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Environmental Technology & International Affairs

Balcony PV power plants in Austria: Public support for adoption and differences in implementation between Austria and Germany

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

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Affidavit

I, **THERESA PAULA BREIT, BSC, BA**, hereby declare

1. that I am the sole author of the present Master's Thesis, "BALCONY PV POWER PLANTS IN AUSTRIA: PUBLIC SUPPORT FOR ADOPTION AND DIFFERENCES IN IMPLEMENTATION BETWEEN AUSTRIA AND GERMANY", 81 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.

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Abstract

In light of climate change and the immediate need for action to reduce anthropogenic greenhouse gas emissions, a rapid energy transition must be pursued. Internationally, Austria has committed to various goals, but to achieve them, all levels of society must be involved in the energy transition. The example of balcony power plants, i.e. plug-in photovoltaic systems with a maximum output of 800 watts, is used to show how Austria is supporting the energy transition from the bottom. The thesis deals with the following research questions: (1) *"What are the differences in the implementation of a balcony PV power plant in Austria compared to Germany?", (2) "How do institutions in Austria monetarily support the installation of balcony PV power plants at different levels?",* and (3*) "How quickly would a balcony PV power plant pay for itself and how much money can a household save?"* The first chapters give insights in the topics of the energy transition and renewable energies, before elaborating on the concept of balcony PV power plants in Austria. The thesis aims to investigate the convenience of implementing a plug-in PV system as well as possible monetary subsidies in order to find out how Austria encourages individuals to participate in the energy transition. Therefore, a comparison regarding the implementation of plug-in photovoltaic systems between Germany and Austria is conducted to disclose possibilities for individuals to participate in the energy transition. After that, the Austrian subsidy system for balcony power plants is analysed to see whether monetary support is available. In a last chapter, a cost-benefit analysis is conducted to show the financial viability of plug-in PV systems.

The results of the thesis show that Austria is offering little incentive for the acquisition of a balcony power plant on the state, federal and city level. There is still room for improvement in order to convert uncertain potential customers into prosumers that produce and consumer their own electricity. However, the implementation of a balcony PV power plant is easier in Austria than in Germany. Furthermore, the cost-benefit analysis shows that plug-in PV amortise increasingly quickly, especially due to the high electricity prices and the ever lower material prices for photovoltaic systems. Already today, a plug-in PV can help a household not only to save money, but also to make a contribution to the energy transition from the bottom.

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List of abbreviations

BMK	Federal Ministry Republic of Austria Climate Action, Environment, Energy, Mobility, Innovation and Technology (Austria)
BMWK	Federal Ministry for Economic Affairs and Climate Action (Germany)
EAG	Renewable Expansion Act
EEG	Renewable Energy Sources Act
ElWOG	Electricity Industry and Organisation Act
EU	European Union
GHG	Greenhouse Gas
GW	Gigawatt
GWp	Gigawatt peak
KW	Kilowatt
KWh	Kilowatt hour
KWp	Kilowatt peak
LCOE	Levelized costs of electricity
MW	Megawatt
MWp	Megawatt peak
NECP	National Energy and Climate Plan
OeMAG	Settlement agency for green electricity
PV	Photovoltaic
RES	Renewable Energy Sources
TWh	Terawatt hours
TWh/a	Terawatt hours/ year
VAT	Value Added Tax
VDE	Association for Electrical, Electronic & Information Technologies
W	Watt

WKO	Austrian Federal Economic Chamber
Wp	Watt peak

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1 Introduction

1.1 Topic and Research Question

In times where climate change has become an omnipresent topic and societies are looking for techniques to make our way of living more sustainable, many see the energy sector in particular as an important field of action. With an energy transition from fossil fuel sources to renewable energy sources, the amount of anthropogenic CO_2 in our atmosphere will decrease significantly. To achieve this goal, a fundamental change must be brought about - one that goes beyond technological improvements and involves all stakeholders in society, from scientists to policymakers to the general public - and enables a change in behavior and culture.

To diversify our energy system, it is important to decentralize and encourage all levels of society to contribute to the energy transition. This is not only important to increase the number of people involved and thus the acceptance towards the energy transition, but also to accelerate it. There are various ways in which policymakers can encourage the public to participate in the energy transition and promote the transformation at lower levels. In addition to monetary subsidies and the promotion of climate-friendly energy generation, it is also the implementation of clear regulations that plays an important role in whether or not new types of energy generation become accepted.

In the Republic of Austria, the energy transition is an important goal of the government and furthermore a concern of broad segments of the population. An important objective of the government is climate neutrality by 2040 as well as the generation of 100 % of electricity consumption from renewable energies by 2030 (Bundesministerium für Nachhaltigkeit und Tourismus, 2019, p. 13). In order to achieve these targets, the population has an increasingly important role to play as well; the aim is to create a change in mentality from the population as traditional consumers of energy to active prosumers. More and more people want to participate in the energy transition for a variety of reasons: On the one hand, it is their own contribution to a more sustainable future; on the other hand, generating their own energy increases independence from the power grid and has financial benefits for individuals - especially in times of high electricity prices. Although the electricity sector accounts for only a portion of the overall energy, along with the transport and heating sectors, this paper will mainly focus on the energy sector in general and the electricity sector in particular.

Energy systems must be easily accessible and simple to install in order to create a broad base in society. Balcony PV power plants are small photovoltaic (PV) modules with a maximum of 800 watts peak per household. They are characterized by the fact that they are comparatively inexpensive, can be installed by non-professionals and feed electricity directly into the household. They are therefore an interesting alternative to drive the energy transition from below and also to promote a change in awareness among the population.

This master thesis will investigate how Austrian policy can support the population in the energy transition from below and in which form this support takes place. Balcony power plants will be used as an example in this thesis. For this purpose, both monetary support and simplifications in the implementation of balcony power plants will be examined.

The research question of this master thesis is therefore the following:

How does the Republic of Austria enable an energy transition from below using the example of balcony PV power plants?

The sub-questions that will be explored in this paper are:

- What are the differences in the implementation of a balcony PV power plant in Austria compared to Germany?
- How do institutions in Austria monetarily support the installation of balcony PV power plants at different levels?
- How quickly would a balcony PV power plant pay for itself and how much money can a household save?

1.2 Methodology

This thesis is mainly based on literature research and analysis as well as a cost-benefit calculation. For the chapter dealing with possible subsidies in Austria, the federal government, the provinces and cities with more than 100,000 inhabitants were examined. The cities assessed were Vienna, Salzburg, Graz, Linz, Innsbruck and Klagenfurt. The purpose was to find out if and how the individual institutions promote balcony PV power plants at different levels. Where the public websites of the individual institutions did not provide sufficient information to answer the question about subsidies, email inquiries were sent to the responsible offices to answer the question about current subsidies, possible subsidies for balcony PV power plants in the future, and reasons why plug-in plants are currently not subsidized. In order to analyse the legal situation of the subsidy system in the Republic of Austria, legal texts, especially the Electricity Industry and Organisation Act (ElWOG), as well as various standards were examined. The aim was to get a broad picture of possible subsidies for plug-in photovoltaics in Austria on different administrative levels. Since subsidies may also exist in cities with less than 100,000 inhabitants, this part of the study does not claim to be exhaustive and is subject to change.

For the second part of the thesis, a comparison between the Federal Republic of Germany and the Republic of Austria was made to examine the convenience of implementation of plug-in PV power plants. This is an important factor as uncertainties regarding the legal situation of plug-in power plants and the installation can have a considerable effect on decision making of possible customers. For this step, a look at legal texts, norms, white papers and similar was taken. It has been especially the view of the regulatory authorities of Germany and Austria respectively, the Association for Electrical, Electronic & Information Technologies in Germany (VDE) and the E-Control that have been of importance in analysing the situation. Additionally, legal information was taken into account. Furthermore, the German strategy paper issued in March 2023 by the Bundesministerium für Wirtschaft und Klimaschutz (BMWK) has been an important document to also take a glance on future possible changes of the situation in Germany. It was essential for this work to analyse information given to the general public to see how far an implementation was eased by the information given, as the balcony PV power plants are mainly installed by private individuals.

In a last step, a Cost-Benefit analysis has been conducted. To ensure that current data is used here, data from the European Commission and the World Bank was used. With the help of a webpage published by the European Commission and the World Bank respectively, exact data for a specific location can be retrieved. In the case of the World Bank, a global solar atlas has been published to calculate the irradiation of a specific spot and furthermore determines the total photovoltaic power output in kilowatt hours (kWh) per year, depending on the tilt, the orientation and the installed capacity of the plant. Further calculation mainly relied on the data by the World Bank group, but did take the data used by the European Commission into account to compare and ensure accuracy of the data. Data that is openly accessible has been used to determine the PV power output in order to easily repeat the calculation to measure future amortisation times with fluctuating electricity prices. In a next step, the data obtained was compared to the current electricity prices in Austria in order to calculate the payback period of a balcony PV power plant. In this context, an inclination of 30° was assumed, as well as no shade on the modules, as this would have a significant impact on the output of the PV system. As a big amount of balcony PV power plants is not mounted on the balcony railing, but rather placed on a plane surface to create an optimal angle for the modules, this option has been considered. Regarding the household, an average four person household in Austria with an electricity consumption of 4,000 kWh was assumed. Here, a closer examination was also given on the self-consumption of the household, as this has an essential influence on the amortisation time of the plant.

In the course of this work, the terms balcony PV power plant, plug-in installation and micro power plants have been used as synonyms.

1.3 Literature Review

For this thesis, an extensive literature review has been carried out. The literature was derived from academic journals and publications, reports, and legal texts, but has also relied strongly on information given on the internet, as it was an important aspect of this work to show the information accessible to the broader public. This is especially true for chapters 4, 5 and 6.

Regarding the energy transition, it is especially the work of Rotmans et al. (Rotmans, et al., 2001) that has to be mentioned, as the team has done important work on the field of transition management in the context of public policies. Furthermore, Kern and Rogge (Kern & Rogge, 2016) have identified central aspects on why an energy transition today will take place at a faster pace than in earlier times. Regarding the energy transition from the bottom, it has been especially Brauner (Brauner, 2016) and Dankert (Dankert, 2014) who have contributed to the scientific literature regarding decentralized energy systems and its advantages. Concerning the current and future state of the energy transition and renewable energies in Austria, information from the Austrian government as well as the European Union was used (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2023a) (Bundesministerium für Nachhaltigkeit und Tourismus, 2019) (European Commission, 2023b). Furthermore, reports by the International Energy Agency have been taken into account (IEA, 2020a) (IEA, 2023). For renewable energies, the study conducted by Deloitte, the Vienna University of Economics, and Business and Wien Energie was particularly relevant, as this also allowed information regarding public opinion to be incorporated into the work (Vienna University of Economics and Business; Deloitte; Wien Energie, 2023). In chapter 4, information has been mainly derived from a study conducted by the Fraunhofer Institut in 2016 (Fraunhofer-Institut für solare Energiesysteme ISE, 2019) as well as sources supplied by E-Control, the Austrian regulatory authority for electricity and gas. In chapter 5, information provided by the Bundesministerium für Wirtschaft und Klimaschutz (Bundesministerium für Wirtschaft und Klimaschutz, 2023) and the Umweltbundesamt (Umweltbundesamt, 2022) has been of essential importance as well as a market analysis of the German Balcony PV market conducted by Hochschule für Technik und Wirtschaft Berlin from 2022 (Hochschule für Technik und Wirtschaft Berlin, 2022). Chapter 6 relies mainly on information provided by the respective counties and cities, while also referring back to legal texts. Finally, chapter 7 contains information derived from the study conducted by the Fraunhofer Institut, E-Control, the World Bank and the European Commission.

1.4 Structure

This master thesis is structured in eight different chapters. The first chapter, Introduction, deals with general questions regarding the thesis, is elaborating on the topic and the research question, gives insights in the methodology used and shows the current state of the literature in this field of study.

In the second chapter, a closer look was taken on the energy transition, its importance and how fast it takes place. It furthermore takes a closer look on what is actually meant by that word and how an energy transition from the bottom might be able to enhance the pace of the transition. In a sub-chapter, the Austrian energy transition has been elaborated on. Here, information about Austria’s role in the international community and international commitments regarding the energy transition, specifically in regard to the Paris Agreement as well as specifications by the European Union (EU), is given.

The third chapter deals with renewable energies in Austria, where especially possible potentials until 2050 were examined. In Chapter (3.2) the photovoltaic sector in Austria has been surveyed. Here a particular importance was, next to the development of PV over the last years, put on the system of subsidies for photovoltaics, as this will also play an important role in later chapters of this thesis.

In chapter 4 the design and characteristics of balcony power plants is examined in more detail, including the discussion around the installation of plug-in systems. Chapter five compared balcony power plants in Germany and Austria. In a sub-chapter (5.1) information on the German PV potential is given before the German balcony power plant market is analysed (5.2). Finally, in a third subchapter (5.3) the differences in implementation between Austria and Germany are shown. Chapter 6 is dedicated to the funding of balcony power plants in Austria, with subchapters (6.1) (6.2) (6.3) examining the national, provincial and city levels respectively. In chapter 7, the last chapter, a cost-benefit analysis is carried out to calculate the payback period of a balcony power plant in Vienna. Finally, the conclusion of the work in chapter 8 elaborates on the findings, and limitations, and provides an outlook to the future.

2 The Energy Transition

The importance of a fast energy transition from a fossil fuel led world to one with low carbon energy sources and renewable energies has been increasing significantly over the years (Fouquet, 2016, p. 7). As CO_2 emissions from energy sources are accountable for 68% of total anthropogenic CO_2 emissions, it is important to push ahead with the energy transition in a determined and efficient manner (Yang, et al., 2020, p. 455). Especially in the light of the Paris Agreement, which was established to limit global warming well below 2° Celsius and preferable at 1.5° Celsius compared to preindustrial levels (UNFCCC, 2023), a reduction of carbon emissions is essential. To keep the rise of the global temperature around the 1.5° Celsius goal, energy-related emissions would need to be reduced by 70% by 2050 compared to 2019 (IRENA, 2019, p. 13).

The term of an energy transition implies a fundamental change in not only the production of energy, but much rather in society as a whole. A transition is a multi-dimensional process, where different changes that are connected to each other trigger different impulses. Many different areas are part of a transition, for example economy, technology, institutions, but also culture, behaviour and the belief system of a society (Rotmans, et al., 2001, p. 16). This is especially important to keep in mind when current popular solutions have already led to a lock in effect and contribute to the rise in carbon dioxide emissions (Seyfang & Haxeltine, 2012, p. 383). To overcome these institutional lock-inns, public acceptance or a popular adoption of the new technology is needed (Komendantova, et al., 2017, p. 143).

Rotmans et al. argue that a transition takes up more than one generation to take place (Rotmans, et al., 2001, p. 15), a quite slow process, especially when looking at the urgent need of an energy transition to avoid severe consequences society would face due to climate change. With this in mind, it seems of importance to find ways to speed up the energy transition. Kern and Rogge argue in their paper that there is a chance that the energy transition we are experiencing now might take place faster due to three factors: Unlike transitions that have taken place in the past, the energy transition we are currently trying to carry out is actively supported and promoted by many different actors, including policy makers. Furthermore, globalisation provides more dynamic feedback loops that could accelerate the energy transition. A third aspect for the authors is the Paris Agreement, which is seen as the start of a global paradigm shift towards decarbonisation

(Kern & Rogge, 2016, p. 13). Pace of transition will also depend on whether it will be possible to adopt the infrastructure already in place with the new technology, or whether it will be necessary to build an entirely new infrastructure. Furthermore, resistance from incumbent players in industry and similar need to be considered (Komendantova, et al., 2017, p. 143).

