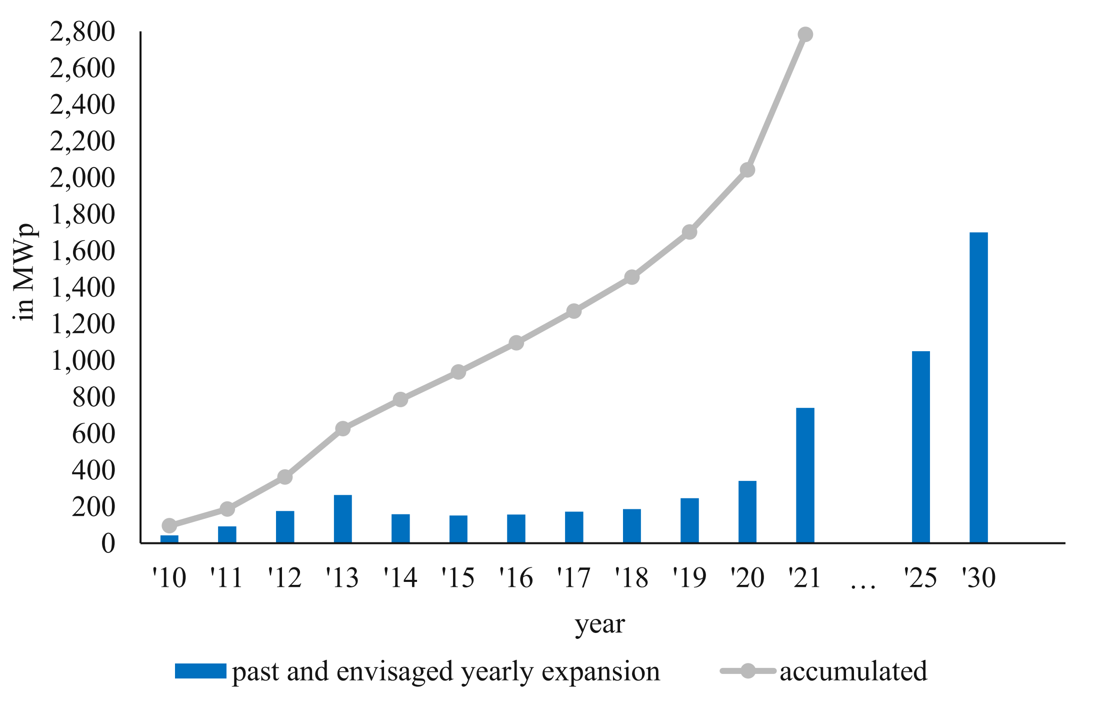

Figure 5: Past and envisaged yearly expansion of solar PV in Austria, rounded (forecast of PV Austria), based on BMK (2022b, pp. 116-118) and PV Austria (2021)

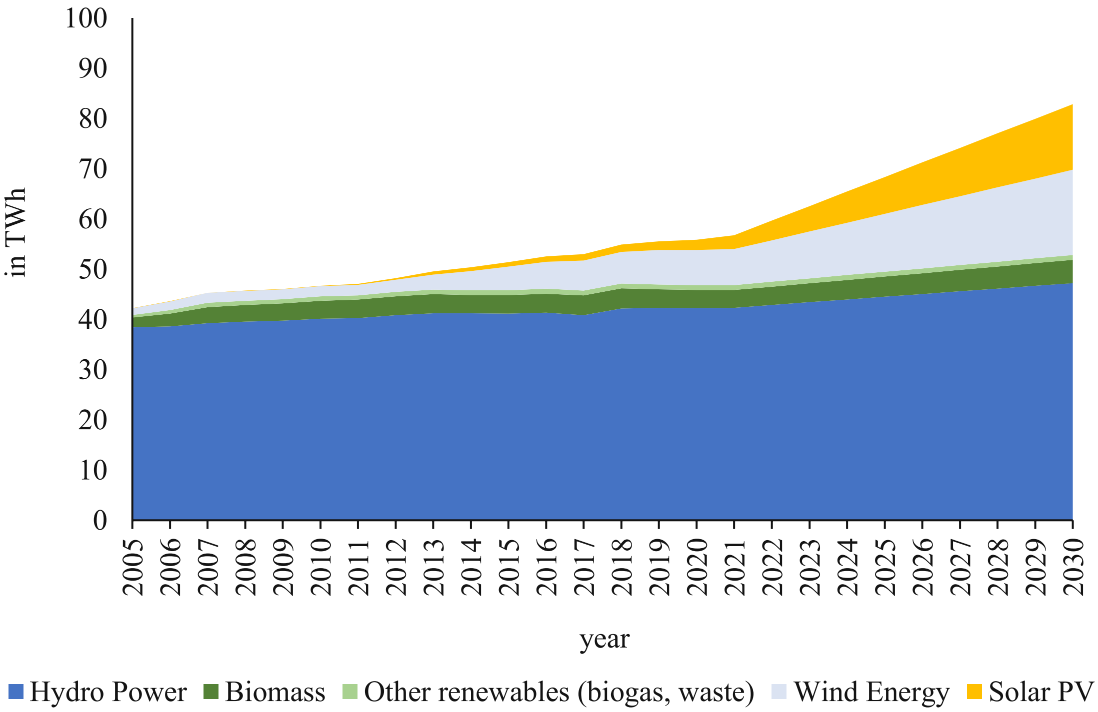

Figure 6: Expansion targets for renewable technologies according to the EAG, based on BMK (2021b), Statistik Austria (2022), and Austrian Parliament (2021a, p. 6)

Solar PV has become interesting for private households as the costs for this technology have decreased in the last few years (Bhandari and Stadler, 2009, p. 1635). Corresponding to the development of household electricity prices, the wholesale electricity price increased significantly in recent months (see Figure 7). On average, private households in Germany pay up to 50% higher prices for electricity than in other EU countries (see Figure 8). However, considering their purchasing power, Germany is ranked in the European middle (Wirth, 2022, p. 20). The currently soaring energy prices can be explained by the multiple crises at the end of 2021 in Europe. During the peak of the Covid-19 pandemic in 2020, electricity prices declined as electricity consumption dropped (Halbrügge et al., 2021, p. 11).

Even though the wholesale electricity price in Germany is cheaper than in Austria, the household electricity price is higher in Germany (see Figure 7 and Figure 8). This is related to higher levies and taxes; see Chapter 4.2.1 (Fina et al., 2018, pp. 14-15).

Germany and Austria had a common electricity bidding zone. In 2018, the bidding zone was split. Since the splitting, Austria has experienced slightly higher wholesale electricity prices than Germany (Hurta et al., 2022, pp. 12045-12046). From 2015 to the beginning of 2020, the wholesale electricity prices were also volatile but never exceeded 70 €/MWh – in August 2022, the price was over 460 €/MWh (see Figure 7). One main influencing factor on the wholesale electricity price before the Covid-19 pandemic was the expansion of renewables, especially solar PV and wind. This is due to their low marginal costs, which have a decreasing impact on the wholesale electricity price (Sorknæs et al., 2019, pp. 312-313; Kolb et al., 2020, p. 10). The share of conventional fossil fuels decreased due to the increasing contributions of renewable technologies in Germany (Haas et al., 2023, p. 5). Furthermore, with more renewables installed, the weather also significantly affects the wholesale electricity price (Tanaka et al., 2022, p. 1821). Before 2022, many EU member states and their economies profited from cheap Russian fuel, ultimately leading to a significant dependence on Russia. The low fuel prices also contributed to low wholesale electricity prices in the EU. Due to the war in Ukraine in 2022, EU member states have imposed sanctions against Russia and implemented embargos (Sturm, 2022, pp. 836-838; 854).

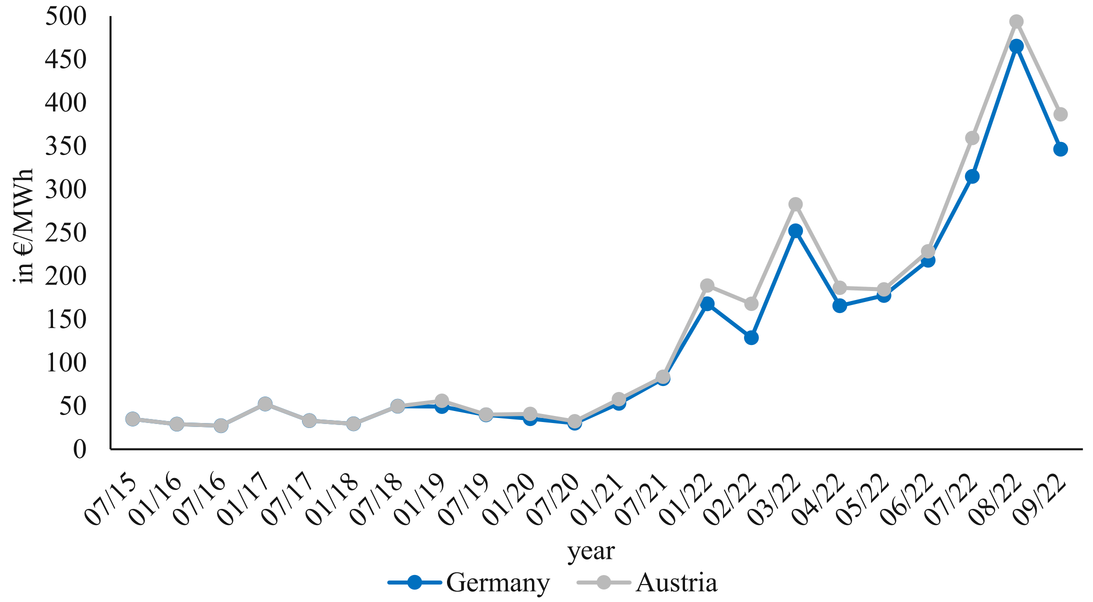

Figure 7: Average monthly wholesale electricity prices in Austria and Germany from 2015 to 2022, based on SMARD (2022)

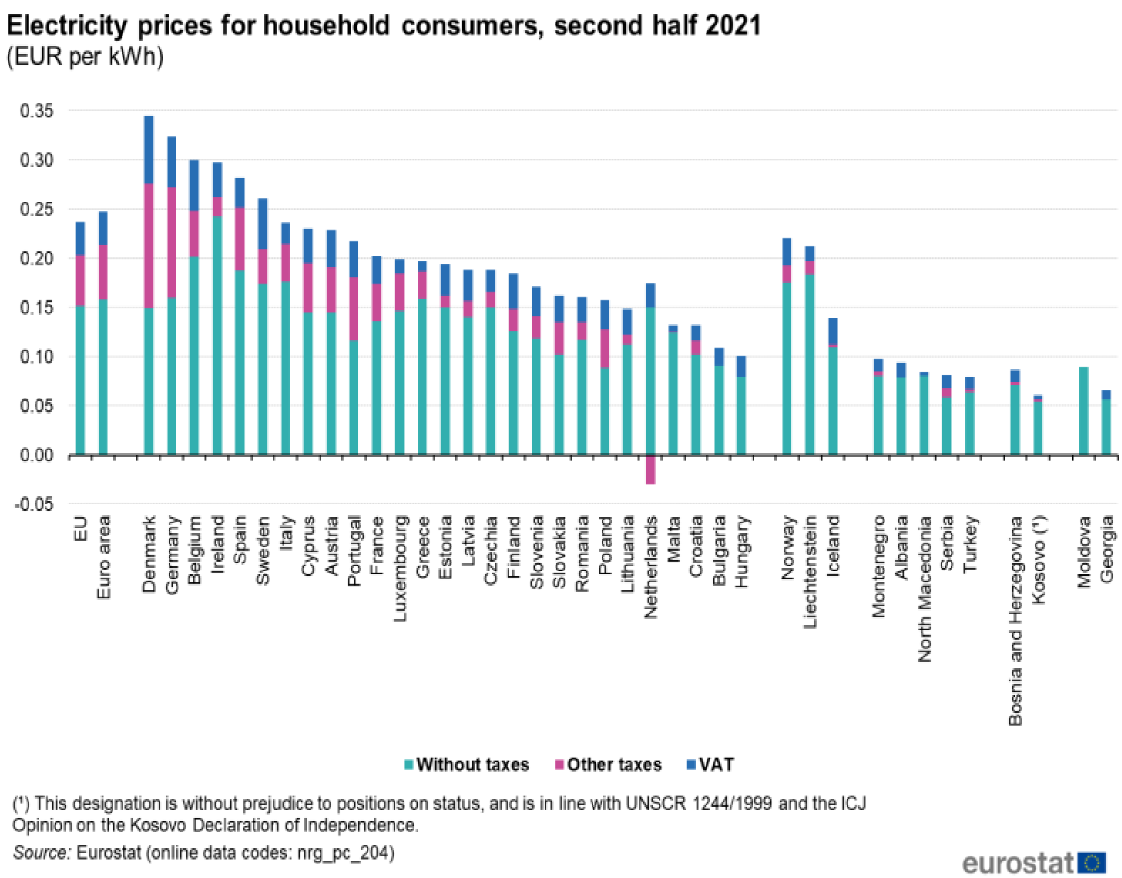

Figure 8: Electricity prices for households in EU countries in the second half of 2021 (Eurostat, 2022b)

However, there are also other reasons to acquire a solar PV system. Especially in Germany, people have become more aware of the positive aspects of producing and consuming green electricity on-site. Furthermore, more private individuals want to become independent from the public grid and the risks associated with energy imports as one reason for the recently soaring energy prices. (Sabadini and Madlener, 2021, pp. 1-2)

Residential solar PV is crucial for the energy transition. There is hardly any other technology as suitable as solar PV for private homes due to its convenient construction on roofs (Haas et al., 2023, p. 1; Breyer et al., 2017, pp. 727-728). This enables private households to become "prosumers" – consumers and producers of electricity at the same time (Haas et al., 2023, p. 12). The large German utilities, by contrast, only made small investments in solar PV plants in the past for several reasons (see Figure 9). One reason for this is that there has not been a CO_2 price introduced for a long time and electricity production costs for solar PV were more expensive some years ago (Wirth, 2021, p. 27). The lucrativeness of a solar PV installation is, among other things, related to the investment costs and the place of the installation due to the solar irradiance (IEA-PVPS, 2017, p. 66). One milestone in Germany was that small solar PV installations reached grid parity before 2012 – which was due to increasing retail electricity prices and high subsidies for solar PV. In Austria, grid parity was reached shortly after 2014 (Haas et al., 2023, p. 6). Grid parity means that the LCOE of solar PV is equal to or lower than the household electricity price (IEA-PVPS, 2017, p. 38).

Solar PV might become one of the most important technologies for electricity generation. It will also depend on the European governments' will to support this transition. Major investments in grid infrastructure are needed and will lead to high costs in the states' budgets (IEA-PVPS, 2017, p. 72). It is assumed that investment prices for solar PV will further decline, resulting in significant deployments. Another issue will be if distribution grids will manage the increasing amount of green electricity from intermittent renewables and the balancing of it (Haas et al., 2023, pp. 12-13).

Solar PV generates electricity especially in times of noon peak load. Consequently, traditional peak-load fossil fuel power plants that large utility companies usually operate are less needed, ultimately decreasing the cost-effectiveness of those power plants. Therefore, those electricity utilities acted with reservations towards solar PV technology. (Wirth, 2021, pp. 27-28)

Moreover, a more flexible energy system is necessary to handle intermittent and noon-oriented solar PV production. In this regard, installing more storage capacities (e.g., more batteries and the integration of the charging process of BEVs) or improved demand side management is crucial. Especially decentral prosumagers, i.e., households that generate and additionally store electricity, digitalization, and smart meters play an essential part in an improved demand side management system. Due to excessive electricity from solar PV, outdated grid infrastructure could be an issue locally. (Haas et al., 2023, pp. 2,12-13)

Figure 9 shows the ownership structure of solar PV in Germany related to the installed capacity. Private persons have the largest share with 32.1%, followed by industry with 24.8%, and farmers with 15.9%. Interestingly, German utilities make up only 6.3%, and the large three utilities, Vattenfall, EnBW, and RWE, only provide 0.2% of the total share (trend:research, 2020). In Austria, several utility companies have constructed solar PV installations recently and engaged in energy community projects for private households. The most significant solar PV installation has a capacity of 14 MW and is operated by OMV, an oil and gas company, and Verbund, a utility company (Fechner, 2021; Verbund, 2020).

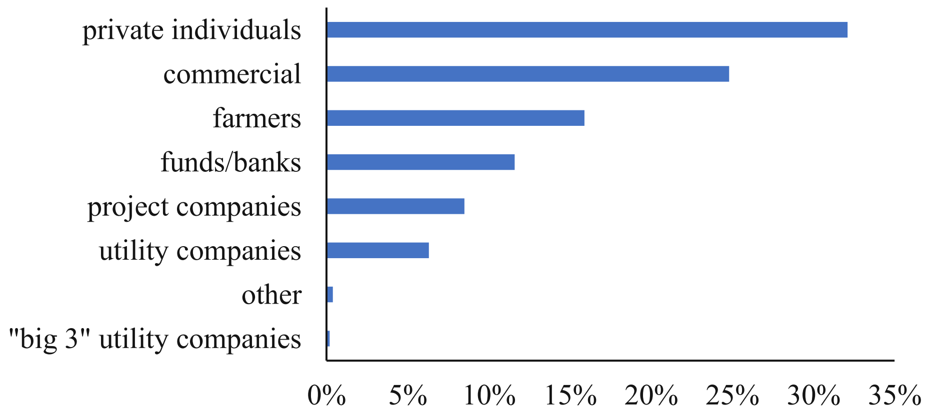

Figure 9: Ownership structure of solar PV in Germany in 2019, based on trend:research (2020)

However, recent years appear to have seen a standstill in the growth of renewable energy (IEA, 2019). At the same time, residential solar PV still has vast potential for renewable electricity production in Germany (Scheller et al., 2022, p. 3). Also, regarding Austria, according to Mikovits et al. (2021), there is the potential to generate 11 TWh solely from residential solar PV by 2030, which is the target in Austria according to the EAG (Austrian Parliament, 2021a, p. 6). Furthermore, in the EU itself, solar PV has enormous potential. According to Bódis et al. (2019, p. 10), there is the potential that one quarter of the electricity consumption of the EU (as of 2019) can be generated from residential solar PV. Therefore, the question is raised if under the EEG and EAG, the incentives for private households are sufficient to promote such an investment.

As private households play such a significant role in the energy transition, an NPV calculation for residential solar PV electricity production and consumption of a private household is conducted in this master's thesis under the respective law in Austria and Germany (Schulte et al., 2022, p. 1).

Regarding academic research, only a few journal articles on the EAG are available, as the law was passed just in 2021. For example, Ennser (2021), Röthlin (2022), and Katalan and Reitinger (2021) published articles that outline the new support scheme of the EAG and the accompanying measures. Moreover, Ennser et al. (2022) published a legal commentary on the EAG package.

Furthermore, the BMK published an expert report on the EAG in November 2021, providing the scientific basis for the new EAG support schemes (BMK, 2022a). In contrast, a lot of academic research is available on the German EEG itself, as it has been effective for more than 20 years (Google Scholar, 2022).

Kapp has published a master's thesis that compares the differences and similarities of federal subsidies for solar PV in Germany and Austria as of the year 2017. Back then, there was the federal Green Electricity Act ("Ökostromgesetz") effective in Austria, the predecessor of the EAG (Kapp, 2021, p. XVII; Austrian Parliament, 2021a).

Most recently, Haas et al. (2023) researched on the history and latest developments of solar PV and its impact on electricity systems, including findings concerning Austria and Germany. E.g., studies regarding the general financial effects of solar PV, specifically for private households, have been conducted by Polzin et al. (2019, p. 1). There is also a study on the potential grid defection of households in Germany available by Sabadini and Madlener (2021).

Palm (2018, pp. 7-8) analyzed the motives for households to invest in solar PV. According to her analysis, the main reasons for purchasing a solar PV installation were financial and economic reasons, pay-back time, and profit. Another barrier was getting in contact with solar installation companies as a one-stop shop.

Polzin et al. (2019, p. 1260) also researched the effectiveness of support scheme policies and investor decisions. According to them, two crucial investment aspects are the return on the investment and the investment risk – which must meet the investor's expectations.

Internal factors are also part of the decision-making process when buying a solar PV installation. Kastner and Matthies (2016, pp. 1, 8) researched the internal and external factors of households. Households that foster eco-social values are likelier to purchase a solar PV installation than homes with conservative or hedonistic tendencies. They suggested different communication measures for those groups to convince households to buy solar PV installations.

1.2. Motivation

The transposition of EU law is complex and differs in every EU member state due to country-specific requirements and objectives (Steunenberg and Rhinard, 2010).

Altogether, the energy production industry is the largest GHG emitter, with 26% as of 2018 in the EU. Energy consumption as a whole made up almost 75% in 2018 (DG for Energy of the EU Commission, 2020, pp. 24; 164-167).

In general, the aim of support schemes is to make renewable systems affordable and an economically feasible investment for households and companies (Palm, 2018, pp. 7-8). This is the primary concern when acquiring a solar PV installation besides awareness for a more sustainable lifestyle. Especially due to currently soaring energy prices and geopolitical crises in Europe, households aim for affordable electricity and energy autarky, at least to some extent. All these circumstances have increased people's interest in energy topics (Stergiou, 2023, p. 7; Schmid and Behrendt, 2023, p. 1).

Therefore, the motivation of this master's thesis is to examine the approach of existing laws in Austria and Germany, the EAG and EEG, on the expansion of solar PV and how they influence the pay-back time of solar PV systems for private households by using an NPV calculation.

Both in Germany and Austria, the feed-in tariffs have decreased in recent years (see Figure 14 and Figure 15). However, the costs of installing the solar PV plant in Germany have not decreased at the same rate (Ritter et al., 2021, p. 5). With the NPV calculation, it shall be analyzed if and how the operation of the solar PV installation is economically feasible.

Specific research on the comparison of the new EAG and the EEG is missing. Therefore, this master's thesis shall provide academic research on the EEG, the EAG, and especially on the commonalities and differences between both laws, focusing on residential solar PV with a case study on their impact on residential solar PV investments.

Furthermore, a large part of academic literature on energy policies in Austria and Germany is written in German. Therefore, another aim of this thesis is to provide research in this area to non-German speakers.

1.3. Objective and Research Questions

This master's thesis aims at comparing both laws and their approaches and policies from an economic, legal, and political point of view with a focus on residential solar PV. The objective of this master's thesis is to show and extract the commonalities and differences between both laws and their associated impacts on residential solar PV for private households.

As there is a research gap and little literature available on the EAG and the comparison of the EAG with the EEG, the two research questions of this master's thesis are:

What are the commonalities and differences between the EAG and EEG and their respective approaches towards expanding residential solar PV?

To ensure climate neutrality in the EU by 2050, not only must the public and private economy fulfill their goals, but also private households need incentives to participate in the energy transition (Woerdman et al., 2021, p. 10; Wolf et al., 2021, p. 99). The electricity sector only makes up one part of the total gross GHG emittance besides other sectors (see Figure 2). However, this sector is crucial to become climate neutral. Both the EEG and EAG must make renewables financially attractive for private households, especially solar residential PV. This technology plays a vital part in the energy transition (Haas et al., 2023, p. 1). Therefore, an additional sub research question is raised:

Which impact do the EAG and EEG financial incentives have on residential solar PV investments?

The central evaluation of the EAG and EEG ultimately depends on the economic viability of the supported renewable technology. Therefore, NPV calculations in multiple scenarios are conducted for private households using a solar PV installation on a roof with a capacity of 6 kWp and 11 kWp respectively. By conducting those NPV calculations, the EAG and the EEG for private households can be compared. Those calculations examine how each support scheme will influence the financial viability and pay-back time for private households using different parameters. Those calculations shall serve as a discussion basis if private households are incentivized enough to invest in solar PV.

1.4. Structure of the master's thesis

The remains of this thesis are structured as follows:

In Chapter 2, the **state of the art** in both countries is displayed. It comprises the impact of the Paris Agreement, the impact of EU climate policies, prior energy policies, an outline of the main climate targets, the current status quo of renewables in both countries, and the development of the feed-in tariffs in Austria and Germany.

In Chapter 3, the **methodology** is described. The methods for the comparison of the EAG and EEG (Chapter 3.1) and the case study parameters for the NPV calculation (Chapter 3.2) are elaborated.

Chapter 4 is the **results** chapter. The results of the comparison of the EAG and the EEG are displayed. It will show the commonalities and differences between both laws and policies (Chapter 4.1). Furthermore, the case study results for the solar PV installation are shown and interpreted (Chapter 4.2).

Chapter 5 provides the **conclusions** in which the main findings and results are summed up.

As Germany and Austria are German-speaking countries, most sources are in German. If available, English sources, especially legal sources, were favored over German sources if they were available.

This master's thesis is based on the events up to the end of December 2022.

2. State of the art

For a proper evaluation of the EAG and EEG, it is necessary to display the state of the art in both countries. This includes the Paris Agreement, EU climate policies, prior energy policies in Austria and Germany, the main national climate targets, and the development of feed-in tariffs in both countries. Elaborating on those topics is vital as they essentially shape the framework conditions for renewables in Austria and Germany.

2.1. The Paris Agreement

The **Paris Agreement** is one of the most important international treaties concerning climate change. It was adopted in 2015, and Austria, Germany, and the EU (as an own entity) have ratified this treaty. In total, there are 194 signing parties (United Nations, 2015).

Art. 2 of the Paris Agreement outlines the 1.5°C targets: "*[…] Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change; […]*" (United Nations, 2015). This 1.5°C target is one of the main goals of this treaty. Besides, state parties must determine nationally determined contributions ("NDCs"). They must arrange and publish long-term strategies to reduce GHG emissions and achieve this treaty's goals, which must be amended every five years. However, there are no legally binding emission targets, which experts criticized (Clémençon, 2016, pp. 8-10).

In their NDCs, the EU (as an own entity) and the EU member states declared to decrease their GHG emittance by at least 40% compared to 1990 until 2030. Moreover, the EU intends to increase the share of renewables to 32% of the overall gross final energy consumption (Lengauer, 2020, p. 197).

