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Challenges of Establishing Solar Power Stations in Hungary

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Abstract: In the context of the ever-growing demand for energy, especially electric energy, from renewable sources, there has been great interest in photovoltaic energy generation. The speed at which the penetration of photovoltaic technology can grow, however, does not simply depend on supply and demand but also on the various policies and schemes adopted by countries around the world. These, in turn, play decisive roles in investment decisions and determine how projects are approached. Investors in photovoltaic (PV) systems need to be aware of the country-specific risk factors for investments and the regulatory environment. The aim of this research was to explore which managerial, economic and technical aspects should be considered in a causal approach when designing PV power plants with over 50 kW of capacity in the Hungarian regulatory environment for the success of the project. The innovative significance of the study is that it presents a validated, practically usable model for the realization of PV power plant projects in Hungary, which provides an in-depth description of the causal steps of their planning and establishment, based on real-life experience. The novel, practical benefit of the research is that it updates and clarifies the steps necessary for the design of PV power plants, since nowadays there are no current scientific works that provide knowledge of a sufficient depth regarding such projects, so these characteristics need to be investigated.

Keywords: solar energy; solar power stations; project management; energy policy; Hungary

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1. Introduction

The advantages of an increasing proportion of renewable electric energy from photovoltaic plants in the energy mix are significant in numerous EU countries, providing further great opportunities related to solar energy [1]. Support schemes promoting the use of green energy show great variation across these nations, and such country-specific systems are typically modified from year to year, making it difficult to keep up with them. Closely related to this is the fact that the laws, technical requirements and regulations that govern the installation of PV power plants often change. Thus, sometimes the information available on specific countries is not up to date anymore [2,3]. Hungary is no exception from this trend either, and the Hungarian photovoltaic sector is also a dynamically developing area, which has an increasing impact on the electricity system and related investments. That is the reason why research into the installation characteristics of PV power plants in Hungary has become necessary [4]. This study examined the process of PV power station projects with capacities over 50 kW; those below this value are subject to different regulations and categorized as household-sized PV systems, so-called HMKEs, in Hungary. PV power plant projects in Hungary typically have capacities ranging from 500 kW up to 100 MW. The planning and realization of PV investments is affected not only by the European Union (EU) but also by country-specific legal and regulatory frameworks [1,5]; therefore, the introductory sections herein mainly provide an overview of the characteristics of and changes in the regulatory and policy environment.

1.1. The Benefits of Renewable Energy: Focus on Photovoltaic Technology

There are many reasons why energy has become one of the most pressing global issues, including the rising demand resulting from growing industries and wealth in many nations; advancements in technology; and the impacts of intensive globalization [6]. These trends have resulted in a discrepancy between supply and demand, and, consequently, in worries about the efficiency of supplies, which calls for the diversification of energy sources and the increased deployment of renewables [7]. Besides these problems, the dominance of fossil fuels in energy mixes [8] has led to the contamination of our environment [9], which, in turn, has heightened certain public health hazards [10]. Based on all of these, it is little wonder that renewable sources have come to the fore [11]. The use of these resources can act as a major instrument in the decarbonization of the electric energy generation industry [12], and help reduce the harmful effects of global warming [13]. Thus, it is clear that, in the process of lowering the carbon intensity of the world's economies, the spread of the use of renewable energies plays a key role [14]. The various benefits of the use of green energy, including its cleanness, lack of pollution and inexhaustible supply, have prompted numerous nations around the world to assign renewable sources of energy a pivotal role in their related policies and strategies [15]. Although technologies based on intermittent renewable energy sources, including wind power and photovoltaics, are indispensable for decarbonizing electricity production, their characteristics are very different from those of the traditional sources of energy commonly used, and this poses huge challenges in electricity systems with an increased share of variable renewable energy sources [16]. PV power plants convert the energy of the sun into electric energy directly [17], and play a significant role in many governments' policies aimed at the diversification of energy supplies [18]. Thus, they provide a means of decreasing the dependence on energy imports and offer a potential to localize policies regarding energy [19]. The measures introduced by governments to promote the spread of PV technology are varied and include, for example, tax incentives, research and development (R&D) policies, renewable portfolio standards (RPS) and the application of feed-in tariffs (FIT). The latter is meant to reduce the costs of investments in the field of PV energy, which has seen a boom in Europe in recent years. An American counterpart of this measure is the so-called tax-rebate regulation, which has also contributed to the proliferation of this technology in the USA. It needs, however, to also be noted that, besides the promotion of PV energy, such regulations may also affect society, in general, and the industry, in particular, in different ways [20].

1.2. Changes in the EU's Renewable Energy Directives

It was Directive 2009/28/EC (Renewable Energy Directive) [21], which was issued by the European Parliament and the Council on 23 April 2009 and repealed Directives 2001/77/EC [22] and 2003/30/EC [23], that set the compulsory goal that by 2020 20% of the energy consumption of the EU had to originate from renewable sources of energy [24]. Furthermore, a 10% target was also adopted for renewables in transport for all EU countries. In order to achieve these proportions, the directive enumerated different mechanisms that EU Member States could use, including guarantees of origin, support schemes, sustainability criteria for biofuels, and projects and collaboration involving EU countries and third nations. The directive also confirmed the Member States' national targets concerning renewables for the period ending in 2020, also considering their current status in terms of the green transition and general potential regarding renewable energy generation. The Member States' plans and schedules for achieving their respective goals were set down in their national renewable energy action plans [25,26]. The biennial national renewable energy progress reports [27] of the countries provided feedback on the progress of the realization of those targets. In order to implement the European Green Deal [28], the Commission submitted a proposal to amend the Renewable Energy Directive to harmonize its renewable energy targets with new ones required by the European Green Deal [28]. According to the proposed figures, the EU would be obligated to raise the share of renewable sources of energy in its energy mix to 40% by 2030, and further targets would also be set to encourage the industry and transport sectors to deploy renewable fuels. At present there is an ongoing debate about the framework of the EU energy policy for the period after 2030 [25]. Provided the Commission's proposal to set a target of 40% of renewable energy in the energy mix by 2030 is accepted by the countries of the EU, it will mean that a total PV capacity of 660 GW needs to be installed by 2030 [29]. In 2020, the capacity of PV technology was 165.5 GW [30], so approximately another 440 GW of PV power plant capacity is still needed to achieve the ambitious figure of 600 GW.

1.3. Promoting the Use of Renewable Energy Sources in Hungary

Over the years, the European Union and its Member States have invested significant resources, including very large amounts of financial instruments, to realize sustainability in practice and reduce carbon emissions [31,32]. However, thanks to technological progress, the cost of deploying renewable energy sources is decreasing [33]. Since the Renewable Energy Directive of the European Union was adopted in 2009, the schemes aiming at promoting the use of renewable energy sources in EU countries have gone through significant changes [21,34]. At present, various loans, investment grants, tenders, feed-in premiums, feed-in tariffs, grant incentives, green certificates, green tariffs and tax granting, and combinations of these, are among the great variety of tools used by governments to encourage the spread of the use of renewable energy sources [34–36].

In Hungary, the conditions of the systems supporting renewable electricity generation operating in recent years have gradually changed. Initially, there was a mandatory off-take system aimed primarily at supporting and stimulating production, ensuring a stable cash flow, before the focus shifted to competitiveness [37]. The system supporting the production of electricity from renewable sources has changed as follows:

- Mandatory Off-Take Funds (KÁP) system, 2003–2007,
- Mandatory Off-Take Support (KÁT) system 2008–2016,
- Renewable Support System (METÁR) from 2017 [38].

In Hungary, the Electricity Act of 2001 [39] and its implementing decree created the regulatory conditions for the construction of a system supporting electric energy production from renewable energy sources. In the KÁP system between 2003 and 2007, utility wholesalers and regional electricity suppliers were obliged by decree to take over the green energy produced and pay the subsidized feed-in tariff. The utility wholesale price and the mandatory off-take price that was paid differed, and the government took it upon itself to compensate the wholesalers and service providers for the difference, which was covered by the amount of the so-called KÁP fee included in the system management fee [38,40].