The energy transition in the transport and heating sectors is making slow progress, while the switch to a renewable energy supply in the electricity sector is well on track (Quaschning, 2020, pp. 112-118). Besides experts, politicians and emerging sectors, it is also the population that should not be ignored in the current energy transition, as they can significantly increase the speed of the transition with perceptions, social visibility, and the like (Komendantova, et al., 2017, p. 144). Scientists argue that citizens should not only be seen as consumers of energy, but rather as active users: With the help of policy, an impact could be made on consumers to turn them into active participants. At the same time, attempts should be undertaken to find new ways to support them in building up a new demand for energy (Schot, et al., 2016, p. 6). By doing so, a change from classical consumers and producers to active prosumers, who take on both roles, can be achieved. (Brauner, 2016, p. 30).

2.1 Advantages of an energy transition from the bottom

While it may seem that contributions to the energy transition from the bottom up are heterogeneous and uncoordinated, with many different actors contributing with various ideas to find effective solutions, this approach also has some outstanding advantages. The lower levels of society, such as companies, regions or private individuals, have multiple opportunities to convert their energy systems to efficient, renewable and decentralized systems more quickly than states or even institutions such as the European Union could (Dankert, 2014, p. 17f). This can be seen at the example of Germany: Of the 100 Gigawatts (GW) produced in renewable electricity generation facilities in 2017, 40% were owned by private individuals (Quaschning, 2020, p. 128).

It is especially the aspect of decentralization that plays an important role in the energy transition from the bottom. A definition for the decentralized energy supply is given by Brauner: The end-user or an end-user in the same grid level owns electricity generation facilities. There may also be storage facilities to compensate for the fluctuation of renewable energies. The end user can feed energy back into the grid and has a meter to measure purchases and feed-backs (Brauner, 2016, p. 29). This leads to the build-up of so called micro grids, which are decentralized and installed close to the point of consumption. This could be a PV installation on a roof or installations of wind turbines in vicinity to a village (Brauner, 2016, p. 24). The installation close to the point of use furthermore reduces the power transmission loss, which would occur if the electricity produced is transported over longer distances (Yang, et al., 2020, p. 465) A small plant could even be financed by end-user investments, which could encourage implementation in the community near the plant (Brauner, 2016, p. 24). To see where the energy is coming from might furthermore motivate citizens to adapt their energy consumption in a responsible and efficient manner, to make the most out of the energy produced nearby (Dankert, 2014, p. 107). Since the design of the installed capacity is adapted to the local demand, there is also little or no need for grid expansion. Due to the fact that decentralized concepts do not require the participation of the entire municipality, a decentralized project can be initiated by a few people and can be implemented with little contractual and financial effort, thus also keeping the risks manageable. This concept will lead to a change in the energy supply system, potentially resulting in new billing models for grid costs, as the amount of electricity purchased from the grid operator will be reduced (Brauner, 2016, pp. 24-25).

The reason why less electricity is bought from the grid is that decentralization makes it possible for consumers to produce and sell their own electricity - they become prosumers (Brauner, 2016, p. 30). Per definition, this would mean that a household is consuming a part of the produced electricity by itself directly without taking advantage of the grid (Flaute, et al., 2018, p. 168). The excessive energy produced should in the best way be used on the same horizontal level to ensure the lowest possible network load. This will lead to challenges especially for grid operators, including a change in the price calculation due to the lower electricity demand from the grid, but a constant grid capacity at the same time. In some cases, it will even be necessary to expand capacity in order to be able to transport surplus electricity (Brauner, 2016, p. 30f).

It has to be clear that an energy transition from fossil energy to renewables will lead to more fluctuation in our electricity systems. This is due to the dependency of PV to the sun and cloud coverage, while wind energy is dependent on the weather as well. This will increase the necessity for storage facilities as well as a change of consumer behaviour to use the energy when available (Brauner, 2016, p. 32f).

2.2 Energy transition in Austria

Energy transition in Austria has been an essential topic for the last few years and is seen as one of the most important aspects to meet the country's emissions targets in the future. Furthermore, Austria is internationally bound to reach certain targets (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2023a) and has potential in the renewables sector, especially for PV and wind electricity (Brauner, 2019, p. 2). The topics of energy security and renewable energy sources in particular play an important role for policymakers on the path to achieving the goals of international agreements and implementing the energy transition in Austria (Komendantova, et al., 2017, p. 141).

At the global level, Austria has committed itself to meeting the emission reduction commitments made in the Paris Agreement. Here, a limit of 2° Celsius warming was set (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2023a), with the goal of keeping global warming below 1.5° Celsius compared to pre-industrial levels (Vienna City Administration, 2022, p. 18). Since the Paris Agreement came into force in 2016, adaptation to climate change has been given the same priority as climate protection itself. This two-pillar principle has been in place in Austria for several years now, and its main aim is to mitigate and prevent the negative effects of climate change on the environment, society and the economy (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2023a).

Furthermore, as a member state of the European Union, the country is part of the EU-wide strategy to reach net-zero Greenhouse Gas (GHG) emissions by 2050 (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2023a), a goal which has been adopted by the European Council in 2019 (IEA, 2020a, p. 18). To be in line with the Paris targets and to contribute to a clean energy transition, the EU has set ambitious targets for its member states: The binding energy and climate targets until 2030 are a reduction of GHG emissions by at least 40% compared to 1990, an increase of energy efficiency by at least 32.5%, an increase on the share of renewable energy to at least 32% of EU energy use and a guarantee for at least 15% electricity inter-connection levels between neighbouring Member States (European Commission, 2023a).

To get an overview and ongoing updates about how the specific EU member states are working towards reaching their targets, the national energy and climate plans (NECPs) have been introduced by the Regulation on the Governance of the Energy Union and Climate Action (EU) 2018/1999. In the specific NECPs, member states are required to disclose their national plans on how to address the five columns of decarbonisation, energy efficiency, energy security, internal energy market, and research, innovation and competitiveness. By the end of 2018, draft NECPs for the period 2021-2030 had to be reported to the Commission by the individual member states. After an assessment by the Commission, the countries were given recommendations and submitted their final NECPs by the end of 2019. For the period covered in the NECPs, countries have to report their status quo in a progress report to the Commission every two years. In June 2023 the first updates of the plans will be submitted (European Commission, 2023b).

In its NECP, Austria is planning on increasing the share of renewable energy in gross final energy consumption to 46-50%, and cover 100% of electricity consumption from renewables by 2030 (nationally/balanced). This goal is to be achieved primarily through tax concessions for biogas and hydrogen, as well as through the expansion of renewable energies within the framework of the Renewable Energy Expansion Act (EAG). Among other things, the share of renewable energy in transport ought to be increased and fossil fuels for heating, hot water and cooling are to be replaced by renewable forms of energy (Bundesministerium für Nachhaltigkeit und Tourismus, 2019, p. 13).

Since the European Union is heavily dependent on fossil energy, but does not have enough fossil fuels itself, the switch to renewable energy is, in addition to the environmental aspect, also a factor of independence from other countries (European Commission, 2022). This will have furthermore the benefit of price stability of the energy sector (Vertretung der Europäischen Kommission in Deutschland, 2023) and has been of increasing importance since the start of the war in Ukraine in 2022 (European Commission, 2022) The European Union has reacted to the Russian invasion in Ukraine and has released the REPower EU strategy in May 2022, where the institution is planning on further increasing the share of renewables in final energy consumption to 45% in 2030

(IEA, 2023, p. 36). Next to accelerating the green transition within the EU, a diversification of the energy supplies and improvements in saving energy are partial objectives of the strategy. To reach independence from Russian fossil fuel, additional investments of €210 billion are required (European Commission, 2022).

With its #Mission2030, Austria has set the ambitious goal to obtain 100% of its total electricity supply on national balance by 2030 through domestic Renewable Energy Sources (RES) (IEA, 2020a, p. 33). To reach this goal, an increase of 22-27 Terawatt hours (TWh) of generation from renewables would be needed (IEA, 2020a, p. 136). In addition to environmental sustainability, which includes next to increasing the share of renewables also an increase in energy efficiency, competitiveness and affordability, as well as security of supply, are key pillars in #Mission2030 (Bundesministerum für Nachhaltigkeit und Tourismus; Bundesministerium für Verkehr, Innovation und Technologie, 2018, p. 15).

In the current election period in Austria (2020-2024), the government has agreed to achieve climate neutrality in 2040. This ambitious goal means that within 20 years, Austria-wide emissions of greenhouse gases and their removals by carbon sinks should be balanced according to the national greenhouse gas inventory (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2023a).

3 Renewable Energy

Given the increasing importance of CO_2 reduction to hinder climate change on our planet and the large role that energy production plays in the creation of various greenhouse gases, renewable energy sources can be seen as an important player in achieving decarbonisation. (United Nations, 2023). The share of electricity from renewables in the energy mix has increased in recent years, and by 2027 renewables are expected to account for nearly 40% of global electricity generation (IEA, 2023, p. 26).

As science has made tremendous progress in developing and increasing the efficiency of electricity from renewable energy sources, it is becoming more competitive and able to compete with other, non-renewable energy sources. This can especially be seen when looking at prices of photovoltaic systems, which experienced a plunge in prices by 75% since 2006 (Fraunhofer ISE, 2023, p. 8). In addition, there has also been a change in energy subsidies over the years. While in 2007 states spent $342 billion on fossil fuel subsidies and only $39 billion on renewables, in 2015 these figures were $325 billion and $150 billion, respectively (Yang, et al., 2020, p. 438).

This change in prices will too help increase the share of renewable energy and electricity over the next few decades. It will be especially solar PV that will increase its cumulative capacity. While the worldwide accumulated PV installation capacity was only 502 MW in 1994 and 16 GW in 2008 (Yang, et al., 2020, pp. 22-23), estimates made by the International Energy Agency expect PV capacity to surpass coal by 2027, making it the largest installed electricity capacity worldwide (IEA, 2023, p. 25).

3.1 Renewable Energy in Austria

Next to saving energy it has been especially the expansion of renewables that is playing an important role in the Austrian energy transition (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2022a, p. 5). In Austria, electricity from renewable sources plays an important role in the country's power supply. 78 % of the electricity generated in 2018 was produced from RES. Due to the geographical conditions, it is especially hydropower that accounted for more than half of the total electricity production in 2018, at 58% (IEA, 2020a, p. 29).

A climate protection law was passed in Austria in 2011 and amended in 2017, setting maximum emission levels for six sectors. It also regulated the development and implementation of effective climate protection measures outside of emissions trading in the European Union (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2023b). A progress report is submitted once a year (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2022b). Although the climate protection law is still in force and progress reports are also published annually, no maximum levels have been set by the government for the years after 2020 (Bundesministerium für Finanzen, 2023a). As a result, the climate protection law in its current version is no longer able to set any maximum levels of greenhouse gas emissions for the different sectors.

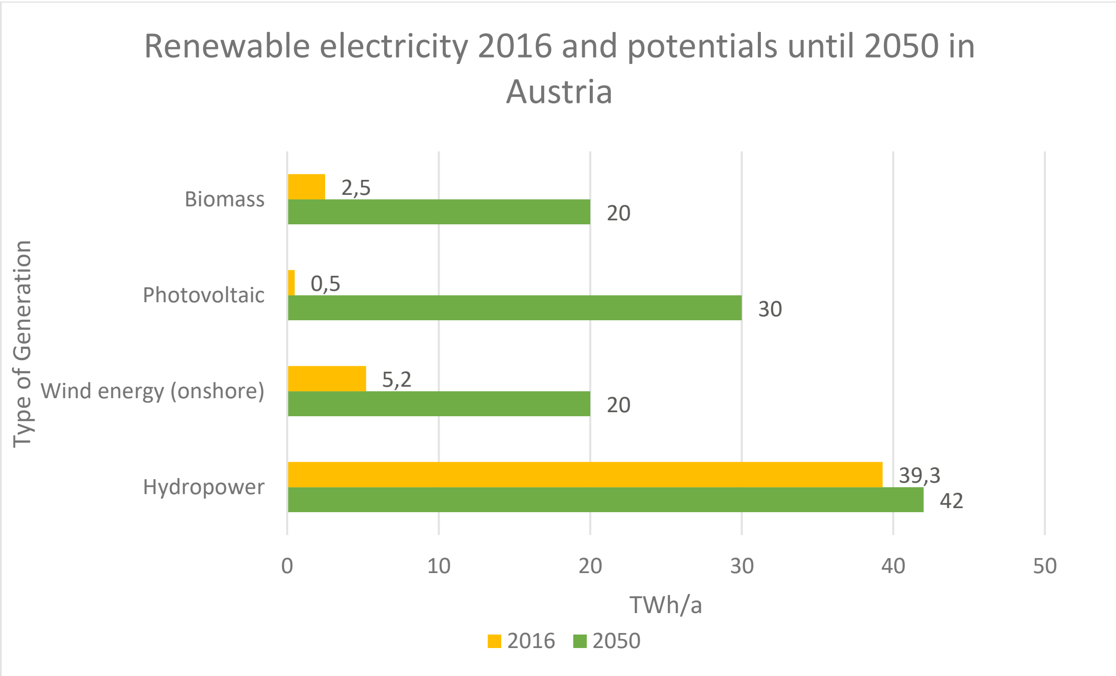

Figure 3.1 Renewable electricity 2016 and potentials until 2050 in Austria (derived from Brauner, 2019, p.19)

A look at figure 3.1 shows the renewable electricity available in 2016 and the potentials until 2050. The graph provides information regarding the renewable types biomass, photovoltaic, wind energy (onshore), and hydropower (Brauner, 2019, p. 19). The graph shows the high share of hydropower, which will certainly play an important role in the future to balance the variable power generation from renewable energies due to the possibility of pumped storage power plants (IEA, 2020a, p. 34). However, possibilities for further expansion of hydropower within Austria are very limited. This is due to a new

EU Water Framework Directive, which might even lead to the calculated potentials to partly decrease (Brauner, 2016, p. 15).The end electricity demand for Austria in 2016 was 68 TWh/a and is expected to increase to 140 TWh/a by 2050. Austria has large potentials in the areas of biomass, wind energy (onshore) and photovoltaics. Photovoltaics in particular has a potential of 30 TWh/a by 2050, whilst only 0.5 TWh/a was produced in 2016 (Brauner, 2019, p. 19).

Within the current government programme the leading parties have set ambitious goals for the expansion of renewables. One of them is the generation of an additional 27 TWh of renewable electricity by 2030. Out of the 27 TWh, 11 TWh are planned to be derived from PV, 10 TWh from wind, 5 TWh from hydro and another 1 TWh from biomass (IEA, 2020a, p. 20). Since Austria has banned nuclear power under its constitution since 1999, the country has set itself the task of achieving the decarbonisation of its electricity system without the help of nuclear power, as it furthermore considers this kind of energy production incompatible with sustainable development (IEA, 2020a, p. 34).

The climate targets set by the federal government are also supported by a large part of the Austrian population: In a study by Deloitte, the Vienna University of Economics and Business and Wien Energie, Austrians were surveyed on the topic of renewable energy. Climate change is considered the most important problem in Austria over the next two decades by the respondents (Vienna University of Economics and Business; Deloitte; Wien Energie, 2023, p. 45). 77% are moreover in favour of accelerating the expansion of renewable energy technologies in Austria, while two-thirds of the respondents also support the federal government's goal of drawing all electricity consumption from renewable sources by 2030 (Vienna University of Economics and Business; Deloitte; Wien Energie, 2023, p. 37f). Furthermore, 68% also stated that they would accept personal sacrifices in order to contribute to saving energy (Vienna University of Economics and Business; Deloitte; Wien Energie, 2023, p. 39).