2.2. EU climate policies

Elaborating on the cornerstones of EU law is necessary as it sets the framework for the legislation in the EU member states. As both Austria and Germany are EU member states, EU law is applicable in both countries and plays a crucial part. From an academic point of view, EU climate law can be subdivided into two categories: **climate mitigation law**, which aims to reduce GHG emissions, and **climate adaptation law**, which refers to the adjustments of society related to climate change (e.g., the construction of flood protection). Policies aiming to increase the expansion of renewables – like the EAG and the EEG – belong to EU mitigation law. Furthermore, EU mitigation policies are usually adopted on the EU level and tend to demand higher extra investments from the current EU budget. In contrast, adaptation policies are set out on the national level of EU member states (Woerdman et al., 2021, pp. 2-3). Generally, climate policies are mostly connected to energy consumption as the energy sector causes the highest amount of GHG emissions (Eurostat, 2019).

According to the United Nations Brundtland Commission, sustainability is "*meeting the needs of the present without compromising the ability of future generations to meet their own needs.*" (United Nations, 2022). Man-made effects of climate change, e.g., sea level rise, natural hazards, and negative impact on agriculture and forestry pose a severe threat to mankind and the livelihood of future generations (Aaheim et al., 2012, p. 960).

Additionally, the impacts of climate change eventually result in financial costs for all countries worldwide, including the EU. Thus, the EU aims to save GHG emissions and promotes sustainable use of natural resources to mitigate its impacts by introducing EU climate policies to protect and preserve the basis of livelihood for human beings. Furthermore, many adaptation measures themselves may lead to costs for EU member states. (Rojas et al., 2013, pp. 1-2)

Generally, there are two types of EU climate policies. On the one hand, there is "**Direct Regulation**". By setting up stricter environmental standards, the environmental impact will be reduced (Woerdman et al., 2021, pp. 12-13).

On the other hand, there are "**Market-based instruments**", such as subsidies, tradable emission allowances, and taxation. In contrast to Direct Regulation, there is no **formal standardization**, but they provide financial incentives to the market participants in order to switch to more sustainable technology solutions. Both the EAG and the EEG are results of the **market-based approach**, as they provide **financial incentives to the market participants**. (Sprenger, 2000, pp. 3-4; Woerdman et al., 2021, pp. 12-13)

In 2020, the European Council approved the proposal of the EU Commission's Green Deal, which aims to decrease the GHG by 55% by 2030 compared to 1990. Prior to this decision, the target defined in the Paris Agreement was at 40%. The legislation on the reduction of GHG emissions is based mainly on three legislative measures (Woerdman et al., 2021, pp. 29-33):

1. The **Emission Trading Directive** which implemented the emissions trading system for the covered sectors (EUR-Lex, 2003).
2. the **Land Use, Land Use Change and Forestry Regulation** (LULUCF), that covers the named areas. It aims to conserve those areas as they play a crucial part in the combat against climate change as stay can store CO_2 (EUR-Lex, 2018c).
3. the **Effort Sharing Regulation**, which covers the sectors that are not covered by the Emission Trading Directive and the LULUCF directive (EUR-Lex, 2018b).

The first major legislative package to enable a joint European Energy Union was the "Clean Energy for all Europeans" package in 2016, which contained **eight legislative proposals** in total. Apart from legislation that concerned climate, the package also included a revision of the European **energy market design** (Woerdman et al., 2021, p. 34; EU Commission, 2023). At the end of 2018, Directive 2018/2001 (see Chapter 1) revised the Renewable Energy Directive 2009/28/EC and ensured new climate and energy targets (EUR-Lex, 2018a).

The most crucial target member, which member states must ensure, is that **renewables must provide 32% of the EU's overall gross final energy consumption** by **2030**. The target of 32% must be achieved **collectively** by the EU member states and **not individually**. The EU Commission is responsible for the supervision of these **targets** (Woerdman et al., 2021, pp. 34-35). In 2021, a new amendment of the **Renewable Energy Directive** (2021/0218) was proposed within the context of the Green Deal, which would set the target from 32% to 40%. This proposal is discussed by the European Parliament and the Council (EUR-Lex, 2018a; European Parliament, 2021).

In 2019, the new president of the EU Commission, Ursula von der Leyen, announced the **EU Green Deal**, which can be seen as a watershed moment in EU climate policy (EU Commission, 2019). This Green Deal also entails the EU's aim of becoming carbon-neutral by 2050 demanding huge investments. Nonetheless, the EU Commission also sees this target as a chance to uplift the European economy to create jobs and foster energy autarky by decreasing the dependency on fossil fuels imported from abroad (Woerdman et al., 2021, pp. 36-37, 101-102).

As of 2018, the overall energy import dependency of the EU accounted for 58.2%. The numbers for specific fuels are even more dramatic, e.g., oil and petroleum products (94.6%) and natural gas (83.2%). Despite existing renewable share goals, energy import dependency has been rising, which is shown in Table 1. (DG for Energy of the EU Commission, 2020, p. 24).

Table 1: Energy Import Dependency of the EU, based on DG for Energy of the EU Commission (2020, p. 24)

Energy Import Dependency of the EU by fuel (in %)						
	2000	**2005**	**2010**	**2015**	**2017**	**2018**
Total	56.3	57.8	55.7	56	57.5	58.2
Solid Fossil Fuels	29.8	35.7	38.2	40.9	43.3	43.6
of which Hard Coal	43.2	52.5	57.7	62.9	67.7	68.3
Oil and Petroleum Products	93.3	93.9	94	96.7	93.8	94.6
of which Crude and NGL	92.5	93	94.4	95.9	95.6	95.7
Natural Gas	65.7	69	67.8	74.5	80.2	83.2

2.2.1. EU renewable support schemes

Among EU member states and the EU institutions themselves, there is consent that renewables need financial support to meet the climate targets. One reason for this is that the market mechanisms currently in place are not likely to ensure such a fast installation of renewable capacity. (Woerdman et al., 2021, pp. 118-119)

Another reason is that investors are still concerned about the financial risk and viability, which is often related to the technical additional requirements for renewables due to their intermittency and often high initial investment. As a result, capacity installations tend to be slow and financial incentives are needed. Furthermore, many industries have relied on fossil fuels – changing the energy infrastructure is also a cost factor that makes them reluctant to switch to renewables. (Haas et al., 2021, pp. 113-114; Woerdman et al., 2021, p. 119)

Therefore, EU member states themselves have supported the expansion of renewables in recent years. This was done by installing public funds that distributed financial support directly or by setting up legal commitments on private market participants (Woerdman et al., 2021, pp. 119-120). This is also acknowledged in the 2018 Renewable Energy Directives, specifically in Art. 2 Para. 5 (EUR-Lex, 2018a). Subsidies are also at the heart of the conflict in the expansion of renewables versus a free energy market – as financial subsidies for renewables are market interventions that can distort competition (Woerdman et al., 2021, pp. 119-121; Weber, 2015, pp. 161-162).

Generally, supporting measures can be divided into **investment support** and **operating support** (EU Commission, 2013, pp. 11-12; Woerdman et al., 2021, p. 120).

The **investment support** grants a certain amount at the beginning of the investment to encourage the finalization of the respective project. Furthermore, tax exemptions and tax reductions for operators and consumers can also lead to a more vital expansion of renewables. As investment supports are less invasive in the market than operating support measures, the EU Commission sees it as an appropriate supporting measure for renewable technologies. (Poullikkas et al., 2012, pp. 558-560; EU Commission, 2013, pp. 11-12; Woerdman et al., 2021, pp. 120-121)

Operating support includes, among other things, **feed-in tariffs** and **premium schemes**. **Feed-in tariffs** provide the operator with a fixed price for a unit of electricity (e.g., in ct/kWh) that the operator feeds into the grid. In the past, feed-in tariffs proved to be a proper measure to support the expansion of renewables (Xydis and Vlachakis, 2019, p. 3; Woerdman et al., 2021, p. 120). However, the EU Commission is skeptical of feed-in tariffs as they strongly interfere with the EU internal market. The EU Commission suggested using feed-in tariffs only for smaller renewable energy projects (Woerdman et al., 2021, pp. 121-122).

Moreover, the EU Commission favors **market premium schemes** over feed-in tariffs**,** especially regarding developed renewable technologies. One significant difference compared to feed-in tariffs is the risk allocation, as the operator must directly sell the electricity on the market. In contrast, the operator does not get a fixed but flexible remuneration due to market price volatility compared to the feed-in tariff. (Held et al., 2014, pp. 38-39; Woerdman et al., 2021, p. 123). Usually, the operator applies for the so-called "guaranteed price"[2] as a calculation basis for the market premium that enables an economical operation of the plant. The guaranteed price is determined by the government or in an auction; see also Sect. 9-11 EAG or Sect. 35 EEG and Chapter 4.1.4 for details (e-control, 2022d, pp. 11-13; BMJ and BfJ, 2023). Market premium schemes can be subdivided into the categories of **"fixed", "floating/sliding", and** "**caps and floors"** premium (see Figure 10).

In the **fixed premium**, the premium is constantly added to the electricity market price (see middle of Figure 10). This may be a costly approach for the public and favors inadequate operators of renewable power plants (Held et al., 2014, pp. 25, 39).

In contrast, **floating/sliding premiums** correlate to a referenced electricity price (see right side of Figure 10). The market premium is the addition on top of the sold electricity price so that operator ultimately receives the value ("guaranteed price") he/she applied for in an auction. The market premium is higher when the referenced electricity price is low and vice versa. Operators of renewable plants which receive floating premiums are exposed to higher risk than operators who receive fixed market premiums. (Held et al., 2014, p. 40)

The **market premium with caps and floors** is a subcategory of a fixed premium with a predetermination of a premium cap and floor. The cap is the top of the premium; the

[2] Also „Guaranteed Value" (or "Anzulegender Wert")

floor is the minimum price that the operator gets. Effectively, the price risk exposure for the operator is still higher than in the feed-in tariff system but highly mitigated. (Held et al., 2014, p. 40)

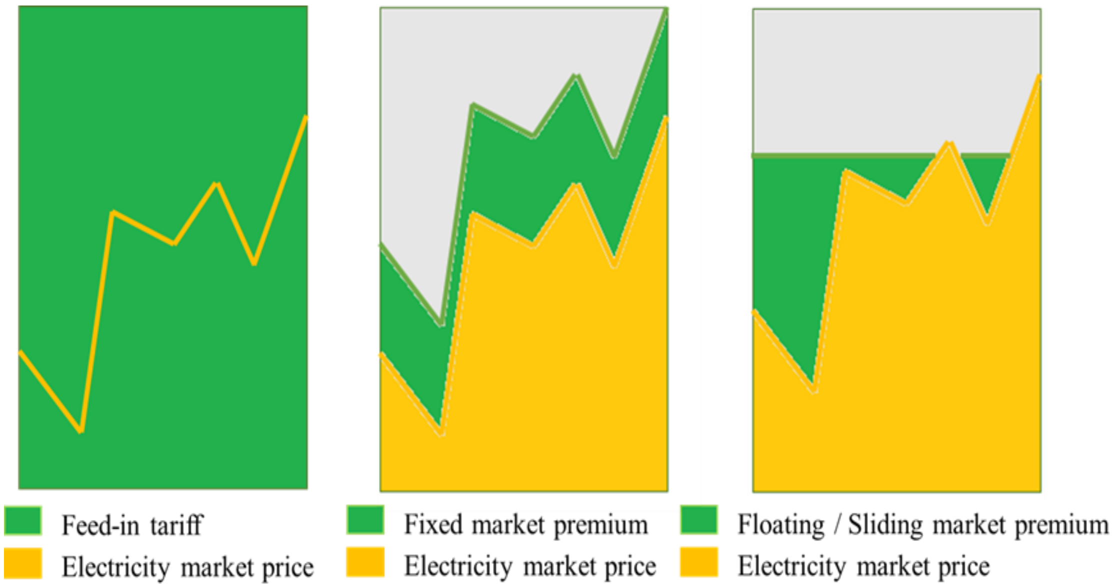

Figure 10: Illustration of operating support schemes, based on Banja et al. (2017, p. 11). In green is what the operator receives as a subsidy. (l.: feed-in tariff, m.: fixed market premium, and r.: floating/sliding market premium

Furthermore, the 2018 Renewable Energy Directive demands the member states to implement premium schemes apart from small plants and demonstration installations (EUR-Lex, 2018a). In order to foster the efficiency of renewables and market integration, the EU Commission demands that the EU member states implement competitive and transparent bidding processes for operating support measures apart from small projects (Woerdman et al., 2021, pp. 122-124).

2.2.2. Compatibility of subsidies with EU treaties

The principle of free movement

The implementation of financial support for renewables also raises the question if they are compatible with the EU treaties ("four freedoms"), especially with the EU internal market that promotes competition (Reinisch, 2012, pp. 99, 170-171). When an EU member state intends to introduce or change support schemes for renewables, the principle of the free movement of goods (Art. 34 TFEU) and the provisions for state aid (Art. 107 TFEU) must be abided (EUR-Lex, 2012; Woerdman et al., 2021, pp. 124-125).

In that regard, the PreussenElektra ruling of the European Court of Justice is relevant for the legal interpretation of Art. 34 TFEU, which is the relevant article for the free movement of goods (EUR-Lex, 2001; EUR-Lex, 2012).

In this case, the "Stromeinspeisungsgesetz", the predecessor of the EEG, obliged German grid operators to buy green electricity from operators at a specific price. The ECJ ruled that this law was incompatible with Art. 28 of the EC Treaty (the predecessor of Art. 34 TFEU). The principle of the free movement of goods prohibits measures that constrain the amount of import of electricity – which can be especially the case with support schemes. In the PreussenElektra case, the ECJ affirmed that the "Stromeinspeisungsgesetz" law specifically constrained the import of electricity. But the ECJ found justification reasons: As the "Stromeinspeisungsgesetz" provides for a "legitimized measure", which is the decarbonization of the energy system, this measure was justified. (Kuhn, 2001, pp. 374-376; Woerdman et al., 2021, pp. 124-126)

State aid

Subsidies for renewables may also fall in the scope of **state aid**. According to Art. 107 TFEU (1) any grant of a member state or through state resources is not compatible with the EU internal market if the measure (2) "*[...] distorts or threatens to distort competition [...]*", and (3) "*[...] affects trade between member states [...]*" (EUR-Lex, 2012, p. 45; Reinisch, 2012, pp. 206-208).

EU member states have to notify the EU Commission if they want to implement measures that can be qualified as state aid. Regarding state aid measures, the PreussenElektra case is relevant once again (EUR-Lex, 2001).

According to the "Stromeinspeisungsgesetz", German transmission and distribution system operators were obliged to buy electricity from renewable energy operators connected to the grid (Bundesanzeiger, 1990).

The core question was how broad the interpretation of "grants of member states or state resources" was. Was this obligation for transmission and distribution operators enough to classify this measure as state aid? How broadly will the ECJ interpret those terms? The ECJ ruled that the state aid provisions did not apply to this specific measure. The electricity consumers actually paid the costs for this subsidy system as the ultimate costs were put on their electricity bill. (Woerdman et al., 2021, pp. 126-128)

In fact, "*[...] only advantages granted directly or indirectly through State resources are to be regarded as aid, and thus that private resources, even if channelled as a result of State intervention, do not constitute State aid.*" (König and Kühling, 2002, p. 7).

This is also the case, even if the result is similar to state intervention. In fact, the funding was not provided by the state or state resources. This means that only directly or indirectly state aid measures can be classified as state aid but not if the costs are ultimately paid by private resources, e.g., private households. (König and Kühling, 2002, pp. 7-10; Thiele, 2021, p. 291).

Moreover, there are general exceptions for measures that may constitute state aid. Art. 107 Para. 2 TFEU provides measures that may be compatible with the EU internal market (EUR-Lex, 2012). Furthermore, the EU Commission published the **General Block Exemption Regulation** in 2014 based on Art. 109 TFEU, which constitutes directly applicable EU law (EUR-Lex, 2014a).

Measures under the scope of the General Block Exemption Regulation are exempt from the notification procedure. According to the EU Commission, the regulation exempts specific measures that may not threaten the EU internal market. The first evaluation if the General Block Exemption Regulation covers the relevant measures is at the discretion of the EU member states. (Thiele, 2021, pp. 293-294)

The EU Commission has also published the **De-Minimis-Regulation** for measures that do not distort or threaten competition within the EU market. (EUR-Lex, 2013) According to the EU Commission, financial contributions not exceeding € 200,000 to a company within three years do not fall under the scope of state aid. (Thiele, 2021, p. 292)

Pursuant to Art. 107 Para. 3 TFEU, there are further exceptions (EUR-Lex, 2012). The EU Commission may, at its discretion, adopt **guidelines** on measures compatible with the EU internal market. In this context, regarding the financial support of renewables, Art. 107 lit c Sentence 3 TFEU is relevant: "*[...] aid to facilitate the development of certain economic activities or of certain economic areas, where such aid does not* *adversely affect trading conditions to an extent contrary to the common interest [...]*" (EUR-Lex, 2012, pp. 45-46). The EU Commission has published the respective Guidelines on State aid for environmental protection and energy 2014-2020 that were also extended to 2021 (EUR-Lex, 2014b; Storr, 2022a, pp. 49-50).

Those guidelines have been replaced by the new **Guidelines on State aid for climate, environmental protection, and energy 2022** (EUR-Lex, 2022). Those new guidelines have been recently practiced by the EU Commission since January 27, 2022, on state aid measures regarding environment protection, energy, and climate. With the new guidelines, the rules on state aid shall be adapted to the new Green Deal of the EU Commission (EUR-Lex, 2022; Storr, 2022a, pp. 48-49).

2.2.3. EU legal competence in the energy sector

The relevant provision for the legal EU competence of energy is Art. 194 TFEU. Among other things, the provision says that EU policy "*[...] on energy shall aim, in a spirit of solidarity between member states to [...] (c) promote energy efficiency and energy saving and the development of new and renewable forms of energy [...]*" (EUR-Lex, 2012, pp. 88-89). Pursuant to Art. 4 TFEU, the areas of energy (including renewable energy) and environment are shared EU competencies (EUR-Lex, 2012; Woerdman et al., 2021, pp. 242-243).

There are two major EU competencies: exclusive and shared EU competencies. Pursuant to Art. 2 TFEU, "exclusive competencies" is an area in which solely the EU has the competence to pass laws (EUR-Lex, 2012). Those competencies are described in Art. 3 TFEU; most important are the rules for competition and customs (Reinisch, 2012, pp. 42-43).

In contrast, if a legal matter falls in the scope of shared competencies, Art. 2 TFEU provides the following: The member states and the EU "*[...] may legislate and adopt legally binding acts in that area [...]*". (EUR-Lex, 2012, p. 4) However, the EU member states cannot pass legislation if the EU adopts legally binding acts. Only if the EU does not exercise competence in the relevant area, the member states can pass legislation (Reinisch, 2012, p. 43; EUR-Lex, 2012).

If the EU passes legal acts in the area of shared competencies, the EU must consider that those legal acts have to be in accordance with the principles of subsidiarity and proportionality (Woerdman et al., 2021, pp. 242-243). Subsidiarity means that the EU shall only exercise its legal competence if the target can be better achieved on the EU level compared to the legislation of the national member states. Proportionality means that the EU shall only take the necessary action and not exceed its power (Horsley, 2012, pp. 268-269; Woerdman et al., 2021, pp. 243-244).

2.3. The path towards EAG and EEG

This chapter elaborates on the history of prior policies concerning renewable energy in Austria and Germany, primarily the Austrian Green Electricity Act and the German Stromeinspeisungsgesetz (Bundesanzeiger, 1990; e-control, 2014).

The current EAG and EEG are compared and analyzed in Chapter 4.1.

2.3.1. History of energy policies in Austria

Before the implementation of the Austrian Green Electricity Act ("Ökostromgesetz"), the predecessor of the EAG, there was just a fragmented supporting scheme for renewables. The nine Austrian provinces had their own widely differing support schemes. (Stöger, 2015, p. 194)

In the 1990s, the only law that aimed to subsidize the renewable sector was the Electricity Sector Act, "ElWOG" (BKA, 1998).

On the one hand, this law was about the liberalization of the grid infrastructure and ensuring the access of renewables to the grid. Moreover, it obliged the provinces to impose an obligation for electricity suppliers to purchase a specific share of renewable electricity for a regulated price and offer it to their clients. In order to finance the additional costs for renewables, the electricity suppliers could pass the use-of-system charges onto their clients. The respective governor of the Austrian provinces determined both the price for renewable electricity and the use-of system charges. This fragmented system led to the problem that the feed-in tariffs and use-of system charges varied among the nine Austrian provinces. (Stöger, 2015, pp. 194-195)

The **Green Electricity Act 2002** was the first national law regarding financial support for expanding all renewable technologies in Austria (BKA, 2002).

The Green Electricity Act 2002 provided feed-in tariffs for ten years, which were determined by ordinances of the responsible ministers. The transmission system operators had to purchase renewable electricity from the operator at the feed-in tariffs. They could resell the renewable electricity at electricity prices at a nationally regulated transfer price ("Verrechnungspreis"). Naturally, the transfer price and the feed-in tariffs were not equal. Therefore, this difference had to be borne by the consumers, who had to pay a supporting contribution sum ("Förderbeitrag") that was collected with the grid tariffs by the distribution system operators. (Stöger, 2015, pp. 195-197)

Many operators applied for the support scheme under the Green Electricity Act as soon as it became effective. The targeted expansion of renewables until 2008 was already met in 2005. Therefore, the government did not approve any further new feed-in tariffs for new renewable plants by the end of 2004. Afterwards, there were several amendments to the Green Electricity Act. In the 2006 amendment, a maximum cap on subsidies for green electricity was introduced. Furthermore, a central authority was established that was responsible for the execution of supporting renewable technology. After conducting an auction procedure, the OeMAG was charged with this task. The Green Electricity Act 2006 amendment provided a contractable feed-in tariff volume of € 17 Mio. every year from 2007 to 2011. If the support volumes were depleted, no further subsidies would be granted. (Stöger, 2015, pp. 197-202) Moreover, investment grants for renewables were also introduced by the amendments to the Green Electricity of 2006 and 2009 (Holzer, 2013, p. 2).

The **Green Electricity Act 2012** became effective by July 1, 2012, which can be seen as a completely new codification for the Austrian supporting scheme (e-control, 2014).

Operators of renewables that still were in the waiting loop for the regular feed-in tariff were offered reduced feed-in tariffs. The electricity traders had to purchase the renewable electricity at the market price. Therefore, the feed-in tariff volume funding had to come from the consumers, which was now based on two pillars. One pillar was the flat rate renewable charge ("Ökostrompauschale") which is a lump sum contribution depending on the network level of the consumer. Secondly, the consumers have to pay a renewables contribution ("Ökostromförderbeitrag") which is dependent on the grid charge of the consumers. The amount of the renewables contribution was determined by an ordinance of the minister responsible for energy. On the one hand, this measure did not place an expensive financial burden; on the other hand, operators enjoyed state-funded subsidies. Furthermore, the contractable feed-in tariff volume was raised to € 50 Mio. every year. However, the volume decreased by € 1 Mio. every year. The feed-in tariffs were granted for 13 years. By doing so, a degressive and unerring supporting scheme was introduced. (Stöger, 2015, pp. 204-206)

In **2017**, another minor amendment to the Green Electricity Act 2012 was made ("**Kleine Ökostromnovelle**"), which included technical adaptations and the implementation of community generation installations that enabled the joint use of a renewable power plant, e.g., a solar PV power plant on a roof of a multi-apartment house (Stöger, 2018; Austrian Parliament, 2017, pp. 1-3). In 2019, another significant amendment to the Green Electricity Act was made, which concerned the increase of the feed-in tariff volume in order to grant subsidies for renewables operators in the waiting loop (Austrian Parliament, 2019, p. 3).

The new EAG, the predecessor of the Green Electricity Act, promotes decreasing GHG emissions in the electricity sector. However, it took the Austrian government very long even to implement the new support scheme. The EAG itself became effective in 2021, but the ordinances that determine the investment support and the guaranteed price for the market premium (i.e., investment grant and market premium) were just published in 2022 after they had to undergo an evaluation procedure. (BKA, 2021; Minister Gewessler, 2022a; Minister Gewessler, 2022b)

Art. 4 It. 3 of the 2018 Renewable Energy Directive is the relevant provision why Austria implemented market premiums: "*[...] Support schemes for electricity from renewable sources shall be designed so as to maximize the integration of electricity from renewable sources [...] Support shall be granted in the form of a market premium, which could be, inter alia, sliding or fixed*." (EUR-Lex, 2018a, p. 25) Due to this provision, most EU member states will switch to support schemes based on market premiums. However, there are exceptions pursuant to Art. 4 It. 4: "*Member states may exempt small-scale installations and demonstrations projects from this paragraph [...]*" (EUR-Lex, 2018a, p. 25; Woerdman et al., 2021, p. 124).

Regarding Austria, the support scheme of the Austrian Green Electricity Act 2012 was approved in 2012 by the EU Commission as it met the requirements of the former 2008 Environmental Aid Guidelines. The support scheme was approved for 10 years (EU Commission, 2012a; EU Commission, 2012b). As the approval expired, a new support scheme had to be implemented. In the meantime, also the 2018 Renewable Energy Directive became effective (EUR-Lex, 2018a). Therefore, the implementation of a new support scheme was necessary. This new support scheme became effective with the EAG that met the requirements of the 2018 Renewable Energy Directive and the Guidelines on state aid for environmental protection and energy 2014 – 2020 (EUR-Lex, 2014b; Austrian Parliament, 2021a, pp. 1, 8).

2.3.2. History of energy policies in Germany

The predecessor of the EEG was the **Stromeinspeisungsgesetz 1990** (Bundesanzeiger, 1990). The core elements and mechanisms of the Stromeinspeisungsgesetz can still be found in the EEG and its amendments. It aimed to increase the share of renewables by providing remunerations to operators of renewables for their feed-in electricity.