In order to ensure that the Hungarian legislation was in line with the rules in force in the European Union, it became necessary to change the KÁP system. In 2007, a new electricity act [41] came into force, one of the important achievements of which was the establishment of the Mandatory Off-Take System (KÁT), which was intended to support the use of renewable energy sources and to overcome the competitive disadvantage of electricity produced from renewable energy sources and waste. The system was responsible for establishing the off-take price, the quantity and the duration of the mandatory off-take period of the electricity subject to the off-take obligation, taking into account the users' financial status, the expected efficiency gains resulting from the development of technologies and the impact of the technology on the operation of the electricity system, as well as the technological specificities. The Hungarian Transmission System Operator Company Ltd. (MAVIR) was responsible for the operation of the KÁT balance circle, which provided the basis for the mandatory off-take system. MAVIR played a significant role in the system: it took over the electricity subject to the mandatory off-take within the framework of the KÁT from the producers (sellers), and then distributed it to the commercial licensees, sold it and accounted for it. In order to be eligible for support, sellers were obliged to join the KÁT balance group, which meant that they had to create a production schedule, on the basis of which the energy fed into the system was received by the one in charge of the balance group at the off-take price with the view to resell it to the commercial licensees (electricity suppliers) obligated to accept it. The producers had the opportunity to sell the energy produced according to the general market rules only after the end of the support period or after the volume limit was reached. The KÁT support could be used for periods between 5 and 25 years in the case of greenfield investments not using second-hand equipment. In other cases, the Hungarian Energy and Public Utility Service Authority (MEKH) determined the KÁT eligibility period individually. The maximum duration of the support was equal to the payback period of the investment. The off-take price was determined based on several factors: the type of renewable energy source used by the power plant, the technology used, the rated electricity-generating capacity of the power plant, the date of obtaining the KÁT entitlement (before or after 2008) and the zone time of production (peak, valley and deep valley period). A significant part of the feed-in tariff was provided by subsidies. The off-take prices developed in a given year as follows: for those qualifying before 2008, they increased by the rate of inflation of the previous year, and for those who qualified after 2008, they increased by the value of the consumer price index of the previous year, reduced by one percentage point. In 2016, the distribution of support paid under the KÁT was as follows: 60% biomass, 27% wind, 10% hydro and 2% solar energy production. The main criticism of the KÁT system is its repelling effect due to its over-bureaucratization. When receiving the support, there was a significant administrative burden on producers (e.g., the obligation to submit production schedules), many of whom chose to carry out their activities without support; furthermore, many producers rather decided not to enter the field of renewable energy production [38].

In 2014, a new directive on the promotion of renewable energy production was adopted in the European Union (2014/C 200/01) [42], under which Member States' support schemes have been operating within a new framework since 2016. The new rule states that producers have to sell the green energy produced directly on the market, and government regulations have to create a regulatory environment that encourages producers not to continue generating electricity in the case of negative prices. It is also stipulated that, from 2017, support can only be granted following a competitive bidding process with clear, transparent and non-discriminatory criteria, except when only one or only a limited number of power plants would thusly receive support, when the rate of project completion would be reduced to a low level, or when the procedure would increase the level of support required. This new regulatory environment was introduced into Hungarian law in several stages. From 1 April 2016, the operation of the KÁT balance circle was changed, according to which the received green energy was no longer handed over to the recipients; it was sold entirely by the organisation in charge of the balance circle, MAVIR, on the organized electricity market (HUPX). Subsequently, the Renewable Energy Support System (METÁR) was introduced on 1 January 2017. The new system replaced the previous KÁT system; however, there was a transitional period first, which meant that the existing contracts in force under the KÁT remained in force under the new system, but it was no longer possible to enter the old KÁT scheme [38]. The new system created competition between producers and investors, thus reducing the production costs of the whole life cycle of electricity. One of the advantages of the shift is that the new system relies much less on government aid. Its costs are built into the price of electricity. However, universal service users are not affected by the obligation to pay the fee element. For all these reasons, the winners of the reduction in the cost of the supports under the new system are industrial energy consumers. Furthermore, a significant advantage of this support system is that the improvements in cost efficiency resulting from technological advancements can also prevail on the Hungarian market. The system is regulated by Government Decree No. 299/2016 [43] and Decree No. 13/2017 of the Hungarian Energy and Public Utility Regulatory Authority [44]. Currently, support can be won by submitting proposals for calls for tenders in the green premium and brown premium categories [37]:

- Green premium: Currently, applications for new renewable electricity investments can only be submitted in the form of a green premium-type entitlement. Among the submitted applications, the decision on the winners is made in one round. The decision is based on the amount of the subsidized price proposed by the bidders. Winning producers receive a premium from MAVIR for electricity produced from renewable energy sources and transferred to the public grid. The premium is the difference between the subsidized price and the reference price [38,45].

- Brown premium: The brown premium is available to biomass and biogas power plants to ensure their ability to operate. Determining the amount of the premium can be done in two ways. In the first case, the subsidised price is determined on the basis of the costs of production using biomass or biogas. The operating costs also have to include maintenance and repairs that allow for a long-term continuous operation. In this case, the premium to be paid is calculated in the same way as the green premium (the difference between the subsidized price and the reference market price). Another way to determine the rate is for producers who can also use fossil fuels. This is a fixed value, independent of the reference market price [38,45].

In the METÁR call for tenders, tenders that undertake the generation of electricity at the lowest price for a period of 15 years win. The introduction of the METÁR tendering system caused the applicants to propose prices that were 40–55 % lower than the KÁT prices, depending on the power plant capacity category [46].

1.4. The Characteristics of the Spread of PV Power Plants in Hungary

For PV systems in Hungary, the year 2010 can be considered a milestone, as the total PV capacity installed in that year exceeded 1 MW. Until 2016, the growth of newly installed PV power plant capacities was slower, but in subsequent years their spread accelerated. This was due to the transformation of the support system from 1 January 2017, which offered less favourable conditions for investors than the KÁT form of subsidies, according to which the producer could sell the electricity at a higher-than-market, fixed price for 25 years. For this reason, in the period preceding the phasing out of the KÁT support scheme (until 31 December 2016), investors fearing the negative effects of the changes submitted a record number of applications, and support for new PV power stations of a total capacity of more than 2.5 GW was gathered. The condition of granting the KÁT subsidy was that the power stations concerned had to be built within a few years' time [46]. In 2021, the total capacity of the PV power stations was 1829 GW (Figure 1) [47], which represented almost 65% of the total PV capacity installed in Hungary (including the capacity of household-sized small PV power plants) [4,48]. By Q1 2022, the PV power stations that benefitted from the KÁT form of support had practically all been built. The PV power stations built under the METÁR scheme are expected to account for an additional 100–200 MW per year. It is worth noting that the forecasts made by MAVIR predict that the capacity of PV power stations may reach 6.7 GW by 2030, and this figure could even increase to almost 12 GW by 2040 [49]. In today's Hungary, PV power station projects tend to be realized with monocrystalline (m-Si) PV technology, using so-called half-cell PV modules because of their better shading tolerance [50]. In connection with this, it is worth noting that the development of solar technologies is continuous [51,52]; nevertheless, it is monocrystalline technology that is the most common for solar investments at present [53].

1.5. The Significance of the Study for the Planning of PV Power Stations

In Hungary, in the case of PV power stations, priority is given to the installation of classic, ground-mounted systems in order to maximize the PV power that can be installed per one hectare [54]. The rules, laws, regulations and economic aspects related to the installation of PV power stations have always been changing over the years. These circumstances have an impact on the feasibility of PV power stations, the investment decisions, as well as on preparation processes. The causal steps related to the feasibility and planning of PV power stations are complex and particularly vague for a foreign investor [55]. In addition, scientific knowledge on the construction of PV power stations is incomplete, not up to date [5], and it typically generalises in several respects [56]. Nevertheless, country-specific information related to the possibilities of establishing PV power stations is extremely important for correct investment decisions and the planning processes. Today, no current scientific works on the planning steps of PV power stations have provided a sufficient depth of knowledge, so it is necessary to examine these characteristics on a country-by-country basis.

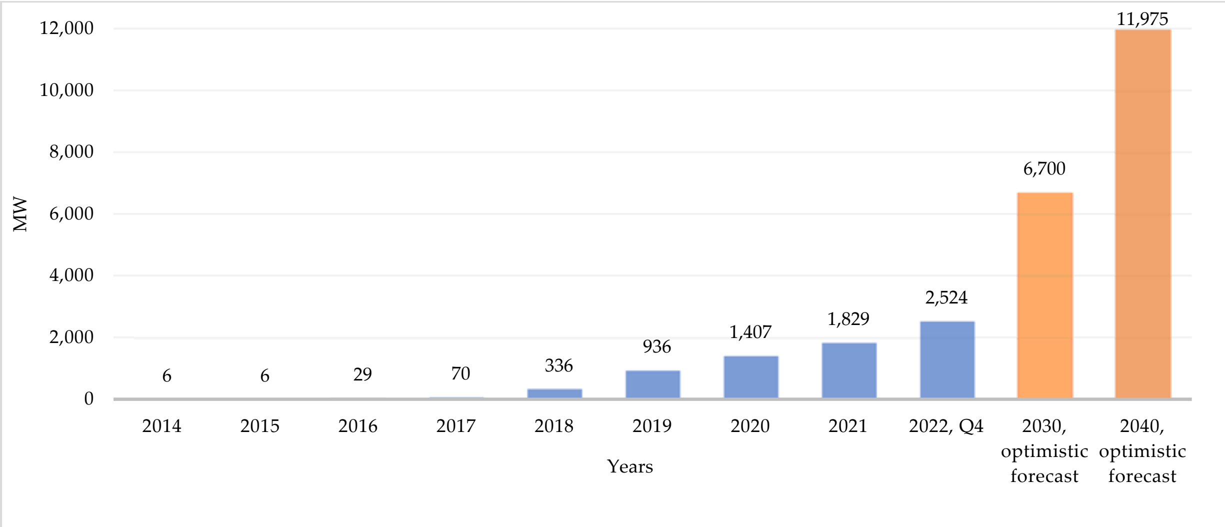

Figure 1. The development of the capacity of PV power stations in Hungary, based on [47,49] (blue colour: PV power stations already built; orange colour: the capacity of future PV power stations according to optimistic MAVIR scenarios).