For the Austrian government, the population plays a major role, as it is to be transformed from passive consumers to active customers and players in order to drive the energy transition forward. This is to be achieved, among other things, through the implementation of smart meters and the possibility of forming a generation community, which has been able since 2017 in Austria (IEA, 2020a, p. 36).

3.2 Photovoltaic in Austria

In the future, wind and solar energy will be of increasing importance in the transformation of the global electricity sector. Wind energy will be accountable for the supply of more than 33% of the total electricity demand, while solar PV will follow with 25% of the total electricity demand. This will result in a rise of solar PV in the generation mix by 10 times when comparing 2016 and 2050 (IRENA, 2019, p. 16). When looking at the international level, photovoltaic has been experiencing an increasingly fast development. While in 2012 only 30 GW of Photovoltaics have been added annually, estimates assume for 2022 approximately 250 GW per year (Bundesministerium für Wirtschaft und Klimaschutz, 2023, p. 4). By 2050, solar PV is expected to reach a cumulative installed capacity of 8,519 GW (IRENA, 2019, p. 16). The increase can also be observed in Austria. Photovoltaics is currently responsible for 4% of the electricity generated in Austria, but from 2005 to 2021, PV output increased by an average of 34.7% per year (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2022a, p. 22) and more than doubled its electricity generation between 2013 and 2018, from 0.6 TWh to 1.4 TWh over this five-year period (IEA, 2020a, p. 31).

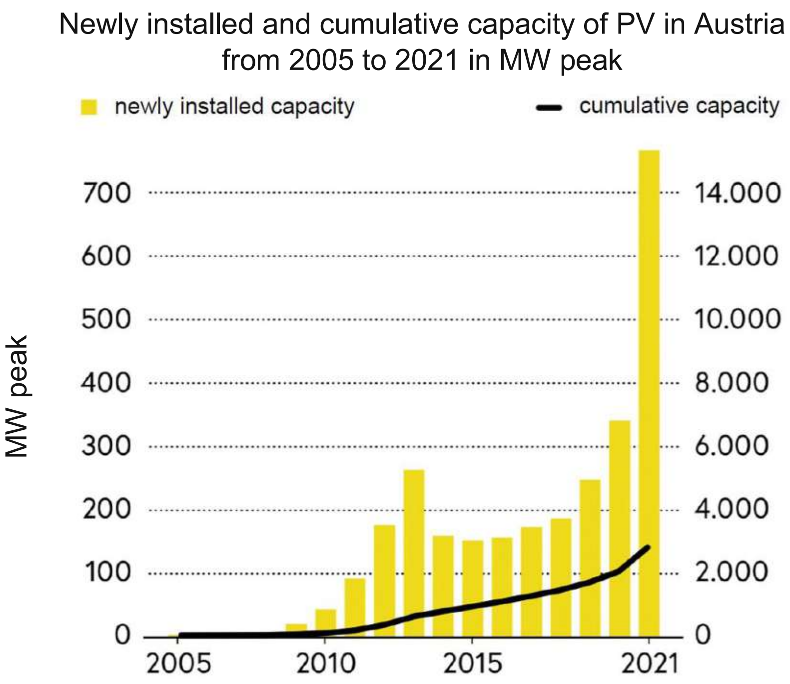

Figure 3.2 Newly installed and cumulative capacity of PV in Austria from 2005 to 2021 in MW peak (BMK, 2022, p.22)

Figure 3.2 shows the capacity of PV in Austria from 2005 to 2021 in MW peak (MWp). Especially between the years 2018 and 2020, and to an even bigger extent from 2020 to 2021, an increase in the newly installed capacity can be seen. Particularly in 2021, a high increase was achieved, with newly installed capacity amounting to 766 MWp (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2022a, p. 22). Although photovoltaic currently only contributes a small share to the renewable final energy supply, it is the sector with the largest relative annual growth (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2022c, p. 26).

The surge in PV around the globe as well as Austria is very closely connected to the plunge in costs of PV. Alone between 2010 and 2018, a decline of 74% of the total installed costs has been experienced, a further decline in prices is expected (IRENA, 2019, p. 27). While the generation costs of PV were still at 16.8 €ct per kWh in 2010, this value is set to decrease steadily. By 2030, a reduction to 6.2 €ct per kWh is expected, and by 2050 this cost is expected to be 3.9 €ct (Brauner, 2019, p. 38).

Acceptance for renewable energy projects has been increasing over the years within the Austrian population, but it is especially photovoltaic with a particularly high level of approval. Accordingly, 89% of respondents to the Renewable Energy Study would approve of a photovoltaic project in or nearby their municipality, while small hydropower projects would only receive 78% approval, and wind energy projects as little as 69% (Vienna University of Economics and Business; Deloitte; Wien Energie, 2023, p. 6). It is especially the share of photovoltaics on roofs and facades that the Austrian population wants to see expanded: 81% of the respondents think that an expansion should take place, 65% believe that PV on roofs and facades should be fully exploited (Vienna University of Economics and Business; Deloitte; Wien Energie, 2023, p. 8). In the current government program, Austria has the goal to increase especially the amount of roof-mounted PVs to 1 million by the year 2030 (IEA, 2020a, p. 20).

The Green Electricity Act (Ökostromgesetz), which regulates the promotion of renewable electricity throughout the Republic, has been in force in Austria since 2003. In this context, operators of wind and photovoltaic plants receive a guaranteed price for their kWh fed into the grid. As a result, their risk in relation to market fluctuations is low

(Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2022a, p. 25).

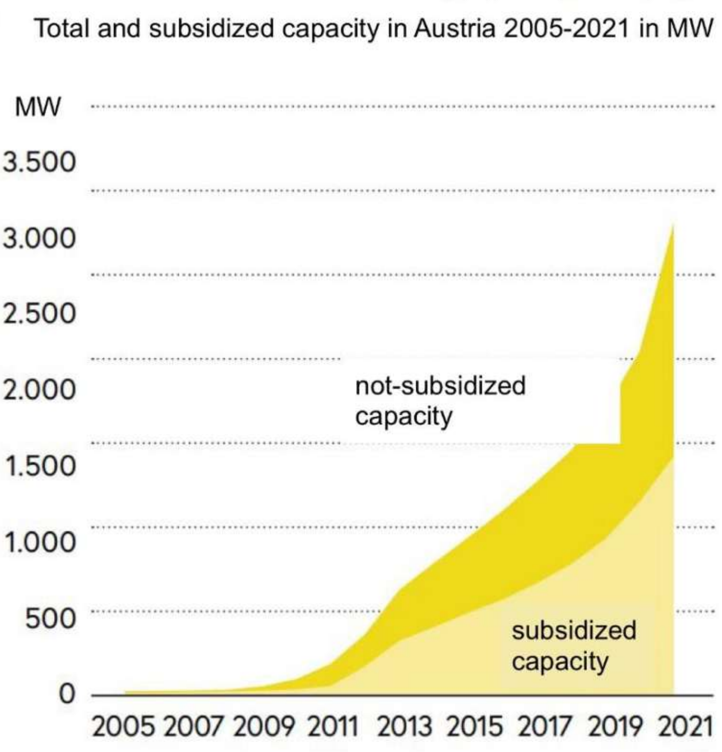

Figure 3.3 Total and subsidized PV capacity in Austria 2005-2021 in MW (BMK, 2022, p.25)

Figure 3.3 shows the total PV capacity in Austria in MW divided into subsidised and non-subsidised capacity between the years 2005 and 2021. The chart shows that while PV capacity has increased significantly in recent years, there has also been a shift within policy to increase unsubsidized capacity. In particular, this change in policy approach is related to the rise in electricity prices and the resulting increasingly economic and competitive green electricity (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2022a, p. 25). A similar approach can also be observed in Germany and will be discussed later.

A study conducted in Italy and Austria in 2013 and 2014 by Braito et al. has shown how state support regarding photovoltaic energy influences photovoltaic investments and has furthermore identified important drivers for individuals as well as groups for investing in photovoltaics. Installing a PV has several economic as well as non-economic benefits. While consumers get a product to a lower price in the case of a subsidy on PV either by the state, county or city they live in, the purchase also pays off after, as the household's energy bill will be lower. Furthermore, the adoption of a PV system in a private home is very often driven by non-economic factors, like an interest in technology or demonstrating an ecological lifestyle to neighbours and friends. Other important motivations for investing in a PV system are the willingness to contribute to environmental sustainability and to help protect the environment, as well as the goal of not becoming completely dependent on electricity producers through decentralized energy generation and of gaining independence from them (Braito, et al., 2017, pp. 143-144). The study showed that above all, environmental protection, followed by decentralized energy production, is the most important aspect for both individuals and collective PV investors. The study also showed that owning a roof was an important aspect for individuals and led to an increase in probability for individual PV investments (Braito, et al., 2017, pp. 148-149). While this fact is not surprising, it shows the important niche for balcony PV power plants, as they do not require a whole roof for a decentralized energy production. Whether a household has a PV installation relates in Austria strongly to the two aspects income and type of building. High income households are more likely to have a PV installed, but it is especially the type of the building the household lives in that plays a crucial role: Houses with multiple families in it are much less likely to be equipped with PV than single-family or two-family homes. This has mainly to do with legal aspects, as obtaining consent for the installation of PV in apartment buildings can often prove difficult (Kettner, et al., 2022, p. 627).

For balcony PV power plants, arguments for an acquisition are rather similar: A study conducted in Germany in 2017 has identified low acquisition costs, environmentally friendly electricity production, the desire for self-sufficiency, as well as interest in the technology as the key drivers for private individuals to invest in a plug-in PV installation. It was also important to the respondents to be an example for others, to tell friends about the installation and to place the system visibly. In this context, the importance of a symbolic contribution to the energy transition can be clearly seen (Burckhardt & Pehnt, 2017, p. 51).

Even though it is evident that the share of the total installed PV capacity will remain small compared to the contribution of ground-mounted or rooftop PV systems, balcony PV power plants are an interesting way for private individuals to produce their own electricity in a decentralized way and make a contribution to the energy transition (Bundesministerium für Wirtschaft und Klimaschutz, 2023, p. 20).

4 Balcony PV power plants in Austria

Balcony PV power plants are subject to different requirements depending on the respective country of installation. It is therefore necessary to define the term "balcony PV power plant" more precisely in order to avoid any misunderstandings.

In Austria, the term is clarified in the Electricity Industry and Organisation Act of 2010 in §7 (1) as the following: "Small-scale generating installations" means one or more generating installations whose total congestion power is less than 0.8 kW per installation of a grid user (Bundesministerium für Finanzen, 2010).

While it is possible to install a storage unit with a balcony PV power plant to ensure self-made electricity also outside hours of sunshine, this aspect will not be part of the thesis.

Important components of a balcony power plant are a photovoltaic module and an inverter. These parts are sold as a set and can be used regardless of the location of installation. It is also important to note the term "ready to plug in", which indicates that the unit can be connected directly to the final electrical circuits of the building (Fraunhofer-Institut für solare Energiesysteme ISE, 2019, p. 7). Since the electricity produced is direct voltage, the inverter is needed to change the electricity produced to alternating voltage to be used in the household and fed back into the public grid if there is an electricity surplus (Quaschning, 2020, p. 143). Other components that may be required for use are supporting structures, a main supply line, a plug and a junction box (Fraunhofer-Institut für solare Energiesysteme ISE, 2019, p. 12). The system is plugged directly into the end circuit and is consumed directly by the appliances in the household, hence without being fed into the general power grid (Burckhardt & Pehnt, 2017, p. 48). Regarding the type of solar cells used, it can be said that producers mainly rely on mono and poly crystal silicone modules, because of the balanced price-performance ratio and the extensive range of manufacturers (Fraunhofer-Institut für solare Energiesysteme ISE, 2019, p. 12f). While it has been especially the PV modules that have kept investment prices for PV high in the past, the price of the modules is nowadays only responsible for a third of the investment costs. Between 2010 and 2020 prices for PV modules went down by nearly 90% due to intensive research and improvements in the production process (Fraunhofer ISE, 2023, p. 8).

In most cases, a balcony power plant is operated by a private individual and without the intention of making a profit (Fraunhofer-Institut für solare Energiesysteme ISE, 2019, p. 7).

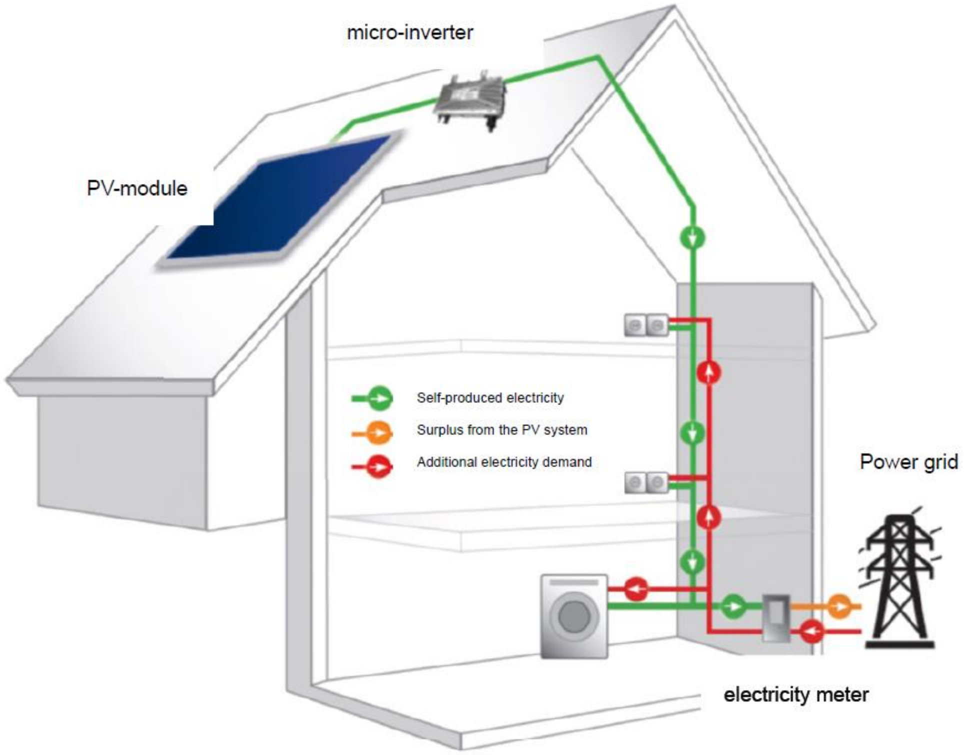

Figure 4.1 Integration of a plug-in plant into the house network (Fraunhofer Institut, 2019, p.12)

Figure 4.1 shows the basic idea of a plug-in PV. Direct current is generated at the PV-module and is converted into alternating current at the micro-converter. It can thus be used directly in the household and enters the household via a plug. If there is more electricity produced than needed, the entity has an electricity surplus, which leads to the surplus electricity being fed back into the public grid. If on the other hand not enough electricity is available, for example during night, a cloudy day or extensive use, electricity can be used from the grid. The electricity meter is able to detect in- and outflows of the entity and can therefore provide exact data of how much electricity is fed back into the grid and how much is taken out of it. The installation of a bidirectional meter is important, otherwise the two currents would cancel each other out, causing a distortion of the household's power supply. As visible on the sketch, there is no storage unit available, which leads to the energy not used being directly fed back into the power grid.

A feed-in tariff for the electricity generated by the balcony power plant, which was not consumed and is therefore fed back into the grid, is not generally not provided for in Austria (Verein für Konsumenteninformation, 2023).