Utility companies were now obliged to accept green electricity. However, they were not obliged to accept renewable electricity at a fixed tariff. In particular, the operators received a certain average share of the revenues of the total electricity sold to the utility companies' end consumers – today, most support schemes are set in a national ordinance or auction (Schwarz, 2014, p. 7). Furthermore, utility companies were exempted from accepting green electricity in case of hardship (Schneider, 2013, p. 1258). In 1998, the Stromeinspeisungsgesetz was amended. One of the major adoptions was the introduction of a "double 5% cap": Utility companies were only obliged to purchase green electricity, which equals 5% of their respective revenue (Espey, 2001, p. 126). With the Stromeinspeisungsgesetz introduced in 1998, Germany became the first country to introduce feed-in tariffs for feed-in electricity (Haas et al., 2023, p. 5).

From 1990 to 2000, the share of renewables more than doubled from 3.1% to 6.42%. However, this was comparatively still a low share (Schwarz, 2014, p. 14).

After the implementation of the Stromeinspeisungsgesetz 1998, the expansion of renewables stagnated (Bundesanzeiger, 1990). One reason was the mentioned "double 5% cap". Back then, one utility company claimed it had already purchased green electricity, which equaled 5% of its revenue. Furthermore, household electricity prices decreased and thus also the remuneration decreased as they were related to the household electricity prices (Schneider, 2013, p. 1259).

Therefore, a new law that should ensure the expansion of renewables, the **EEG 2000**, was passed (Bundesanzeiger, 2000). The main provisions were the following: fixed, technology-dependent feed-in tariffs, a degression of those feed-in tariffs every year, grid operators were obliged to accept green electricity primarily, and implementation of a compensation mechanism for the grid operators. In general, the feed-in tariffs were guaranteed for 20 years (Schwarz, 2014, p. 9). With the EEG 2000, the EEG levy was also introduced as part of the household electricity bill. The EEG levy provided the financing of the funding scheme (Government of Germany, 2022c).

In the following years, **several amendments** to the **EEG** were made (Schwarz, 2014, pp. 13-25). One important milestone was the EEG 2012 amendment, which introduced the market premium system besides feed-in tariffs. The last amendment, the "EEG 2023", was in 2022 (Government of Germany, 2022b).

In December 2022, the EU Commission approved the EEG 2023, the latest amendment to the EEG succeeding the EEG 2021. By 2030, 80% of electricity generation shall come from renewables. The central subsidy is the market premium. However, there are still feed-in tariffs for small-scale solar PV installations available. The EU Commission already approved this measure under the Guidelines on State aid for climate, environmental protection, and energy 2022. The application is valid until the end of 2026. (EU Commission, 2022b)

Summing up the above-mentioned, Austria had to introduce a new support scheme as the approval of the EU Commission expired (Austrian Parliament, 2021a, p. 1). In contrast, the approval for Germany's support scheme was not necessarily related to "normal" regulatory requirements but rather connected to the currently soaring energy prices (Government of Germany, 2022b).

2.4. Main targets and status quo of renewables in Austria and Germany

Table 2 illustrates the central climate and renewables targets in Austria and Germany.

Table 2: Climate statistics and renewables targets in Austria and Germany, based on Austrian Parliament (2021a, p. 1), Government of Germany (2022a, p. 1), BMJ and BfJ (2021), Eurostat (2022e), Statistisches Bundesamt (2022a), and Ennser et al. (2022, p. 19)

Country	Aim/Current Statistics	Description
Austria	Expansion targets for renewable energy	100% electricity from renewable energy by 2030
Austria	Current share of renewables in the electricity sector	78% (by 2021)
Austria	Climate Neutrality	Target: by 2040
Austria	Current share of renewables in the energy sector	36.5% (by 2020) Target: 46-50% by 2030
Germany	Expansion targets for renewable energy	80% until 2030 (according to Sect. 1 EEG)
Germany	Current share of renewables in the electricity sector	39.6% (by 2021)
Germany	Climate Neutrality	Target: by 2045 (according to the German Climate Law)
Germany	Current share of renewables in the energy sector	19.3% (by 2020)

Regarding gross final energy consumption, Austria has already achieved a share of app. 36% of renewable energy in 2020 – it overachieved its initial target of 34% for 2020 (see Figure 11, which shows the share of renewables in energy consumption in Austria and Germany). The next target for 2030 is a 46%-50% share of renewables. (BMNT, 2019, p. 78)

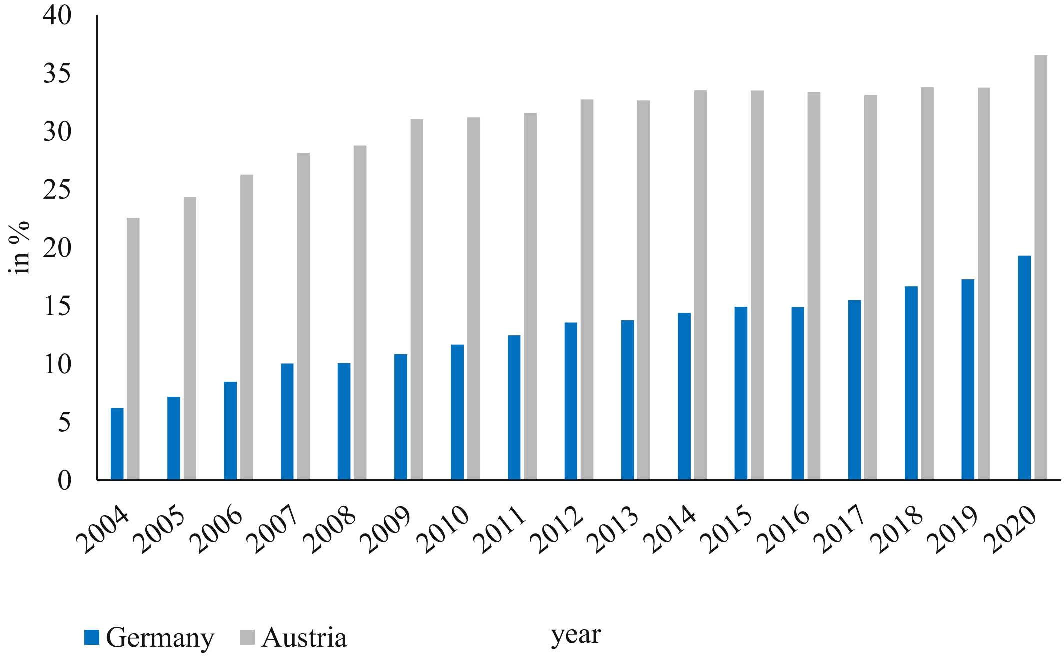

Figure 11: Share of renewables of total energy consumption in Austria and Germany from 2004 to 2020, based on Eurostat (2022e)

Germany achieved a share of 19.3% in 2020, having an initial target of 18% for 2020 (see Figure 11). By 2030, Germany wants to gain a share of 30% of renewables of gross final energy consumption (BMWi, 2020, p. 41; Eurostat, 2022d).

Compared to Austria, Germany follows less ambitious climate goals. Two important laws that regulate Germany's path to net-zero are the EEG and the German Climate Protection Law (BMJ and BfJ, 2021; BMJ and BfJ, 2023).

By 2050, Germany shall become climate neutral (see Sect. 1 Para. 3 EEG). However, this provision is revised by a separate provision (entered into force later) in the Climate Protection Law that already earmarks climate neutrality by 2045; see also Sect. 3 Para. 2 KSG. (BMJ and BfJ, 2021)

Looking at the electricity mix of Austria (see Figure 12) and Germany (see Figure 13), several differences and similarities can be discovered:

As Figure 12 displays, the total electricity generation in Austria is vastly based on hydropower, which makes up more than 60% of the total electricity generation. With the other renewable energy technologies (wind accounts for 9.8%, bioenergy for 6.1%, and solar PV for 1.9%), renewables made up approximately 78% in 2021 (Ember, 2022).

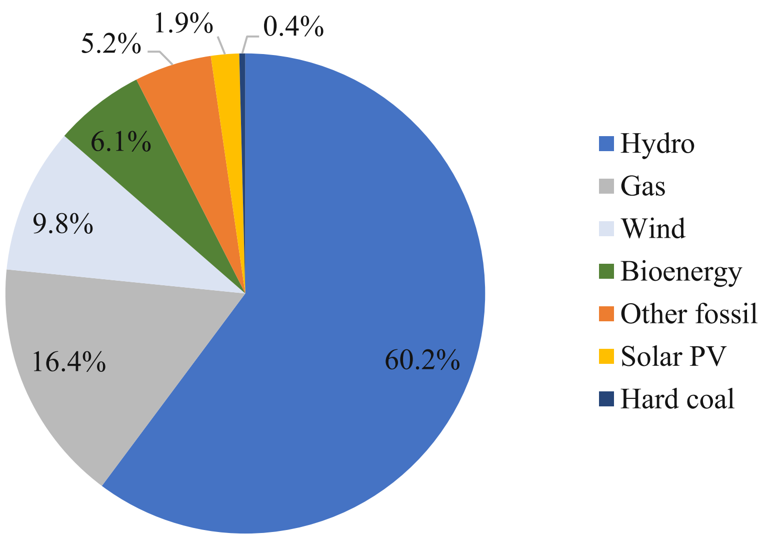

Figure 12: Distribution of electricity generation in Austria in 2021, in %, by source, based on Ember (2022)

In contrast, 39.6% of the overall electricity share was supplied by renewables in Germany in 2021 (see Figure 13). Of this total 39.6%, 19.3% are contributed by wind power, 8.5% by solar PV, 7.6% by biomass, 3.2% by hydro and pumped storage, and 1% by municipal waste.

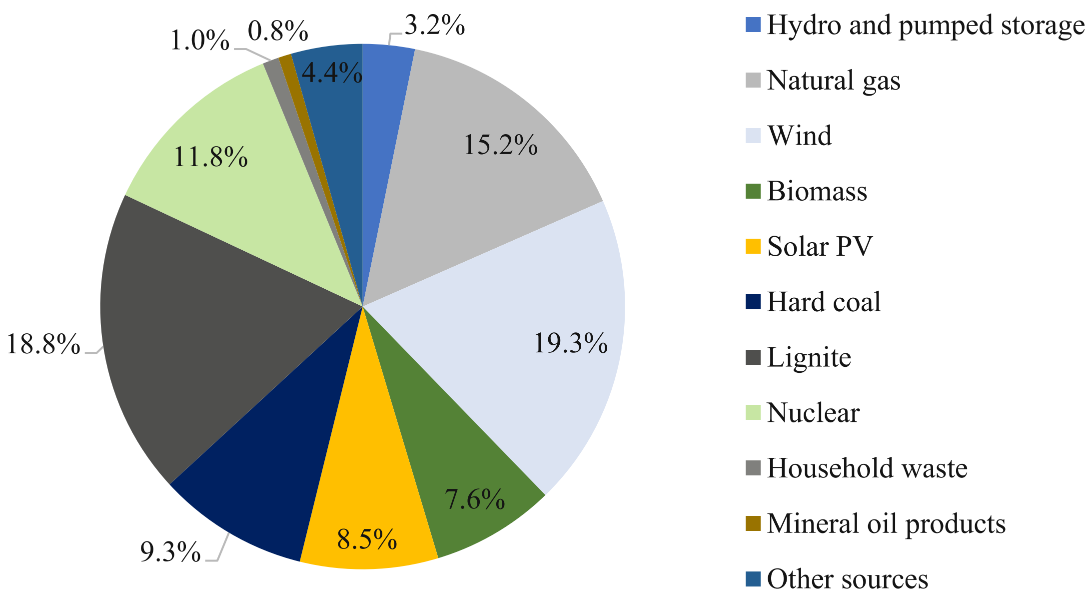

Figure 13: Distribution of energy sources used for gross electricity generation in Germany in 2021, in %, by source, based on Statistisches Bundesamt (2022a)

When looking at Figure 12 and Figure 13, it can be discovered that Austria has an app. 38% higher share of renewables in the electricity sector compared to Germany. The share of wind power and bioenergy is relatively equal. However, there is a disparity of electricity from solar PV, with Germany having a much higher share of 8.5%.

2.5. Development of the feed-in tariffs in Austria and Germany

The following chapters show, display, and compare the development of feed-in tariffs in Austria and Germany.

a. Development of the feed-in tariffs for solar PV in Austria

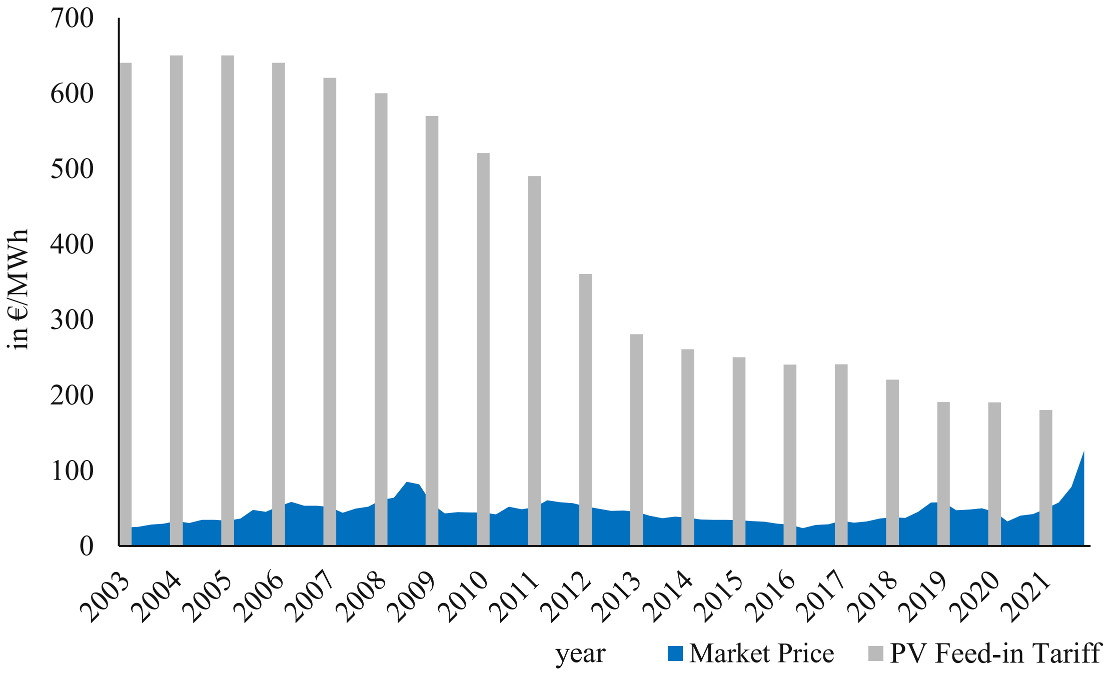

Figure 14: Development of the average feed-in tariffs for solar PV and wholesale electricity price in Austria from 2003 until 2021, based on e-control and OeMAG (2022, p. 31) and e-control (2022a)

Figure 14 shows that Austria's feed-in tariffs have decreased significantly since 2003. Also, with the implementation of market premiums pursuant to the EAG, this trend continues. The EAG market premium ordinance provides maximum bids for the guaranteed values of 9.33 ct/kWh. As the guaranteed price is determined via auction, the ultimate value for the operator will be below the maximum bid (Minister Gewessler, 2022b).

One remark to Figure 14 is necessary: Under the old Green Electricity Act, operators of solar PV installation could apply both for a feed-in tariff and an investment grant (Kapp, 2021, pp. 44-45). In Figure 14, the graph for the feed-in tariff values considers the investment grants. Therefore, these values in the graph are higher than the feed-in tariffs themselves. A combination of investment grant and market premium is not possible pursuant to the new EAG; see Sect. 55 Para. 9 EAG (e-control, 2022d, p. 25).

Concerning the future development, the EAG provides a total subsidy volume of € 1 Bio. on a three-year basis. If the amount of € 1 Bio. is exceeded, the support volume shall be cut by the respective percentage share and shall be equally distributed in the years afterwards until the year 2030; see Sect. 7 EAG (e-control, 2022d, pp. 9-10).

b. Development of the feed-in tariffs for solar PV in Germany

Figure 15 shows the development of feed-in tariffs in Germany. With the EEG 2023, the degression of the feed-in tariffs was put on hold: Pursuant to Sect. 49 EEG, the feed-in tariffs will not decrease until February 1, 2024. After February 1, 2024, there will be a degression of the feed-in tariffs biannually at the rate of 1% compared to the previous guaranteed prices. Before the amendment, the EEG provided for a degression of feed-in tariffs of a rate of 0.4% compared to the previous month if the solar PV targets were met. Figure 15 shows the decrease of the feed-in tariffs in Germany, which is related to the degression provisions in the EEG. (Ritter et al., 2021; Offene Gesetze, 2022, p. 1263; BMJ and BfJ, 2023)

The EEG 2023 amendment also provides for operators that feed in their total generated electricity to the grid ("Volleinspeiser", in contrast to operators that partly feed in the generated electricity, the "Überschusseinspeiser"). They receive higher feed-in tariffs; see Sect. 48 Para. 2a EEG (Offene Gesetze, 2022, pp. 1262-1263).

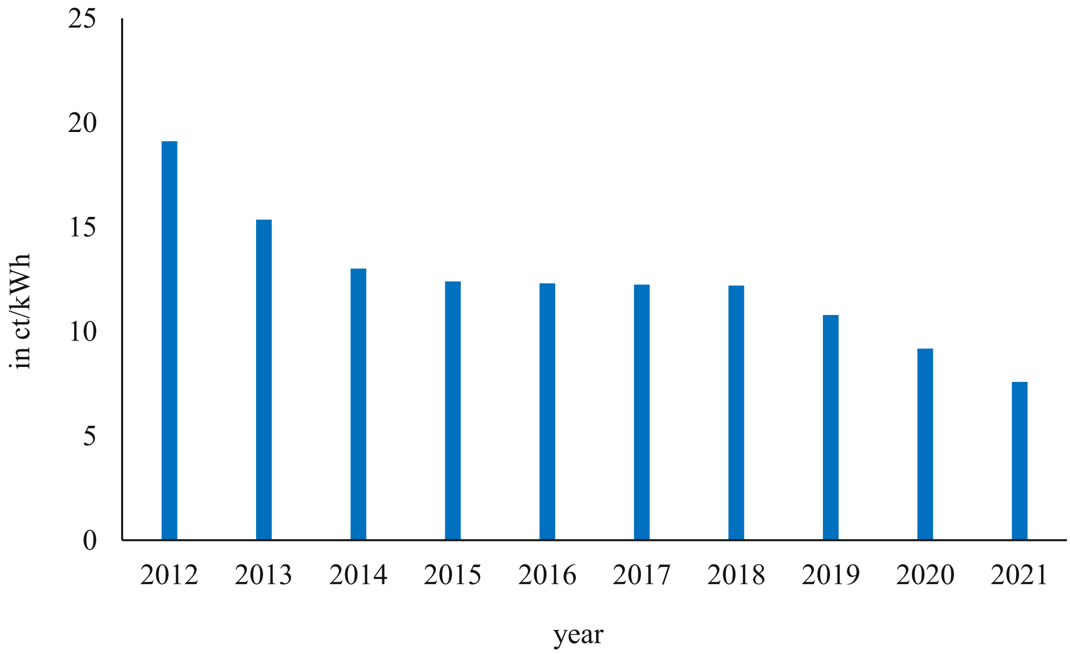

Figure 15: Development of feed-in tariffs for solar PV in Germany, up to 10 kWp capacity, values taken from June of every year, based on Bundesnetzagentur (2022b)

c. Comparison of the development of the subsidies

Looking at both subsidy schemes of the EAG and EEG, there is one main commonality: the significant decrease of the feed-in tariffs in recent years. This is related to the steady decrease in PV modules' price development. (Strategies Unlimited/Navigant Consulting/EuPD, 2021, p. 9)

According to IRENA (2020, pp. 11,12) the costs for large solar PV systems decreased by 82% from 2010 until 2019. The maximum price of the guaranteed price is slightly higher in the EAG (9.33 ct/kWh) than in the EEG (up to 10 kWp: 8.6 ct/kWh; up to 40 kWp: 7.5 ct/kWh). Furthermore, the guaranteed prices in Austria are not related to the capacity. In contrast, in Germany, the guaranteed prices are related to the capacity. The operator gets the higher guaranteed price for the first 10 kWp. The EAG market premium, the EEG market premium, and the EEG feed-in tariffs are paid to the operator for 20 years, beginning with the operation of the solar PV installation; see Sect. 16 EAG and Sect. 25 EEG. (BMWK, 2017, p. 28; e-control, 2022d, p. 14)

Regarding further development, there is no degression of the guaranteed prices until February 2024 in Germany (BMWK, 2022b, p. 1).

Due to the currently soaring energy prices, it is questionable if a degression will be introduced after February 2024 in Germany. In Austria, there is no degression for the market premium and the investment grant provided in the EAG law. However, the respective amount of the investment grant and the maximum bids for the guaranteed price are published in the respective EAG ordinances. This entitles the responsible minister to increase or decrease the subsidies concerning the electricity market situation. (Minister Gewessler, 2022a; Minister Gewessler, 2022b)

As of 2022, the market prices are higher than the maximum guaranteed prices. In July 2022, the market price in Germany was 31.5 ct/kWh (maximum guaranteed price in 2022: 8.6 ct/kWh), and in Austria, even 35.9 ct/kWh (maximum guaranteed price in 2022: 9.3 ct/kWh); see Figure 7 and Table 8. As the (reference) market price is higher than the guaranteed price, the operator receives no market premium. Thus, the market premium can be seen as a "safety net" if the reference market price is lower than the guaranteed price. However, operators that feed in with the market premium profit immensely from the high electricity prices as they profit from the high market prices.

In contrast, operators in Germany that receive a feed-in tariff only get 8.2 ct/kWh for their feed-in electricity and do not profit from high electricity prices. On the other hand, they also do not have the risk like the operators that receive the market premium. Nonetheless, as of 2022, it is questionable if the market prices will be lower than the guaranteed prices in the future.

In 2018, the German Fraunhofer Institute for Solar Energy Systems published a report which stated that wind and solar PV have reached the lowest LCOE and are therefore the cheapest technologies for generating electricity (Kost et al., 2018, pp. 22-23). This might be the reason why the subsidies have been declining enormously in the last few years. Supposedly, governments believe that subsidies for renewables are unnecessary, with the declining LCOE for solar PV. With regard to the climate and energy targets (see Table 2), this is a wrong belief. There is hardly any time left for the ambitious targets. Therefore, the market premiums must be increased, and general automatic degressions (like in the EEG) must be abolished. The expansion goals are ambitious and cannot be reached with the status quo (Kost et al., 2018, pp. 22-23).

3. Methodology

This chapter outlines the methodology applied in this master's thesis.

3.1. EEG and EAG analysis on residential solar PV subsidies: qualitative and quantitative approach

A thorough literature review was conducted to compare the EEG and EAG. As the EAG has just been recently effective, a large share of the research was based on the legal texts in the Austrian law Gazette in the Austrian Legal Information System of the Republic of Austria. (BKA, 2021) The webpages "Gesetze im Internet" and "OffeneGesetze.de" were consulted regarding the legal text of the EEG (BMJ and BfJ, 2021; Offene Gesetze, 2022). The legal texts of the EAG, the EAG ordinances, and the explanatory notes of the law were consulted to better understand the lawmaker's intentions. (e-control, 2022d; Minister Gewessler, 2022a; Minister Gewessler, 2022b) Besides, journal articles on the EAG and especially the legal commentary of Ennser et al. (2022) on the EAG – just published in October 2022 – provided crucial background information. Concerning the EEG, the legal commentary "Recht der

Energiewirtschaft" provided valuable input on the system, history, and mechanism of the EEG (Schneider, 2013).

Kapp (2021) provided valuable research on the old Green Electricity Act and the EEG and significantly impacted the structure of this thesis.

3.2. Case study parameters: residential solar PV installation under the EEG and the EAG

3.2.1. Assumptions

The support schemes under the EAG and the EEG are compared for a 4-person family household using a solar PV system on a roof of a detached house.

The solar PV installation is financed with 100% equity, so no loan or extra interest rates are considered. The scheduled start of the operation of the solar PV installation is January 1, 2023. The operation time is scheduled for 20 years.

The capacities of the solar installations are 6 kWp and 11 kWp, respectively. The reason for those specific values is that only solar PV installations with a capacity larger than 10 kWp are entitled to the EAG market premiums pursuant to the new EAG (regarding the EAG investment grant, there is not such a restriction). Below 10 kWp, the operator of the solar PV installation can only apply for the EAG investment grant; see Sect. 10 Para. 1 It. 3 EAG. (e-control, 2022d, pp. 11-13) By choosing those values, the impacts of the investment grant (as investment support) and the market premiums and feed-in tariffs (as operating support) can be illustrated ceteris paribus. Nonetheless, also theoretical NPVs calculations under the EAG market premium case for the 6 kWp solar PV installation are conducted to evaluate if the EAG market premium shall also be eligible for solar PV installations smaller than 10 kWp. According to the explanatory notes to the EAG, there is no actual reason for the 10 kWp limit mentioned (Austrian Parliament, 2021a). One reason for this might be that the government wants operators to apply for the investment grant.

On average, residential solar PV installations in Germany have a capacity lower than 10 kWp. (Wirth, 2021, p. 20). Also, in Austria, the average capacity of a solar PV installation is 7 kWp (enerix, 2022). Therefore, an 11 kWp is a rather large installation for a 4-person family household and is likely to feed in a large share of the generated electricity. The results chapter will show if the market premium makes the operation of an 11 kWp residential solar PV installation attractive. If the pay-back time significantly differs between the 6 kWp and 11 kWp installations, the 11 kWp installation is too large for the demand of the 4-person household.

Due to the recent increase of electricity prices and the high volatility of the electricity market (see Figure 7 and Figure 30), NPV calculations in three scenarios are conducted:

- **Scenario 1:** The values refer to electricity prices of the second half of 2021 (**“**mid-Covid-Crisis” scenario)
- **Scenario 2:** The values refer to the currently soaring electricity prices price of the second half of 2022 (“energy crisis” scenario)
- **Scenario 3:** The values refer to electricity prices in the second half of 2019 (“pre-crisis” scenario)

Scenario 1 shall illustrate the effects before the currently soaring electricity prices. Scenario 2 shall show the effects under the current market conditions. Scenario 3 shall show the effects before the recent crises (Covid-19 and currently soaring energy prices). The significant impact of specific parameters shall be illustrated by comparing those three scenarios.