The goal of this research, which was inspired by the insights presented above, was to explore, in the context of the Hungarian regulatory environment, which interdependent managerial, economic and technical aspects must be taken into consideration in a causal manner for a project to be feasible when planning PV power stations. The innovative significance of the study is that it presents a validated model of the establishment of PV power stations that can be put into practice, and it provides an in-depth description of the causal steps related to the planning and realisation of PV power station projects in Hungary, based on real-life experience. The fundamental importance of the research lies in the fact that today there is a lack of knowledge about the managerial aspect of the planning of such projects.

The present paper has the following structure: Part two introduces the methods used in the research, Section 3 presents the results, and the discussion and the conclusions are included in Sections 3 and 4, respectively.

2. Materials and Methods

2.1. The Sources of the Information on Establishing PV Power Stations in Hungary

This work introduces a validated model of the establishment of PV power stations in Hungary that can be used in practice, and it presents the causal steps related to the planning and implementation of PV power station projects, based on the actual experience of PANNON Green Power Ltd. PANNON Green Power Ltd. is a Hungarian-owned, dynamically expanding, innovation-leading energy enterprise, which has realized a series of successful renewable energy investment projects in recent years and has concluded strategic partnership agreements with the world's leading renewable energy service companies. It has its own portfolio of power stations and is working on several solar power station projects currently under development. The model developed in this study is based on experience gathered in 35 projects that were realized until Q2 2022.

2.2. The Description of the Aspects of Modelling and the Methods Used in the Study

Currently there are numerous guides and methodologies pertaining to project management [57], for example PMBOK [58] and PRINCE2 [59], which provide a useful framework of reference for thinking and communicating about the topic. The first one, PMBOK (Project Management Body of Knowledge), is a guide with a treasure trove of best practices, containing definitions as well as processes for project management, arranged in process groups (e.g., planning, execution, closing) and knowledge areas (e.g., stakeholder engagement, quality and communication management). The latter, Prince2 (PRojects IN Controlled Environments), is a method which has an integrative approach to project management by incorporating principles, themes, processes and project environments. PM^2, a project management methodology developed by the European Commission, represents a great milestone towards the standardization of the terminology related to project management concepts, and thus eases the communication of project teams. This methodology, which is available for use free of charge, was primarily meant to facilitate the work of EU institutions and projects. It draws heavily on internationally available project management guides, best practices and methodologies. It uses the four [60] subsequent phases of initiation, planning, execution and closing to describe projects, complemented by a set of activities spanning the whole process (monitoring and controlling) [61,62].

The project processes presented in this paper were visualized using the Project Libre software. First, a work breakdown structure (WBS) was defined, which means the logical connections of tasks. Following the WBS, the schedule was also illustrated in a traditional Gantt chart. The critical path, i.e., all the tasks whose cumulative duration clearly determines the time of the completion of the project and therefore do not contain any slack, is marked in red. Noncritical tasks, that is, those whose possible delays do not affect the completion of the project, are represented by blue bars. In addition, each task group that consists of several logically related tasks is indicated by black bars. In Section 3.4, the time required for the completion of each activity is indicated, as expressed in working days (8 h/day, 40 h/week). As the subject matter of this study was the process of establishing solar power stations, the research focused exclusively on this aspect and not on operations. Therefore, this is not a full life cycle analysis. All project developments start from a so-called project core. This project core contains the planned location for the construction of the potential solar power station and the technical and economic information (TEI) including the connection conditions. Essentially, this project core corresponds to the project initiation phase. In the literature related to project management, the initiation phase is followed by the planning phase, the execution and the closing phase. In the present study, the process of establishing solar power stations in Hungary is presented, which lasts until the completion of the solar power station, i.e., until the start of operation. The Gantt diagram visualized in Project Libre also follows this logic. Based on the international literature [60], thus, only the first three of the separate project phases are detailed:

- the initiation phase in which all the elements that fundamentally define the project are clarified;
- the planning phase, whose final milestone marks the ready-to-build phase (RTB), when all the permits necessary to start construction are already available;
- the execution phase, during which the power station is built according to the construction plans prepared on the basis of the previously authorized plans, and the various operating permits are obtained.
- the closing phase, however, is not investigated, i.e., the necessary feedbacks, checks and evaluations are not addressed in this research;
- the operation of the solar power station and the later recultivation required after the end of its useful life are not dealt with herein either.

3. Results and Discussion

3.1. The Process of Establishing Solar Power Stations in Hungary: The Initiation Phase

In a power station project, the first stage is the so-called preparation phase (WBS, 1), during which the search and modelling of a potential plot is carried out (WBS, 1.1). When designing a PV power station, the unique features of the potential installation site should be thoroughly mapped, for example, the topography, plant cover and possible shading objects; this will make it possible to get acquainted with the terrain conditions of the area, as well as the landscaping and related risk factors.

3.2. The Process of Establishing Solar Power Stations in Hungary: The Planning Phase

At the licensing stage (WBS, 2), the landowner makes the land available to the investor for the construction and operation of the project, of which basically two ways are known in Hungary:

1. Land purchase pre-contract, which includes the subsequent purchase price of the land and the relevant rights of way and encumbrances.
2. Land tenancy/land use agreement, which includes the annual rent/land use fee and the relevant rights of way and encumbrances.

In Hungary, a legal entity cannot buy or lease agricultural land, so it is necessary to conclude a pre-contract with the owner of the land (WBS, 2.1), as the investor cannot and does not want to take the risk of concluding a contract with the owner of the land only when the site of the power station is withdrawn from agricultural cultivation. A land use contract gives stronger rights than a lease agreement, as the former is also added to the title deed, but its conclusion is more complicated,; however, it is indispensable in certain cases. These contracts usually include a clause stating that there is a lien on the land for the benefit of investors to ensure that the owner of the land cannot terminate the contract free of charge during the planning phase. In connection with the construction area, it is important to note that based on the relevant legislation/local regulations/technical aspects, the following areas are preferred: arable lands, pastures, areas withdrawn from cultivation (sports grounds, undeveloped land, etc.). There are areas that may be suitable for the realisation of the project after a conversion, but there are also areas in which construction is not possible currently, or would cause very great difficulties, which should be avoided (e.g., Natura 2000 sites, nature reserves, cemeteries, swamps, forests, etc.). When selecting a suitable area, it is also important to explore what public network the power plant to be connected can connect to.

In Hungary, the permits to be obtained during the developments can be divided into three large groups, depending on which authority/electricity supplier issues them. The most important of these are the interdependent licenses of the transmission and network licensees (Á-HE), which are based on Act LXXXVI of 2007 on Electricity (VET) [63], Government Decree 273/2007 (X. 19.) on the implementation of certain provisions of Act LXXXVI of 2007 on Electricity (VET Vhr) [64] and the relevant Operation Regulations of MAVIR (TSO) [65] (TSO—Transmission System Operator) or DSO's Distribution Regulations (e.g., [66,67]) (DSO—Distribution Network Operator). The Distribution Code must be as consistent as possible with the TSO Network Code [65]. After 1 July 2021, according to the Electricity Act, both simple and individual network connection requests (WBS, 2.2) can only be submitted by a public tendering procedure. The Hungarian Energy and Public Utility Service Authority (MEKH) periodically announces calls for tenders aimed at encouraging renewable energy production. The conditions for the periodic calls are the amount of spare capacity that can be allocated to producers wishing to connect to the high- or medium-voltage grid and the available amount of support funding. In all cases, the amount of spare capacity is reviewed by the MEKH and this is what decisively determines if it is possible to announce a new tender procedure. The first call under the new regulation took place in the spring of 2022. In such calls, the TSOs and the DSOs inform the market about the technical and financial conditions under which the available substation (node) capacities are available. This is based on the so-called load-flow calculations, which show

how much load there is in terms of power and voltages in relative units in given sections of the grid.

Applicants have 20 days to apply for capacities at the above-mentioned substations of the seven Hungarian organizations (one TSO, six DSOs). During the application process, it is necessary to pay the claim submission guarantee of HUF 900,000/MW (approx. EUR 2200/MW). Applicants, thusly applying, receive the preliminary Technical and Economic Information, which the TSO/DSOs are required to send within 20 days. These may still be waived by the potential investor if the connection costs differ by more than 10% from those previously announced, or if more applicants have applied for the capacity. At this point the capacity is divided between them, based on a score system. This is because if more applicants apply for a given capacity, they are ranked according to different criteria. If the winners' scores are equal, the advertised capacity is divided between them. If the investor, having become aware of these new circumstances, withdraws their application, they get back the claim submission guarantee. Otherwise, they submit the confirmation statement, after which they have to wait to receive their final claim application at the same time as those joining by the so-called individual procedure.

