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# Using renewable energies in the corporate environment:

*An investigation of the potentials and barriers for the corporate use of photovoltaic systems in Germany using the case study of osthaus & beckert GmbH.*


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# Abstract

The implementation of the "Erneuerbare Energien Gesetz"(EEG) in 2000 for the expansion of renewable energies in Germany has led to a continuous increase in electricity costs. Industrial companies, in particular, with very high electricity consumption, consider themselves threatened in their international competitiveness. Experts believe that one way of countering this situation is for companies to acquire a photovoltaic system.

Using the example of osthaus & beckert GmbH as a case study, this study aimed to show the potential and possible barriers regarding the acquisition and corporate use of photovoltaic systems. In the process, expert interviews, document analysis, and the simulation of four photovoltaic systems in the planning and simulation software PVSOL Premium 2022 R5 were carried out for data collection.

The data collection and analysis results have shown that achieving economic advantage and reducing the ecological footprint represent the potentials of a company-owned photovoltaic system. In terms of barriers, it was found that there are legal, technical, and socio-economic barriers to the acquisition and sustainable corporate use of a PV system. Finally, the researcher concludes that especially the legal barriers as well as information deficits have a significant influence on the economic potential and thus also on the sustainable entrepreneurial use of a PV system.

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# Acknowledgements

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# Abbreviations

| | |
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| **AC grid:** | Alternating current grid |
| **AM:** | Air mass |
| **BDEW:** | Bundesverband der Energie- und Wasserwirtschaft |
| **BSW:** | Bundesverband Solarwirtschaft e.V. |
| **DC grid:** | Direct current grid |
| **EEG:** | Erneuerbare Energien Gesetz |
| **EVA:** | Ethyl vinyl acetate |
| **GW:** | Gigawatt |
| **HIT:** | Heterojunction with Intrinsic Thin-Layer |
| **IEC:** | International Electrotechnical Commission |
| **KfW:** | Kreditanstalt für Wiederaufbau |
| **kWh:** | Kilowatt hour |
| **kWp:** | Kilowatt peak |
| **MAD:** | Mean absolute deviation |
| **MW/ha:** | Megawatt/ Hectare |
| **PV:** | Photovoltaic |
| **PV-FFA:** | Photovoltaik Freiflächenanlagen (PV ground-mounted systems) |
| **STC:** | Standard Test Conditions |
| **TWh:** | Terawatt hour |
| **UV:** | Ultraviolet |
| **v1:** | Version 1 |
| **v2:** | Version 2 |
| **v3:** | Version 3 |
| **Vac:** | Volt alternating current |

# 1 Introduction

Reducing greenhouse gases and the associated fight against climate change is one of the central issues in Germany. In particular, the energy industry, which causes around 37 % of energy-related greenhouse gas emissions, must be revolutionized in this sense. The main focus of German energy policy is, therefore, on the production of ecologically sustainable electricity through renewable energy sources (Umweltbundesamt, 2021b). This led to the introduction of the so-called "Erneuerbare Energien Gesetz" (EEG) in 2000, which implies a fixed state subsidy for new renewable energy production plants (Bundesministerium für Wirtschaft und Klimaschutz, 2022). By creating a financial incentive, 45 % of the electricity consumed in 2020 already came from renewable sources. However, there is also a flip side to the coin. In addition to accelerating the expansion of renewables, government intervention has also had a significant impact on energy prices. According to Bundesverband der Energie- und Wasserwirtschaft (BDEW) the price for electricity have risen by around 6 % annually since 2000 (Entega, 2021). Werner (2004) states that this has resulted in considerable cost disadvantages, especially for industrial production. He goes on to say that energy is essential as a competitive factor but that German industrial companies pay the second-highest price for electricity in Europe by international comparison. To remain competitive, energy must be both environmentally compatible and available at competitive prices. One way for industrial companies to remain competitive, despite the high electricity prices is to produce their own electricity by using photovoltaic systems. Following the idea of Schiffer (2019), additional costs, such as the EEG surcharge or grid usage fees, can be saved by generating one's own electricity. Sinß and Simon (2013) also conclude that industrial companies can achieve economic added value by using photovoltaic systems. Additionally, if one follows Weniger *et al.* (2021), it is particularly commercial buildings that could enormously contribute to the further expansion of photovoltaics in Germany due to their often considerable roof areas. Nevertheless, the trend of entrepreneurial use of PV systems has not yet been able to gain sufficient acceptance. According to a study by the Bundesverband Solarwirtschaft e.V. (2021) (BSW), the willingness of German companies to invest in the expansion of commercial rooftop PV systems even decreased significantly in 2021. While in 2020, 790 MWp of additional capacity was recorded by commercial rooftop PV systems, in 2021, this amount was only 474 MWp. This corresponds to a decrease of 40 % of the new installed capacity. BSW identifies the cause of the enormous decline in the current relationship between the price of a new plant and the subsidy to be received. Figure 1 shows this relationship particularly clearly. While the cost of a new PV system has increased by 18 % between quarter one in 2020 and quarter three in 2021, the subsidies in the form of feed-in tariffs have been reduced by 24 %. In addition, the so-called tendering obligation (see chapter 2.3.2) for plants above 750 kW/h has a deterrent effect on companies, as this process is often associated with a high time expenditure (NATURSTROM AG, 2021).