3.2.2. Net Present Value approach

The NPV calculation is a dynamic investment calculation tool. Compared to a static investment calculation, the dynamic investment calculation considers the time value of money by discounting the cash flows. In this example, a discount rate (in %) will discount the cash flows every year (Stöhr, 2014, pp. 49-50).

The NPV calculations in this thesis show the NPV after 20 years of operation of the solar PV installation.

With the NPV calculation, the expected future cash flows are discounted into today’s present value to compare different investments equally. The investment with the highest NPV is the best choice. The NPV of an investment should be at least positive for a viable investment (Benninga and Sarig, 1997, p. 2).

For the NPV calculations, the calculation tool for solar PV installations of the Linz AG and Österreichischen Energieagentur is used and consulted (Linz AG and Österreichische Energieagentur, 2022).

The equation for the NPV calculation, based on Brealey et al. (2017, pp. 25, 105), is as follows:

$$NPV = C_0 + \frac{C_t}{1 + r} + \frac{C_t}{(1 + r)^2} + \cdots \qquad (1)$$

This equation, based on Brealey et al. (2017, p. 25), can also be expressed in a shorter version:

$$NPV = C_0 + \sum_{t=1}^{T} \frac{C_t}{(1 + r)^t} \qquad (2)$$

C_0 .... investment costs for the solar PV installation in year 0 (€)
T .... investment horizon (years)
C_a .... annual cash flow – revenues-expenses (€)
t .... year
r .... discount rate (%)

For a solar PV installation, the yearly cash flow consists of the revenue and the operating costs for the solar PV installation. Only in year 0, the cash flow consists of the initial investment costs. The revenue results from the generated electricity, the energy yield multiplied by the total remuneration (Linz AG and Österreichische Energieagentur, 2022).

The yearly operating cash flows from year 1 to year 20, based on Linz AG and Österreichische Energieagentur (2022), are calculated as follows (in year 13, additionally the costs for the inverter are considered):

$$\underbrace{(E_{yield} * E_R)}_{Revenue} - \underbrace{O\&M}_{Expenses} \qquad (3)$$

E_{yield} .... generated energy yield (kWh)

E_R .... remuneration for the generated electricity (€/kWh)

$O\&M$ ....operating and maintenance cost incl. inflation (€)

One crucial component of a solar PV installation is the inverter. The replacement for the inverter takes place in year 13 and its costs are added to the expenses, significantly decreasing the cash flow (Linz AG and Österreichische Energieagentur, 2022).

A positive cash flow surplus is generated if the revenue exceeds the expenses. This cash flow surplus is then discounted with the discount rate ***r*** (Stöhr, 2014, pp. 52-53). The revenue is based on two pillars: the feed-in electricity (when the operator does not consume the electricity him/herself) and the saved electricity due to the own consumption of the operator. The operator saves the electricity that he/she would have purchased from the utility company. Depending on the amount of the feed-in electricity and the own consumption, the operator receives the revenue (see Chapter 3.1.3 for details).

The total remuneration for the operator, based on Haas et al. (2023, p. 6), is calculated as follows:

$$E_{self} * P_{HH} + E_{feed-in} * P_{feed-in} \tag{4}$$

E_{self} .... PV electricity self-consumption (kWh/year)

P_{HH} .... variable part of household electricity price (€/kWh)

$E_{feed-in}$ .... PV electricity grid feed-in (kWh/year)

$P_{feed-in}$ .... Feed-in tariff (€/kWh)

The NPV calculation’s purpose is to compare the effects of the federal laws EAG and the EEG. Regarding the subsidies, only subsidies of those laws are considered in the NPV calculation, not any further subsidies from the regions/provinces or municipalities. The same economic parameters and same investment costs are assumed for both the solar PV installations in Austria and Germany. One significant difference is the solar irradiance (see Table 9).

3.2.3. PV capacity installation

Regarding the investment costs, **1,700 €/kWp** are assumed for the 6 kWp installation. For the 11 kWp installation, **1,500 €/kWp** are assumed. Those values also consider the costs for mounting the installation, in fact an "all-inclusive price" (Energie-Experten, 2020).

The **electricity consumption** of the 4-person household is assumed with **4,800** kWh every year (Durchblicker, 2020). Based on the calculation with the tool SUSI ("Strom-Unabhängigkeits-Simulation"), the household's own consumption is assumed at 30% for the 6 kWp installation and 20% for the 11 kWp installation (SUSI, 2022). Those values are weighted, which results in a "mixed tariff". The mixed tariff multiplied by the energy yield results in revenue. E.g. for the 11 kWp market premium case under scenario 1 in Austria: The remuneration for the feed-in electricity of 0.092 €/kWh (weighted with 80%) multiplied by saved electricity due to own consumption of 0.23 €/kWh (weighted with 20%) results in mixed tariff of 0.119 €/kWh. (See Chapter 4.2 for details).

There are also other costs, such as operation and maintenance costs (including insurance costs). Those costs are assumed at 1% of the total investment price of the solar PV installation annually. As solar PV plants degrade, 0.5% are assumed as annual yield degradation (Wirth, 2022, pp. 23, 43).

For the yearly specific electricity yield in Germany, the average value of 950 kWh/kWp is assumed (Wesselak et al., 2017, p. 96). In contrast, for Austria which has more Southern parts than Germany – 1,000 kWh/kWp are assumed (Weiglhofer et al., 2016, p. 4). As both solar PV installations are located in Europe and the Northern hemisphere, the solar PV installation is oriented towards the South (N'Tsoukpoe, 2022, p. 2).

The value for the **discount rate** used in the NPV calculation is related to the project's expected returns **and other possible investment projects**. As the investor invests in one specific project, the project shall have higher returns than an alternative project. The discount rate is the minimum interest rate of the project. As the solar PV installation is a relatively safe investment, the interest rate of Austria's 20-year bond is assumed. As the operator can estimate with a certain value of solar irradiance every year, he/she receives a subsidized income, and the solar PV plant is insured. (Kapp, 2021, pp. 168-169; ter Horst, 2009, pp. 44-46; Brealey et al., 2017, pp. 22-23)

As of the end of November, Austria's 20-year bond yield was at app. **2.5%** (World Government Bonds, 2022). Therefore, this value is assumed for the **discount rate**. The 20-year bond is explicitly selected as it corresponds to the 20 years of operation of the solar PV installation.

The lifespan of an inverter is usually 10 to 15 years. Therefore, it has to be replaced once during the 20 years of operation (Richardson, 2021). In year 13, the inverter will be replaced with a new one. For the 6 kWp installation € 1,500 are assumed, based on the Delta RPI M8A inverter, and for the 11 kWp installation € 2,200 are assumed, based on the Fronius Symo 10.3-3-M inverter (Energiespeicher-Online GmbH, 2022a; Energiespeicher-Online GmbH, 2022b). Concerning the inverter, a European efficiency factor of 97% is assumed (Mertens, 2020, p. 213).

Due to the impacts of the currently soaring energy prices, it is difficult to forecast future **inflation rates**. Figure 16 shows the high volatility of inflation. After 2023, the IMF expects lower inflation rates at app. 2%. (IMF, 2022) Therefore, 2% are assumed for the inflation rate in the NPV calculation both for Austria and Germany.

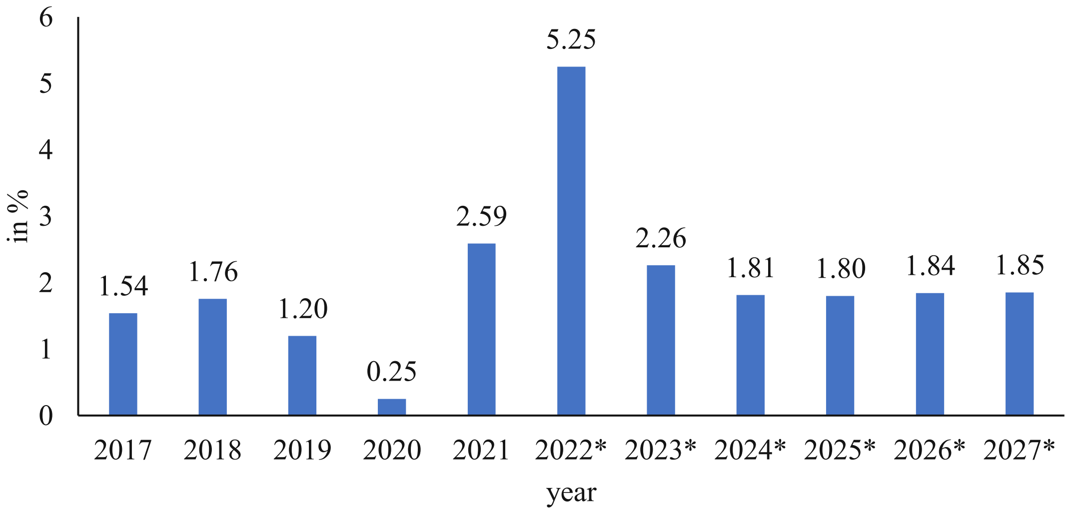

Figure 16: Inflation rate in the EU from 2017 to 2027 (=expected inflation rate), based on IMF (2022)*

4. Results

This chapter consists of the general comparison of the EAG and EEG (Chapter 4.1) and the results of the case study (Chapter 4.2).

In the general comparison of the EAG and EEG, the main targets of each country are illustrated at first. Then, the functioning of the funding system, the support schemes in detail, and the development of the feed-in tariffs are examined.

The chapter on the NPV calculation encompasses the results and remarks on the calculations. The conclusions of the case study are drawn in Chapter 5.

4.1. Comparison of the EAG and the EEG

4.1.1. The new EAG

On July 7, 2021, the bill of the EAG was passed in the Austrian Parliament. Pursuant to this legal act, the state will provide € 1 Bio. for the expansion of renewable energy technologies every year. Furthermore, the legal framework was provided for energy communities. (BMK, 2021a)

The Austrian government aims to achieve a 100% electricity supply from renewables by 2030 on the national balance level. Moreover, the Austrian government intends an even more ambitious national target with climate neutrality already by 2040 – ten years before the EU's target (Austrian Parliament, 2021a, p. 1; EU Commission, 2019).

The EAG legislative package consists of the new EAG and the amendments of nine other laws, including the Ökostromgesetz, Elektrizitätswirtschafts- und organisationsgesetz 2010, and Energie-Controlgesetz. The core of this legislative package is the implementation of the EAG (BKA, 2021).

The EAG provides minimum budgets for the subsidies of renewables (in contrast to the Green Electricity Act, which provided maximum budgets; see Chapter 2.3). On average, over three years, at least € 1 Bio. shall be provided for the expansion of renewables (Ennser et al., 2022, p. 2).

The support scheme of the EAG is based on three pillars (Ennser et al., 2022, p. 2):

- The **market premium** (which replaces the feed-in tariff of the Green Electricity Act)
- The **investment grant for electricity** generated by renewable technology
- The **investment grant for gas** generated by renewable technology (the latter is not treated in this thesis)

One significant change of the new EAG is the substitution of the feed-in tariff by the market premium. Now operators of renewable technologies have to directly sell their generated electricity on the market. For solar PV, the market premium is determined in auctions. The details for the procedure are determined in the EAG market premium ordinance. (Ennser et al., 2022, p. 2; Minister Gewessler, 2022b)

Contrary to the feed-in tariff, the EAG also provides the investment grant as a subsidy like the Green Electricity Act. The values and the details of the procedure are determined in the EAG investment grant ordinance (Ennser et al., 2022, pp. 2-3; Minister Gewessler, 2022a).

4.1.2. The EEG 2023 amendment

The source regarding the legal text of the EEG used in this chapter is the current version of the EEG that was adopted in July 2022. However, if applicable, also an English translation of the BMWK is used as reference. This is an old version from 2017. The German translation of the EEG uses for the "Anzulegender Wert" (bid value) the term "value to be applied" (Sect. 3 It 3 EEG), which is equivalent to "guaranteed price" of the Austrian EAG pursuant to Sect. 5 It. 4 EAG (BMWK, 2017, p. 2; BMJ and BfJ, 2023; e-control, 2022d, pp. 5-6). Both terms are treated as synonyms in this thesis.

Pursuant to Sect. 19 EEG, there are three options for operators of renewable energy systems to receive financial subsidies (BMJ and BfJ, 2023):

- the market premium (Sect. 20 EEG)
- the feed-in tariff (Sect. 21 EEG)
- and the landlord-to-tenant supply premium (Sect. 21 EEG) – the latter will not be treated in this thesis

In April 2022, the German Federal Ministry for Economy and Climate Protection published this legislative package as an amendment to the EEG. Particularly in the context of soaring energy prices and the geopolitical crises in Europe, Germany wants to reduce its dependency on fossil fuels faster than the status quo. Renewable energy is now in the highest "public interest" of Germany. By 2035, the electricity supply shall rely on almost 100% renewables. In that respect, regarding solar PV, framework conditions (like approval procedures) shall be accelerated, and new areas shall be enabled for the installation of solar PV. Moreover, 80% of the electricity consumption in Germany shall be provided by renewables in 2030, corresponding to 600 TWh of electricity. This will be a major challenge for Germany as renewables only made up 39.6% of gross electricity production in Germany in 2021. Furthermore, the EEG levy (as part of the electricity bill) will be abolished. (BMWK, 2022b, pp. 1-6)

The expansion targets for solar PV will be increased. Every year until 2030, there shall be an expansion rate of 22 GW for solar PV, adding up to a total of 215 GW in 2030. The subsidies for installations on roofs will be distinctly increased – especially the subsidies for solar PV plants with no own consumption (so-called "*Volleinspeiser*", they are not treated in this thesis) that entirely feed their generated electricity into the grid. This is because solar PV operators with a share of own consumption ("*Teileinspeiser*") are profiting from the high electricity. Operators that entirely feed in electricity to the grid were not as profitable as operators with own consumption. Consuming own generated electricity is more lucrative than feeding electricity to the grid. Another important change is that there is no degression (which was provided in the older versions of the EEG) of the guaranteed prices for the market premiums and the feed-in tariffs (that are determined by law) until the beginning of 2024. (BMWK, 2022b, pp. 5-6).

4.1.3. Overview of EEG and EAG funding scheme

Figure 17 and Figure 18 illustrate the basic functioning of the subsidy system of the German **EEG**. The electricity consumers pay the EEG levy, which is part of the electricity bill, to the network operator. These payments are then stored on the so-called "EEG account," of which the grid operators pay the **feed-in tariff** to the renewable operators for their feed-in electricity. The feed-in electricity is then sold by the grid operator on the electricity exchange. The income flows of the EEG account are funded by the EEG levy, the federal budget, and the achieved revenues on the spot market. The four large transmission system operators are responsible for managing the EEG account. (Enercity, 2022)

The EEG levy is going to be abolished with the new EEG 2023 by January 2023 as a measure against soaring energy prices. Instead, the federal Energy and Climate Fund will provide the funds. By this measure, consumers save app. 3.72 ct/kWh, which corresponds to app. € 300 for a year per family. (Enercity, 2022)

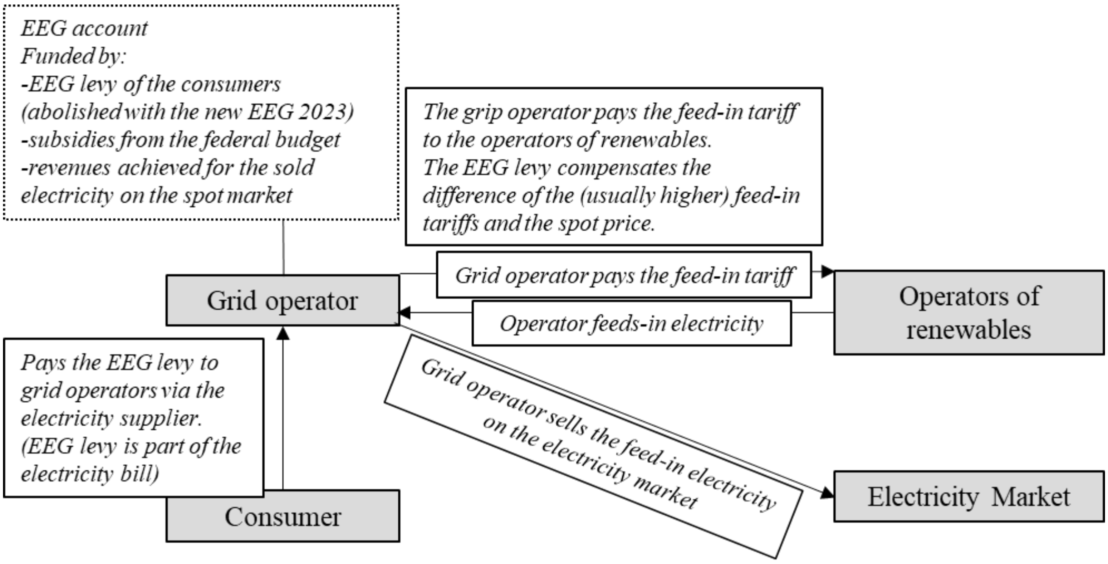

Figure 17: Basic illustration of the funding system of the EEG feed-in tariff, based on FfE München (2020) and Enercity (2022)

In the **EEG market premium model** (Figure 18), the operator of renewables has two sources of income: On the one hand, a market premium from the grid operator, on the other hand, proceeds according to the purchase agreement with the direct seller (Virtuelles Kraftwerk - EnBW, 2020).

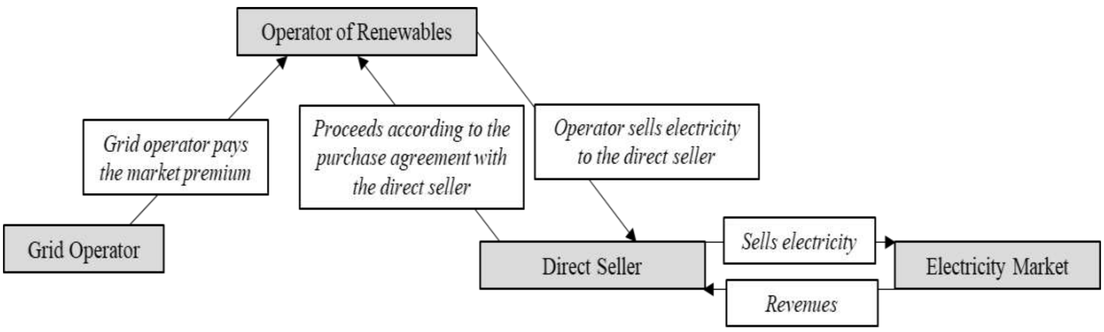

Figure 18: Basic illustration of the cash flows in the EEG market premium model, based on Virtuelles Kraftwerk - EnBW (2020)

Sect. 37 - Sect. 41 Green Electricity Act outline the basic functioning of the **old Austrian funding system** under the Green Electricity Act shown in Figure 19 (BKA, 2022b, pp. 27-29).

This is relevant as the funding mechanism of the EAG is based on the funding scheme of the Green Electricity Act 2012. Electricity consumers pay the Renewables levy (Flat Rate Renewable Charge and the Renewables contribution) as part of the electricity price to the grid operator that passes it to the Renewable Energy Settlement Agency. The Renewable Energy Settlement Agency pays the operators of renewables the feed-in tariff for the feed-in electricity. It also allocates the feed-in electricity to the electricity traders who have to pay a specific transfer price for the received electricity. (Austrian Parliament, 2021a, p. 2)

The OeMAG acts as Renewable Energy Settlement Agency and is therefore responsible for managing the EAG support schemes. (Ennser et al., 2022, p. 4)

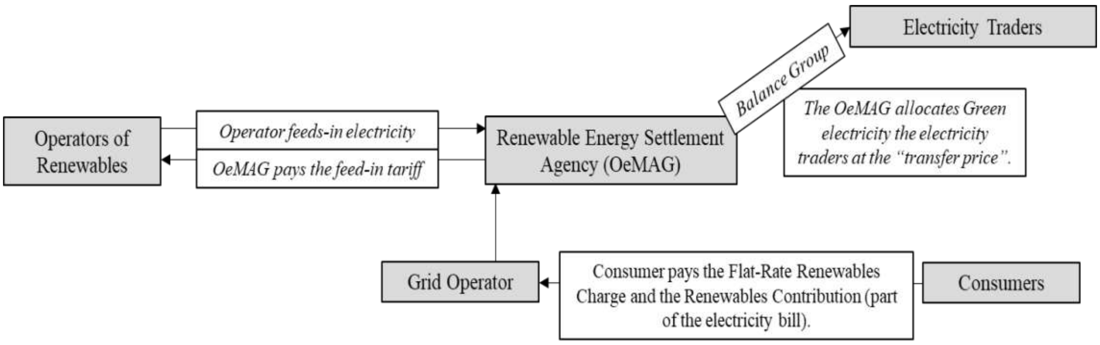

Figure 19: Basic illustration of the funding system of the Green Electricity Act for the feed-in tariff, based on e-control (2017, p. 17), OeMAG (2022c), and OeMAG (2022b)

Pursuant to the EAG, the market premium model replaces the feed-in tariff model; see Figure 20 (Austrian Parliament, 2021a, p. 8). Sect. 71 - Sect. 78 EAG outline the basic functioning of the funding system of the **new EAG market premium model** (e-control, 2022d, pp. 35-40). Like in the EEG market premium, the operator of renewables has two sources of income: the market premium from the Renewable Support Management Entity and the proceeds according to the purchase agreement with the direct seller (Austrian Parliament, 2021b, pp. 35-40). The Flat-Rate Renewables Charge is now named Renewable Electricity Flat Rate and the Renewables Contribution is now named Renewable Electricity Contribution in the EAG (Austrian Parliament, 2021a, p. 17).

Both the Flat Rate Renewable Charge and the Renewables contribution are considered as state aid by the EU Commission. The Renewables support management entity acts as an intermediary of those fundings. Vulnerable households are exempted from paying both the Renewables Electricity Flat Rate, “Erneuerbaren-Förderpauschale”, and the Renewable Electricity Contribution, “Erneuerbaren-Förderbeitrag”. (Ennser et al., 2022, pp. 198-204)

Like in Germany, Austria has suspended the Renewable Charges, but only for the years 2022 and 2023 to financially support private households (Austrian Parliament, 2022).

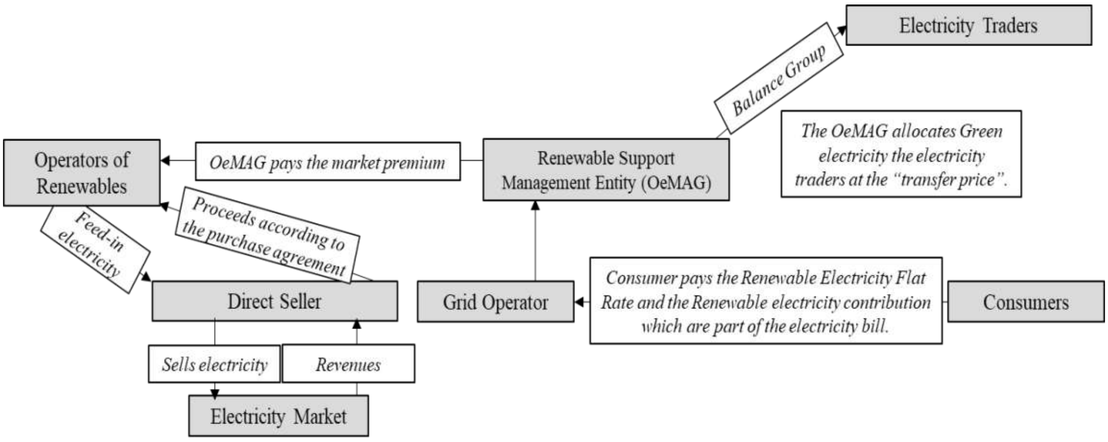

Figure 20: Basic illustration of the funding system of the EAG market premium, based on e-control (2017, p. 17), OeMAG (2022a), OeMAG (2022b), and Sect. 71-78 EAG (e-control, 2022d, pp. 35-40)

Regarding the investment grant, operators of renewables will have to apply for the grant at the Renewable Support Management Entity. The RSME also pays the investment grant to the operator if the application is successful; see Sect. 55 Para. 7 EAG (e-control, 2022d, p. 55).

The support scheme under the **EAG**, the successor to the Green Electricity Act, earmarks a new support scheme for renewables in Austria. Pursuant to the EAG, financial subsidies for renewables can be granted via the investment grant or via the market premium. The investment grant is a lump sum payment that supports the construction of a renewable power plant at the beginning of its installation. In contrast, the market premium (in the EAG, the so-called “feed-in premium”) supports the operation of the renewable plant. The operator must choose if he/she either wants to apply for the investment grant or the market premium. Both subsidies cannot be combined; see Sect. 55 Para. 9 EAG. (Ennser, 2021, p. 82; e-control, 2022d, p. 25)

The subsidies are granted by Renewables Support Management Entity (RSME). The Minister responsible for energy matters must contract an entity and conduct a tendering process pursuant to Sect. 66 EAG (e-control, 2022d, pp. 33-34). The OeMAG, which operated as the Green Power Settlement Agency under the Green Electricity Act, won the tendering procedure in May 2022 and has been charged with the tasks of the RSME (Ennser et al., 2022, p. 4; Government of Upper Austria, 2022; e-control, 2022d, pp. 33-34; Röthlin, 2022, pp. 35, 41). Therefore, the OeMAG is now responsible for both subsidies according to the EAG and the existing subsidies according to the Green Electricity Act (Ennser et al., 2022, p. 4).