Applications for the individual procedure have to be submitted at the same time as for the simple procedure, but this is only possible if:

1. the applicant wants to connect by power line, not on a substation, or
2. the capacity requested exceeds that described in the call for tenders, or
3. the applicant would like to apply for a special facility, such as an electricity storage facility, in which consumption capacity is also needed in addition to production capacity, and at the time of the call for tenders it is not known whether the given connection point has a sufficient consumption load option.

In the case of individual procedures, after the investor has paid the claim submission guarantee and the participants in the simplified procedure have already received the preliminary TEI, the TSO/DSOs will either prepare the Feasibility Study (FS) (WBS, 2.3) or require the potential investor to prepare it. The time available for this is one month in the former case and three months in the latter. In the latter case, this power station also gets eliminated from this tendering procedure and will be automatically transferred to the next one. This study assumed that 100 days are necessary for this point. The most important parameters of the FS are the load-flow calculation and, if the capacity is for the expansion of an existing substation, the examination of whether the substation can be safely expanded (e.g., whether there is enough space on the site for expansion). After the network calculation, the TSO/DSOs will send the applicant a preliminary TEI prepared for their individual application (WBS, 2.4). This TEI may include a refusal by the one inviting tenders, or if the content is not suitable for the applicant, the claim submission guarantee is refunded to the investor. In the case of acceptance, the investor submits the acceptance declaration and the final TEI is then sent to all applicants. After acquiring the final TEI, the investor has 120 days to prepare a detailed Network Connection Plan (NCP) (WBS, 2.5). This plan already includes in detail:

- AC and DC side power of the power station;
- the technical parameters of the small solar power station (layout, data of solar modules, inverter (string or central));
- the supporting structure (fixed installation or solar tracking solution);
- the details of the transformer with concrete housing (TWCH);
- provider's terms and conditions that are prescribed or specified for the connection point;
- the data and design of the account metering;
- the assessment of the expected grid effects for the small power station (e.g., calculation of short-circuit power);
- the design of the protection system;
- the control technology chapter;
- the operating conditions;

- in the case of substation connections, the plans for the new substation or the expansion of the existing one, if either of these are necessary.

The planning and/or authorisation of these conditions is essential for the conclusion of a subsequent operation agreement or network connection contract (NCC) with the Network Licensee (TSO/DSOs). After the approval of the NCP by the TSO/DSOs (WBS, 2.6), the investor has 40 days to start the conclusion of the Network Connection Agreement. This contract between the TSO/DSOs and the Investor specifies the following:

1. the conditions for connection;
2. the time available to connect the power plant;
3. the financial conditions under which all these are possible.

Here, too, the investor has to pay a security deposit, and this capacity reservation guarantee was set at HUF 3,600,000/MW (approx. EUR 8800/MW) by the Transmission and Network Licensees (TSO/DSOs). It is important to note that, just like the claim submission guarantee, this is also returned at the end of the process, in the case of a successful and timely connection to the grid. The NCC signed by both parties will be effective only if the investor presents the final building permit to the Transmission or Network Licensee within one year after the conclusion of the contract.

The above paragraphs have provided the reader with a presentation of the TSO/DSO side authorization process during the planning phase. However, all buildings/structures in Hungary that are stationary, including all special facilities, are required to obtain permits from the relevant Government Office (GO). These permits are construction-type permits (WBS, 2.7). The power station is covered by the construction permit, while the power line is covered by the power line right permit. Then, after the construction phase, it is necessary to obtain the occupancy-type counterparts of these permits, known as occupancy permits and operating permits. Since small-scale solar power stations are special facilities, it is necessary to obtain these not from the General Department of the Government Office, but from the Technical and Metrology Safety Department (TMSD) of the respective county. However, TMSDs cannot be found in every county, in which case the claimant has to contact a suitable TMSD in another county. The basis for the permits here is not the Electricity Act, but the relevant construction/land regulation (Government Decree 382/2007 (XII. 23.) on the permit-granting procedures of the electric energy industry building authority [68]).

In connection with the electrical energy plans of the power stations/power lines, the Government Offices examine how they conform to the building regulations in force, the appearance of the settlements, whether the facilities are safe, etc. In order to obtain a building permit, it is essential, first of all, that the investor has a declaration of consent from the owner of the site, in which they declare that they are aware of it and unconditionally consent to the establishment of a small solar power station on the territory in their possession. The NCP provides the basis for the building permit documentation, which is complemented by further necessary plans and permits, which can basically be divided into three groups:

1. technical plans;
2. plans/permits demonstrating compliance with settlement/settlement planning regulations;
3. other.

Technical plans include, for example, the engineering static plan chapter (WBS, 2.7.4) based on an expert's opinion of the soil mechanics (WBS, 2.7.3), which shows whether the selected supporting structure and its installation mechanism (ground screw, concreting, piling, etc.) comply with the relevant engineering static regulations. Further technical plan chapters include lightning protection, noise protection (mandatory inside built-up areas, outside those dependent on GO), protection against electric shocks, protection against overvoltage, grounding, health and safety. However, lightning protection can potentially be substituted by a lightning protection risk analysis. Another important task is to make sure that it is legally possible to install a small-scale solar power station in the selected area. For this, it is necessary to obtain a permit for permanent other use from the Land

Registry (WBS, 2.7.2), which is based on the soil protection plan (WBS, 2.7.1). Although the energy production sector is a priority sector in Hungary, it is important to note that it is not the goal to involve very high-quality agricultural land or empty areas resulting from deforestation in power station development projects instead of potentially using them for food production/forestry. Furthermore, it is not a goal either to build in areas of nature reserves/national parks, but the examination of this belongs to environmental protection. For this reason, the Land Registry Offices have determined that, in a given region in a certain branch of cultivation, lands of only below-average quality can be withdrawn from agricultural cultivation. Today, among the agricultural areas in Hungary, arable land and meadows/pastures are the most in demand, as well as areas already taken out of cultivation, but the built-up areas of settlements are usually avoided, due to residential and settlement appearance concerns. What is considered to be below average in a given branch of cultivation in a given municipality is determined by the agricultural experts of the Land Registry Office (WBS, 2.7.5). Quality grades are marked with a number, in which one is the best and eight is the worst. In extreme cases, a field with a score of four may be below average in a region, and in others a score of five may be above average. In addition to the quality classification, there is also a so-called golden crown value, the value of which is taken into account in the calculation of the withdrawal duty. The gold crown is a land evaluation measure that is an indicator of the potential income generated on a unit of land, i.e., an index of fertility, location and cultivability.

The soil protection plan examines how humus-containing soil layers can be saved during construction, so the commissioned soil protection expert (Agricultural Administration Office, having a National Food Chain Safety Office ID number) determines what precise actions are needed to protect it, taking into account the location, water regime, the scientific classification of the soil as well as the results of sampling (agrochemical examination). Additionally included in the plan is a recultivation plan chapter related to the installation of the underground cables. After drawing up the soil protection plan, the Land Registry Office examines whether the area can be withdrawn from agricultural cultivation (if the area has been already taken out, neither the soil protection plan nor the other land use permit is required) and, if so, it issues a final permit for other land use for the area, the mandate of which is 4 years.

It is also important to examine whether the power station to be built suits the built environment (appearance of the settlement), and if the local building regulations and zoning plan (town planning tools) and the county's zoning plan (spatial planning tools) allow for the installation of the power station. The former must be examined in all cases, the latter only in the case of AC capacities above 5 MW. If the classification of the area does not allow for the installation of a solar power station, its classification needs to be modified, usually, to a special building zone or zone not intended for building. The modification must be initiated by the local government and prepared by an architect with the appropriate qualifications, and then approved by the government chief architect responsible for the county, with the involvement of the various specialized authorities. In the fastest case, this is a roughly 100-day process. At the end of the process, the Municipal Council must approve the completed amendment. It is under these conditions that the town clerk can issue a preliminary specialized authority's consent.

The other permits typically include three additional plans/permissions. First of all, it is important to mention the environmental permit. For projects of AC capacities below 50 MW and above 2 hectares for the installation area size, preliminary examination documentation (PED) or the preparation of Annex 13 to Government Decree 314/2005 (XII.25) is necessary. This plan examines the impact of the power station on wildlife in a complex way. In this the planners identify the impact factors and impact processes (air protection, groundwater and underground water protection, surface water protection, waste management, noise and vibration protection, wildlife protection) defining the area of impact and taking into account the size and location of the power station (WBS, 2.7.6). This plan forms the basis of the permit subsequently issued by the Environmental Department of the GO and the conditions under which it will authorise the installation. Most often, these include the planting of protective forests, polarotactic insect examinations in the first three years of operation, or extended plantings that suit the already existing, locally known ecosystem. Environmental approval is a potential risk associated with any project, so many investors make sure to obtain it regardless of everything at the beginning of the planning phase.