Regarding the installation of a balcony PV power plant, there are different opinions on whether an installation can be carried out without professional support and what kind of plug can be used. Even though there is a norm that is dealing with this subject, the applicability for balcony PV power plants is not entirely certain. In particular, the Austrian standard ÖVE/ÖNORM E 8001-4-712 deals with the implementation of electrical systems with nominal voltages up to AC 1000 volts and DC 1500 volts. However, this is not directly applicable to balcony power plants, as the standard deals specifically with planning and construction. Yet, as a finished product, balcony power plants are neither individually planned nor constructed (Fraunhofer-Institut für solare Energiesysteme ISE, 2019, pp. 19-22). This standard has led to an increased discussion regarding the installation of Balcony PV Power Plants, as the system- and safety-related requirements cannot be directly applied to balcony power plants and a gap in the regulations has occurred in this regard (Fraunhofer-Institut für solare Energiesysteme ISE, 2019, p. 24).

The Austrian Federal Economic Chamber (WKO) is opposed to an installation being carried out by a private individual and is furthermore strongly convinced that power generation equipment must not be connected to the final circuit by means of a plug and socket (Bundesinnung der Elektro-, Gebäude-, Alarm- und Kommunikationstechniker, 2019). This comes as no surprise, as the Federal Guild of Electrical Engineers does not want to be held responsible for any safety risk in this respect.

E-Control, the Austrian regulatory authority for electricity and gas, commented on the debate about plug-in photovoltaic systems in October 2022 and clarified that they may also be used with a Schuko plug (Kurier, 2022). E-Control further comments that a professional inspection of the electrical installation may be necessary, for example in the case of old installations. However, the regulatory authority does not provide a precise explanation of whether an inspection must be carried out (E-Control, 2023a, p. 1).

EET, an Austrian company producing balcony PV power plants, points out the certification of inverters in this context: These must be without any voltage after a maximum of 200 milliseconds, should the plug be unplugged and no longer connected to the house network (EET, 2023).

What can be seen is that the question of what plug to use is still a grey area and not yet entirely discussed and legally defined. The same is true for the need of an installation by a professional. This discussion is responsible for increasing the factor of uncertainty among potential users and might therefore also affect the number of balcony PV power plants bought to a negative extent. It is however obvious that the obligatory installation of a Wieland socket or similar means that the predicate plug and play is no longer valid, as an expert has to be consulted for the installation.

How a balcony PV power plant is in the end connected to the grid depends on the location of installation, as this lies within the operating field of the respective grid operator. There are currently 122 electricity grid operators active within Austria (E-Control, 2023b). Vorarlberg Netz for example recommends the installation with the help of an electrician (Vorarlberger Energienetze GmbH, 2023), Oberösterreich Netze recommends that the balcony power plant should not be operated from a socket, but rather that an electrician should be consulted for safety reasons and have the plant permanently connected (Netz Oberösterreich GmbH, 2023). Energie Klagenfurt, on the other hand, requires installation by an electrician even for small-scale generation systems. They furthermore state the importance of a proof of conformity of a certified inspection body and the fact that any power fed back into the grid will not be compensated (Energie Klagenfurt GmbH, 2022).

The number of Balcony PV Power Plants installed could not be recorded within the scope of this thesis, however, the Fraunhofer Institute had carried out an estimate based on market developments in other European countries in the course of their study. Here, it is assumed that 100,000 micro PV systems will be installed over the next 20 years (Fraunhofer-Institut für solare Energiesysteme ISE, 2019, pp. 64-65). Many companies like EET have seen enormous growth over the last few years: While the company sold 100 units of balcony power plants to distributors or via the Internet in 2018, the number increased to 2,000 in 2021, reaching 10,000 units in 2022. Of these, 80% were sold without storage. The company sells its units in Germany, Austria, Italy and Switzerland, about half of the units are sold in Austria (EET, 2023).

When comparing a regular PV with a balcony PV power plant, several differences become visible: While regular PV power plants are planned individually and need to be installed by professionals, balcony PV power plants are offered ready to be plugged in by individuals with no further expertise (Fraunhofer-Institut für solare Energiesysteme ISE, 2019, p. 8). As already mentioned above, this this highly dependent on the grid operator, as it is up to them to decide whether they require or only recommend installation by a professional. Furthermore, small scale Photovoltaic systems do not need a metering point in Austria, which is determined in ElWOG §66a (Bundesministerium für Finanzen, 2010). Regular PV systems must feed the generated electricity into a separate circuit, which must not have any consumers or sockets. Balcony power plants, on the other hand, feed the generated electricity directly into the household circuit via a socket (Fraunhofer-Institut für solare Energiesysteme ISE, 2019, p. 8).

5 Comparison of Germany and Austria

The neighbouring countries Austria and Germany have been chosen for a comparison regarding the installation of balcony PV power plants, as both countries are part of the European Union and have therefore particular goals they have to reach within a specific timeframe until 2050. Furthermore, they both have big potentials in the photovoltaic sector for the future.

In Germany, the Renewable Energy Sources Act (EEG) is of major importance in the energy transition. In particular, the promotion of electricity from renewable energies is the main focus of attention (Bundesministerium für Wirtschaft und Klimaschutz, 2022a). In addition, feed-in tariffs for green electricity were established with the help of the act (Korcaj, et al., 2015). However, the implementation of the EEG also brought about changes in the ownership structure of German utilities. Whereas previously four-fifths of the power plant capacity was in the hands of four large companies, the EEG created the opportunity for many small suppliers to enter the market at low risk. A large number of private individuals have started to participate in the market, especially by installing PV systems on roofs (Dankert, 2014, p. 113). Already at the end of 2012, 1.3 million PV systems with a capacity of 32 GWp were connected to the German grid. Roughly 90% of the plants installed in 2012 were systems with less than 30 kWp and were purchased by homeowners (Korcaj, et al., 2015, p. 407).

In the 2010 Energy Concept (Energiekonzept), the German government formulated the most important goals of the energy transition (IEA, 2020b, p. 26). The Federal Republic of Germany has set itself the goal of halving primary energy demand by 2050 compared to 2008. At the same time, the share of renewable energies in gross final energy consumption is to be increased to 60 % (Umweltbundesamt, 2022). Germany has invested significantly in renewables in recent decades, with renewable electricity generation growing from less than 5% in 1998 to 35% in 2018 (IEA, 2020b, p. 83).

In contrast to Austria, Germany has long produced nuclear energy on its territory as well. In 2002, the government finally decided to phase out the commercial uses of nuclear energy, only to modify nuclear energy as a bridging technology after the 2009 elections. Following the Fukushima Daiichi nuclear accident in 2011, the German government reassessed the risks of nuclear power and decided on a phase out until 2022 (IEA, 2020b, pp. 27-28), and by April 2023, the last German nuclear power plants were finally shut down (Bundesamt für die Sicherheit der nuklearen Entsorgung, 2023).

Over the last years, subsidies for RES exploded in Germany, which led to the country reforming its EEG (IEA, 2020b, p. 30). Since 2017, the level of financial support for green electricity produced by facilities bigger than 1 MW has no longer been set by the state, as was previously the case, but has been determined by a competitive auction system. This is intended to drive competition and be more cost-efficient (Bundesministerium für Wirtschaft und Klimaschutz, 2022b). In addition, as electricity prices rise, the feed-in tariff is lower than the price a consumer would pay for electricity from the public grid. This means that self-consumption of electricity saves more money than the prosumer would receive by feeding the generated electricity into the grid. This shows that the feed-in tariff, which used to be a valuable tool for introducing PV to the German market, is becoming less and less relevant (Korcaj, et al., 2015, p. 408). By 2030, the EEG envisages an expansion target of 215 GW. This would mean a tripling of installed capacity compared to the level of expansion at the end of 2022 (Umweltbundesamt, 2023).

5.1 PV in Germany

Germany has a long history of photovoltaics and implemented a "1,000 Solar Roof Plan" as early as 1990. By 1995, 5 MW of PV systems had been installed on residential buildings in Germany followed by the implementation of the "100,000 Solar Roof Plan" in 1999. Due to favorable political conditions, the installed capacity of PV systems increased to 40 MW in 2000 (Yang, et al., 2020, p. 22).

In addition to other aspects such as the expansion of ground-mounted systems, the facilitation of rooftop photovoltaics or the securing of skilled workers, the facilitated access to plug-in solar systems is an important element of the German photovoltaic strategy, which was published by the Federal Ministry of Economics and Climate Protection (BMWK) in March 2023 (Bundesministerium für Wirtschaft und Klimaschutz, 2023, pp. 2-4). In 2022, the cumulative electrical capacity of all PV systems in Germany connected to the grid was around 67 GW peak (Statista, 2023a). In 2023, two-thirds of the photovoltaic capacity installed in Germany consists of rooftop systems and one-third of ground-mounted systems. Particularly due to the steady increase in module output, the area required for one MW of ground-mounted photovoltaics has permanently decreased in recent years (Umweltbundesamt, 2023).

PV systems are also generally accepted by the population. Today, of the more than 2 million PV systems installed in Germany, around 64% are small systems with outputs of less than 10 kW, which speaks strongly for the decentralized expansion of PV systems. According to surveys, PV systems are among the most popular power plants (Fraunhofer ISE, 2023, p. 37), as is also the case in Austria (Vienna University of Economics and Business; Deloitte; Wien Energie, 2023, p. 6).

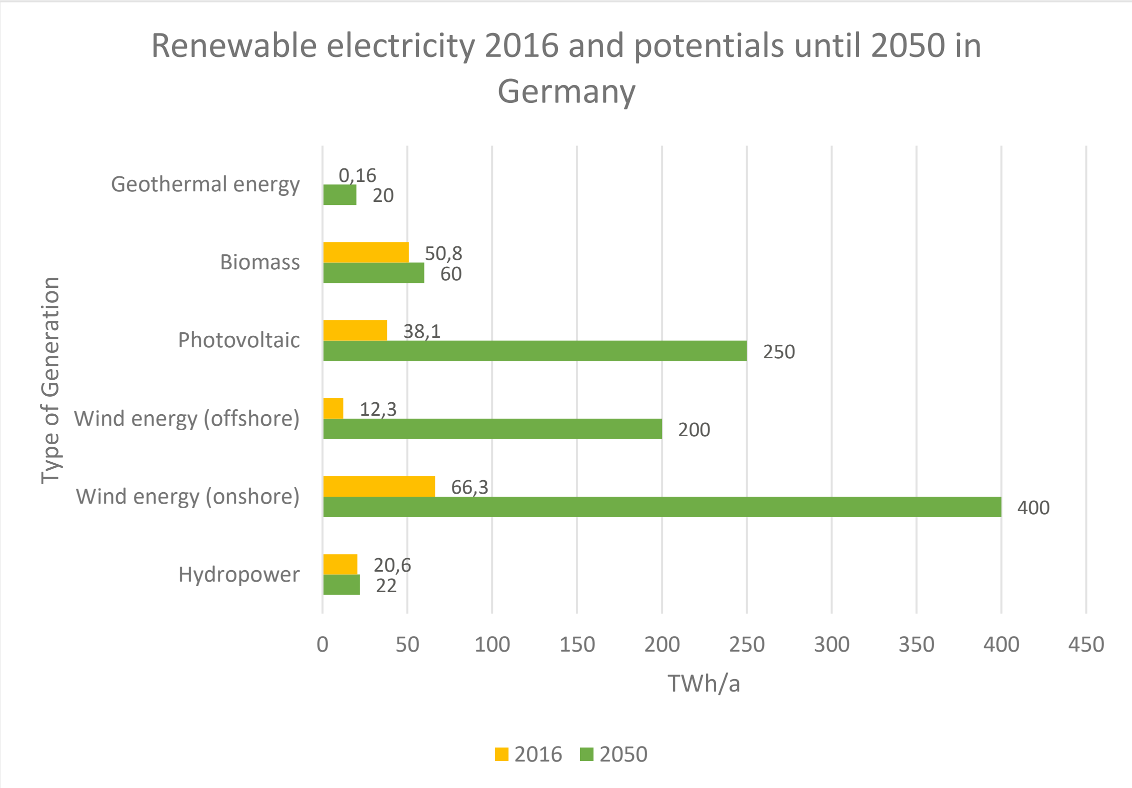

Figure 5.1 Renewable electricity 2016 and potentials until 2050 in Germany in TWh/a (derived from Brauner, 2019, p.19)

Figure 5.1 shows the renewable electricity in Germany in 2016 in TWh/a and potentials until 2050. The types of generation given are geothermal energy, biomass, PV, wind energy on- as well as offshore, and hydropower. The potentials in Germany until 2050 show great opportunities in the field of photovoltaics as well as wind energy, both on- and off-shore. On the other hand, the potentials for biomass and hydropower in particular seem to be almost exhausted. With a generation of 0.16 TWh/a, geothermal energy seems to play only a minor role in the German sustainable energy mix of today. Here, a potential of 20 TWh/a is forecast for the year 2050 (Brauner, 2019, p. 19).

5.2 The German balcony PV market

The University of Applied Sciences (HTW) in Berlin conducted a survey in 2022 to analyse the market for plug-in solar systems in Germany. The data collected shows that there has been a sharp increase in the number of suppliers in recent years and especially since 2019, with a large proportion of small and medium-sized companies[1] entering the market. Most notably, microenterprises with fewer than 10 employees are competing, accounting for about 72% of providers. Of the 56 vendors surveyed, 62% started selling plug-in solar devices after 2019 (Hochschule für Technik und Wirtschaft Berlin, 2022, pp. 11-12).

As part of the survey, suppliers were additionally asked about their sales figures. The data revealed sales of 81,000 plug-in solar devices in Germany, 66% of which were sold in 2020 and 2021 alone. This shows the increasing popularity of plug-in solar devices in recent years, which is also reflected in the overall market growth of 84% from 2020 to 2021. (Hochschule für Technik und Wirtschaft Berlin, 2022, pp. 16-17). An estimate carried out in the course of the study puts the total number of units sold in Germany at around 190,000, with a megawatt output of 66 MW (Hochschule für Technik und Wirtschaft Berlin, 2022, p. 24). The Federal Ministry for Economic Affairs and Climate Protection estimates the number of balcony power plants currently installed even higher, at 250,000 with a total output of 100 MW (Bundesministerium für Wirtschaft und Klimaschutz, 2023, p. 20).

As of January 2023, the value added tax (VAT) on photovoltaic systems with a gross output of less than 30 kWp was reduced to 0% in Germany, as §12 shows (Bundesamt für Justiz, 2022). As a result, balcony PV power plants are no longer subject to VAT, as the supply of solar modules is favored regardless of whether the solar modules are part of a set or are purchased individually (Bundesministerium der Finanzen, 2022).

5.3 Differences Austria and Germany

In a document issued by the BMWK in March 2023, the German strategy with regard to photovoltaics is discussed. In this context, a separate chapter was also dedicated to

[1] Definition of the European Commission; SME employ less than 250 persons and should have an annual turnover lower than €50 million (Eurostat, 2023a).

balcony power plants and possible future legislative changes (Bundesministerium für Wirtschaft und Klimaschutz, 2023, pp. 20-22).

While the Austrian government allows an inverter output of up to 800 watts per household (Bundesministerium für Finanzen, 2010), German households can currently only make use of an installation with a total inverter output of up to 600 watts. This fact is presently the subject of discussion in Germany, and the Federal Ministry of Economics and Climate Protection is currently considering increasing the permitted number of watts to 800. (Bundesministerium für Wirtschaft und Klimaschutz, 2023, pp. 21-22). This increase is also discussed in the BMWK strategy paper. Additionally, as a transitional solution, backward-turning meters are to be allowed until the meter is replaced. This is intended to reduce the bureaucratic burden and adapt the threshold to the maximum of 800W communicated by the EU in the regulation 2016/631 "Requirements for Generators" (Bundesministerium für Wirtschaft und Klimaschutz, 2023, p. 21). In addition to the BMWK, the VDE has also recently recommended the introduction of 800 watts as a de minimis limit for simplified registration within the framework of European standardization (VDE Verband der Elektrotechnik Elektronik Informationstechnik e.V., 2023a, p. 3).