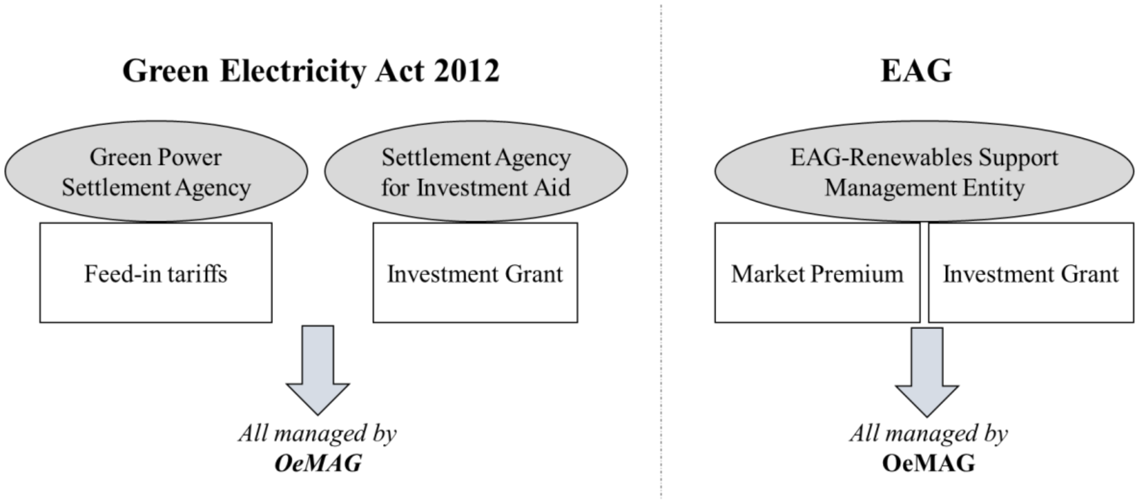

Figure 21: Overview of the support schemes of the Green Electricity Act 2012 and the EAG, based on and translated from Röthlin (2022, p. 35)

The EAG is based on a two-pillar support scheme like the Green Electricity Act. However, the operators will get market premiums instead of feed-in tariffs as operating support. Under the Green Electricity Act, the OeMAG oversaw the management of the subsidy schemes. On the one hand, the OeMAG managed the feed-in tariffs as Green Power Settlement Agency; on the other hand, it handled the investment grants as Settlement Agency for Investment Aid. In contrast, the EAG provides only one EAG-Renewable Support Management Entity that is solely responsible for handling the market premium and the investment grant; see Figure 21. (Katalan and Reitinger, 2021, p. 120; Röthlin, 2022, p. 35)

As the **investment grant** is a financial subsidy, it may fall under the scope of the EU state aid regime; see 107 and 108 TFEU (EUR-Lex, 2012). However, it is exempt pursuant to Sect. 41 General Block Exemption Regulation and does not need a notification or approval by the EU Commission (EUR-Lex, 2014a; Ennser, 2021, p. 83).

In contrast to the EAG investment grant subsidy, the EAG market premium was notified by Austria and approved by the EU Commission pursuant to the Guidelines on state aid for environmental protection and energy 2014-2020 (EU Commission, 2021; Storr, 2022a, p. 50). In 2022, after negations between the Austrian Government and the EU Commission, the subsidies of the EAG were approved for 10 years. This is also the reason why the EAG had to be adjusted after it had already become effective in 2021 (Ennser et al., 2022, p. 2).

The only **mutual support scheme** of the EEG and the EAG is the **market premium**, as there is only the market premium and the investment grant in the EAG and only the market premium, the feed-in tariff, and the landlord-to-tenant supply premium in the EEG.

In general, the funding systems of the EEG and EAG are similar in their structures (see Figure 17 to Figure 20). One significant difference is that in the EEG model, the market premium is disbursed by the grid operator, and in the EAG model, the market premium is disbursed by the Renewable Support Management Agency.

Also, the EEG feed-in tariff model is similar to the old Green Electricity Act feed-in tariff model. The (same) significant difference is that the feed-in tariff is disbursed by the grid operator in the EEG model, whereas the feed-in tariff is disbursed by the Renewable Energy Settlement Agency.

As mentioned above, Germany has abolished the EEG levy and Austria has abolished the Renewables Charges, but only for the years 2022 and 2023 (Austrian Parliament, 2022; BMWK, 2022b, p. 2).

4.1.4. Detailed review of potential EAG support measures

a. EAG investment grant

Generally, solar PV installations with a capacity of up to a maximum of 1,000 kWp are entitled to an investment grant (or also "investment aid") pursuant to Sect. 56 EAG. Both the construction and the extension of the plant are under the scope of the investment grant. The investment grant typically supports operators of plants that show a high share of own consumption and feed in only a low share to the public grid. The investment grant for operators of solar PV installations on agricultural land or green land is reduced by 25%. The rationale behind this provision is that solar PV installations shall be constructed on already sealed areas and shall not compete with food cultivation. (Ennser, 2021, pp. 82-84; e-control, 2022d, pp. 26-27)

The investment grants for solar PV power plants are divided into four categories depending on the capacity of the solar PV installation (see Table 3):

Table 3: Categories of the investment grant for solar PV plants pursuant to Sect. 56 EAG, based on e-control (2022d, pp. 26-27)

Category	Capacity of the solar PV installation
A	up to 10 kWp
B	between 10 and 20 kWp
C	between 20 and 100 kWp
D	between 100 and 1000 kWp

Each category of a solar PV installation is awarded with a different respective funding rate. Pursuant to Sect. 58 EAG, the support rounds, the funding volume, and the funding rates are determined in the EAG investment grant ordinance. The ordinance is published by the Minister of the BMK in accordance with the Minister for Agriculture, Regions, and Tourism; see Sect. 58 EAG. (e-control, 2022d, p. 29)

The first ordinance was published in April 2022, and the first support round was from April 21, 2022, to May 19, 2022 (see Table 4). Every year, at least two support rounds ("Fördercalls") shall be conducted (see Sect. 56 Para. 5 EAG). The applications for category A are ranked "*[...] according to the first come, first served principle [...]*" pursuant to Sect. 56 Para. 6 EAG (e-control, 2022d, p. 26). The appropriate amount of the investment grant for category A is determined in the respective ordinance (see Sect. 56 Para. 4 EAG). In contrast, the categories B, C, and D are ranked according to the requested support rate per kWp, which must be stated by the operator in his/her application beforehand. In the ordinance, only the maximum support rates for categories B, C, and D are stated. This is, in fact, an element of a price-based auction procedure (e-control, 2022d, pp. 25-29). If the support funds are exhausted or the requested support rate for the investment grant "*[...] exceeds the maximum support rate [...]*" (Sect. 56 Para. 6 EAG), the application has to be declined (e-control, 2022d, p. 26).

Table 4: Support rounds, support funds, and funding rates for solar PV power plants pursuant to the first EAG investment grant ordinance; table adapted and translated from the ordinance, based on Minister Gewessler (2022a, p. 5)

Support Rounds	**Support Funds**	**Funding Rates**
Category A: 21 April 2022 - 19 May 2022 Category B, C, and D: 21 April 2022 - 2 June 2022	Category A: € 40 Mio. Category B: € 20 Mio. Category C: € 20 Mio. Category D: € 20 Mio.	Category A: 285 €/kWp Category B: 250 €/kWp (max) Category C: 180 €/kWp (max.) Category D: 170 €/kWp (max.)
Category A and B: 21 June 2022 - 19 July 2022	Category A: € 60 Mio. Category B: € 10 Mio.	Category A: 285 €/kWp Category B: 250 €/kWp (max.)
Category A: 23 August 2022 - 20 September 2022 Category B, C, and D: 23 August 2022 - 4 October 2022	Category A: € 5 Mio. Category B: € 10 Mio. Category C: € 10 Mio. Category D: € 10 Mio.	Category A: 285 €/kWp Category B: 250 €/kWp (max.) Category C: 180 €/kWp (max.) Category D: 170 €/kWp (max.)
Category A: 18 October 2022 - 15 November 2022 Category B, C, and D: 18 October 2022 - 29 November 2022	Category A: € 5 Mio. Category B: € 10 Mio. Category C: € 10 Mio. Category D: € 10 Mio.	Category A: 285 €/kWp Category B: 250 €/kWp (max.) Category C: 180 €/kWp (max.) Category D: 170 €/kWp (max.)

The values for the EAG investment grant of each category match with the proposed values of a survey on the subsidies of the EAG that the BMK commissioned before publishing the ordinance (BMK, 2022a).

b. EAG market premium

The respective EAG market premium ordinance provides for the support rounds, support funds, the guaranteed price, the price caps in the auction process, and the reduction of the market premium for solar PV installations on agricultural land or green land. The aim of the market premium is "*[...] to fully or partially compensate awardees for the difference between renewable electricity generation costs and the* *average electricity market price […]*" according to Sect. 9 Para. 2 EAG (e-control, 2022d, p. 11; Minister Gewessler, 2022b).

The reason why the EAG market premium ordinance has been published so late – the EAG was published in July 2021 – is that it had to undergo a long EU Commission state aid review; see also above for the topic on state aid (Storr, 2022b, p. 250). Regarding solar PV, only power plants with a capacity larger than 10 kWp are eligible for the market premium (Röthlin, 2022, pp. 39-40). Another requirement for eligibility is that the solar PV installation has to be provided with a smart meter and has access to the Austrian electricity grid pursuant to Sect. 10 Para. 2 EAG (e-control, 2022d, pp. 11-12).

Contrary to the Green Electricity Act, there is no general obligation to accept feed-in electricity for a utility company or an "authority" like the OeMAG. Operators of solar renewable plants must directly sell their electricity on the market ("direct selling"). However, there are exceptions for operators with solar PV installations smaller than 500 kWp, which addresses primarily private households. (Storr, 2022b, p. 250)

In this case, the regulatory authority will allocate an electricity trader to sell the electricity on the market to such an operator; see also Sect. 12 Green Electricity Act and Sect. 97 EAG (e-control, 2014, p. 22; e-control, 2022d, pp. 50-51).

As already mentioned, the EAG market premium replaced the feed-in tariff of the Green Electricity Act as operating support. The feed-in tariffs pursuant to the Green Electricity Act are an "all-in-one solution" for operators. The responsible authority (OeMAG) is obliged to purchase the feed-in electricity of operators under the Green Electricity Act. In contrast, in a market premium model, the operator must directly sell the produced electricity on the electricity market ("direct selling"). Generally, the EAG provides for market premiums awarded via auction or application. For solar PV plants, market premiums are only awarded via auction, which is conducted by the RSME. The RSME has to announce the auction, including the relevant content, e.g., price cap, auction volume, auction deadline, etc. (see Sect. 19 EAG). The applicants must submit their bid-size, bid-price, and project description during the auction procedure. The eligible biddings are ranked according to the bid-value, beginning with the cheapest bid. Bids that are within the auction volume will be accepted. (Röthlin, 2022, pp. 39-40; e-control, 2022d, pp. 15-16)

For solar PV, "*[…] the annual auction volume is at least 700,000 kWp […]*", and at least two auction rounds must be conducted annually, according to Sect. 31 EAG (e-control, 2022d, p. 18). Like for the investment grant, there is a reduced market premium of 25% for solar PV plants on agricultural land or green land (for instance, for "Agri-PV"; see Sect. 33 EAG). Solar PV plants smaller than 100 kWp must start operation within six months from the acceptance of the bid (Röthlin, 2022, p. 40).

The EAG market premium is partly based on the EEG market premium mechanism. This is true, especially for the calculation and the technical terms of the EAG market premium, e.g., the same term for guaranteed value – "Anzulegender Wert" (Ennser et al., 2022, pp. 54-46).

Pursuant to Sect. 11 EAG, the market premium is the difference between the guaranteed price (i.e., the bidding price after a successful auction) and either the general market price or weighted market price (e-control, 2022d, p. 13).

Regarding the PV market premium, the **weighted market price** is relevant pursuant to Sect. 13 EAG. The weighted market price is based "*[…] on the hourly price achieved in single day-ahead coupling for the bidding zone that is relevant for Austria […].*" according to Sect. 13 Para. 1 EAG (e-control, 2022d, pp. 13-14). For each renewable technology, the weighted market price is "*[…] calculated separately for each technology […] based on the quantity of electricity (kWh) generated by each technology during each hour*" according to Sect. 13 Para. 2 EAG (e-control, 2022d, p. 14). In order to calculate the weighted market price, the hourly day-ahead price has to be "*[…] multiplied by the hourly quantity of electricity generated by a technology […]*" (e-control, 2022d, p. 14). So, for each technology (solar PV, wind energy, etc.), there is an own weighted market price. Then, the "*[…] hourly values are summed up and then divided by the total amount of electricity generated by that technology during the month […]*"; see Sect. 13 Para. 3 EAG (e-control, 2022d, p. 14; Katalan and Reitinger, 2021, p. 121; Janisch, 2021, p. 9). In simplified terms, it is the weighted day-ahead price multiplied by the generated solar PV electricity (Röthlin, 2022, pp. 39-40). The e-control is responsible for calculating and publishing the weighted market price each month; see Figure 22 for the published weighted market price from January to July 2022 (e-control, 2022d, pp. 13-14).

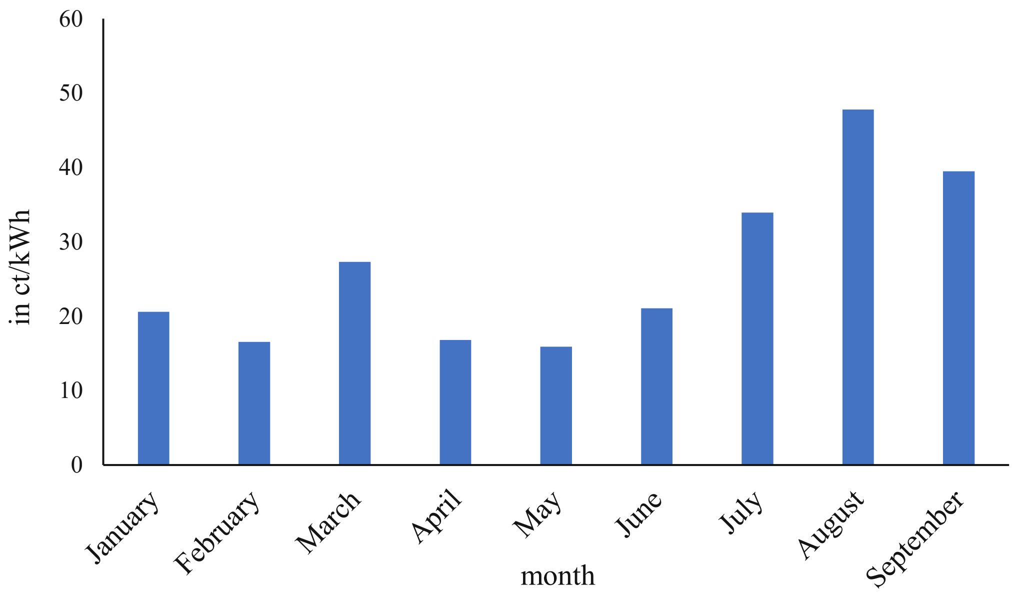

Figure 22: The calculated weighted market price from January 2022 to September 2022 according to Sect. 13 EAG for solar PV in Austria, based on e-control (2022c)

Regarding solar PV, the guaranteed price is determined via auctions (e-control, 2022d, pp. 18-19). Based on the maximum bidding price that is stated in the EAG market premium ordinance, the market premiums for the applicants are determined in auctions. The bidders within the auction volume shall receive the market premiums. The maximum guaranteed price for the years 2022 and 2023 is 9.33 ct/kWh according to the EAG market premium ordinance (e-control, 2022d, p. 18; Minister Gewessler, 2022b, p. 4).

Table 5 shows the next support rounds and respective support volumes according to the EAG market premium ordinance (Minister Gewessler, 2022b).

Table 5: Support rounds and support volumes for the market premium pursuant to the EAG market premium ordinance, adapted and translated from Minister Gewessler (2022b, pp. 4-5)

Support Round	Support Volume
13 December 2022	700 000 kWp
14 February 2023	175 000 kWp
25 April 2023	175 000 kWp
25 July 2023	175 000 kWp
10 October 2023	175 000 kWp

As already mentioned, there are certain types of market premiums (see above). The market premium under the EAG is a **floating market premium** (see Figure 10) that the operator of the solar PV installation will receive for 20 years of operation (BMK, 2022a, pp. 15-17).

To calculate the ultimate proceeds for the operator, it has to be distinguished between the **guaranteed price** (also "**bid**" as the value is determined and based on the bid in the auction procedure) that the operator receives from the RSME and the **proceeds** which the operator receives by directly selling electricity on the market. The guaranteed price is composed of the market premium and the weighted market price (see Figure 23).

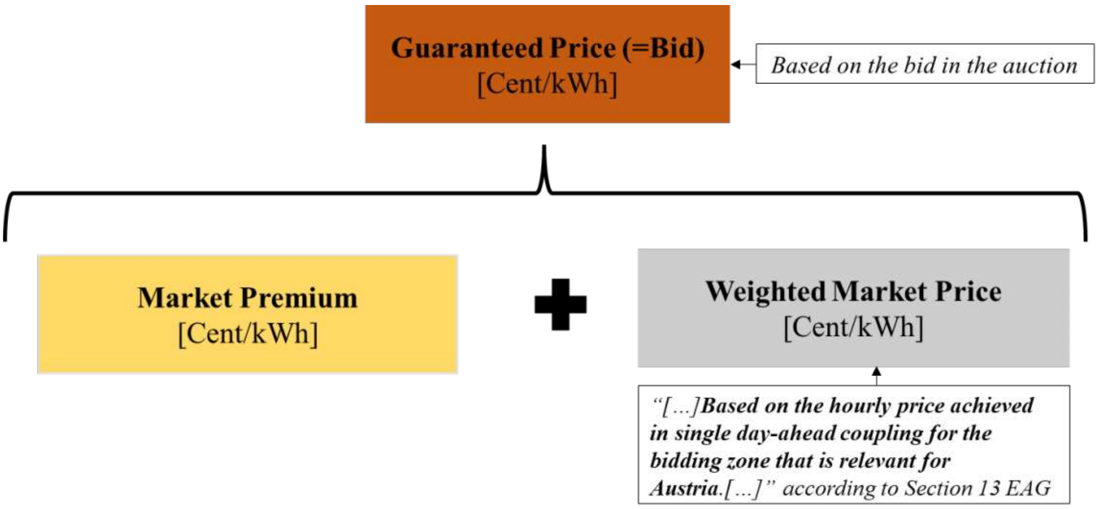

Figure 23: Calculation of the market premium, translated from and based on Janisch (2021, p. 9) and e-control (2022d, pp. 13-14)

According to Sect. 11 EAG, the market premium is calculated as follows (e-control, 2022d, p. 13):

$$Market\ Premium = Guaranteed\ Price - Weighted\ Market\ Price \qquad (5)$$

Figure 24 displays multiple scenarios on the interaction of the market premium and the weighted market price. The market premium is added on top of the market value to reach the bid amount. In the first scenario, the weighted market price is low; therefore, the operator is awarded a higher market premium. In the second scenario, the weighted market price is higher. Therefore, the market premium is lower. Basically, they complement each another to reach the value of the bid. However, there are also extraordinary scenarios. The market premium is set to zero if there is a negative weighted market price (see Sect. 15 EAG). Furthermore, the market premium is set to zero if the weighted market price exceeds the guaranteed price as well. This concerns solar PV plants below 5 MWp. Under specific conditions, operators of solar

PV installations larger than 5 MWp have to make repayments; see Sect. 11 Para 6 EAG. (Janisch, 2021, p. 11; e-control, 2022d, pp. 13-14)

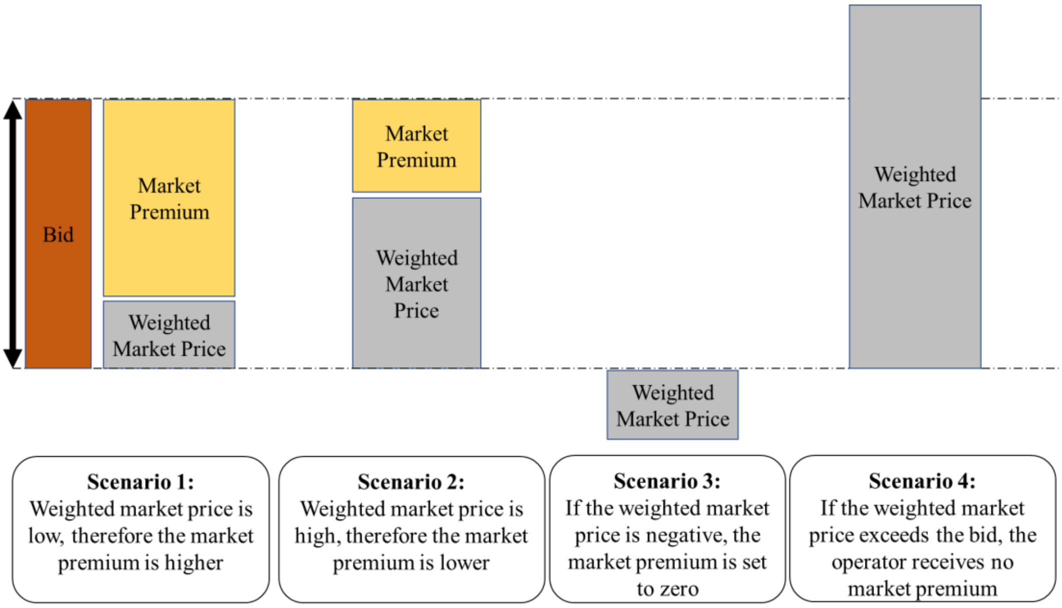

Figure 24: Market premium scenarios, translated from and based on Janisch (2021, p. 11)

The scenarios above show how the market premiums are generated. However, this must not be mistaken with the total, "real" proceeds the operator receives in the end. The total income is comprised of the market premium and the proceeds according to the purchase agreement with an electricity trader acting as a direct seller (see Figure 25). As mentioned, solar PV plant operators must directly sell their electricity on the market. (Janisch, 2021, p. 12)

Therefore, they have to sign a purchase agreement with an electricity trader. If the operator has a power plant that is below 500 kWp – which is the case for most households – the operator may address the regulatory authority, which assigns the operator to an electricity trader (see Sect. 97 EAG, there are also exceptions for operators of power plants larger than 500 kW). Furthermore, operators can close a purchase contract with the OeMAG at market prices. The respective provisions of the Green Electricity Act are still in place; see Sect. 13 in connection with Sect. 41 and 57f Green Electricity Act. (e-control, 2022d, p. 50; BKA, 2022b, pp. 9, 29, 35)

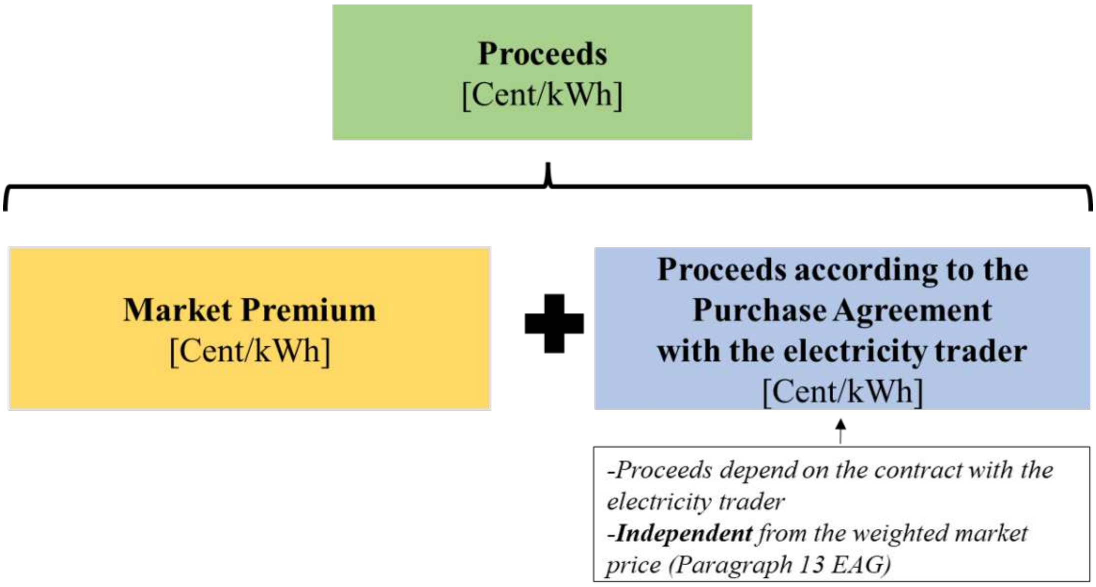

Figure 25: Composition of the proceeds for the solar PV operator, translated from and based on Janisch (2021, p. 12)

The proceeds according to the purchase agreement are independent from the weighted market price, which acts as a reference. This is the exact reason why the ultimate proceeds and the guaranteed price may differ. If the proceeds from the purchase agreement are higher, then the proceeds are higher than the actual bid – while the market premium is always put on top of the proceeds of the purchase agreement. In contrast, if the proceeds from the purchase agreement are lower, the ultimate proceeds are lower; see examples 1 and 2 in Figure 26. (Janisch, 2021, p. 13)

If the weighted market price is negative, the operator receives no market premium (Sect. 15 EAG) but the proceeds according to the purchase agreement, which is the achieved price on the electricity market; see example 3 in Figure 26 (e-control, 2022d, p. 14).