It is important to mention the preliminary archaeological documentation (PAD) (WBS, 2.7.7), which is mandatory above an investment value of HUF 500 million (EUR 1.2 million). It is the responsibility of the Department of Heritage Protection to check if the selected site is on any list of archaeological sites. If it is not listed, it is sufficient to have only the PAD prepared, provided the investment value of the development exceeds HUF 500 million (EUR 1.2 million). The PAD may contain information on whether it is necessary to involve an archaeologist from a suitable museum during construction, as well as what other excavation tasks/investigations are required before or during construction. In addition, it is important to mention approval by Disaster Management. The plan necessary to obtain this examines what tasks apply to the operator in the event of any emergency, and what risks the installation may pose to nearby residents in the event of a breakdown.

The prepared materials ready for submission have to be submitted in a folder (WBS, 2.7.8), and they are sent by the GO to the various departments for review. Once approved, the appealable building permit is issued, followed by its legal finalization (WBS, 2.7.9).

The power line permit is effectively a building permit (WBS, 2.8); it applies to the power line from the TWCH to the connection point. These are usually medium- (MV) or high-voltage lines (HV) (depending on the size of the power plant, 22 kV–400 kV) and their lengths usually range from 0 m to 10 km. In the case of power line rights, there are usually two critical points:

1. receiving owners' consents from owners whose territory the power line traverses or who are within the protective zone of the power line;
2. if an area of more than 400 M2 in agricultural cultivation under a single lot number is affected by a section of the power line, a temporary permit for other land use, requested from the Land Registry, is required (WBS, 2.8.1).

Prior to the owner consents (WBS, 2.8.2), it is a basic condition of obtaining power line rights (WBS, 2.8.3) that the investor and the architect together with a surveyor walk along the whole length of the potential route(s) and determine where the power line can go. This is necessary in order to identify all physical obstacles (trees, built structures, etc.) at the outset. After that, during the planning, the lot numbers (Hrsz.), from whose owners consent must be requested, are identified. Today in Hungary, mostly underground cables are installed. Although they are more expensive than overhead lines, their authorisation is not challenged by so many obstacles. In general, it is advisable to avoid crossing undivided common property, areas managed by the Hungarian State or one of its trustees, forests, watercourses and major roads managed by the Hungarian Public Roads, if possible. In extreme cases, obtaining owner consents can take up to half a year and may require payment of green damage upon installation. It is important to determine the installation depth, which should be deep enough to prevent the cables being torn out of the ground even in the course of deep ploughing.

Once the temporary other use(s) and the owner consents have been secured, the complete documentation can be prepared, and then, as in the case of the building permit, the GO forwards them to the various departments for their opinion. After the approval, the appealable power line right authorisation is issued (WBS, 2.8.4) and then it is finalized.

With the building permit having been granted, the network connection contract (WBS, 2.8.5) can be validated, and by submitting it together with the building permit, the combined small power station permit (above 0.5 MW) can be obtained from the Hungarian Energy and Public Utility Service Authority (MEKH) (WBS, 2.8.6).

This permit is the last one to be obtained during the planning phase, with which the project reaches the ready-to-build (RTB) phase.

3.3. The Process of Establishing Solar Power Stations in Hungary: The Execution Phase

Entering the construction phase (WBS, 3), if the power plant has the preliminary permits, it is necessary to invite tenders from construction companies and then select them (WBS, 3.1). During the tendering of contractors, the final costs of the investment take shape, so it becomes possible to plan the financing (WBS, 3.2). It should be noted here that in some cases the construction company can be selected at the very beginning of the project (knowing the main parameters), and then it cooperates in the determination of the technical parameters, but the planning of the financing only becomes active when the permits presented in Section 3.2 have been obtained. At this stage of the project implementation, the business plan must be finalized, which thus already includes the final licensing costs, the costs of construction and the operating costs together with the revenues. On the income side, the situation is made easier if the power station is connected to the network under the Mandatory Off-Take Support (KÁT) or the Renewable Energy Support System (METÁR) scheme, which means that the revenues can be calculated more easily for the duration of the financing, and on the expenditure side only the costs of maintenance, insurance and scheduling appear, making the planning relatively simple. The situation is different if the revenue is planned for direct sale on the electricity market. In this case, it is not possible to determine the revenue side due to market conditions; however, in Q4 2022 it may be much higher than in the case of KÁT or METÁR.

Concerning financial matters, the simplest situation is when the owner(s) invest their own capital, which may be the result of an already operating business or, in the case of a project company, a members' loan by the owners. In many cases, however, a bank loan or possibly a support grant provides the financial background. In the case of bank financing, if a preliminary agreement has been concluded, a bank expert who prepares the zero report, which examines the current state of the project and verifies the business model, joins the process. In Hungary, bank financing can be fully market-loan-based, or possibly based on subsidized interest schemes, such as the so-called green growth loan program (GGP) or the growth loan program (previously more widely available between 2016 and 2020), which allows for better predictability and an even simpler business plan through fixed interest rate loans. In the case of market-based loans, the interest rate follows inflation, which was a predictable arrangement in years earlier than 2021, but it has now been proven that global developments strongly influence this, and market loans taken out earlier have a great influence on the annual business balances of solar power stations and, with it, on their returns. In addition, since the established feed-in tariffs in the KÁT and METÁR systems are for a full financial year and inflation is only followed in the following year, the significant inflation in Hungary in 2022 may also result in losses for project companies. In the longer term, the ratio of the real inflation to the bank interest rate set by the Hungarian National Bank will show whether it is worth maintaining these projects. After the financial conditions have been secured, the construction area must be made accessible to the contractor (WBS, 3.3). Before and during the realization of the project, the construction plan (WBS, 3.4) is prepared according to the preliminary plans and updated with the products available on the market, so the manufacturers, types of the solar modules, the inverters and the transformers may also change. Other project elements, such as cabling, lightning protection and property protection/communication systems, are generally not manufacturer-specific. The contractor starts the construction work first (WBS, 3.5), which begins with the construction of the supporting structure and the MV power line, but MV/HV transformer development may also be part of the work phase, if the existing capacities are not sufficient; however, this had to be revealed earlier, already in the licensing phase. All small power stations also have a low-voltage (LV)/MV side, and in some cases medium/high-voltage (MV/HV) development may also be required.

The construction of the supporting structure for a <0.5 MWp system takes 2–3 weeks, if there is no need for any special technology based on the geodetic survey. Normally, piling, ground screws or concrete foundation constitutes the substructure, on which the supporting structure, which is mostly made of galvanized steel, is placed. The installation of solar modules is only a few days' work after this, even if it means mounting 1200–2000 solar modules for a 0.5 MW small power station. Inverters are typically project inverters with a capacity of 35–50 kW (but can be up to 100 kW), which typically contain only one working point controller for the multiple input DC side strings in total. Here, during the planning, care must be taken to have the same number of solar modules on the different strings, as these inverters cannot handle the differences, and obviously this must be taken into account during construction too. The DC side includes an overcurrent protection melting fuse and DC overvoltage protection placed on each string, which protect the inverter and the additional systems in the event of a malfunction. In addition, based on the plans, the lightning protection system and the LV cabling from the inverters to the field or project transformer by an underground cable are also installed, possibly in addition to a property protection system, since it is known that in many cases inverters may be vulnerable. The field transformer, also known as the project transformer, is usually delivered in a single house with the AC collector cabinet and with the appropriate protection systems, such as AC overvoltage protection and the ground rod for this. If it has not already been done, the area has to be surrounded by fencing, and the installation of a fence protection system and a camera system on the site perimeters is strongly recommended.

After the completion of the construction and installation (WBS, 3.6), the measurements related to protection against electric shocks need to be carried out, and the idle voltages of the system not yet in operation have to be checked by measurements. The measurement of the MV cable has to be carried out as well and a report made.

It is after this that the Operation Agreement (WBS, 3.7) is signed with the owner of the MV/HV transformer, in which the system is connected via the 35kV production cable. In this agreement, the method of communication is laid down for the event of any breakdown of the transformer station or the announcement of a break due to maintenance. A related step is to conclude a Balance Circle membership agreement with MAVIR ZRt, during which the account point identification is provided, as well as the expected connection date of the power station is specified, after which MAVIR becomes entitled to impose a regulatory surcharge. The operation start program of the small power station (with prior arrangement of the switch-on time) is submitted to the area owner (e.g., E.ON Hungária Zrt., MVM Energetika Private Limited Company, etc.), in which the electrical characteristics and the conditions of the switchboards before the start of operation are also recorded (e.g., the load separators and the 0.4 kV network circuit breakers are still in the off state in this case). Its annexes are a one-line drawing of the solar power station and the MV power lines.

Before switching it on, it is necessary to conclude a network use licence (WBS, 3.8) if the power plant is connected to a public network. Immediately before switching on, the following documents have to be sent to the area owner:

- Statement of permit to energize;
- Responsible technical manager's declaration;
- Contractor's declaration;
- MV cable measurement report;
- Commercial contract (Balance Circle Membership Agreement).