Usually, tenants and flat owners in Germany need permission from their landlords or the condominium association to operate their plug-in solar devices, regulations for the installation are specified in the respective standards of the grid operators. In the strategy paper of March 2023 the inclusion of plug-in solar devices in the catalogue of privileged measures (Katalog privilegierter Maßnahmen WEG/BGB) is being considered by the BMWK in order to guarantee flat owners and tenants the right to obtain approval from the condominium association or the landlords respectively (Bundesministerium für Wirtschaft und Klimaschutz, 2023, pp. 20-21).

In the future, the Federal Republic furthermore wants to simplify or completely abolish the obligation to register balcony power plants. At the moment, German customers are obliged to report the commissioning of the installation not only to the grid operator, but also to the core energy market data register (Marktstammdatenregister) (Bundesministerium für Wirtschaft und Klimaschutz, 2023, p. 21). Here, data for the gas and electricity market is officially registered and can be used by both authorities and participants in the energy sector (Bundesnetzagentur, 2023). However, since this involves a higher administrative effort and there are also almost no sanction mechanisms in place, only an estimated 10 to 20 percent of the devices sold are in the end reported to the core energy market data register (Hochschule für Technik und Wirtschaft Berlin, 2022, p. 26).

Likewise, Schuko plugs are to be approved as "energy plug-in devices", regarding to the strategy paper (Bundesministerium für Wirtschaft und Klimaschutz, 2023, p. 21). Currently, a Wieland plug or similar must be used to install a balcony PV system in Germany. Since the DIN EN 61140 (VDE 0140-1) standard does not specify the type of construction, but rather the protection goals, alternative variants may also be used. The VDE classifies balcony PV power plants currently not as electrical equipment but as a generation system, which makes a specific plug and socket necessary (VDE Verband der Elektrotechnik Elektronik Informationstechnik e.V., 2023b). This type of power socket must be installed by a qualified electrician in most cases and needs to be connected with its own supply line. It is mainly safety concerns that are used to argue in favour of this standard (VDE Verband der Elektrotechnik Elektronik Informationstechnik e.V., 2023c).

Figure 5.2 Wieland-plug (home & smart, 2022)

Figure 5.3 Schuko-plug (easygoinc, 2023)

Figure 5.2 and 5.3 show a Wieland and a Schuko-plug respectively. The difference between the two is that Wieland connectors provide more safety as the contacts of the plug as well as the socket are protected against accidental contact even when unplugged, as can be seen in figure 5.3. This reduces the risk of electric shock (Wieland Electric GmbH, 2023, p. 1). As the socket is permanently installed to ensure protection against contact, installation by an electrical engineer is necessary in most cases. The installation would cost customers another 100-150€, which would be high expenses (EET, 2023), especially in connection with the comparatively low purchase price of balcony power plants. This would increase the amortisation time of the balcony PV power plant significantly. In the case of the Schuko, on the other hand, the two contact pins are not built into the plug and could therefore be touched. Nevertheless, dangerous voltages are discharged in advance through the plug (elektrofachkraft.de, 2022).

In Austria, the use of a Schuko-plug is sufficient to connect a balcony PV power plant to the household electrical circuit, a connection with a Wieland plug is only necessary if requested by specific grid operators. This is true if a classification of plug-in PVs as electrical equipment is assumed, which was also the conclusion reached by the experts in the study carried out by the Fraunhofer Institut in 2019 (Fraunhofer-Institut für solare Energiesysteme ISE, 2019, p. 10).

For Germany, the situation is not entirely clear. The VDE has for a long time only considered the installation with a Wieland plug as permissible from a safety point of view (VDE Verband der Elektrotechnik Elektronik Informationstechnik e.V., 2023b), but after a lot of debate regarding the safety of Schuko plugs for balcony PV power plants, it seems like the big players in Germany are coming to terms in this question: In addition to the BMWK, the VDE also came forward in favour of tolerating a Schuko plug as a plug device in January 2023 (VDE Verband der Elektrotechnik Elektronik Informationstechnik e.V., 2023a, p. 4). The tendency is strongly moving toward the use of a regular Schuko plug, as modern PV inverters are set to shut down within 0.1 and 0.2 seconds, depending on the producer, if they cannot find a connection to a plug anyways and are therefore ensuring a certain level of safety (Brauner, 2023).

With the implementation of DIN VDE V 0100-551-1 in May 2018, electricity can be fed into the existing final circuit in Germany (VDE Verband der Elektrotechnik Elektronik Informationstechnik e.V., 2023b). According to the VDE, plug-in PV systems also fall under the EEG, which makes it possible for prosumers to benefit from the EEG feed-in tariff. However, since the amount of electricity fed into the grid is very low and the installation is rather designed for self-consumption, the amount of electricity remunerated will be limited (VDE Verband der Elektrotechnik Elektronik Informationstechnik e.V., 2023b).

Although the name of the product indicates an attachment to the balcony site, 44% of the plug-in solar units sold by the suppliers surveyed in Germany are sold with an upstand and only 29% with mounting kits for balconies. 22% are used for tilted roofs, a small part

(5%) are mounted on facades (Hochschule für Technik und Wirtschaft Berlin, 2022, p. 28f).

Table 1 comparison of balcony PV power plants in Austria and Germany (own depiction)

	Austria	Germany
Inverter output	800 watts	600 watts
plug	Schuko	Wieland plug or similar
Installation by a professional	Depends on grid operator	Needed for the installation of a Wieland plug or similar
Obligation to report	Notification to the grid operator	Registration in the core energy market data register and notification to the grid operator
Compensation for energy fed into the public grid	not intended	Yes, but not intended

6 Public Funding of balcony PV power plants in Austria

6.1 State level

Since the Green Electricity Act came into force in 2003, there has been the possibility in Austria to regulate subsidies for renewable electricity on a nationwide basis (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2022a, p. 25). The Renewable Energy Expansion Act (Erneuerbare-Ausbau-Gesetzespaket-EAG-Paket) of 2021 brought about renewals and a new subsidy system was implemented with the Renewable Energy Expansion Act (EAG). This now reaches further and, in addition to the promotion of electricity and gas generation from renewable energy sources, also addresses the issue of energy communities, guarantees of origin, certificates for gas from renewable energy sources and a creation of an Austrian grid infrastructure plan (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2021).

Applications for investment subsidies under the EAG can be submitted several times a year. The Abwicklungsstelle für Ökostrom AG (OeMAG) is the concessionaire for the processing of subsidies under the Renewable Energy Expansion Act. Its tasks are the settlement and remuneration of the green electricity fed into the grid, the administration of the subsidy quotas, the drawing up of contracts, and other tasks (OeMAG, 2023a). The photovoltaic subsidy is divided into 4 different categories A to D, depending on the peak power of the modules in kWp. As such, an application for a balcony power plant would be classified in category A (0.01-10 kWp). In 2023, the subsidy rate for category A is 285€ per kWp. In the four subsidy calls spread over the year, 168€ million of funding is available for category A (OeMAG, 2023b). In 2023, however, balcony power plants will not be eligible for subsidies, as the support only applies to feed-in plants and a balcony power plant does not qualify as such and is not equipped with a metering point (OeMAG, 2023c, p. 8).

Interestingly, this same information is not given in all of the information sheets provided. (OeMAG, 2023c). Therefore, a lack of coherent information for private individuals, but also professionals in the counties, can be observed. While an older document from 2022 does not state any information regarding possible subsidies of balcony PV power plants, the version from 2023 does specifically exclude plug-in power plants from the investment grants under Article 22 of Förderablauf/Bedingungen, as they are not considered as feed-in plants. This is particularly interesting because even public websites such as that of the Federal Ministry Republic of Austria Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK) refer to the older FAQ sheet (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2023c).

Arguably, the OeMAG subsidies only exclude power plants that do not have a metering point. Therefore, if a metering point is applied for and granted by the grid operator for a balcony power plant, for which an electrician's company must carry out a technical inspection, subsidies by OeMAG for balcony power plants in category A would theoretically be possible (ENU, 2023). This would, on the other hand, increase the administrative and financial effort that needs to be undertaken by the individual to register the balcony PV power plant and get the plant installed by an electrician.

6.2 Federal state level

In the course of this work, requests were sent to all federal offices in Austria to gain information on subsidies for balcony PV power plants, planned support in the future and reasons on why subsidies are not offered for private individuals. In all nine federal states, no subsidies were given to households installing a plug-in PV system. While some of the federal states do offer some kind of financial support for PV installations, balcony PV power plants were not included in the funding. Arguments against a subsidy were mainly the lack of a feed-in metering point and no grid access contract with the grid operator.

Upon request, the province of Upper Austria stated that subsidies for micro power plants do currently not exist and are presently not considered for the future. In the county, regular photovoltaic subsidies are granted on the basis of a grid access contract and a feed-in metering point by the grid operator. Neither of these prerequisites are required for micro power plants, given the simple installation of the balcony power plant and thus its unique selling point (Land Oberösterreich, 2023).

For its subsidies for photovoltaic systems, the province of Tyrol also requires the metering point number and consequently does not subsidise balcony power plants either (Land Tirol, 2023). In Tyrol, however, the expansion of PV in general is supported: Thus, the

6th and 7th kWp of a plant are supported, regardless of whether it is a new installation or an expansion (Amt der Tiroler Landesregierung, 2023).

The county of Vorarlberg is currently not subsidizing photovoltaic for private individuals, neither on roofs, nor on balconies. However, there are federal subsidies for photovoltaic systems on sealed surfaces, for building suitability checks for photovoltaics and green roofs, as well as for photovoltaic systems on agricultural buildings in place. Furthermore, there is funding for citizen participation and energy communities (Land Vorarlberg, 2023).

In recent years, the province of Lower Austria has set up a complex system of subsidies for housing construction and home renovation. Here, depending on the improvement of the heating demand of the house before and after a renovation, points are awarded, the number of which determines the amount of subsidy to be paid out. In addition, it is also possible to collect complementary points. These points include efficient heating systems, measures for the protection of historical monuments or the installation of a PV system. However, since the photovoltaic system to be installed must have a total inverter output of at least 2 kWp, no subsidies are available for balcony power plants in this case (NÖ Wohnbauförderung, 2022, p. 13). Regarding the implementation of a plug-in solar system, the county of Lower Austria emphasised especially on the communication with the grid operators as a vital aspect (ENU, 2023).

In the course of the climate and energy strategy SALZBURG 2050, the province of Salzburg has taken measures to achieve climate neutrality, energy autonomy and sustainability. Within the framework of SALZBURG 2050, the construction of photovoltaic systems is also promoted. According to the current status, balcony power plants do not fall into the eligible area, as the construction of PV systems for private households is only supported from a capacity of more than 1 kWp (Land Salzburg, 2023). With 0.8 kWp, balcony power plants are therefore not in the eligible area.

In the province of Carinthia, newly installed photovoltaic systems connected to the grid are subsidized for homes with a maximum of two flats. The subsidy takes the form of a one-off grant. Either 35% of the costs or a maximum of €480 per kWp up to 10 kWp are subsidised. If a federal subsidy has also been applied for, a maximum subsidy rate of 70% is permitted, otherwise the county subsidy will be reduced. Only owners or co-owners can apply for funding (Amt der Kärntner Landesregierung, 2023, pp. 3-4). Systems that are installed by the customer themselves are not eligible, requiring installation by a professional in order to receive the subsidy (Amt der Kärntner Landesregierung, 2023, p. 10).

The province of Styria also promotes the expansion of photovoltaic systems, but its programme focuses mainly on the promotion of municipal buildings. This The funding can only be applied for by Styrian municipalities (Energie Agentur Steiermark gGmbH, 2023, pp. 3-4) and not by private individuals and is therefore not relevant in the course of this work.

In the province of Burgenland, the construction and upgrading of grid-connected PV systems with a maximum output of 20 kWp as well as electricity storage systems are supported. Double subsidies are not permitted (Land Burgenland, 2023). Like the other federal states, the province of Burgenland also does not subsidize plug-in systems.

6.3 Municipal level

This sub-chapter will elaborate on how different municipal authorities in Austria are supporting the installation of balcony PV power plants. The following cities were examined for evaluation in terms of subsidies: Vienna, Graz, Linz, Salzburg, Innsbruck and Klagenfurt. Each of these cities is the capital of an Austrian province and has a population bigger than 100,000 (Statista, 2023b). Looking at the capital cities in Austria will on the one hand ensure a geographical spread over the whole country, while on the other hand also provide information for a big number of inhabitants. The chapter does not claim to be exhaustive, as smaller municipalities and cities in Austria may also offer subsidies for balcony PV power plants. Rather, this chapter will focus on cities with more than 100,000 inhabitants and provide an overview of possible support.

The City of Vienna with 1,982,442 inhabitants in 2023 is by far the most populated city in Austria (Statista, 2023b). Many cities, including the City of Vienna, refer enquiries about subsidies regarding PV installations to OeMAG, if there is an application period ongoing (Stadt Wien, 2023). As discussed above, balcony PV power plants are generally not covered by these subsidies because they are not classified as feed-in plants and generally do not have a metering point, a requirement for receiving subsidies for a PV system (OeMAG, 2023c). With the image of being the world's most liveable city and a pioneer in climate protection, the city's decision-makers are keen to keep standards high:

The city has therefore published a Vienna Climate Guide for a climate-friendly city. A first climate protection program was already published in the 1990s, and with the "Smart City Wien Strategy" the city committed itself to achieving climate neutrality by 2040. Another important pillar in this context is Vienna's goal of increasing not only climate protection but also climate adaptation (Vienna City Administration, 2022, p. 19). While the City of Vienna is known for its progressive approach regarding the energy transition, there are currently no subsidies regarding balcony PV power plants available. However, relief for the installation of a plug-in system was created in January 2023, as it is now possible for tenants of municipal buildings (Gemeindebauten) to install a balcony PV power plant under certain conditions. As with all other balcony PV power plants in Austria, the installation must be reported to the electricity grid operator. Furthermore, a permit from Wiener Wohnen, which manages municipal buildings in the City of Vienna, is required to ensure that the installation does not impair the external appearance of the building. Additionally, the installation must be executed by a professional (Stadt Wien - Wiener Wohnen, 2023, p. 5).

With 298,512 inhabitants in 2023, Graz is the second largest city in Austria after Vienna (Statista, 2023b) and has the goal to become climate neutral by 2040. To this end, a climate protection plan was initiated that comprises two parts: While climate protection goals were defined and existing measures were collected in the first part, action plans are being developed within the frame of the second part, in order to be able to implement concrete measures. In this context, the Graz City Council also adopted a climate protection fund incentive package in April 2021, which provided for subsidies for photovoltaics, citizen energy communities and green roofs. A subsidy for small-scale photovoltaic systems for balconies was also established in this context. This stipulated that PV systems with a maximum output of 800 Wp would be subsidised up to 60% of the expenditure, but with a maximum of 600€. This subsidy also included the commissioning of an expert for the installation. In April 2023, the City of Graz had already exhausted its climate subsidy pot and no new applications could be submitted (Stadt Graz, 2023). A request made to the City of Graz to gain more information about a possible increase of the fund or the share of the money spent on balcony PV power plants has remained unanswered.

Linz with 210,165 inhabitants is the third biggest city in Austria (Statista, 2023b) and subsidises the installation of photovoltaic systems and/or electricity storage if permanently installed (Stadt Linz, 2023). If the roof is greened at the same time or the PV is installed on a green roof, the subsidy for the PV system increases. The City of Linz subsidises 125€ per installed kWp of the photovoltaic plant, with a maximum subsidy sum of 625€. In the case of a solar green roof, the subsidy amount increases to 225€ per kWp and a maximum subsidy amount of 1,125€. It is explicitly stated on the homepage of the City of Linz that micro photovoltaic systems are excluded from funding (Stadt Linz, 2023).