Also, suppose the weighted market price exceeds the bid. In that case, the operator also gets no market premium but still the proceeds according to the purchase agreement. In example 4 in Figure 26, those proceeds are lower than the weighted market price – however, they also may be higher depending on the contract with the electricity trader. (Janisch, 2021, p. 13)

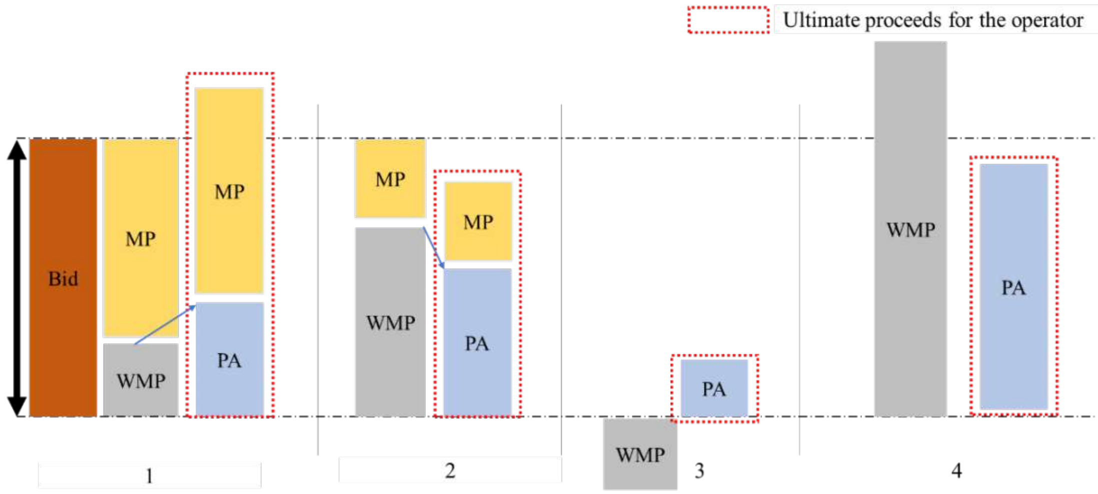

Figure 26: Market premium scenarios: Illustration of bids and ultimate proceeds for the operator of the solar PV power plant, translated from and based on Janisch (2021, p. 13)

4.1.5. The support schemes under the EEG in detail

a. EEG feed-in tariffs

Apart from market premiums, operators of solar PV installations in Germany may apply for feed-in tariffs pursuant to the EEG. The feed-in tariff can be classified as operating support. Table 6 displays the development of the values for the feed-in tariffs in 2022. Operators will get the rate of the feed-in tariff in ct/kWh at the time when they apply for it. The feed-in tariff is paid for 20 years by the grid system operator to the operator of the solar PV installation (see Sect. 25 EEG). Pursuant to Sect. 53 Para. 1 It. 2 EEG, the feed-in tariff is based on the respective guaranteed price minus 0.4 ct/kWh. (BMWK, 2017, pp. 28, 72)

Pursuant to Sect. 23d, there is a "*pro rata payment*" (see Table 6) depending on the capacity of the solar PV installation: the "*[…] entitlement shall be determined for solar installations […] in each case on a pro-rata basis in line with the installed capacity of the installation in relation to the respective threshold value to be applied […]*" (BMWK, 2017, p. 27).

The operator of the 6 kWp solar PV installation will receive 8.20 ct/kWh. The operator of the 11 kWp solar PV plant will receive 8.20 ct/kWh for the first 10 kWp and for the remaining 1 kWp 7.10 ct/kWh, which amounts to 8.1 ct/kWh (in detail: 10/11*8.2 + 1/11*7.10 = 8.1); see also Sect. 19, 21, and 25 EEG (BMJ and BfJ, 2023).

Table 6: Recent development of the feed-in tariffs of the EEG for solar PV operators with own consumption ("Teileinspeiser") on buildings pursuant to Sect. 48 EEG, translated from and based on Bundesnetzagentur (2022a).

Feed-in tariffs (in ct/kWh:)			
Start of operation	For solar PV installations on buildings		
	up to 10 kWp	up to 40 kWp	up to 100 kWp
by August 1, 2022	8.2	7.1	5.8
by September 1, 2022	8.2	7.1	5.8
by October 1, 2022	8.2	7.1	5.8
by November 1 2022	8.2	7.1	5.8
by December 1, 2022	8.2	7.1	5.8
by January 1, 2023 until January 1, 2024	8.2	7.1	5.8

b. EEG market premium

The EEG market premium acts – like the EAG market premium and EEG feed-in tariff – as an operating support for the operation of the renewables. The relevant provision for the market premium is Sect. 20 EEG (BMJ and BfJ, 2023). The market premium is the difference between the guaranteed price and the respective monthly market value, similar to the EAG market premium (Kapp, 2021, p. 72).

Pursuant to Annex 1 of the EEG, the **monthly** market value "*[...]shall be the actual average monthly value of the market value of electricity from solar PV on the spot market [...]*" (BMWK, 2017, p. 155). For operators that won the auction or started the solar PV installation after January 1, 2023, the market premium is the difference between the guaranteed price and the respective **yearly** market value (instead of the monthly market value; see Annex 1 EEG 4.3.4 (BMJ and BfJ, 2023, pp. 117-120).

The following is the equation, based on BMJ and BfJ (2023, pp. 117-118), for the calculation of the EEG market premium **before** January 1, 2023 (value to be applied equals guaranteed value):

$$Market\ Premium\ = Value\ to\ be\ applied - monthly\ market\ Value \qquad (6)$$

This is the equation, based on BMJ and BfJ (2023, pp. 118-119), for calculating the EEG market premium **after** January 1, 2023:

$$Market\ Premium\ = Value\ to\ be\ applied - yearly\ market\ Value \quad (7)$$

Operators of solar PV installations with a capacity of up to 100 kWp can either apply for the market premium or the feed-in tariff (see Sect. 21 EEG). Pursuant to Sect. 20 and 21 EEG, the operator has to feed in the produced electricity him/herself or via an electricity trader, and the electricity has to be metered every 15 minutes. (BMJ and BfJ, 2023)

As already mentioned, the maximum guaranteed price for the market premium for solar PV installations is 0.4 ct/kWh higher than the feed-in tariff (due to a so-called management fee). This was introduced to encourage operators to apply for the market premium and to directly sell their produced electricity on the market. (Kapp, 2021, pp. 70-72)

Table 7 shows the maximum guaranteed prices for the EAG market premiums pursuant to the EEG (Bundesnetzagentur, 2022a).

Table 7: Recent values of the maximum guaranteed prices for the EEG market premium pursuant to the EEG, translated and based on Bundesnetzagentur (2022a)

Start of operation	**Maximum guaranteed prices for market premiums for solar PV installations on buildings (in ct/kWh)**				
	up to 10 kWp	up to 40 kWp	up to 100 kWp	up to 300 kWp	up to 750 kWp
by August 1, 2022	8.6	7.5	6.2	6.2	6.2
by September 1, 2022	8.6	7.5	6.2	6.2	6.2
by October 1, 2022	8.6	7.5	6.2	6.2	6.2
by November 1 2022	8.6	7.5	6.2	6.2	6.2
by December 1, 2022	8.6	7.5	6.2	6.2	6.2
EEG 2023					
	up to 10 kWp	up to 40 kWp	up to 100 kWp	up to 400 kWp	up to 1 MW
by January 1, 2023 until January 1, 2024	8.6	7.5	6.2	6.2	6.2

4.2. Case Study: residential solar PV installation under EEG and EAG

This chapter shows the results of the NPV calculations for scenario 1, scenario 2, and scenario 3 based on the parameters defined in the EAG and EEG.

4.2.1. Case study parameters from EEG and EAG for scenario 1 ("mid-Covid-Crisis" scenario)

First, the solar PV installation parameters in scenario 1 (values of the second half of 2021 – mid-Covid-Crisis) are illustrated. Afterwards, the relevant values of scenario 2 (values of the second half of 2022 – energy crisis) and scenario 3 (values of the second half of 2019 –pre-crisis) are explained.

a. Electricity Price

Figure 8 displayed the electricity price composition for household consumers in the EU in the second half of 2021. German households pay the second-highest price for electricity, whereas Austria ranks in the midfield (Eurostat, 2022b).

Figure 27, Figure 28, and Figure 29 show that significant parts of the electricity price for private households are made up of levies and taxes. However, the renewable energy surcharge in Germany will be abolished for households from the second half of 2022 and in Austria in the years 2022 and 2023 (BMWK, 2022b, p. 2; e-control, 2022b).

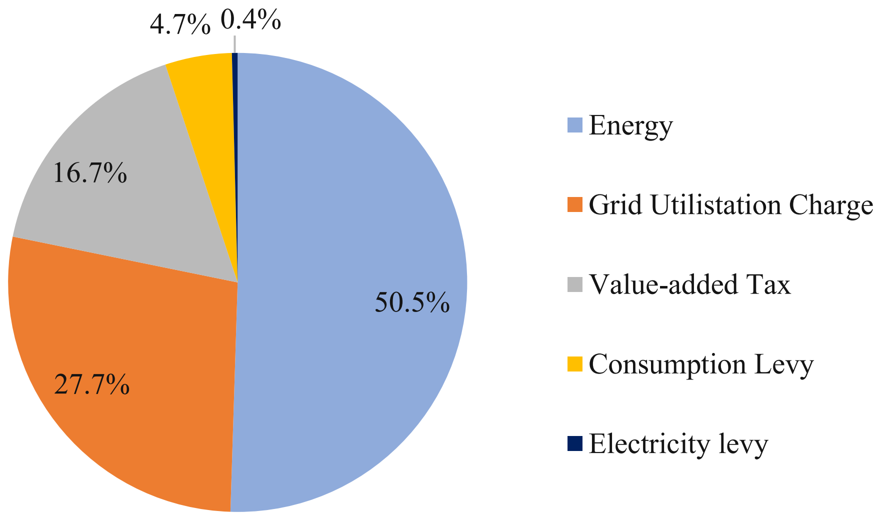

Figure 27: Composition of the electricity bill for households in Austria in 2022 in %, based on e-control and Oesterreichs Energie (2022)

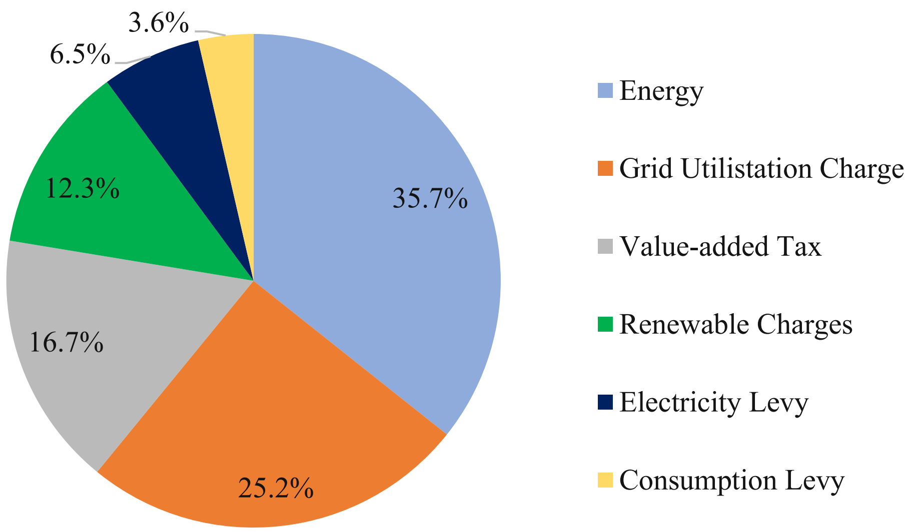

Figure 28: Composition of electricity bill for households in Austria 2021 in %, based on e-control and Oesterreichs Energie (2022)

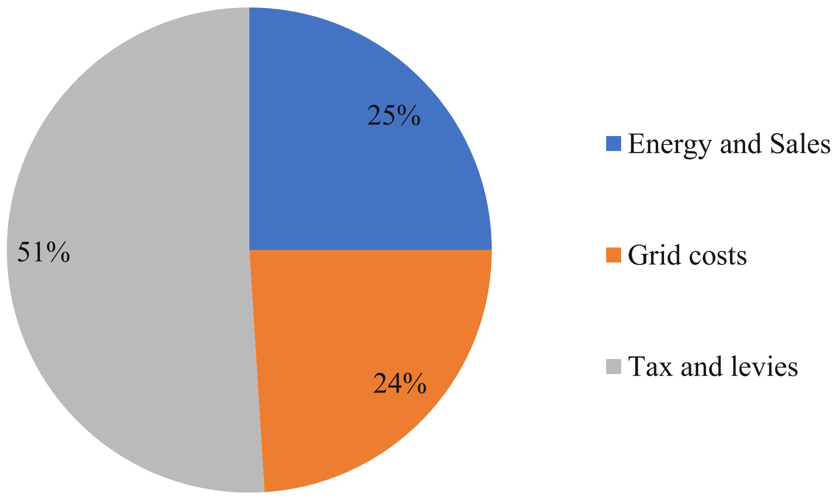

Figure 29: Composition of the average electricity price for a German household in 2021 in %, with annual consumption between 2,500 kWh and 5,000 kWh, based on Statistisches Bundesamt (2022b)

Figure 7 illustrated the dramatic increase of the wholesale electricity price in Austria and Germany in 2022. For instance, the average monthly wholesale electricity price in Austria was more than ten times higher in August 2022 than in July 2017 (SMARD, 2022).

Thus, it is difficult to estimate the value of the electricity price that is true for the next 20 years. It is uncertain how long the currently soaring energy prices will last and how the electricity price will develop related to the expansion of renewables.

The values for **household electricity prices** are oriented on the prices before the currently soaring energy prices in scenario 1. The values are taken from Eurostat (2022a) as of the **second half of 2021**, which are **0.32 €/kWh** for Germany and **0.23 €/kWh** for Austria. It is also inherently difficult to predict the development of future electricity prices. Especially building the infrastructure for the expansion of renewable energy, CO_2 prices will increase the electricity price. An annual **electricity price** increase of **3%** is assumed (Schmitt, 2022).

In the EAG investment grant scheme, the operator receives the investment grant and the remuneration for the feed-in electricity (contrary to the EEG, there is only operating support with the EEG market premium and EEG feed-in tariff and no investment support). For that, the operator must sign a purchase agreement with a utility company or the OeMAG. The OeMAG has an obligation to purchase at market prices if operators want to sign a contract with it; see also Sect. 13 and Sect. 41 Green Electricity Act (e-control, 2014, pp. 23-34; 67-68). The market price is published and calculated by the e-control according to Sect. 41 Green Electricity Act (e-control, 2014, pp. 66-67; e-control, 2022a). For the NPV calculation, the operator is assumed to sign a **purchase contract** with the **OeMAG that purchases at market prices**. For the NPV calculation, the result of Q3 2021, **0.078 €/kWh** (see Figure 30), is assumed for the remuneration for the feed-in electricity (e-control, 2022a).

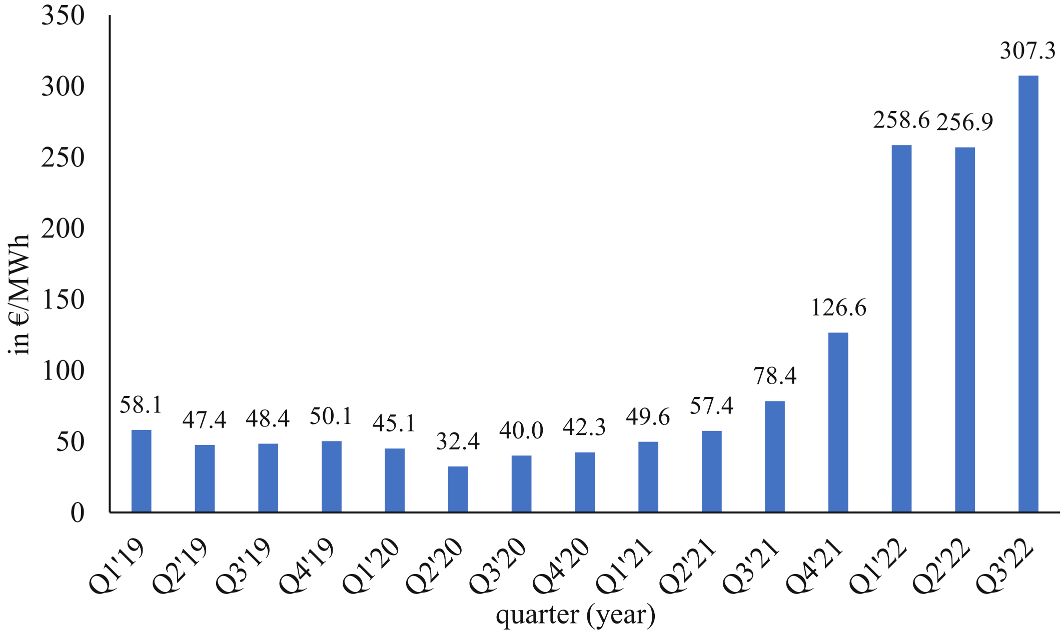

Figure 30: Development of the electricity market price in Austria (calculated according to Sect. 41 Green Electricity Act), based on e-control (2022a)

b. Determination of Subsidies

For the NPV calculations, three types of subsidies are relevant: **investment grant**, **market premium,** and **feed-in tariffs**. As mentioned above, only the investment grant and the market premium are available under the EAG, and only the market premium and feed-in tariff are available under EEG. So the only **mutual subsidy scheme** of both laws is the **market premium**.

The market premium values are based pursuant to the guaranteed prices of the EAG and EEG (see Table 8). As the maximum values of the guaranteed prices are determined via auctions, the assumed values for the NPV calculation are slightly below the maximum values – in particular, **0.1 ct/kWh**. Thus, the **guaranteed price** in Austria is assumed with **9.2 ct/kWh** (9.3 ct/kWh is the maximum value). Regarding Germany, **8.5 ct/kWh** are assumed for the 6 kWp installation (8.6 ct/kWh is the maximum value). Regarding the values for the 11 kWp installation in Germany, **8.4 ct/kWh** are assumed – the maximum value for the guaranteed price for the first 10 kWp is 8.6 ct/kWh, and for the next 40 kWp the maximum value is 7.5 ct/kWh – which ultimately equals to 8.5 ct/kWh (Bundesnetzagentur, 2022a).

Regarding the **EAG investment grant**, **285 €/kWp** are assumed for the 6 kWp solar PV installation. For the **11 kWp** solar PV installation, **250 €/kWp** are assumed (it falls under category B as it is larger than 10 kWp), which is based on the investment grant ordinance (Minister Gewessler, 2022a, pp. 4-5).

In Germany's EEG **feed-in tariff** case, **8.2 ct/kWh** are assumed for the **6 kWp** installation and **8.1 ct/kWh** for the **11 kWp** installation, which results from 8.2 ct/kWh for the first 10 kWp and 7.1 ct/kWh for the last 1 kWp (Bundesnetzagentur, 2022a).

Table 8: Comparison of the guaranteed prices of the EEG and EAG, based on Sect. 4 EAG market premium ordinance (Minister Gewessler, 2022b, p. 4) and Bundesnetzagentur (2022b)

	EAG Market Premium for 2022 and 2023	**EEG Market Premium until February 2024**	**EEG Feed-in tariff**
Maximum value for the guaranteed price (in ct/kWh)	9.33	-up to 10 kWp: 8.6 -up to 40 kWp: 7.5	-up to 10 kWp: 8.2 -up to 40 kWp: 7.1

c. Tax

As the operator makes a profit with the operation of the solar PV plant, tax-related questions might be raised. Regarding the NPV calculation for the operator of the solar PV installation in **Germany**, tax is not considered. Regarding solar PV installations smaller than 10 kWp, the German Federal Ministry generally assumes the operation of the plant as a ”hobby activity.” Therefore, there is **no income tax** and no commercial tax charged. In this regard, the operator only has to submit an application to the authorities in which he/she states that there is no intention to realize a profit beforehand (Bundesministerium der Finanzen, 2021, pp. 1-6; Verbraucherzentrale, 2022).

However, there is no general assumption for solar PV installations larger than 10 kWp. Therefore, the 11 kWp solar PV installation would not be covered. However, the German Bundestag decided in a resolution proposal in 2022 that the German government shall provide an amendment that those assumptions shall also apply to solar PV installations **larger than 30 kWp**. Therefore, it is assumed that the above-mentioned assumption also will apply to solar PV installations **of a capacity of up to 30 kWp** soon. Therefore, no income tax for the 11 kWp solar PV installation is considered as well. (Deutscher Bundestag, 2022, pp. 6-7; Willuhn, 2022)

Furthermore, **no value-added tax** is considered for the solar PV plant in Germany. The small business regulation (“Kleinunternehmerregelung”) applies to small businesses whose revenues do not exceed € 22,000 annually and may opt out of the value-added tax procedure. This right to opt out is applied in the NPV calculations. However, they need to pay the value-added tax that is included in the price for the purchase and installation of the solar PV plant. (Doormann, 2022)

Also, for **Austria**, no **income tax** is considered. Due to an amendment of the Austrian Income Tax Act, operators who feed in less than 12.500 kWh electricity with a solar PV installation smaller than 25 kWp do not pay income tax for the feed-in electricity; see Sect. 3 It. 39 Income Tax Act. (Essletzbichler, 2022, p. 18; BKA, 2022a, p. 18)

Regarding the **value-added tax**, there is also a “small business regulation” in **Austria**. Businesses whose revenues do not exceed € 35,000 annually can opt out of the value-added tax procedure (“Kleinunternehmer”); see Sect. 6 Para. 1 Item 27 Austrian VAT Act (BKA, 2022c, p. 15). Like for the solar PV installation in Germany, the right to opt-out is applied for the NPV calculation (Essletzbichler, 2022, p. 13). Another tax, the electricity duty, might also be relevant. However, generated electricity from solar PV is exempted from the electricity duty (Essletzbichler, 2022, p. 30).

4.2.2. Amendments for scenario 2 ("energy crisis" scenario)

The currently soaring electricity prices – and therefore the remuneration for the operator – are much higher than in scenario 1, assuming prices of 2021 (see Figure 7 and Figure 30). This has a significant influence as the operator receives a higher cash flow yearly if he/she can directly sell it on the electricity market. The remunerations exceed the guaranteed values for the market premium (see Figure 30 and Table 7).

Therefore, the values are adopted in **scenario 2**. The market price for **Q3 2022** in Austria, **30 ct/kWh**, is assumed as remuneration instead of the market premium for the operator (see Figure 30). It is assumed that the operator can achieve this relatively high value in the electricity market. This value is also applied to Germany as it is difficult to predict a specific price in a volatile situation in the electricity market. As this is a high value, the electricity price increase is set to **0%**.

In **scenario 2**, the market premium subsidy is not necessary, as the operator receives a higher revenue on the electricity market, which is higher than the guaranteed price (see Table 9). In this case, the market premium can only be seen as a "safety net" if the electricity price is lower than the guaranteed price.

The values for the EAG investment grant are assumed, like in scenario 1, based on the EAG investment grant ordinance 2022 (Minister Gewessler, 2022a, pp. 4-5).

For the household electricity price, 0.41 €/kWh are assumed in Austria, accessed in July 2022 (EVN, 2022). For Germany, the value is assumed with 0.38 €/kWh in **scenario 2**, accessed in September 2022 (Heidjann, 2022).

4.2.3. Amendments for scenario 3 ("pre-crisis scenario")

Furthermore, the average electricity price values from the second half of 2019 are assumed for the household electricity price and the electricity market price (as remuneration for the feed-in electricity in the EAG investment grant case) in scenario 3. It shall show the theoretical effects of the subsidies on the profitability of the solar

PV installation under "normal" circumstances before the Covid-19 crisis in 2020 and the soaring energy prices in Europe in 2022.

For **Austria**, in the investment grant case, the wholesale electricity price is assumed with **0.039 €/kWh** as remuneration for the feed-in electricity. This is the average value from July 2019 to December 2019 (SMARD, 2022). Regarding the **household electricity price**, **0.20 €/kWh** are assumed, which is the average value of the second semester of 2019 for the household electricity price (Eurostat, 2022a). The guaranteed values for the market premium are like in scenario 1.

The values for the EAG investment are the like in scenario 1 and scenario 2, based on the EAG investment grant ordinance 2022 (Minister Gewessler, 2022a, pp. 4-5).

For **Germany**, the household electricity price is assumed with 0.28 €/kWh, which is the average value of the second semester of 2019 for the household electricity price (Eurostat, 2022a). The values for the guaranteed price as the basis for the EAG market premium, the EEG market premium and for EEG feed-in tariff are the same as in scenario 1.

In scenario 3, the electricity price increase is assumed at 3%.

4.2.4. Summarized Parameters

Table 9 summarizes the parameters under scenario 1.

Table 9: Summarized parameters for the NPV calculations under scenario 1 (the different parameters for each capacity are highlighted in grey)

Parameters	Austria	Germany	Unit
Specific electricity yield	1,000	950	kWh/kWp/a
Capacity	6; 11	6; 11	kWp
Share of own consumption	6 kWp: 30 11 kWp: 20	6 kWp: 30 11 kWp: 20	%
Investment Grant *(only for the 6 kWp + 11 kWp installation in AT in the EAG Investment Grant case)*	6 kWp: 285 11 kWp: 250	-	€/kWp
Specific investment costs for the solar PV installation	6 kWp: 1,700 11 kWp: 1,500	6 kWp: 1,700 11 kWp: 1,500	€/kWp

Costs for the replacement of the inverter in year 13	6 kWp: 1,500 11 kWp: 2,200	6 kWp: 1,500 11 kWp: 2,200	€
O&M (including running costs and insurance)	1	1	%
Degradation (p.a.)	0.5	0.5	%
Inflation (p.a.)	2	2	%
Household electricity price (from the utility company)	0.23	0.32	€/kWh
Remuneration for the feed-in electricity from the OeMAG *(in the EAG investment grant ≙ wholesale electricity price)*	0.078	-	€/kWh
Guaranteed price *(for the EAG and EEG market premium)*	0.092	6 kWp: 0.085 11 kWp: 0.084	€/kWh
Feed-in tariff *(for the EEG feed-tariff)*	-	6 kWp: 0.082 11 kWp: 0.081	€/kWh
Electricity price increase (p.a.)	3	3	%
Discount rate	2.5	2.5	%

Table 10 summarizes the different parameters under scenario 2.