The procedure of switching it on is as follows:

1. Signing the attendance list and joint declaration by those present stating that all installed equipment in the area of the small power stations and switchboard station is considered to be energized, and the launch is conducted by the sole person responsible.
2. Handing over the operation launch documentation to the representative of the area owner.
3. Checking the starting conditions.
4. Requesting permission for the launch of the operation from the district dispatch centre (DDC) by the person solely responsible for the operation launch.
5. Checking the appearance of voltages on the capacitive voltage indicator in the line field marked +J01 of the transformer station.
6. Turning on the load section marked -Q1 in the line field marked +J01 of the transformer station.

7. Turning on the fuse sectioning switch marked -Q3 of the field marked +J03 of the transformer station. After switching it on, the transformer is energized in an idle state.
    a. Carrying out control measurements:
        i. measurement of line voltages;
        ii. measurement of phase voltages.
8. Switching on the transformer station auxiliary distribution equipment marked +SE1.
9. Switching on the transformer station 0.4 kV circuit breaker marked -Q0.
10. Hrsz. AC-1 field distributor:
    a. turning on inverter power supply small circuit breakers;
    b. turning on AC isolator switches for inverters;
    c. turning on DC isolator switches for inverters;
    d. starting to connect the inverters to the grid and checking the appearance of standard voltage.
11. Visual inspection of the equipment of the transformer station.
    a. Performing control measurements:
        i. measuring line voltages;
        ii. measuring phase voltages.
12. Checking the transformer station accounting metering (main meter and control meter).
13. Completing the launch of the solar power station.
14. Reporting the completion of the launchof the operation of the small-scale PV power station to the DDC.

After that, the new network connection contract is concluded (WBS, 3.9). At this point, the power station is already producing, and the balance group member has to submit a schedule to MAVIR every day for the expected production of the next day. The power station can join a scheduling balance circle (WBS, 3.10.1), which is usually a service company (in Hungary e.g., Ewiser Forecast Kft, NRG Forecast Kft.), with the advantage that the scheduling is then undertaken by the service provider and integrated into the balance circle of up to several hundred members. The advantage of this is that it is easier to estimate the total production of territorially dispersed solar power plants, since any unpredictable intraday cloudiness can be compensated by the production of other solar power stations. In addition, such service providers work with forecasting methods that are not available to individual actors.

After the start of operation (WBS, 3.1.1), the application for a licence to use (WBS, 3.11.1) is submitted to the territorially suitable government office. This is followed by the withdrawal of the area from cultivation (WBS, 3.11.2) and the conclusion of the final land contract (WBS, 3.11.3). Upon the completion of these procedures, the project can be considered realized. In the case of using a bank loan, after obtaining the licence of use, an expert prepares the final report, with which the remaining loan amounts can be accessed (WBS, 3.11.4).

3.4. The Summary of the Process of Establishing Solar Power Stations in Hungary

The research concluded that in the Hungarian regulatory environment, the realization of a PV power station project requires more than 3 years. The detailed aspects of this are shown in Figure 2, which not only illustrates the results by the Gantt chart, but also displays the WBS codes, processes, duration and the sequence of the processes by activity number for clarity. The critical paths are marked in red, while the noncritical tasks are indicated by blue bars, and individual task groups are marked with black ones. The realization of a solar power plant consists of 43 activities practically. There are 2 tasks (WBS 1, 1.1) in the initiation phase, 24 tasks (WBS 2–2.8.6) in the planning phase and 17 tasks (WBS 3–3.11.4) in the execution phase. The abbreviation SS in Figure 2 means the start-to-start relationship, while FF refers to finish-to-finish. In the case of SS, the start of the subsequent task is bound to the start of the previous task, while in the case of FF, the completion of the subsequent task is bound to the completion of the preceding task. Figure 2 illustrates a validated, actionable model of establishing PV power plants in Hungary, which details the causal steps related to their planning and installation.

Activity number	WBS	Process name	Duration	Sequence of processes by activity number
1	**1**	**Preparation stage**	**40 days**	
2	1.1	Searching for and modeling of potential site	40 days	
3	**2**	**Licensing stage**	**531 days**	
4	2.1	Signing pre-contract for the land	20 days	2
5	2.2	Submitting electrical grid connection request	20 days	4
6	2.3	Preparation of a feasibility study	100 days	5
7	2.4	Preparation of technical and economic information	20 days	6
8	2.5	Creating electrical grid connection plan	120 days	7
9	2.6	Approval of electrical grid connection plan	40 days	8
10	**2.7**	**Obtaining building permits and plans**	**160 days**	**8**
11	2.7.1	Preparing soil protection plan	20 days	
12	2.7.2	Obtaining final licence for other uses	20 days	11
13	2.7.3	Preparation of a soil mechanical expert's opinion	20 days	
14	2.7.4	Preparation of a structural plan chapter	20 days	13
15	2.7.5	Preparation of a settlement and spatial plan chapter	100 days	
16	2.7.6	Preparation of Annex 13 to Government Decree No 314/2005 (XII.25)	20 days	
17	2.7.7	Preparation of preliminary archaeological documentation and obtaining disaster management approvals	20 days	
18	2.7.8	Submitting building permit documentation	140 days	12SS;14SS;15SS;16SS;17SS
19	2.7.9	Approval of building permit	31 days	10
20	**2.8**	**Obtaining transmission line rights and temporary other uses licences**	**151 days**	**8**
21	2.8.1	Obtaining temporary other uses licence	60 days	
22	2.8.2	Obtaining owner consent	120 days	
23	2.8.3	Preparation of transmission line rights documentation	120 days	21SS;22SS
24	2.8.4	Approval of transmission line rights	31 days	23
25	2.8.5	Conclusion of electrical grid connection contract	20 days	9;19
26	2.8.6	Obtaining single small power plant license	40 days	25
27	**3**	**Start of the construction phase**	**530 days**	
28	3.1	Selection of construction company	40 days	25
29	3.2	Financing planning	260 days	9;28FF+60 days
30	3.3	Handing over construction site to the contractor	20 days	29
31	3.4	Preparation of construction plan	60 days	29
32	3.5	Start of construction	80 days	29;31SS+30 days
33	3.6	Measurements	20 days	32
34	3.7	Conclusion of operating agreement	40 days	33
35	3.8	Concluding electrical grid use licence	40 days	34SS
36	3.9	Conclusion of new electrical grid connection contract	40 days	33
37	**3.10**	**Joining a scheduling balance circle**	**240 days**	
38	3.10.1	Conclusion of contracts related to of scheduling	240 days	21;34FF;35FF;36FF
39	**3.11**	**Tasks after the starting of operation**	**100 days**	
40	3.11.1	Submitting a licence to use	40 days	34;33
41	3.11.2	Taking land area out of cultivation	20 days	40
42	3.11.3	Conclusion of final land contract	20 days	41
43	3.1.1.4	Preparing final report	20 days	42

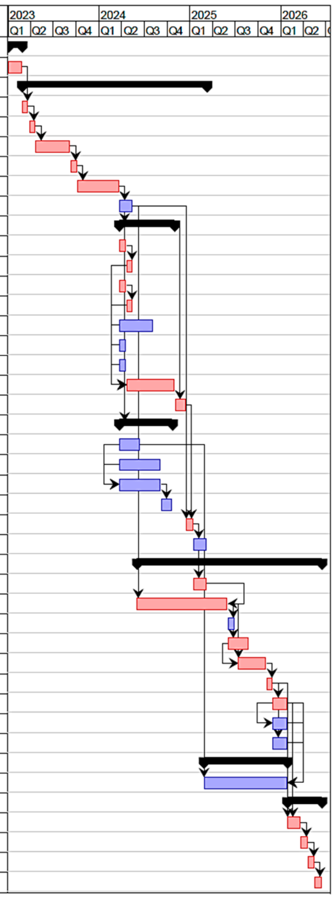

Figure 2. The summary of the process of establishing solar power stations in Hungary.

4. Conclusions

There is absolutely no doubt that both global long-term energy trends and recent developments in the world affecting the energy markets boost interest in photovoltaic technologies. The changes in supply and demand in the international markets, however, do not determine by themselves how fast photovoltaic technology is adopted and spread in the various countries, but individual nations' and supranational organizations' policies and measures, which have the power to fundamentally influence investment decisions as well as attitudes and approaches to renewable energy projects, play a decisive part too.

The present research revealed the interdependent management, economic and technical aspects essential to the planning and establishment of PV power stations in Hungary, based on actual experience. The exploration of this is significant from a practical point of view, on the one hand, since the research has updated and clarified the steps necessary for the planning of these types of power stations and, on the other hand, because there are currently no up-to-date scientific works available that would provide knowledge of sufficient depth in connection with PV power station planning. Being aware of country-specific information related to the establishment of PV power stations is extremely important for making right investment decisions and planning processes. According to the findings of the research, it takes more than 3 years to establish a PV power plant in the Hungarian regulatory environment by a long process, consisting of 43 activities.