The City of Salzburg with 156,621 inhabitants is the fourth biggest city in Austria (Statista, 2023b). In 2011, the city set a goal to install 140,000 m² of solar panels by 2025. As part of this aim, a photovoltaic subsidy was introduced. The subsidy is permissible for a photovoltaic system with a capacity between 1 and 20 kWp with an annual energy yield of at least 800 kWh per year and kWp, as systems with a lower value are not considered efficient. Furthermore, a primary residence in the city of Salzburg is required for private individuals. For these installations, a one-time subsidy of 750€ or 30% of the total eligible gross investment costs is granted. However, the subsidy can be reduced if a subsidy from the state or federal government is already available (Magistrat der Stadt Salzburg, 2023, p. 1). The funding is limited to the end of 2025 (Magistrat der Stadt Salzburg, 2023, p. 3). Upon request, the city stated that the municipal subsidy does not include balcony power plants, as the benefit of these was estimated to be marginal by experts during the development of the subsidies program. As a consequence, no subsidies are planned for the future (Stadt Salzburg, 2023).

Innsbruck had 131,319 inhabitants at the beginning of 2023 (Statista, 2023b) and its Energy Plus program promotes increased heat and sound insulation as well as environmentally friendly measures to reduce energy consumption and pollutant emissions. As of September 2022, the installation of photovoltaics is also part of the Energy Plus Programme. The funding consists exclusively of one-time grants and is provided in addition to federal and state funding (Landeshauptstadt Innsbruck, 2022a). The subsidies for photovoltaic systems refer to installations with a system output of more than 5 kWp, the largest eligible value of kWp is 10 (Landeshauptstadt Innsbruck, 2022b, p. 3). With a system output of 0.8 kWp, balcony PV power plants do subsequently not fall within the scope of subsidies in Innsbruck.

Klagenfurt is Austria's sixth biggest city with 104.333 inhabitants (Statista, 2023b). Requests to the city regarding subsidies for balcony PV power plants or general information regarding subsidies of photovoltaics have remained unanswered.

7 Cost Benefit Analysis

In May 2023, the costs for a balcony PV power plant in Austria without a storage capacity can be located between 550€ and 1200€, depending on the amount of watts (Home & Smart, 2023). Improvements have been made over the years, which leads to the fact that today's PV modules have only very little power loss. A study by Fraunhofer ISE found an average annual degradation of the nominal power of approximately 0.15%. Most manufacturers offer a guarantee for a maximum power loss of the PV modules of 10-15% over 25-30 years (Fraunhofer ISE, 2023, p. 42), which is assumed as the life time of the plug-in PV in the calculation later.

For a balcony PV power plant, opportunity costs can be regarded 0, as it is in many cases directly installed to the balcony railing or put up on the balcony and is therefore not occupying space that could have been used otherwise. Especially for owners of an apartment in a multi-apartment building or tenants, it is easier to install a plug in PV rather than a regular PV on the roof of the building, since this is connected with higher administrative and furthermore higher financial effort.

Operating costs should also not be ignored in the cost-benefit analysis of a balcony power plant. For PV systems, one can assume 2-5% of the purchase price per year in repair and maintenance work (Quaschning, 2020, p. 159).

In 2022, an average of 2,053.67 hours of sunshine was recorded in the Austrian federal capitals, although there were geographical variations. Graz, for example, recorded the biggest amount of sunshine hours with 2,236, while Salzburg was the capital city with the fewest hours of sunshine with 1,730, a difference of more than 500 sunshine hours per year (Statista, 2023c). The amount of hours of sunshine plays an important role in calculating the benefit and the pace of amortisation of a balcony PV power plant, since this is one of the key factors of how much electricity can be produced in the end.

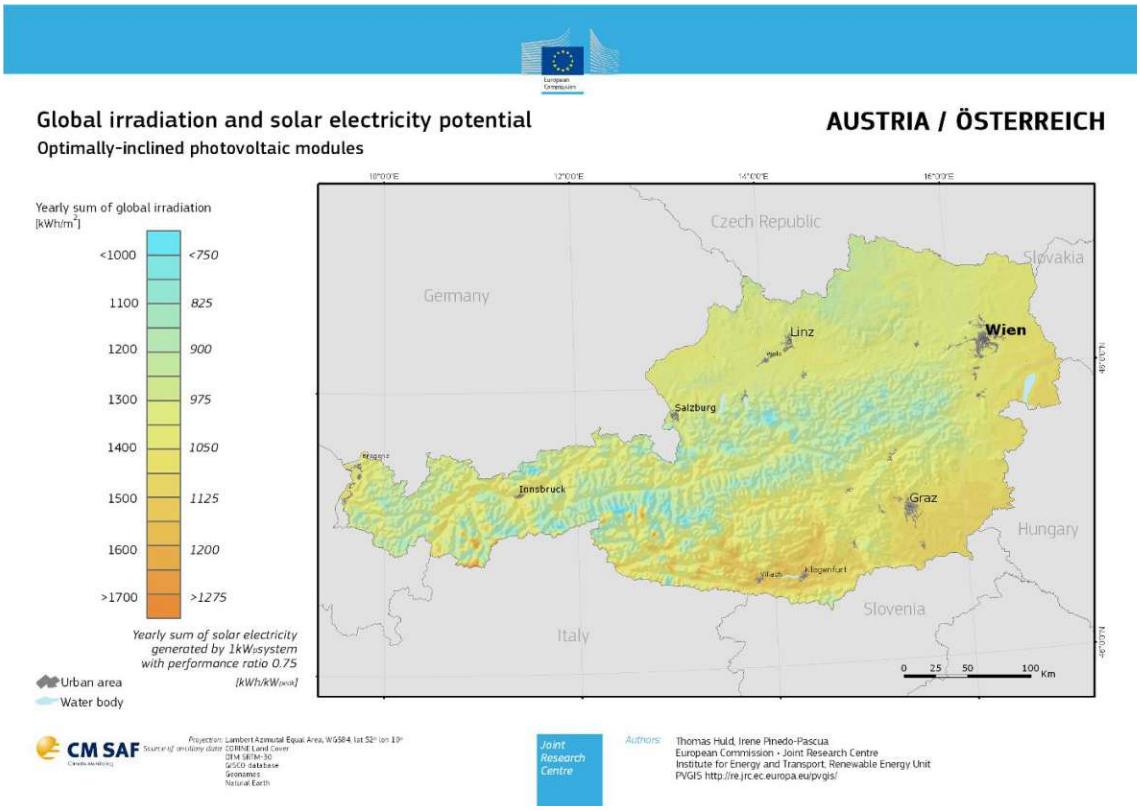

Figure 7.1 Global irradiation and solar electricity potential (European Commission, 2019)

Figure 7.1 shows the global irradiation and the solar power potential in Austria for optimally oriented photovoltaic modules. The potential for PV in Austria is mainly in the south and east, while it is not as pronounced in the Alpine region.

Other important aspects are the angle at which the balcony power plant is mounted and its direction. The most favourable angle to optimize efficiency in Austria would be between β 30° and 40°. A south-facing roof is considered as azimuth α = 0. In general, a southward orientation will have the most efficient effect on electricity generation (Mertens, 2020, p. 57f), but in certain cases it may also be advantageous to orient the installation towards the west or east (Magistrat der Stadt Wien, 2022, p. 39). This depends on when the household wants to consume most of its electricity and also the area available for the instalment. This aspect should be considered especially in connection with the absence of a storage unit.

The number of full load hours depends on the respective latitudes. Due to the irradiation conditions, PV-installations very often only work less than half of the possible 8,760 annual hours, and the hours working often in partial load (Fraunhofer ISE, 2023, p. 43). In Central Europe, the annual yields range between 950 and 1100 kWh/kW (Brauner, 2019, p. 24). Compared with other types of electricity generation, the amount of full load hours per year is comparably low.

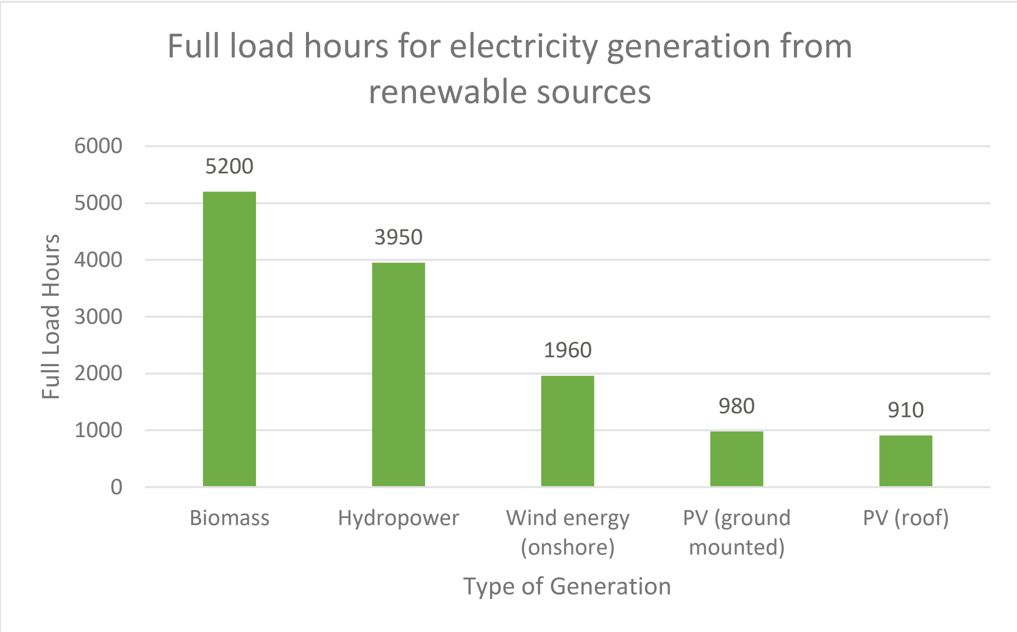

Figure 7.2 Full load hours for electricity generation from renewable sources (derived from Fraunhofer ISE, 2023, p.45)

Figure 7.2 shows the projected full load hours for electricity generation from RES (Fraunhofer ISE, 2023, p. 44). What can be seen is that PV, both ground mounted and installed on roofs, has comparably few full load hours. This is due to the dependency on irradiation.

Furthermore, shading of the installation by neighbouring buildings, trees and the like must be taken into account (Mertens, 2020, p. 190) and should be avoided to ensure high efficiency. PV-systems react extremely sensitive to shade and there can be strong loss of performance even with little shading (Quaschning, 2020, p. 144).

How quickly the balcony PV power plant ultimately amortises, is strongly dependent on the current electricity prices, as the latter indicate how much electricity costs a private person saves per year as a result of the installation. The profit is constituted by the difference between the grid electricity price and the self-generation costs of the plant

(Brauner, 2019, p. 41). In Austria, electricity costs are comprised of the energy price, the grid fee, as well as taxes and levies (E-Control, 2023c). Therefore, higher electricity prices will increase the pace of amortisation.

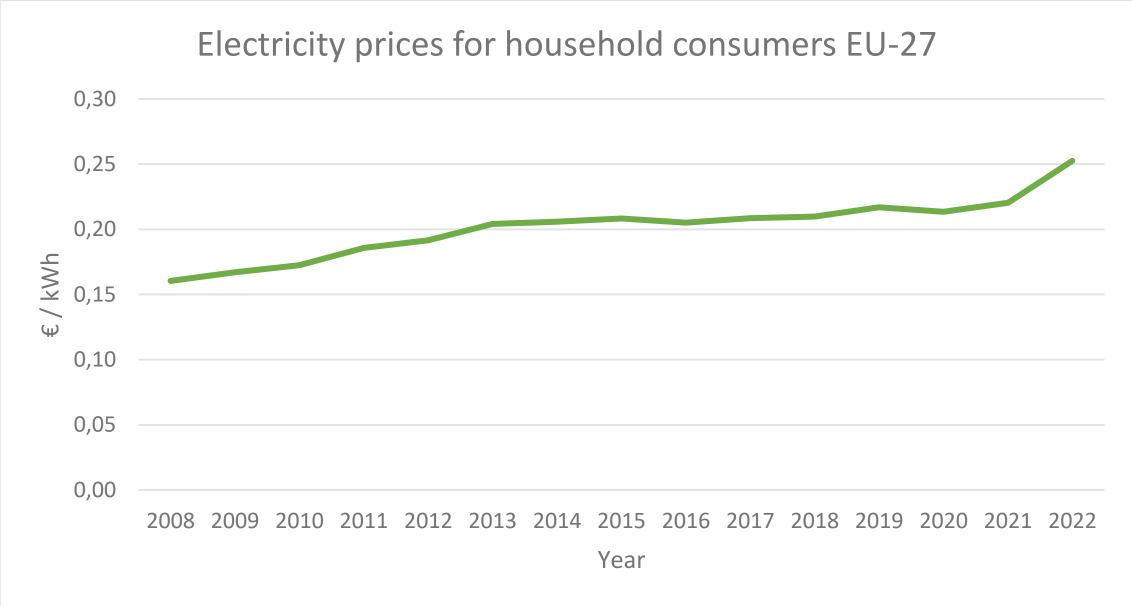

Figure 7.3 Electricity prices for household consumers EU-27 (derived from eurostat, 2023)

Figure 7.3 shows the increase in electricity prices for household consumers in EU-27 from 2008 to 2022 (Eurostat, 2023b). Especially due to the war in Ukraine and the associated increase in gas prices, electricity prices have been surging over the last years (Kettner, et al., 2022, p. 629). The data is based on an average annual consumption of 2,500 to 5,000 kWh. Electricity prices have been rising in EU-27 over the last years, from 2008 to 2022 an increase of 0.09 €ct has taken place (Eurostat, 2023b). This would mean an increased electricity bill of 360€ for household consumers with an annual consumption of 4,000 kWh from 2008 to 2022. Households that have a PV system are significantly less affected by the increased electricity prices, and in the best case, if the electricity is drawn entirely from their own system, not at all (Kettner, et al., 2022, p. 629).

Regarding the electricity prices for consumers in the future, a further rise over the next years is expected. Brauner calculated an increase in electricity prices in Austria and Germany by 2050.

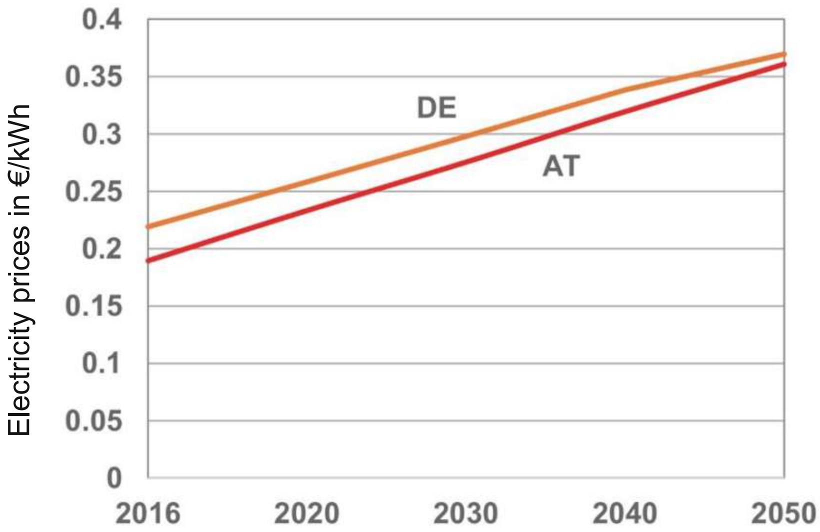

Figure 7.4 Development of electricity prices in Austria and Germany from 2016 to 2050 (Brauner, 2019, p.41)

Figure 7.4 shows the calculated increase of electricity prices in Austria and Germany from 2016 to 2050 in €/kWh. Until 2050, the electricity price in Austria is expected to increase to 37 €ct/kWh by 2050. This is an increase of 18 €ct compared to the electricity price of 2016, which would mean almost a doubling (Brauner, 2019, p. 41). These calculations were conducted before the COVID-19 pandemic as well as the war in Ukraine, which has led to electricity prices skyrocketing within the last years. Even though the graph is therefore not depicting the actual current energy prices, it does project a direction of electricity prices in the future and is therefore essential to bear in mind.