Table 10: Summarized relevant parameters for the NPV calculations under scenario 2

Parameters	Austria	Germany	Unit
Household electricity price (from the utility company)	0.41	0.38	€/kWh
Achieved market price for the feed-in electricity *(Remuneration in the EAG market premium, EEG market premium, and EAG investment grant cases)*	0.3	6 + 11 kWp: 0.3	€/kWh
Feed-in tariff *(for the EEG feed-in tariff)*	-	6 kWp: 0.082 11 kWp: 0.081	€/kWh
Investment Grant (*only for the 6 kWp + 11 kWp installation in AT in the EAG Investment Grant case*)	6 kWp: 285 11 kWp: 250	-	€/kWp
Electricity price increase (p.a.)	0	0	%

Table 11 summarizes the different parameters under scenario 3.

Table 11: Summarized relevant parameters for the NPV calculations under scenario 3

Parameters	Austria	Germany	Unit
Household electricity price (from the utility company)	0.2	0.28	€/kWh
Guaranteed price *(for the EAG and EEG market premium)*	0.092	6 kWp: 0.085 11 kWp: 0.084	€/kWh

Feed-in tariff *(for the feed-tariff scenario in GER)*	-	6 kWp: 0.082 11 kWp: 0.081	€/kWh
Remuneration for the feed-in electricity from the OeMAG (*for the EAG investment grant ≙ wholesale electricity price)*	0.039	-	€/kWh
Investment Grant (*only for the 6 kWp + 11 kWp installation in AT in the Investment Grant scenario*)	6 kWp: 285 11 kWp: 250	-	€/kWp
Electricity price increase (p.a.)	3	3	%

The EAG market premium is not applicable for solar PV installations smaller than 10 kWp; see Sect. 10 Para. 1 Item 3 EAG (e-control, 2022d, p. 11).

However, also **theoretical calculations** are conducted for the **6 kWp** solar PV installation with the guaranteed values according to the EAG market premium ordinance to evaluate if the EAG market premium should also be eligible for solar PV installations smaller than 6 kWp (Minister Gewessler, 2022b).

4.2.5. Interpretation of results

NPV calculations for residential solar PV installations with a capacity of 6 kWp and 11 kWp on a roof are conducted under the EAG and EEG support schemes. As explained with parameters throughout Chapter 4.2.1., a 4-person household operates the solar PV installation with a yearly electricity consumption of 4,800 kWh. The annual specific electricity yield is assumed with 1,000 kWh/kWp/a in Austria and 950 kWh/kWp/a in Germany. The specific investment costs for the solar PV installation are assumed with 1,700 €/kWp for the 6 kWp and 1,500 €/kWp for the 11 kWp installation. The costs for a new inverter in year 13 are assumed with € 1,500 for the 6 kWp installation and € 2,200 for the 11 kWp installation. An own consumption of 30% is assumed for the 6 kWp installations and 20% for the 11 kWp installations. Altogether, four subsidy schemes are applied in the NPV calculations: The EAG investment grant, the EAG market premium, the EEG market premium, and the EEG feed-in tariff. The results of the calculations for the NPV and the break-even points are presented according to each scenario (scenarios 1/2/3) and each capacity (6/11 kWp). The calculated NPV is the result after 20 years of operating the solar PV installation.

The results of the NPV calculations under the three scenarios are summarized in Table 12, Table 13, and Table 14. First, the results are presented in general and then in detail for the EAG and EEG.

Table 12: NPV and break-even point for the solar PV installations under ***scenario 1*** *(after 20 years of operation), based on Linz AG and Österreichische Energieagentur (2022)*

Scenario 1		
Solar PV system (6 kWp)	**Break Even Point (year)**	**NPV (€)** - *in year 20*
EAG Investment Grant (AT)	16	2,975
EAG Market Premium (AT)	*17* *not applicable - only for > 10 kWp installations; solely theoretical*	*2,411*
EEG Market Premium (GER)	15	4,086
EEG Feed-in Tariff (GER)	15	3,853

Solar PV system (11 kWp)	**Break Even Point (year)**	**NPV (€)** - *in year 20*
EAG Investment Grant (AT)	16	4,819
EAG Market Premium (AT)	17	4,470
EEG Market Premium (GER)	16	5,551
EEG Feed-in Tariff (GER)	16	5,062

Table 12 summarizes the results of the NPV calculations under **scenario 1**. The EEG market premium case is the most profitable scenario for both solar PV installations. By contrast, the EAG market premium for the 6 kWp installation shows the lowest NPV both for the 6 kWp and 11 kWp solar PV installation resulting in the longest payoff time. Even though the operator in Germany has a disadvantage due to less solar irradiance than in Austria, the revenues for the generated electricity from the solar PV installations are higher. This is due to the household electricity price and guaranteed price for the market premium, which is higher in Germany than in Austria. The operator in Germany saves more by not consuming electricity from the utility company and higher remuneration for the feed-in electricity.

Table 13: NPV and break-even point for the solar PV installations under ***scenario 2*** *(after 20 years of operation), based on Linz AG and Österreichische Energieagentur (2022)*

Scenario 2		
Solar PV system (6 kWp)	**Break Even Point (year)**	**NPV (€)** - *in year 20*
EAG Investment Grant (AT)	5	18,361
EAG Market Premium (AT)	6 *not applicable - only for > 10 kWp installations; solely theoretical*	16,651
EEG Market Premium (GER)	7	14,392
EEG Feed-in Tariff (GER)	18	1,402

Solar PV system (11 kWp)	**Break Even Point (year)**	**NPV (€)** - *in year 20*
EAG Investment Grant (AT)	5	34,478
EAG Market Premium (AT)	6	31,728
EEG Market Premium (GER)	6	28,147
EEG Feed-in Tariff (GER)	19	804

Table 13 summarizes the NPV calculations under **scenario 2**. In contrast to scenario 1, the EAG investment grant shows the highest NPV by far for the 6 kWp and 11 kWp installations. The operator profits in two separate ways. Firstly, by the investment grant and secondly, by the high remuneration of the feed-in electricity. The EEG feed-in tariff has the lowest NPV as the operator cannot profit from the high market prices.

Table 14: NPV and break-even point for the solar PV installations under ***scenario 3*** *(after 20 years of operation), based on Linz AG and Österreichische Energieagentur (2022)*

Scenario 3		
Solar PV system (6 kWp)	**Break Even Point (year)**	**NPV (€)** - *in year 20*
EAG Investment Grant (AT)	24	-1,270
EAG Market Premium (AT)	*18* *not applicable - only for > 10 kWp installations; only theoretical*	*1,358*
EEG Market Premium (GER)	17	2,753
EEG Feed-in Tariff (GER)	17	2,520

Solar PV system (11 kWp)	**Break Even Point (year)**	**NPV (€)** - *in year 20*
EAG Investment Grant (AT)	26	-3,156
EAG Market Premium (AT)	18	3,184
EEG Market Premium (GER)	17	3,921
EEG Feed-in Tariff (GER)	17	3,433

Table 14 shows the NPV calculations under **scenario 3**. Only in scenario 3 it is the case that the EAG investment grant shows a negative NPV after 20 years of operation. In scenario 3, the EAG subsidies show lower NPVs than those of the EEG subsidies. The EEG market premium has the highest NPV. This relates to Germany's higher household electricity price and lower remuneration in the EAG investment grant case. Scenario 3 also shows why the subsidies have been necessary in Austria so far as both Austrian subsidies show a low NPV.

Apart from the EAG and EEG, there is one significant difference. Austria has a better "starting position" – the solar irradiance. The yearly specific electricity yield for Austria is assumed with 1,000 kWh/kWp/a and 950 kWh/kWp/a in Germany, ultimately leading to a higher energy yield in Austria. (Wesselak et al., 2017, p. 96; Weiglhofer et al., 2016, p. 4).

A general conclusion of the NPV results is that, apart from the EEG feed-in tariff, the impact of the specific subsidies on the break-even point is relatively small. When selecting the subsidy scheme, an important aspect is whether the operator can profit from a higher market price, which is particularly the case with the market premium subsidies. However, the EEG feed-in tariff has one main advantage: it is a "safe" subsidy.

In contrast, regarding the market premium, there might be exceptional cases in which the operator does not receive the market premium, e.g., if there are negative electricity prices or if the operator sells at a lower price than the reference electricity price; see Sect. 15 EAG. (e-control, 2022d, p. 14)

It is a risk assessment of the operator if he/she wants a "safer" subsidy with the feed-in tariff or the market premium, which is slightly less safe. However, selecting the market premium over the feed-in tariff is recommended in times of soaring energy prices. Even if there are periods of negative electricity prices, there is a high chance that those losses can be compensated, as it can be assumed that there will be periods of high electricity prices again during the operation time of 20 years. Furthermore, the investment grant is, like the feed-in tariff, relatively independent from the electricity market conditions.

Regarding Austria, the main point when selecting the EAG investment grant or the EAG market premium is the difference between the guaranteed price and the electricity market price (as remuneration under the EAG investment grant). The more significant the difference between the usually higher guaranteed price (except in scenario 2) and the remuneration, the more profitable the EAG market premium case is. Especially this is the case in scenario 3. In this scenario, the guaranteed price is twice as great as the remuneration in the EAG investment grant case.

However, it is estimated that guaranteed prices and market electricity prices will converge. One reason is that solar PV installations will become cheaper (Haas et al., 2023, p. 4). The guaranteed value is a value that shall enable a feasible and economic operation of the solar PV installation (Janisch, 2021, p. 9). Therefore, also the investment costs for the installation of the solar PV plant are important in this aspect. If solar PV technology becomes even more cheaper, then guaranteed values will also decrease as they relate to the profitability of the solar PV installation. Subsidy policies and the regulation of guaranteed prices can change and will probably adapt to current market prices and market conditions (see Sect. 30 and Sect. 31 EAG). In Austria, this is done by the responsible ministers by ordinance (e-control, 2022d, p. 18).

Closely related to the convergence of guaranteed prices and market electricity prices is the question of the **extension of the EAG market premium for solar PV installations smaller than 10 kWp**. In this regard, one important aspect is that in the EAG market premium auction, there are no separate auctions for small, medium, or large solar PV installations, which was already criticized by PV Austria, the Austrian solar PV association. For instance, an operator of a 15 kWp solar PV installation must participate in the same tender as an operator of a 500 kWp solar PV installation (Energiegemeinschaft, 2021). Furthermore, operators of large solar PV projects can compete at a much lower guaranteed price than operators of smaller solar PV installations. So, it is likely that operators of small-scale installations will not succeed in the auctions for the guaranteed prices with very low values, which probably makes the operation of small-scale solar PV installations not economically feasible. In fact, this would be a challenging market condition for the private household as an operator. Additionally, there is probably an increased administrative effort associated with the

EAG market premium for the operator as he/she has to directly sell the electricity on the market.

Out of three scenarios, in only one scenario, scenario 3, the EAG market premium is more profitable than the EAG investment grant. Scenario 3 is a scenario that assumes past values of 2019 contrary to the scenarios 1 and 2, which are "more future-oriented" and probably rather depict the future development of market conditions. In scenarios 1 and 2, the EAG investment grant is more profitable than the EAG market premium. Considering all those arguments, extending **the EAG market premium to solar PV installations smaller than 10 kWp is not recommended**.

Using the NPV approach is considered the proper calculation method for the profitability of solar PV installations and support schemes. The support scheme cases with the highest NPV also show the earliest amortization time. (Linz AG and Österreichische Energieagentur, 2022)

a. EAG results

The investment costs for the solar PV installation in year 0 make up a major part of the total expenses in the 20 years of operation. The cash flows in the years 1 to 20 are composed of the savings and the remuneration of the generated electricity (as revenues) and the costs for O&M (as expenses). In year 13, the costs for the new inverter are added to the expenses. The cash flows are discounted with a discount rate of 2.5%.

The **EAG investment grant** for the 6 kWp solar PV installation is assumed with 285 €/kWp and the 11 kWp solar PV installation with 250 €/kWp (see Table 3). The remuneration for the feed-in electricity is assumed with 0.078 €/kWh.

In the **EAG market premium** scheme, the market premium is assumed with 0.092 €/kWh for the feed-in electricity.

Scenario 1

Table 15: Relevant parameters for the EAG support schemes under ***scenario 1***

Parameters	**Austria**	**Unit**
Household electricity price (from the utility company)	0.23	€/kWh
Remuneration for the feed-in electricity from the OeMAG *(for the EAG investment grant ≙ wholesale electricity price)*	0.078	€/kWh
Guaranteed price *(for the EAG market premium)*	0.092	€/kWh
Investment Grant *(only in the EAG investment grant case)*	6 kWp: 285 11 kWp: 250	€/kWp
Electricity price increase (p.a.)	3	%

The values of **scenario 1** are based on the household electricity price of the second half of 2021 (Eurostat, 2022a). For the remuneration for the feed-in electricity, 0.078 €/kWh is assumed, which is the market price of Q3 2021 (e-control, 2022a). The guaranteed price for calculating the EAG market premium is assumed with 0.092 €/kWh (see Table 15) according to EAG market premium ordinance (Minister Gewessler, 2022b, p. 4).

In **scenario 1**, the EAG subsidies show a lower NPV (see Table 12) than the EEG results. The theoretical EAG market premium has the lowest NPV for both capacities, followed by the EAG investment grant. The break-even points range from 15 to 17 years in scenario 1.

The reason for the lower NPV and later amortization compared to the EEG subsidies is that the household electricity price in Austria is **0.09 €/kWh lower** than in Germany. Therefore, the operator in Germany automatically saves more money by generating electricity.

Even though Austria shows a **higher specific electricity yield with 50 kWh/kWp/a** than Germany and in the market premium cases Austria also has a **0.007 €/kWh higher** guaranteed price (see Table 9), the NPV is higher in Germany. The high household electricity price in Germany makes the difference why the EEG cases are more profitable and have a shorter pay-back period in scenario 1.

Scenario 2

Table 16: Relevant parameters for the EAG support schemes under ***scenario 2***

Parameters	**Austria**	**Unit**
Household electricity price (from the utility company)	0.41	€/kWh
Achieved market price for the feed-in electricity *(Remuneration in the EAG market premium and EAG investment grant cases)*	0.3	€/kWh
Investment Grant *(only in the EAG investment grant case)*	6 kWp: 285 11 kWp: 250	€/kWp
Electricity price increase (p.a.)	0	%

In **scenario 2**, the household electricity is assumed with 0.41 €/kWh, which was the household electricity offered by EVN (2022) in July 2022 in Austria. The achieved market price as remuneration for the feed-in electricity of 0.3 €/kWh (see Table 16) is the market price in Austria in Q3 2022 (e-control, 2022a). The values for the investment grant are based on the EAG investment grant ordinance 2022 (Minister Gewessler, 2022a, pp. 4-5).

The EAG subsidies in **scenario 2** show the shortest pay-back period and highest NPV of all scenarios. Generally, the break-even points for the EAG subsidies in scenario 2 range from 5 to 6 years.

In the **EAG investment grant** cases for the 6 kWp and 11 kWp installations, it is assumed that the operator receives the market price (0.3 €/kWh) as remuneration for the feed-in electricity; see the obligation to purchase at market prices pursuant to Sect. 13 Green Electricity Act (e-control, 2014, pp. 22-23). So the operator profits both from the high electricity prices and the investment grant. The NPV for the 6 kWp solar PV installation in the investment grant case is € 18,361 and has a pay-back period of only 5 years. The NPV for the 11 kWp solar installation shows the highest NPV with € 34,478 and has a pay-back period of only 5 years as well (see Table 16).

Generally, in the **EAG market premium** (and also EEG market premium) cases, the operator receives the assumed guaranteed price for the feed-in electricity (e.g., in scenario 1). If the market price is higher than the guaranteed price – as it is the case in scenario 2 – the market price is assumed for the remuneration for the feed-in electricity (see Table 10). Here, the market premium just acts as a safety net in case the (reference) market price drops below the guaranteed price. Compared to the EAG investment grant cases, the only difference is that the operator does not receive the investment grant for the solar PV installation in the market premium cases.

Additionally, the EAG investment grant and the EAG market premium cases show the highest NPV for the 11 kWp installation. In scenario 2, the remuneration for the feed-in electricity is the highest of all scenarios. In this respect, the market premium can only be seen as a “safety net” in case the (reference) market price drops below the guaranteed price. In the EAG investment grant case, the operator profits both from the investment grant and the high market prices. In the market premium case, the operator only profits from the high market price.

Scenario 3

Table 17: Relevant parameters for the EAG support schemes under ***scenario 3***

Parameters	**Austria**	**Unit**
Household electricity price (from the utility company)	0.2	€/kWh
Guaranteed price *(for the EAG market premium)*	0.092	€/kWh
Remuneration for the feed-in electricity from the OeMAG (*in the EAG investment grant; ≙ wholesale electricity price)*	0.039	€/kWh
Investment Grant *(only in the EAG investment grant case)*	6 kWp: 285 11 kWp: 250	€/kWp
Electricity price increase (p.a.)	3	%

In **scenario 3**, values of the second half of 2019 are assumed for the household electricity price and for the remuneration for the feed-in electricity (in the EAG investment grant case). For the household electricity price, 0.2 €/kWh are assumed. It equals the average value of household electricity prices in Austria in the second semester of 2019 (Eurostat, 2022a). For the remuneration of the feed-in electricity, 0.039 €/kWh are assumed, which equals the average of the wholesale electricity price from July 2019 until December 2019 (SMARD, 2022). The guaranteed price of 0.092 €/kWh is based on the EAG market premium ordinance 2022, like in the scenarios 1 and 2 (Minister Gewessler, 2022b, p. 4). The values for the investment grant are based on the EAG investment grant ordinance 2022; see Table 17 (Minister Gewessler, 2022a, pp. 4-5).

In scenario 3**,** the EAG investment grant shows the longest pay-back period with 24 years for the 6 kWp solar PV installation and 26 years for the 11 kWp installation. It also has the lowest NPV with € -1,270 for the 6 kWp installation and € -3,156 for the 11 kWp installation. The (theoretical) EAG market premium case for the 6 kWp solar PV installation is positive with an NPV of € 1,358. Under the EAG market premium for the 11 kWp installation, the NPV is € 3,184. The break-even points of the EAG subsidies range from year 18 to 26 years. Summing up, the EAG subsidies have the lowest performance under scenario 3.

b. EEG results

As in the calculations under the EAG scheme, the major expenses are the investment costs for the solar PV installation in year 0. The composition of the cash flows and the economic parameters (e.g., inflation and electricity price increase) is the same as in the calculations for the EAG.

In the **EEG market premium** scheme, the guaranteed price is assumed with 0.085 €/kWh for the 6 kWp installation and 0.084 €/kWh for the 11 kWp installation. The **EEG feed-in tariff** is assumed with 0.082 €/kWh for the 6 kWp installation and 0.081 €/kWh for the 11 kWp installation. In scenario 2, the achieved market price is assumed with 0.3 €/kWh as remuneration for the feed-in electricity in the EEG market premium case. (see Chapter 4.2.4.)

Scenario 1

Table 18: Relevant parameters for the EEG support schemes under ***scenario 1***

Parameters	Germany	Unit
Household electricity price (from the utility company)	0.32	€/kWh
Guaranteed price *(for the EEG market premium)*	6 kWp: 0.085 11 kWp: 0.084	€/kWh
Feed-in tariff *(for the EEG feed-in tariff)*	6 kWp: 0.082 11 kWp: 0.081	€/kWh
Electricity price increase (p.a.)	3	%

In **scenario 1**, the value for the household electricity price of 0.32 €/kWh is based on the average value of the second half of 2021 (Eurostat, 2022a). The guaranteed prices, 0.085 €/kWh for the 6 kWp installation and 0.084 for the 11 kWp installation, are based on Bundesnetzagentur (2022a), which is 0.1 ct/kWh lower than the maximum guaranteed prices at the end of 2022. Also, the feed-in tariffs of 0.082 €/kWh for the

6 kWp installation and 0.081 €/kWh for the 11 kWp installation are based on Bundesnetzagentur (2022a); they are also referred to the end of 2022 (see Table 18).

In scenario 1, the NPV values of the EEG subsidies are close to one another and all higher than the EAG subsidies. The break-even points for the EEG subsidies range from 15 to 16 years. The EEG market premium case shows the highest NPV for both capacities and the shortest pay-back period (see Table 12). The 6 kWp solar PV installation shows an NPV of € 4,086 under the EEG market premium and an NPV of 3,853 €/kWh under the EEG feed-in tariff. In the 11 kWp installation calculation, the NPV is € 5,551 under the EEG market premium and € 5,062 under the EEG feed-in tariff.

Scenario 2

*Table 19: Relevant parameters for the EEG support schemes under **scenario 2***

Parameters	Germany	Unit
Household electricity price (from the utility company)	0.38	€/kWh
Achieved market price for the feed-in electricity *(Remuneration in the EEG market premium cases)*	6 + 11 kWp: 0.3	€/kWh
Feed-in tariff *(for the EEG feed-in tariff)*	6 kWp: 0.082 11 kWp: 0.081	€/kWh
Electricity price increase (p.a.)	0	%

The household electricity price is based on the values of September 2022 in Germany. The achieved market price for the feed-in electricity is assumed with 0.3 €/kWh. This value is also assumed in Austria, which was the market price in Austria in Q3 2022; see Figure 30 and Table 19 (e-control, 2022a). The values for the EEG feed-in tariff are based on the EEG feed-in tariffs published at the end of 2022 (Bundesnetzagentur, 2022a).

In contrast, the NPVs and pay-back period under the EEG subsidies in **scenario 2** differ from each other significantly. For the 6 kWp solar PV installation, the NPV under the EEG market premium is 14,392 €/kWh with a break-even point in year 7. In contrast, under the EEG feed-in tariff, the 6 kWp solar PV installation has an NPV of 1,402 €/kWh and a break-even point in year 18. The NPV for the 11 kWp installation is € 28,147, with a break-even point in year 6 under the EEG market premium. Under the EEG feed-in tariff, the NPV is € 804 and the break-even point is in year 19. Altogether, the break-even points range from 6 years to 19 years. The significant difference of the values can be explained by the fact that the operator does not profit from the high electricity prices in the feed-in tariff scheme – in contrast to the market premium scheme, in which the operator directly sells electricity at the market.

Scenario 3

Table 20: Relevant parameters for the EEG support schemes under ***scenario 3***

Parameters	Germany	Unit
Household electricity price (from the utility company)	0.28	€/kWh
Guaranteed price *(for EEG market premium)*	6 kWp: 0.085 11 kWp: 0.084	€/kWh
Feed-in tariff *(for the EEG feed-in tariff)*	6 kWp: 0.082 11 kWp: 0.081	€/kWh
Electricity price increase (p.a.)	3	%

The household electricity price is assumed with 0.28 €/kWh, which is a value that refers to the second semester of 2019 (Eurostat, 2022d). The guaranteed prices are the same as in scenario 1 and based on Bundesnetzagentur (2022a) published at the end of 2022.

In **scenario 3**, the NPV for the 6 kWp installation under the EEG market premium is € 2,753 and for the 11 kWp installation € 3,921. Both cases show a break-even point in year 17. Regarding the EEG feed-in tariff, the 6 kWp solar PV installation shows an NPV of € 2,520 and the 11 kWp installation of € 3,433. The break-even points for the 6 kWp and 11 kWp under the EEG subsidies are in year 17 (see Table 20).

c. Evaluation of the solar PV investments under the different support measures of the EAG and EEG

The following figures – Figure 31 to Figure 36 – show the development of the NPV under each scenario and capacity from year 0 to year 20.

Figure 31 shows the development of the NPV for the **6 kWp** installation under **scenario 1**. At the beginning of the operation, the EAG investment grant naturally has the highest NPV as the operator receives the investment grant as a lump sum payment. However, due to the higher remuneration in the EEG feed-in tariff and EEG-market premium cases, they show a higher NPV after 20 years of operation. The NPV under the theoretical EAG market premium for the 6 kWp installation shows the lowest NPV.

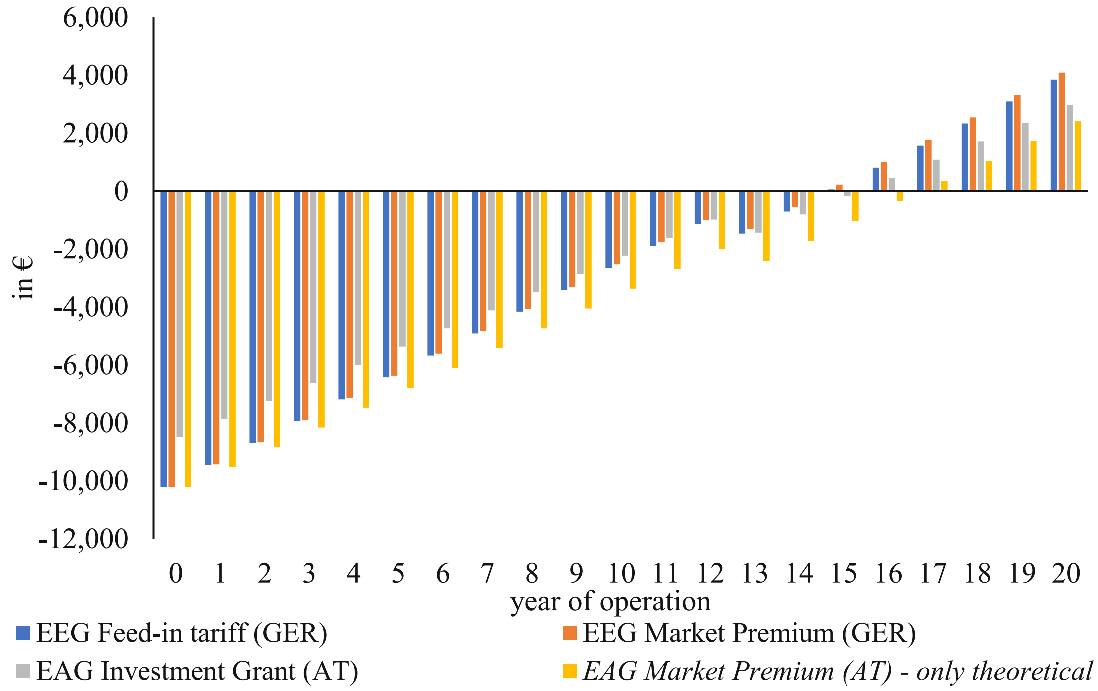

Figure 31: Results of the development of the NPV for the 6 kWp solar PV installation under scenario 1, based on Linz AG and Österreichische Energieagentur (2022)

Figure 32 shows the development of the **11 kWp** plant in **scenario 1**. The EAG market premium case shows the lowest NPV at the operation's beginning and end. There are two main reasons: the low remuneration for the feed-in electricity and the operator does not receive a lump sum payment. Like for the 6 kWp installation, the EAG market premium shows the lowest NPV for 11 kWp installation.