The aim of further research is to identify the processes necessary for the planning and establishment of PV power stations in as many EU countries as possible. Research of this kind would allow us to study more complex relationships and develop complex models. For future research, Germany would be of great importance, as it has the largest number of PV power stations in the EU (57.7 GW/Q4 2022).

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References

1. Wolniak, R.; Skotnicka-Zasadzień, B. Development of Photovoltaic Energy in EU Countries as an Alternative to Fossil Fuels. *Energies* **2022**, *15*, 662. [CrossRef]
2. Fraunhofer Institute for Solar Energy Systems. *Photovoltaics Report*; Fraunhofer Institute for Solar Energy Systems: Freiburg im Breisgau, Germany, 2021.
3. European Commission. Legal Sources on Renewable Energy. Available online: http://www.res-legal.eu/ (accessed on 21 January 2022).
4. Steiner, A. The Role of Energy Storage in Hungary. In *Proceedings of the III Hungarian Power-to-Gas Conference*; Budapest University of Technology and Economics: Budapest, Hungary, 2021; pp. 1–10.
5. Aragonés-Beltrán, P.; Chaparro-González, F.; Pastor-Ferrando, J.P.; Rodríguez-Pozo, F. An ANP-Based Approach for the Selection of Photovoltaic Solar Power Plant Investment Projects. *Renew. Sustain. Energy Rev.* **2010**, *14*, 249–264. [CrossRef]
6. Armin Razmjoo, A.; Sumper, A.; Davarpanah, A. Development of Sustainable Energy Indexes by the Utilization of New Indicators: A Comparative Study. *Energy Rep.* **2019**, *5*, 375–383. [CrossRef]
7. Roozbeh Nia, A.; Awasthi, A.; Bhuiyan, N. Industry 4.0 and Demand Forecasting of the Energy Supply Chain: A Literature Review. *Comput. Ind. Eng.* **2021**, *154*, 107128. [CrossRef]
8. Yang, L.; Wang, X.C.; Dai, M.; Chen, B.; Qiao, Y.; Deng, H.; Zhang, D.; Zhang, Y.; Villas Bôas de Almeida, C.M.; Chiu, A.S.F.; et al. Shifting from Fossil-Based Economy to Bio-Based Economy: Status Quo, Challenges, and Prospects. *Energy* **2021**, *228*, 120533. [CrossRef]
9. Yang, X.; Zhang, J.; Ren, S.; Ran, Q. Can the New Energy Demonstration City Policy Reduce Environmental Pollution? Evidence from a Quasi-Natural Experiment in China. *J. Clean Prod.* **2021**, *287*, 125015. [CrossRef]
10. Lelieveld, J.; Klingmüller, K.; Pozzer, A.; Burnett, R.T.; Haines, A.; Ramanathan, V. Effects of Fossil Fuel and Total Anthropogenic Emission Removal on Public Health and Climate. *Proc. Natl. Acad. Sci. USA* **2019**, *116*, 7192–7197. [CrossRef]
11. Jäger-Waldau, A.; Kougias, I.; Taylor, N.; Thiel, C. How Photovoltaics Can Contribute to GHG Emission Reductions of 55% in the EU by 2030. *Renew. Sustain. Energy Rev.* **2020**, *126*, 109836. [CrossRef]
12. Yu, B.; Fang, D.; Yu, H.; Zhao, C. Temporal-Spatial Determinants of Renewable Energy Penetration in Electricity Production: Evidence from EU Countries. *Renew. Energy* **2021**, *180*, 438–451. [CrossRef]
13. Nguyen, K.H.; Kakinaka, M. Renewable Energy Consumption, Carbon Emissions, and Development Stages: Some Evidence from Panel Cointegration Analysis. *Renew. Energy* **2019**, *132*, 1049–1057. [CrossRef]
14. Qin, Q.; Liu, Y.; Huang, J.P. A Cooperative Game Analysis for the Allocation of Carbon Emissions Reduction Responsibility in China's Power Industry. *Energy Econ.* **2020**, *92*, 104960. [CrossRef]
15. Tang, S.; Zhou, W.; Li, X.; Chen, Y.; Zhang, Q.; Zhang, X. Subsidy Strategy for Distributed Photovoltaics: A Combined View of Cost Change and Economic Development. *Energy Econ.* **2021**, *97*, 105087. [CrossRef]
16. Sinsel, S.R.; Riemke, R.L.; Hoffmann, V.H. Challenges and Solution Technologies for the Integration of Variable Renewable Energy Sources—A Review. *Renew. Energy* **2020**, *145*, 2271–2285. [CrossRef]
17. Hyder, F.; Baredar, P.; Sudhakar, K.; Mamat, R. Performance and Land Footprint Analysis of a Solar Photovoltaic Tree. *J. Clean Prod.* **2018**, *187*, 432–448. [CrossRef]
18. Chen, Z.; Su, S.I.I. Multiple Competing Photovoltaic Supply Chains: Modeling, Analyses and Policies. *J. Clean Prod.* **2018**, *174*, 1274–1287. [CrossRef]
19. Kılıç, U.; Kekezoğlu, B. A Review of Solar Photovoltaic Incentives and Policy: Selected Countries and Turkey. *Ain Shams Eng. J.* **2022**, *13*, 101669. [CrossRef]
20. Xu, T.; Ma, J. Feed-in Tariff or Tax-Rebate Regulation? Dynamic Decision Model for the Solar Photovoltaic Supply Chain. *Appl. Math. Model.* **2021**, *89*, 1106–1123. [CrossRef]

21. EUR-Lex. Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the Promotion of the Use of Energy from Renewable Sources and Amending and Subsequently Repealing Directives 2001/77/EC and 2003/30/EC. Available online: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32009L0028 (accessed on 13 March 2022).
22. EUR-Lex. Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the Promotion of Electricity Produced from Renewable Energy Sources in the Internal Electricity Market. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2001.283.01.0033.01.ENG&toc=OJ%3AL%3A2001%3A283%3ATOC (accessed on 13 March 2022).
23. EUR-Lex. Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the Promotion of the Use of Biofuels or Other Renewable Fuels for Transport. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2003.123.01.0042.01.ENG&toc=OJ%3AL%3A2003%3A123%3ATOC (accessed on 13 March 2022).
24. Tutak, M. Using MCDM Methods to Assess the Extent to Which the European Union Countries Use Renewable Energy. *Multidiscip. Asp. Prod. Eng.* **2021**, *4*, 190–199. [CrossRef]
25. European Parliament. Renewable Energy. Available online: https://www.europarl.europa.eu/factsheets/en/sheet/70/renewable-energy (accessed on 13 March 2022).
26. Knodt, M. EU Energy Policy. In *Handbook of European Policies: Interpretive Approaches to the EU*; Edward Elgar Publishing: Cheltenham, UK, 2018; pp. 224–240. [CrossRef]
27. European Commission. Progress Reports. Available online: https://wayback.archive-it.org/12090/20210802082910/https://ec.europa.eu/energy/topics/renewable-energy/progress-reports_en (accessed on 13 March 2022).
28. European Commission. Delivering the European Green Deal. Available online: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en (accessed on 13 March 2022).
29. Bhambhani, A. European Commission Targets 40% Renewable Energy Share & 55% Net Reduction in GHG Emissions By 2030; SolarPower Europe Expects 660 GW Solar Power By 2030 With This Target. Available online: https://taiyangnews.info/markets/european-commission-proposes-40-re-in-energy-mix-by-2030/ (accessed on 13 March 2022).
30. Burrett, R.; Clini, C.; Dixon, R.; Eckhart, M.; El-Ashry, M.; Gupta, D.; Haddouche, A.; Hales, D.; Hamilton, K.; House, C.; et al. *Renewable Energy Policy Network for the 21st Century*; REN21 Renewables Global Status Report; REN21: Paris, France, 2022.
31. European Commission. *EU Reference Scenario 2020 Energy, Transport and GHG Emissions—Trends to 2050*; European Commission: Brussels, Belgium, 2021.
32. Giacomarra, M.; Bono, F. European Union Commitment towards RES Market Penetration: From the First Legislative Acts to the Publication of the Recent Guidelines on State Aid 2014/2020. *Renew. Sustain. Energy Rev.* **2015**, *47*, 218–232. [CrossRef]
33. International Renewable Energy Agency (IRENA). *Renewable Power Generation Costs in 2020*; IRENA: Abu Dhabi, United Arab Emirates, 2021.
34. Council of European Energy Regulators. *Status Review of Renewable Support Schemes in Europe for 2016 and 2017—Public Report*; Council of European Energy Regulators: Brussels, Belgium, 2018.
35. Banja, M.; Monforti-Ferrario, F.; Bódis, K.; Economidou, M.; Dallemand, J.-F.; Scarlat, N.; Medarac, H.; Kona, A. *Sustainable Energy in the Danube Region as an Integral Part of the EU 2020 Strategy: Analysis of NREAPs, NEEAPs and Renewable Energy Progress Reports of Danube Region Countries*; European Commission: Brussels, Belgium, 2016.
36. Banja, M.; Jégard, M.; Motola, V.; Sikkema, R. Support for Biogas in the EU Electricity Sector—A Comparative Analysis. *Biomass Bioenergy* **2019**, *128*, 105313. [CrossRef]
37. Magyar Nemzeti Bank. *Financing the Hungarian Renewable Energy Sector*; Central Bank of Hungary: Budapest, Hungary, 2021.
38. Haffner, T. Institutional Changes in Support for Renewable Energy Production—Introduction of Renewable Energy Support Scheme. *Közép-Európai Közlemények* **2018**, *11*, 1.
39. Wolters Kluwer Hungary Kft. Act CX of 2001 on Electricity. Available online: https://mkogy.jogtar.hu/jogszabaly?docid=a0100110.TV (accessed on 14 March 2022).
40. Wolters Kluwer Hungary Kft. *2001 CX. Act 180/2002. (VIII.23.) on the Implementation of the Act on Electricity in a Unified Structure*; Wolters Kluwer Hungary Kft: Budapest, Hungary, 2001.
41. Wolters Kluwer Hungary Kft. Act LXXXVI of 2007 on Electricity. Available online: https://net.jogtar.hu/jogszabaly?docid=a0700086.tv (accessed on 14 March 2022).
42. EUR-Lex. Guidelines on State Aid for Environmental Protection and Energy 2014-2020 (2014/C 200/01). Available online: https://eur-lex.europa.eu/legal-content/HU/TXT/?uri=CELEX%3A52014XC0628%2801%29 (accessed on 14 March 2022).
43. Wolters Kluwer Hungary Kft. Government Decree 299/2017 (X. 17.) on Mandatory Feed-in and Premium Support for Electricity Produced from Renewable Energy Sources. Available online: https://net.jogtar.hu/jogszabaly?docid=A1700299.KOR (accessed on 14 March 2022).
44. Wolters Kluwer Hungary Kft. 13/2017. (XI. 8.) MEKH Decree on the Rate of Operating Support for Electricity Produced from Renewable Energy Sources. Available online: https://net.jogtar.hu/jogszabaly?docid=a1700013.mek (accessed on 14 March 2022).
45. Hungarian Energy and Public Utility Regulatory Authority (MEKH). *Information on the Renewable Energy Support Scheme (METÁR)*; MEKH: Budapest, Hungary, 2020.
46. Ádám, S.B. Hungarian Solar Panels Are Already Outperforming Paks Power Plant. Available online: https://g7.hu/tech/20220211/a-magyar-napelemek-mar-paksot-is-lepipaljak/ (accessed on 14 March 2022).