An average household of four has an electricity consumption of 4,000 kWh per year (Magistrat der Stadt Wien, 2022, p. 39), which will also be the basis for the cost benefit analysis conducted in this chapter. Over the last few years, electricity prices have been rising steadily, but have surged in late 2021 in the European Union as well as other parts of the world. With the ongoing war in Ukraine, fuel prices have continued to rise, which had a negative impact on electricity prices as a whole (European Council, 2023). For April 2023, E-Control has indicated the price for 1 kWh for an average household of four that consumes 4,000 kWh per year at 41.3 €ct/kWh (E-Control, 2023d). When calculating for the whole year, this would lead to average electricity costs of 1,652€ for a household of four.

An electricity cost cap was introduced to reduce the rapidly increasing electricity prices in Austria and to relieve the population (Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie, 2023d), but is not dealt with further in this paper.

Especially with higher electricity costs and lower costs for photovoltaics, PV installations as a whole and therefore also balcony PV power plants will amortise faster in the future. The costs for PV have been decreasing steadily over the last few decades (Wien Energie GmbH, 2021), and with it the levelized cost of PV-produced electricity. Alone between 2010 and 2021, the global weighted average levelized cost of PV-produced electricity dropped from 0.417 $/kWh to 0.048 $/kWh, a decrease of 88%. In 2021, the year-on-year reduction was at 13% (IRENA, 2022, p. 79). The levelized costs of electricity (LCOE) can be defined as the *"costs of the production unit of electricity"* (Yang, et al., 2020, p. 429) which is the sum of the investment costs over the actual amount of electricity produced (Yang, et al., 2020, p. 429). Reasons for this sharp decline are an increased demand, the possibility for mass production and a higher degree of competition on the market. Furthermore, the technical possibilities have been improved (Wien Energie GmbH, 2021). Since there is still potential in improving the entire value chain as well as all components, a decrease in price of PV can be expected in the future (Fraunhofer ISE, 2021, p. 19).

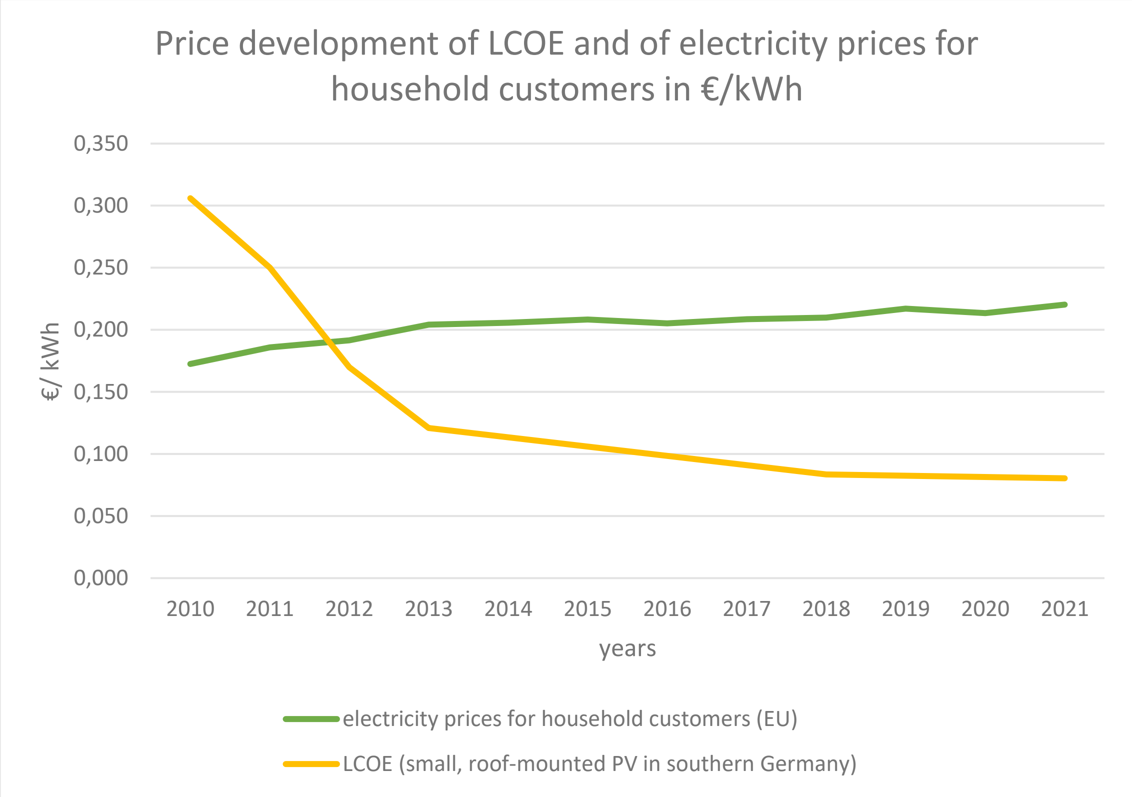

Figure 7.5 Price development of LCOE and of electricity prices for household customers in €/kWh (derived from eurostat, 2023, and Fraunhofer ISE 2021)

The development of both factors, the LCOE and the electricity prices for household customers in €/kWh can be seen in figure 7.5. While LCOE have dropped from €0.306 in 2010 to €0.0804 in 2021, electricity prices for household customers in the European Union have been increasing from €0.1725 in 2010 to €0.2203 in 2021. As the LCOE is strongly dependent on the size of the system and the geographical area, a small PV system installed on a roof (5-15 kWp) in Southern Germany has been assumed for the data of this graph. This shows that also for small PV, the LCOE is decreasing steadily. The developments of the past years show an increased economic benefit for investments in photovoltaics.

Another important aspect regarding the amortization time of the balcony PV power plant is the behaviour of the individual using the electricity. In order to minimize the amount of electricity that is fed back into the grid, and therefore increase the self-consumption, it is necessary to orient habits to the availability of sunlight (Quaschning, 2020, pp. 156-157). This is especially true in the cases of Balcony PV Power Plants with no storage unit, as the energy can only be used directly in the household- or is otherwise fed back into the public grid. Therefore, a high level of self-consumption is required to make a plug-in PV economically viable.

For the cost-benefit analysis, an installation with α=0° and β=30° was assumed. The city of Vienna was adopted as the location for the balcony power plant. Here the direct normal solar irradiation is 1105.8 kWh/m², the perfect inclination of the PV modules would be 36° (The World Bank Group, 2023). By changing β to 90°, the balcony power plant would only generate about 70% of an optimally oriented solar installation due to its tilt (Mertens, 2020, p. 58). But, as already elaborated earlier, a big amount of plug-in PV is mounted not at the balcony railing, but is rather placed on the ground directly.

Under these conditions, a total photovoltaic power output of a balcony PV power plant with 800 Wp was calculated with 908.323 kWh per year (The World Bank Group, 2023). To actually reach this value, we assume that no loss through shade or other kinds have occurred. When multiplying the PV power output with the current electricity prices of a household of four, the following value is obtained:

$$908.323 \text{ kWh/year} \times 0.413 \text{ €/kWh} = 375.137 \text{ €/year}$$

A household of four would therefore save 375.14 € per year on electricity costs by installing a balcony PV power plant in southward direction and with an inclination of the modules of 30°.

It should be noted, however, that this value only applies if all the electricity generated is actually consumed in the household and not fed into the grid. Therefore, it must be a priority for the respective households to keep the self-consumption of the system as high as possible in order to prevent too much energy from being fed back into the public grid. The self-consumption depends strongly on the system performance of the installation as well as the household size and electricity consumption.

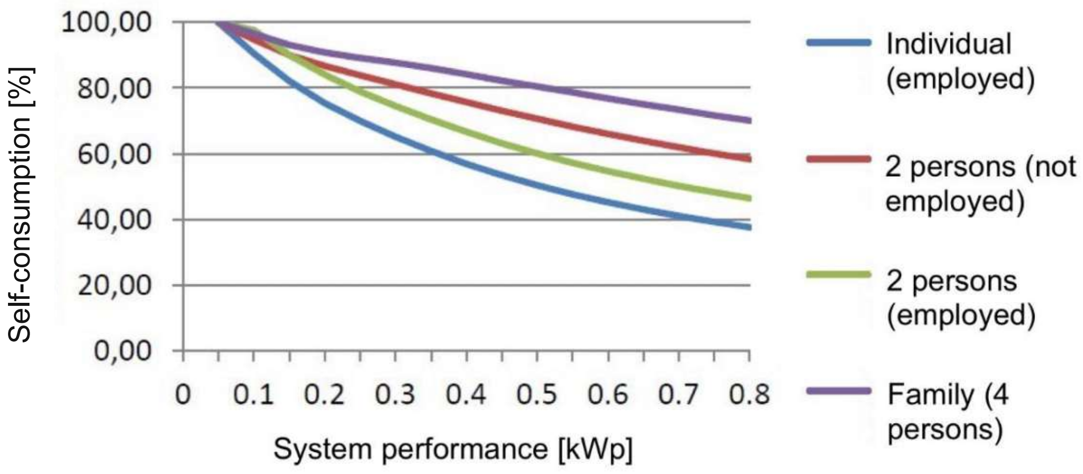

Figure 7.6 Household self-consumption depending on the system performance (south-facing, 30° inclination) (Fraunhofer ISE, 2019, p.70)

Figure 7.6 shows the dependency of self-consumption on the system output in the output range from 0 to 800 Wp. The system used for the calculation faces south and has an inclination of 30°. The different lines indicate different household sizes and employment and therefore different electricity consumption and self-consumption shares. What can be seen from the graph is that with higher system performance, the self-consumption in all four types of electricity consumption decreases, since not all of the electricity produced can be actually consumed by the household. This is true for all types of households, even though the differences are less severe for bigger households. This is due to the fact that more energy is consumed within the household in total, therefore more of the electricity produced by the plug-in PV will be used rather than fed back into the grid.

For the purple line (family, 4 persons), an energy consumption of 5,060 kWh/year was assumed by the Fraunhofer Insitute. The household of four with an energy consumption of 4,000 kWh, which is assumed for the cost benefit analysis, can be located between the purple (5,060 kWh consumption) and the red line (3060 kWh consumption), which means that the household would still reach a self-consumption rate of little under 70% with the 800 Wp installation placed in a 30° angle facing south (Fraunhofer-Institut für solare Energiesysteme ISE, 2019, p. 71).

As customers normally do not sign a purchase agreements for the electricity fed back into the public grid, it is assumed that the amount back into the grid is lost for the prosumer and does not get compensated by grid operators. This fact once again underlines the relevance of a high self-consumption rate for a fast amortisation.

Assuming that 68% of the electricity produced by the balcony PV power plant is actually used by the household, a more realistic calculation of the money saved per year can be made. This would mean that the household is consuming 617.66 kWh of the electricity produced by its installation. When multiplying the value with the current electricity prices as indicated by E-Control, the following value is obtained:

908.323 kWh x 68% = 617.66 kWh

617.66 kWh x 0.413 €/kWh = 255.1 €

This value indicates that a household of four with an energy consumption of 4,000 kWh/year would be able to save 255.1€ of electricity costs by installing a balcony PV power plant that faces South with an inclination of 30°.

Since operating costs are recurring expenses, a subtraction from the money saved must be carried out. The operating costs of a PV can be calculated with 2-5% of the acquisition cost. In this case, operating costs of 28.5€ (3%) per year were assumed. Therefore the benefit per year after the subtraction of the operating costs is 225.6€ (255.1€ -29.50€).

To attain the payback period of the balcony PV power plant, an offset of the saved costs per year against the acquisition costs of the installation has to be carried out. In addition to the energy prices and the calculated self-consumption, this is strongly dependent on the prices of the installation. For the calculation, an average price of 1,000€ was assumed.

1,000€ / 225.6€ = 4.43 years

This would indicate that the amortisation of the plant is achieved after 4.43 years.

This example also shows the need for clear regulations on the use of a Wieland plug, as the installation of a Wieland plug by a qualified electrician prolongs the payback period. When assuming costs for the installation of a Wieland plug at 150€, this would increase the amortisation period of the balcony PV power plant.

(1,000€ + 150€) / 225.6€ = 5.1 years

The calculation shows that with the installation of a Wieland plug, as it is required in Germany, the amortization time for a balcony PV power plant increases to 5.1 years.

The calculation shows that due to the sinking acquisition prices of PV as a whole and especially balcony PV power plants and the steadily increasing electricity costs, the amortization time of a plug-in PV is comparably short. The calculation has also shown that, due to the low purchase price, installing a Wieland plug would considerably increase the costs and thus also the payback period. It is furthermore the share of self-consumption that plays a vital role in the payback time, as this indicates how much electricity is actually consumed in the household and thus does not have to be drawn from the public grid.

8 Conclusion

Action over the next few decades will be crucial to whether we as society achieve the climate targets set under the Paris Agreement and additionally in the European Union. It is therefore of utmost importance to increase the pace of the energy transition and to involve the public to a greater extent. The goals of a fully green energy sector can only be achieved with broad participation not only in energy efficiency but also in sufficiency, for which public support is imperative.

In Austria, the energy transition towards an energy sector based on renewable energy is an essential issue and crucial for achieving the ambitious greenhouse gas reduction targets set by the Austrian government in recent years in line with the European Union and the Paris Agreement. Bringing about change at all levels and ensuring an energy transition that includes behavior and culture in addition to technology and policy must be a priority for the current and future government. It is therefore essential to involve all levels of society and give the general public the opportunity to participate in this transition. Thus, it is necessary to expand the range of low-cost and easy-to-implement options to involve as many people as possible in the task of changing our energy system.

The aim of this work was to identify whether Austrian institutions support the energy transition from below, either through subsidies or through simple ways of implementing renewable energy sources, using balcony PV power plants as an example.

A comparison was made with the Federal Republic of Germany to evaluate the practicality of implementing a balcony PV power plant. It became apparent that there is a lack of clear and precise specifications in both countries. This applies in particular to the installation of the balcony power plant, namely the question of whether this may be carried out by a non-professional and whether a standard Schuko plug is sufficient for use. In general, the situation in Germany is less developed than in Austria, however, especially due to the strategy paper of the Federal Ministry of Economy and Climate Protection, which was published in March 2023, as well as the concession of the VDE, changes in the field of balcony power plants in Germany are to be expected in the near future. These changes are intended to increase the maximum output of balcony power plants on the one hand, and to reduce administrative hurdles on the other, thus facilitating implementation in households. The abolition of VAT on photovoltaic systems at the beginning of 2023 in Germany has already provided further incentives for the purchase of a PV system, whether it is a balcony power plant or a regular system. The comparison has shown that clear legal regulations must be created in both countries to encourage uncertain consumers to participate in the energy transition. While in Austria at least the question of the Schuko plug has been clarified by e-control, there is still no clear regulation on this matter in Germany. The higher electricity capacity limit also gives Austrian prosumers an advantage over their German neighbors, allowing them to generate more of their own electricity and thus pay off their balcony power plant more quickly. Moreover, the administrative effort for the registration of the balcony power plant is easier to handle in Austria with a simple notification to the grid operator, whereas in Germany a double notification to the grid operator and the core energy market data register is required.