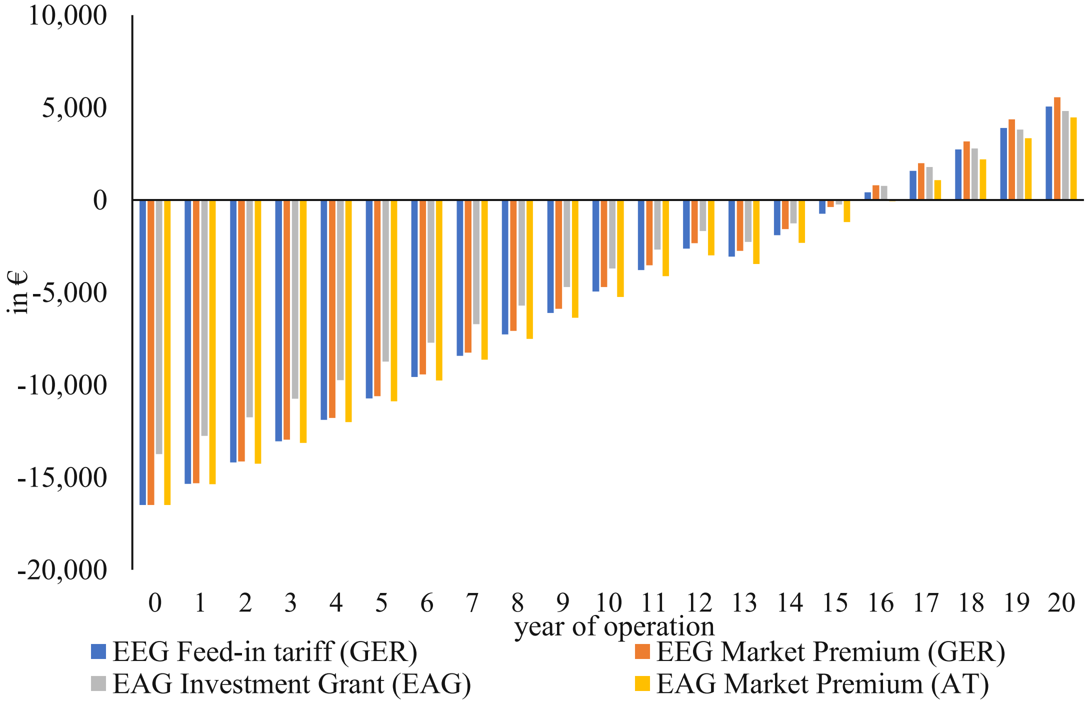

Figure 32: Results of the development of the NPV for the 11 kWp solar PV installation under scenario 1, based on Linz AG and Österreichische Energieagentur (2022)

Figure 33 shows the development of the NPV for the **6 kWp** installation under **scenario 2**. From the construction until the end of the operation time, the EAG investment grant case shows the highest NPV. As already referred above, this is due to the investment support as a lump sum at the beginning and the operator also profits from the high remuneration from the electricity market prices. The EEG feed-in tariff case shows the lowest NPV by far; it is slightly profitable with an NPV of € 1,402 after 20 years of operation. The EEG market premium is higher than in scenario 1 as the parameters for the household electricity price and the remuneration for the feed-in electricity are higher. The theoretical EAG market premium shows the second-highest NPV. This is due to the high remuneration for the feed-in electricity and saving of household electricity from the utility company.

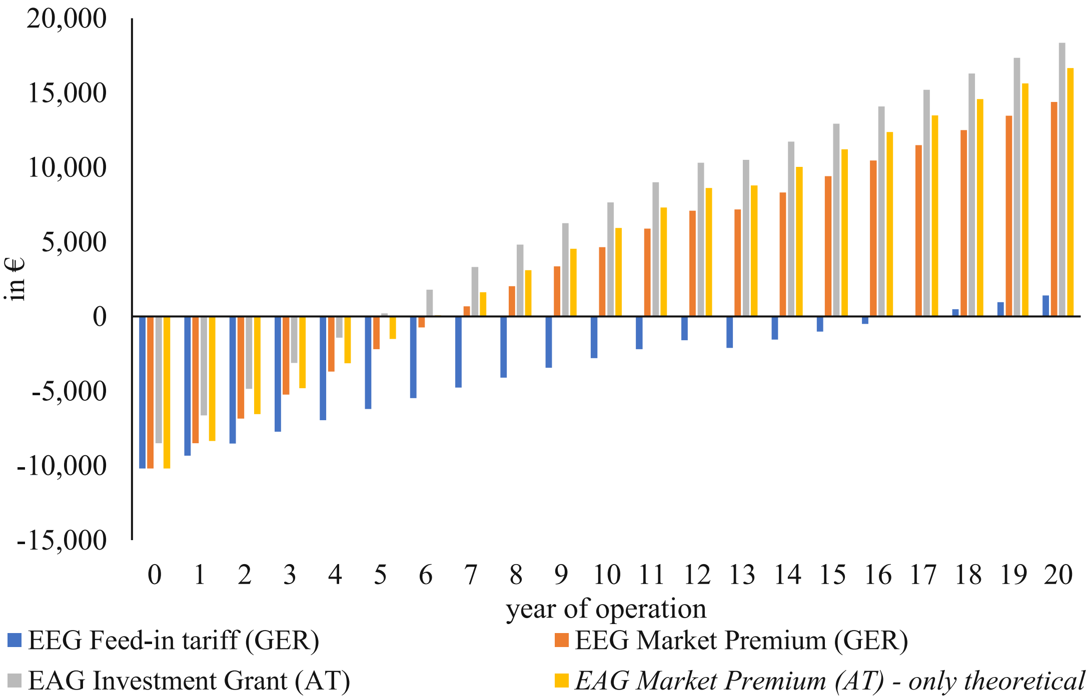

Figure 33: Results of the development of the NPV for the 6 kWp solar PV installation under scenario 2, based on Linz AG and Österreichische Energieagentur (2022)

The explanations of Figure 33 are also true for **Figure 34**, which shows the development of the NPV for the **11 kWp** solar PV installation under **scenario 2**. The NPV in the EAG market premium case is also high. It is not as high as in the EAG investment grant case as the operator does not receive a lump sum payment at the beginning of the operation. The NPV of the EAG market premium is higher than the NPV of the EEG market premium as a higher specific electricity yield is assumed for Austria. In both cases, the same value for the remuneration of the feed-in electricity is assumed. The operation under the EEG feed-in tariff case is hardly profitable with an NPV of € 804.

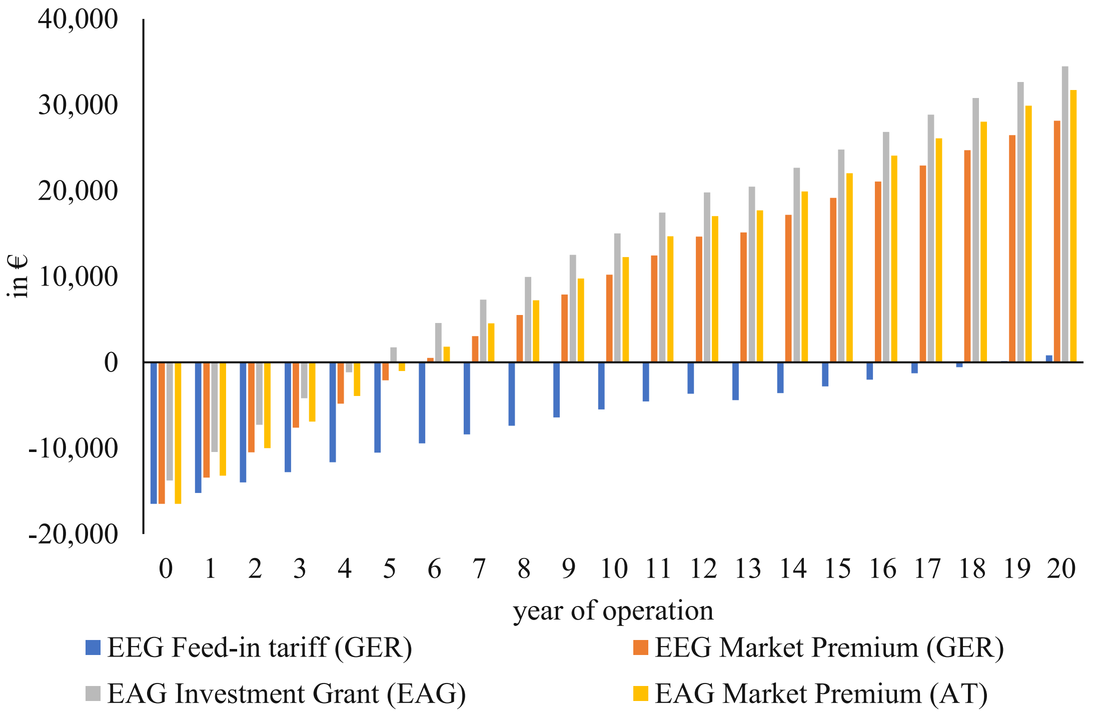

Figure 34: Results of the development of the NPV for the 11 kWp solar PV installation under scenario 2, based on Linz AG and Österreichische Energieagentur (2022)

Figure 35 shows the development of the NPV for the **6 kWp** solar installation under **scenario 3**. Here, the EEG market premium is the most profitable case, whose NPV is slightly higher than the NPV of the EEG feed-in tariff. One reason for this is that the household electricity price is higher than in Austria, so the operator saves more money by generating electricity in Germany. The guaranteed price under the EAG market premium is slightly higher than under the EEG market premium price. As the German household electricity price is significantly higher than the Austrian household electricity price, the yearly revenue for the generated electricity is higher in the EEG market premium case. The EAG investment grant case shows the lowest NPV. Even after 20 years of operation, the NPV is negative. This is related to the relatively low remuneration for the feed-in electricity. Scenario 3 is the only scenario in which the EAG market premium shows a higher NPV than the EAG investment grant. This is related to the low remuneration for the feed-in electricity under the EAG investment grant case (0.039 €/kWh for the remuneration in the EAG investment grant case, under the EAG market premium the guaranteed price is 0.092 €/kWh; see Table 11).

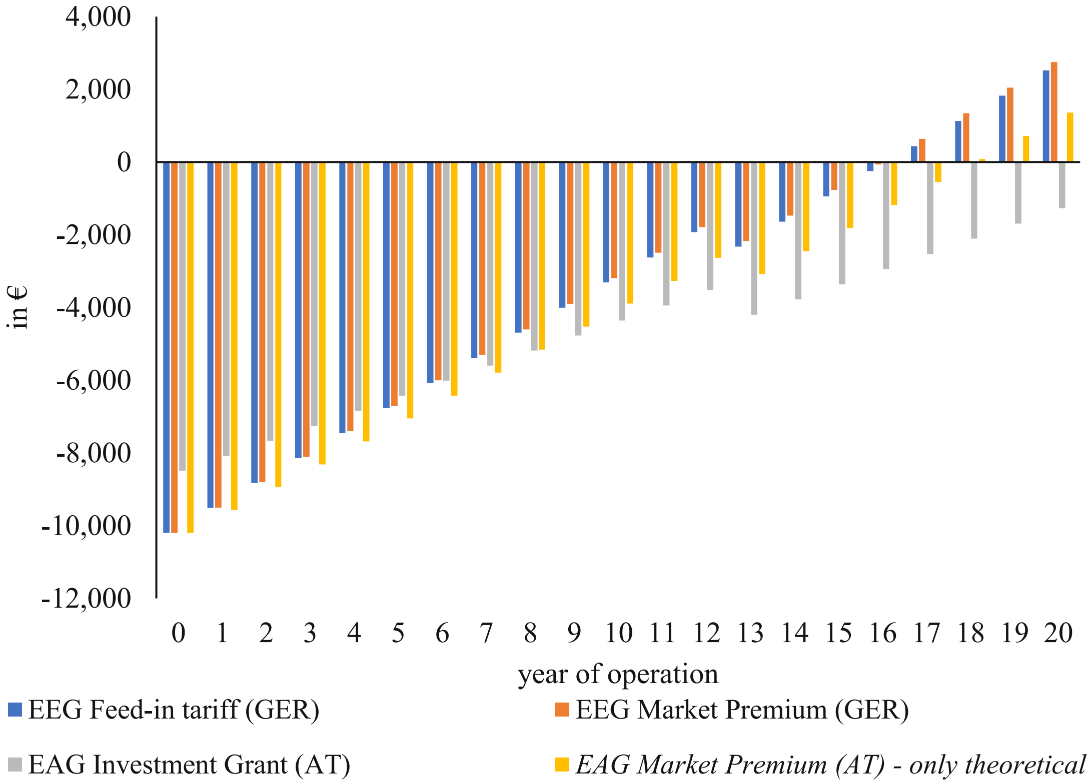

Figure 35: Results of the development of the NPV for the 6 kWp solar PV installation under Scenario 3, based on Linz AG and Österreichische Energieagentur (2022)

Figure 36 illustrates the results of the development of the NPV for the **11 kWp** solar PV installation under **scenario 3**. The explanations for Figure 35 also apply to Figure 36. The NPVs of the EEG market premium, the EEG feed-in tariff, and the EAG market premium cases are closer to each other than in the 6 kWp calculation as the mixed tariffs (as the basis for the yearly revenue) are also closer to each other. This is due to the lower guaranteed values for larger solar PV installations under the EEG. Like in the 6 kWp calculation, the NPV in the EAG investment grant case is negative due to the low remuneration for the feed-in electricity. The explanations for the EAG market premium for the 6 kWp installation under scenario 3 do also apply here for the 11 kWp installation.

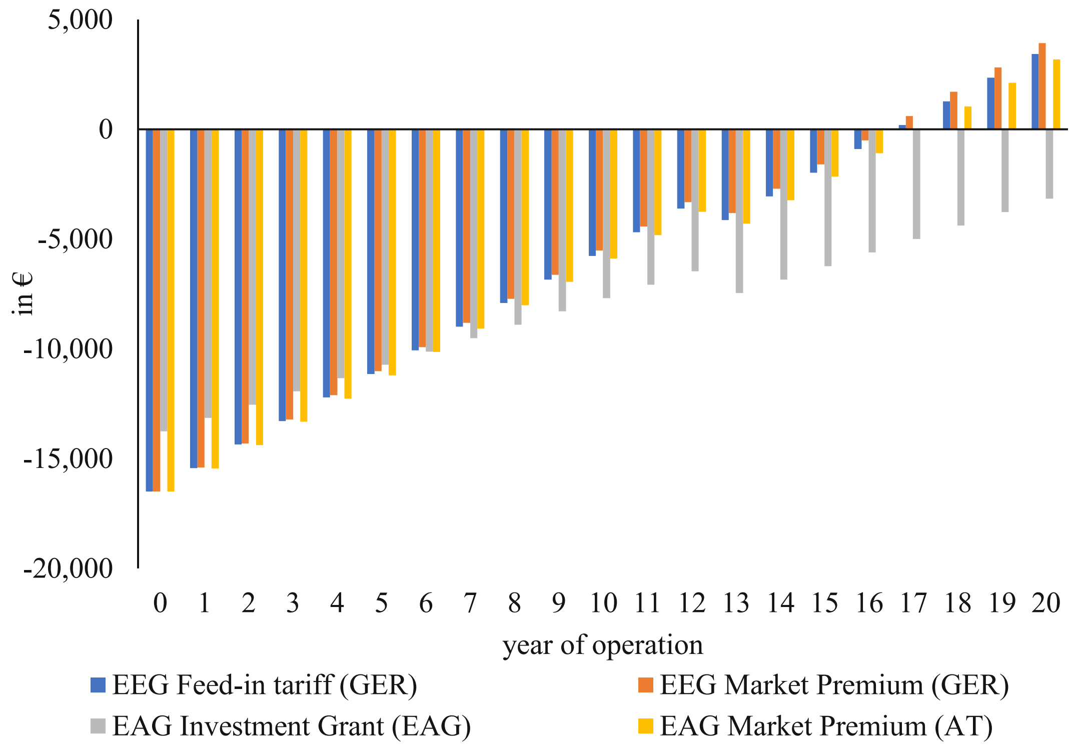

Figure 36: Results of the development of the NPV for the 11 kWp solar PV installation under scenario 3, based on Linz AG and Österreichische Energieagentur (2022)

Summing up, if **scenario 1** is applied, the EEG market premium shows the highest NPV and shortest pay-back period for both capacities. For the household electricity price 0.32 €/kWh and for the guaranteed price 0.085 €/kWh (6 kWp) respectively 0.084 €/kWh (11 kWp) are assumed. In contrast, the EAG market premium case shows the lowest NPV and longest pay-back period assuming a household electricity price with 0.23 €/kWh and a guaranteed price with 0.092 €/kWh. In scenario 1, an annual electricity price increase of 3% is assumed.

In **scenario 2**, the EAG investment grant case shows the highest NPV and the shortest pay-back period for both capacities. In the EAG investment grant case, 0.41 €/kWh are assumed for the household electricity price and 0.3 €/kWh for the achieved market price. The EEG feed-in tariff case shows the lowest NPV and the longest pay-back period assuming a household electricity price of 0.38 €/kWh and a feed-in tariff of 0.082 €/kWh (6 kWp) respectively 0.081 €/kWh (11 kWp). In this scenario, an annual electricity price increase of 0% is assumed.

In **scenario 3**, the EEG market premium shows the highest NPV and the shortest pay-back period. In the EEG market premium case, 0.28 €/kWh are assumed for the household electricity price and for the guaranteed price 0.085 €/kWh (6 kWp) respectively 0.084 €/kWh (11 kWp). In contrast, the EAG investment grant case shows the lowest NPV and longest pay-back period assuming 0.2 €/kWh for the household electricity price, 0.039 €/kWh as remuneration for the feed-in electricity, and 285 €/kWp (6 kWp) respectively 250 €/kWp (11 kWp) for the investment grant. In this scenario, an annual electricity price increase of 3% is assumed.

5. Conclusions

In general, Austria and Germany have similar support schemes with the EAG and the EEG. Austria aims to generate 100% of its electricity supply from renewables by 2030 and become climate neutral by 2040. Germany aims to generate 80% of its electricity supply by renewables by 2030 and become climate neutral by 2045.

EU policies influence the EAG and EEG. Closely related to this is the introduction of the market premium in the EAG, which is a more market-integrating tool than feed-in tariffs. The EU Commission also favors them as a subsidy tool for the expansion of renewable technologies. Another commonality is that the EAG – as the younger law – partly adopts technical terms from the EEG, e.g., the guaranteed price ("Anzulegender Wert"). Furthermore, the calculation of the market premium is similar to the EEG. Both in the EAG and EEG, the operator of the solar PV installation receives the market premium throughout 20 years of operation.

A significant difference is that the EEG provides for feed-in tariffs and market premiums as operating support, whereas the EAG only provides for market premiums and investment grants. However, keeping the feed-in tariffs of the Green Electricity Act in the new EAG, at least for small-scale solar PV installations, would have generally been compatible with EU law. In Austria, only solar PV installations larger than 10 kWp are entitled to market premiums; in contrast, the EEG market premiums do not require a minimum capacity. Those installations might be excluded in the EAG because operators shall be motivated to apply for the investment grant. On the other hand, the value of the market premium in the EEG depends on the capacity of the solar PV installation. In contrast, the EAG only provides a coherent market premium.

Contrary to the investment grant in the EAG, there is not any kind of investment support available under the EEG. Even the EU Commission is in favor of investment support mechanisms for the expansion of renewables. More importantly, the investment support does not have an impact on operating costs and therefore does not interfere with the price setting in energy markets.

As electricity prices have been highly volatile in recent months, it is difficult to predict the affordability and the break-even point of residential solar PV installation on a roof. Therefore, a case study with three different scenarios for a 6 kW and an 11 kW solar PV use case was conducted: **scenario 1** (average electricity prices of the second half of 2021 – mid-Covid-Crisis), **scenario 2** (average electricity prices of the second half of 2022 – energy crisis), and **scenario 3** (average electricity prices of the second half of 2019 – pre-crisis). The results of the three NPV calculation scenarios are quite different and show different break-even points.

When selecting the proper subsidy for a solar PV installation, the operator must be aware of their interrelation – the subsidies can be based on reaction to the market and also influence the market. This is underlined by the results in the NPV calculations of the different scenarios whose parameters differ widely. Especially nowadays, when electricity prices are highly volatile, it is crucial to select the proper subsidy to benefit from those market conditions. Overall, the NPV calculation method is considered the right tool to estimate the profitability of solar PV installations. The solar PV installations with the highest NPV show the earliest pay-back period.

In **scenario 1**, both the 6 kWp and 11 kWp solar PV installations that receive the EEG market premium show the highest NPV. This is mainly related to the high household electricity costs, which are higher in Germany than in Austria. In **scenario 2**, both the 6 kWp and 11 kWp solar PV installations that receive the EAG investment grant show the highest NPV since electricity prices are exorbitantly high. So the operator benefits both from the grant for the investment at the beginning and from the high electricity prices. In scenario 2, the operating support schemes, such as the market premiums and the feed-in tariffs, only provide a safety net. In this scenario, the market price is higher than the guaranteed prices and feed-in tariffs. In **scenario 3**, the EEG market premium cases show the highest NPV both for the 6 kWp and 11 kWp solar PV installations. Similar to scenario 1, Germany's higher household electricity price is the reason for this. In both EAG investment grant cases, the NPV is negative after 20 years and therefore would not support the investment to be feasible.

From the investigations throughout this work, it is concluded that the extension of the EAG market premium to solar PV installations smaller than 10 kWp is not recommended, especially as it is expected that guaranteed prices and electricity market prices (as remuneration in the EAG investment grant case) will further converge.

Becoming aware of the inherently contradictory development of the decreasing subsidies on the one hand and the ambitious climate targets on the other hand was crucial while conducting the research. However, the soaring electricity prices function as a type of subsidy for the feed-in electricity and, at the same time, decrease the own electricity bill through own consumption, which ultimately increases the NPV of the solar PV investment.

The guaranteed prices in both countries are exceptionally low from a historical point of view, contrary to the electricity prices of 2022, which are exceptionally high. In 2012, the feed-in tariffs in Germany were at approximately 19 ct/kWh and in Austria, they were at approximately 36 ct/kWh (including consideration of investment support). In 2019, the remuneration for green electricity in Germany was below 10 ct/kWh, and in Austria was at approximately 20 ct/kWh. Now with the new EEG 2023 and the new EAG, the maximum guaranteed prices, as a basis for calculating the market premiums, are 8.6 ct/kWh in Germany and 9.3 ct/kWh in Austria – which are low values for the maximum guaranteed prices as well.

With the current market situation referring to scenario 2, it is **recommended** that residential solar PV operators in Austria choose the EAG investment grant instead of the EAG market premium. By doing so, the operator profits from the high electricity price and receives a grant for his solar PV installation. Regarding Germany, as of 2022, it is recommended to prefer the EEG market premium over EEG feed-in tariff as the operator profits from high electricity market prices.

From an economic perspective, current market conditions make a solar PV installation attractive, specifically with the current available EAG investment grant or EEG market premium. As the guaranteed prices in both countries are low, the market premiums just act as safety nets. It remains open how private households will deal with those circumstances and if they are encouraged to acquire a solar PV installation. Apart from the important financial viability, also the allocation of the financial risk, legal requirements (e.g., approval procedures), and psychological reasons (e.g., desire for energy self-sufficiency or leading a sustainable lifestyle) play a crucial role among other things.

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List of Tables

List of Figures

List of Abbreviations

app.	approximately
Art.	Article
AT	Austria
BDEW	Bundesverband der Energie- und Wasserwirtschaft e.V.
BEV	Battery Electric Vehicles
BfJ	Bundesamt für Justiz (=German Federal Office of Justice)
Bio.	Billion
BKA	Bundeskanzleramt (=Federal Chancellery of Austria)
BMJ	Bundesministerium der Justiz (= German Ministry for Justice)
BMK	Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (=Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology)
BMNT	Federal Ministry of Sustainability and Tourism (=Austrian Bundesministerium für Nachhaltigkeit und Tourismus)
BMWi	Bundesministerium für Wirtschaft und Energie (=German Federal Ministry for Economic Affairs and Energy)
BMWK	Bundesministerium für Wirtschaft und Energie (=German Federal Ministry for Economic Affairs and Climate Action)
B-VG	Bundes-Verfassungsgesetz (Austrian Constitutional Law)
CO_2	Carbon dioxide
Ct	Cent
DG	Directorate General
EAG	Austrian Renewable Energy Expansion Act (Erneuerbare-Ausbau-Gesetz)
ECJ	European Court of Justice
EEG	German Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz)
ElWOG	Elektrizitätswirtschafts- und -organisationsgesetz
etc.	et cetera
EU	European Union
EVN	Energieversorgung Niederösterreich (Austrian Utility Company)
GER	Germany
GHG	Greenhouse Gases
GW	Gigawatt
i.e.	id est, (in other words)
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
It.	Item (“Ziffer”)
KSG	Klimaschutzgesetz (German Climate Protection Law)
kWp	Kilowatt Peak
Mio.	Million
MP	Market Premium
NDCs	Nationally Determined Contributions
NPV	Net Present Value

O&M	Operation and Maintenance
OeMAG	OeMAG Abwicklungsstelle für Ökostrom AG
PA	Proceeds from the Purchase Agreement with the electricity trader
Para.	Paragraph (“Absatz”)
Q[x]	Quarter
RIS	“Rechtsinformationssystem des Bundes” (the legal information system for Austria)
RSME	Renewables Support Management Entity
Sect.	Section (German/Austrian “Paragraf”/§)
TFEU	Treaty on the Functioning of the European Union
VAT	Value-added Tax
WMP	Weighted Market Price