47. European Network of Transmission System Operators for Electricity (ENTSO-E) ENTSO-E Transparency Platform. Available online: https://transparency.entsoe.eu/dashboard/show (accessed on 1 January 2022).
48. Major, A. While We Were Focused on the War, the Paks Nuclear Power Plant Was Outperformed by PV Systems. Available online: https://www.portfolio.hu/uzlet/20220304/amig-a-haborura-figyeltunk-paksot-szepen-csendben-lenyomtak-a-napelemparkok-530783 (accessed on 14 March 2022).
49. Hungarian Transmission System Operator—MAVIR ZRt. Capacity Analysis—Consultation Input Data 2020-2040. Available online: https://www.mavir.hu/web/mavir/kapacitaselemzes (accessed on 2 December 2020).
50. PANNON Green Power Ltd. Interview on PV System Modeling Aspects, Design Processes and PV Scheduling Service. Available online: https://pannongreenpower.hu/en/home/ (accessed on 26 November 2022).
51. Wu, S.; Liu, L.; Zhang, B.; Gao, Y.; Shang, L.; He, S.; Li, S.; Zhang, P.; Chen, S.; Wang, Y. Multifunctional Two-Dimensional Benzodifuran-Based Polymer for Eco-Friendly Perovskite Solar Cells Featuring High Stability. *ACS Appl. Mater Interfaces* **2022**, *14*, 41389–41399. [CrossRef] [PubMed]
52. Gao, Y.; Wang, Z.; Zhang, J.; Zhang, H.; Lu, K.; Guo, F.; Yang, Y.; Zhao, L.; Wei, Z.; Zhang, Y. Two-Dimensional Benzo[1,2-b:4,5-B′]Difuran-Based Wide Bandgap Conjugated Polymers for Efficient Fullerene-Free Polymer Solar Cells. *J. Mater. Chem. A* **2018**, *6*, 4023–4031. [CrossRef]
53. Fraunhofer Institute for Solar Energy Systems ISE. *Photovoltaics Report*; Fraunhofer Institute for Solar Energy Systems ISE: Freiburg, Germany, 2022.
54. Zsiborács, H.; Baranyai, N.H.; Vincze, A.; Pintér, G. An Economic Analysis of the Shading Effects of Transmission Lines on Photovoltaic Power Plant Investment Decisions: A Case Study. *Sensors* **2021**, *21*, 4973. [CrossRef] [PubMed]
55. Mészáros, L. *Solar Power Plant Design Experience—Planning and Licensing of Solar Power Plants*; Budapest, Hungarian Chamber of Engineers: Budapest, Hungary, 2018. Available online: https://docplayer.hu/105703837-Naperomu-tervezoi-tapasztalatok-napelemes-eromuvek-tervezese-engedelyeztetese.html (accessed on 2 December 2020).
56. Goh, H.H.; Li, C.; Zhang, D.; Dai, W.; Lim, C.S.; Kurniawan, T.A.; Goh, K.C. Application of Choosing by Advantages to Determine the Optimal Site for Solar Power Plants. *Sci. Rep.* **2022**, *12*, 4113. [CrossRef]
57. Heagney, J. *Fundamentals of Project Management*, 5th ed.; HarperCollins Focus: Nashville, TN, USA, 2018.
58. Project Management Institute. *A Guide to the Project Management Body of Knowledge (PMBOK Guide)*, 6th ed.; Project Management Institute, Inc.: Newtown Square, PA, USA, 2021.
59. AXELOS. *Managing Successful Projects with PRINCE2*; The Stationery Office Ltd: London, UK, 2017; ISBN 978-0113315338.
60. Azhar, M.T.; Khan, M.B.; Zafar, M.M. Architecture of an Enterprise Project Life Cycle Using Hyperledger Platform. In *2019 13th International Conference on Mathematics, Actuarial Science, Computer Science and Statistics (MACS)*; IEEE: Piscataway, NJ, USA, 2019. [CrossRef]
61. Publications Office of the European Union. *The PM2 Project Management Methodology Guide 3.0*; The PM2 Guide v3.0.; Publications Office of the European Union: Luxembourg; Brussels, Belgium, 2018; ISBN 9789279918292.
62. Takagi, N.; Varajão, J. Integration of Success Management into Project Management Guides and Methodologies—Position Paper. *Procedia Comput. Sci.* **2019**, *164*, 366–372. [CrossRef]
63. Wolters Kluwer Hungary Kft. VET—2007. Évi LXXXVI. Törvény a Villamos Energiáról—Act LXXXVI of 2007 on Electric Energy. Available online: https://net.jogtar.hu/jogszabaly?docid=a0700086.tv (accessed on 7 April 2022).
64. Wolters Kluwer Hungary Kft. 273/2007. (X. 19.) Korm. Rendelet a Villamos Energiáról Szóló 2007. Évi LXXXVI. Törvény Egyes Rendelkezéseinek Végrehajtásáról—Government Decree 273/2007. (X. 19.) on the Implementation of Certain Provisions of Act LXXXVI of 2007 on Electric Energy. Available online: https://net.jogtar.hu/jogszabaly?docid=a0700273.kor (accessed on 7 April 2022).
65. Hungarian Transmission System Operator—MAVIR ZRt. Üzemi Szabályzat—Operating Rules. Available online: https://www.mavir.hu/web/mavir/uzemi-szabalyzat (accessed on 14 April 2022).
66. E.ON Hungária Zrt. Elosztói Szabályzat—Distribution Rules. Available online: https://www.eon.hu/hu/rolunk/vallalatcsoport/kozlemenyek/szabalyzatok-jogszabalyok/aram/eon-eszakdunantuliaramhalozati/elosztoi-szabalyzat.html (accessed on 14 April 2022).
67. MVM Émász Áramhálózati Kft. Elosztói Szabályzat—Distribution Rules. Available online: https://mvmemaszhalozat.hu/tarsasagunkrol/szabalyzatok/elosztoi-szabalyzat (accessed on 14 April 2022).
68. Wolters Kluwer Hungary Kft. 382/2007. (XII. 23.) Korm. Rendelet a Villamosenergia-Ipari Építésügyi Hatósági Engedélyezési Eljárásokról—Government Decree 382/2007. (XII. 23.) on the Permit Granting Procedures of the Electric Energy Industry Building Authority. Available online: https://net.jogtar.hu/jogszabaly?docid=a0700382.kor (accessed on 7 April 2022).