Therefore, to answer the sub-question regarding the simplicity of implementing balcony power plants in Germany and in Austria, it is argued that the implementation of a balcony PV power plant is easier in Austria than in Germany, simply because a higher amount of electricity can be produced, the administrative effort is lower and, as one of the most important aspects, there are less uncertainties in the implementation and especially in the installation of the plug-in solar system.

The Austrian government currently does not support plug-in solar power plants monetarily, due to the fact that they are not considered feed-in plants, since the predominant consumption is assumed to be for one's own household, they are not equipped with a metering point, and they do not have a feed-in contract with the responsible grid operator. With a professional installation and a feed-in contract, a balcony power plant would theoretically be eligible for the sustainable energy subsidy pot, but the question will arise whether the administrative and financial effort for such a small investment as that of a balcony power plant is ultimately worth it and whether OeMAG will accept the application. No subsidies for balcony PV power plants were identified at the provincial level. The work also examined the municipal level in cities with populations greater than 100,000. The results showed that in most cities there is no subsidy to be obtained for the installation of a balcony power plant. This is mainly justified by the non-existing feed-in to the public grid and the lower efficiency of the plug-in plant compared to regular PV systems. Only the city of Graz has provided funding for photovoltaic systems, including balcony power plants for residents, as part of its goal of climate neutrality by 2040. Thus, balcony power plants were subsidized with 60% of the purchase price or a maximum of 600€. This subsidy also included installation by a professional. In the city of Vienna, likewise there was no subsidy for balcony power plants, but installation in municipal buildings has been made possible since 2023, enabling more people in the Austrian capital to generate their own sustainable electricity.

To answer the second sub question concerning the monetary support of individuals by Austrian institutions, the following can be said: While there is financial support for balcony PV power plants in the city of Graz, this is not the case in other large cities in Austria. Similarly, the government and other public institutions do not see balcony PV power plants as relevant enough to actually subsidize their implementation among the population.

As the third pillar of this work, the payback period of a balcony PV power plant was calculated. To obtain the average kWh produced by a balcony PV power plant, data from the World Bank and the European Commission was used. With the ever-increasing cost of electricity and the generally decreasing cost of photovoltaics due to better technology and more competition, among other reasons, the payback of a balcony PV power plant would be possible within four years with proper orientation and tilt, no shading of the panels, and use by an Austrian four-person household with an annual consumption of 4,000 kWh. With an assumed service life of approximately 25 years, this would enable a large savings potential, depending on the development of electricity prices in the future. The instalment of a Wieland plug would extend this amortisation time to five years.

All in all, the main research question can be answered as follows: The Republic of Austria facilitates the energy transition through citizen participation to a certain extent, but has room for improvement in the areas of monetary support as well as simplified implementation. Compared to Germany, the implementation of a plug-in system is easier in Austria, but there is still a lack of concise information and legal requirements to eliminate ambiguities for future prosumers. It is therefore necessary, firstly, to create a legal basis and, secondly, to communicate this jointly and concisely to the public in order to avoid misunderstandings in the future. Regarding the subsidy system, Austria hardly provides any monetary support to balcony PV power plants. Even if the efficiency is not as high as conventional PV plants and only little electricity is fed back into the grid, plug-in photovoltaics might still play an important role in the energy transition, as it is a simple way to let society itself participate in the energy transition, produce its own electricity, and perhaps even change its consumption behavior to make the best use of the electricity generated by themselves. This would be an important behavioral change towards a greater use of renewable energy and can be seen as an essential aspect of the energy transition. One recommendation would therefore be to find ways to actively support citizens in becoming part of the energy transition and making their own contribution. The balcony PV power plant model is of particular interest to citizens living in apartments and people living in rented buildings. This group of society should be included in the pursuit of green energy production.

Despite this master thesis and the work conducted regarding the topic, there are still certain limitations related to this subject. For example, this thesis did not consider other types of behaviour-changing approaches that are being pursued by Austria, such as energy conservation education and the like, and these should be explored further. There are many different ways that governments can incentivize the general public to participate in the energy transition, and the energy transition itself is not only limited to increase the share of green electricity. While this thesis focuses mainly on sustainable electricity generation, transportation and heating are essential aspects that need additional consideration to achieve a complete energy transition. It should also be mentioned that there are other ways for citizens to become prosumers than with a balcony PV power plant. Plug-in installations were used as an example because they are comparatively easy for private individuals to implement and not too costly. However, other possibilities of energy generation, which could also be supported by Austria, were not further discussed in this paper. Furthermore, the consideration of possible subsidies within Austria does not claim to be exhaustive, as it is also possible for smaller municipalities to support their citizens in the acquisition of a balcony PV power plant. Another shortcoming of the thesis that did not allow for all the insights hoped for was the response rate to inquiries regarding the balcony PV power plant subsidies when not sufficient information was given online.

Uniform terminology should be agreed upon to foster scientific discussion of the topic in the future. Currently, it is difficult to review the existing literature on balcony PV power plants due to the disparate terms which are used. Due to the different requirements in different countries, the plant itself also needs to be standardized in order to make better comparisons between various countries.

The above limitations offer interesting options for further research and show the relevance of the topic. Possible research in this area could be a potential analysis of balcony PV power plants to work out different potentials for different areas and to analyse in which areas an implementation would make sense. In addition, it will be interesting to revisit the situation in a few years to see where this fast-moving sector has developed. Even if the electricity production of balcony PV power plants is rather small, they could play a crucial role in changing consumption in civil society and thus make an important contribution to the energy transition. Furthermore, research can be conducted on balcony PV power plants with a storage capacity. The role of prosumers in the energy market is increasing, and it is therefore important to adjust the playing field and explore different options for involving the lower strata of society in the energy transition. While plug-in photovoltaic prices are decreasing, electricity prices are increasing, and the demand for plug-in photovoltaics is steadily growing, it is up to policy makers to set a strong government direction with clear rules and adjust the subsidy system to make plug-in solar systems part of the energy transition.

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A. Annex

A.1 Solar Global Atlas Vienna

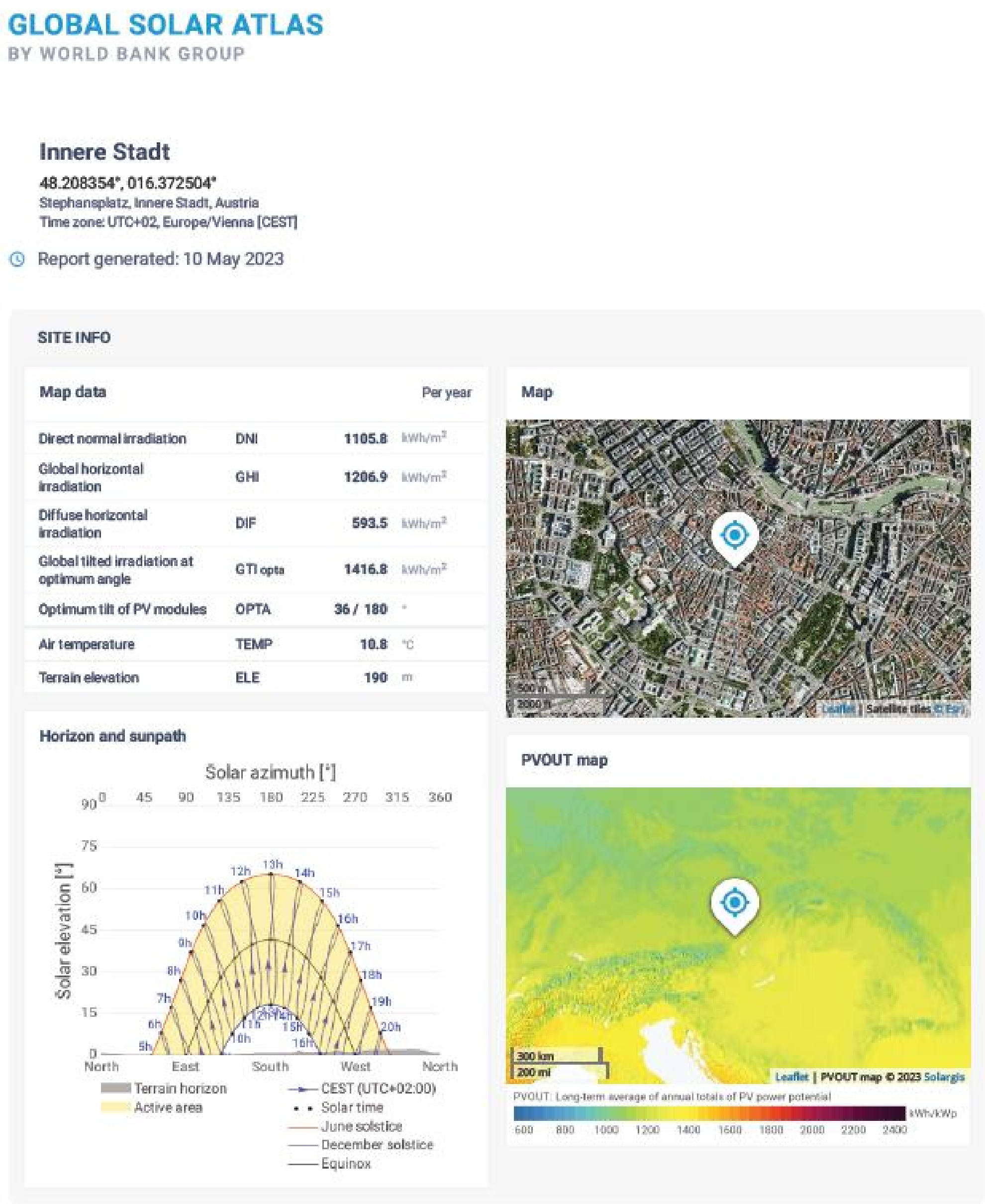


Figure A.1 Global Solar Atlas Vienna (The World Bank Group, 2023)

GLOBAL SOLAR ATLAS
BY WORLD BANK GROUP

PV ELECTRICITY AND SOLAR RADIATION

PV system configuration

Pv system: **Small residential**
Azimuth of PV panels: **Default** (180°)
Tilt of PV panels: **30°**
Installed capacity: **0.8 kWp**

Annual averages

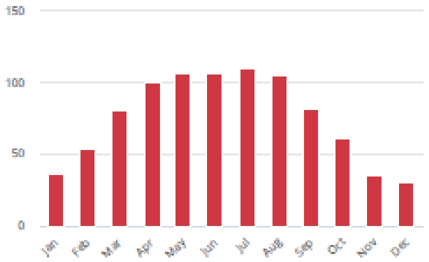
Total photovoltaic power output and Global tilted irradiation

908.323 kWh per year

1411.6 kWh/m² per year

Monthly averages

Total photovoltaic power output



Average hourly profiles

Total photovoltaic power output [Wh]

Average hourly profiles

Total photovoltaic power output [Wh]

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1												
1 - 2												
2 - 3												
3 - 4												
4 - 5					2	5	2					
5 - 6				5	27	35	26	9	1			
6 - 7			8	62	93	102	87	69	38	6		
7 - 8		23	89	167	195	199	187	169	131	79	16	
8 - 9	60	124	192	280	294	297	290	274	233	165	93	53
9 - 10	139	209	281	367	366	376	371	364	317	235	151	126
10 - 11	179	261	332	416	403	424	421	415	360	270	180	157
11 - 12	208	301	365	438	417	437	433	435	381	298	201	178
12 - 13	217	313	373	435	420	423	430	429	379	308	203	186
13 - 14	191	291	352	401	387	392	396	396	337	270	175	158
14 - 15	141	226	282	330	323	328	337	332	271	201	118	105
15 - 16	55	146	198	239	249	258	266	251	187	114	36	26
16 - 17	0	47	107	145	161	173	180	160	97	16		
17 - 18			13	50	72	88	89	66	11			
18 - 19				2	16	30	28	7				
19 - 20						3	2					
20 - 21												
21 - 22												
22 - 23												
23 - 24												
Sum	1,190	1,940	2,592	3,339	3,423	3,568	3,544	3,375	2,742	1,961	1,173	989

Figure A.2 Electricity and Solar Irradiation (The World Bank Group, 2023)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0 - 1												
1 - 2												
2 - 3												
3 - 4												
4 - 5					9	25	9					
5 - 6				19	117	142	117	44	7			
6 - 7			26	174	218	231	220	198	121	17		
7 - 8		59	183	285	303	308	304	293	233	150	33	
8 - 9	116	214	273	360	364	377	379	367	307	223	142	100
9 - 10	194	273	326	406	394	416	421	421	359	261	183	177
10 - 11	214	297	341	418	394	426	436	443	371	274	194	192
11 - 12	228	318	354	421	385	417	422	445	374	289	211	202
12 - 13	233	325	361	415	391	394	413	429	369	308	215	213
13 - 14	221	319	356	400	378	377	395	410	342	293	206	201
14 - 15	193	282	321	363	345	342	366	375	317	260	170	163
15 - 16	95	234	275	314	313	313	334	337	275	201	70	57
16 - 17		112	223	267	270	273	288	292	213	38		
17 - 18			43	174	206	224	227	208	36			
18 - 19				18	83	141	135	35				
19 - 20						15	13					
20 - 21												
21 - 22												
22 - 23												
23 - 24												
Sum	1493	2431	3083	4034	4171	4421	4479	4297	3323	2315	1424	1304

Figure A.3 PV Electricity and Solar Radiation (The World Bank Group, 2023)

GLOBAL SOLAR ATLAS
BY WORLD BANK GROUP

GLOSSARY

Acronym	Full name	Unit	Type of use
DIF	Diffuse horizontal irradiation	kWh/m², MJ/m²	Average yearly, monthly or daily sum of diffuse horizontal irradiation (© 2021 Solargis)
DNI	Direct normal irradiation	kWh/m², MJ/m²	Average yearly, monthly or daily sum of direct normal irradiation (© 2021 Solargis)
ELE	Terrain elevation	m, ft	Elevation of terrain surface above/below sea level, processed and integrated from SRTM-3 data and related data products (SRTM v4.1 © 2004 - 2021, CGIAR-CSI)
GHI	Global horizontal irradiation	kWh/m², MJ/m²	Average annual, monthly or daily sum of global horizontal irradiation (© 2021 Solargis)
GTI	Global tilted irradiation	kWh/m², MJ/m²	Average annual, monthly or daily sum of global tilted irradiation (© 2021 Solargis)
GTI_opta	Global tilted irradiation at optimum angle	kWh/m², MJ/m²	Average annual, monthly or daily sum of global tilted irradiation for PV modules fix-mounted at optimum angle (© 2021 Solargis)
OPTA	Optimum tilt of PV modules	°	Optimum tilt of fix-mounted PV modules facing towards Equator set for maximizing GTI input (© 2021 Solargis)
PVOUT_total	Total photovoltaic power output	kWh, MWh, GWh	Yearly and monthly average values of photovoltaic electricity (AC) delivered by the total installed capacity of a PV system (© 2021 Solargis)
PVOUT_specific	Specific photovoltaic power output	kWh/kWp	Yearly and monthly average values of photovoltaic electricity (AC) delivered by a PV system and normalized to 1 kWp of installed capacity (© 2021 Solargis)
TEMP	Air temperature	°C, °F	Average yearly, monthly and daily air temperature at 2 m above ground. Calculated from outputs of ERA5 model (© 2021 ECMWF, post-processed by Solargis)

Figure A.4 Glossary (The World Bank Group, 2023)