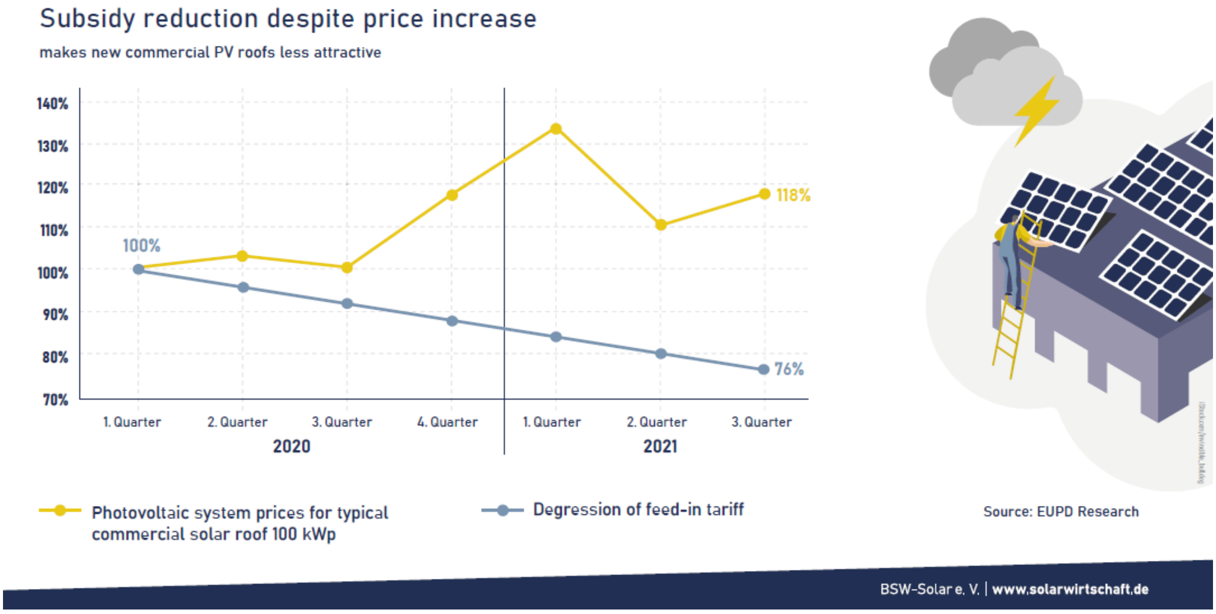



*Figure 1 - Ratio of costs for a new PV system and feed-in tariffs (Bundesverband Solarwirtschaft e.V., 2021)*

## 1.1 Background of osthaus & beckert GmbH

The osthaus & beckert GmbH was founded in 1994 by Christian Osthaus and Andreas Beckert (osthaus & beckert GmbH, 2022b). As a metal processing company, osthaus & beckert GmbH also belongs to the industrial production sector. For the processing of metals, the company uses many large machines, which cause correspondingly high energy consumption. Since not only electricity prices have continued to rise in recent years but also the company's own electricity consumption, osthaus & beckert GmbH is looking for a sustainable solution to reduce the electricity costs incurred in the future and, at the same time, contribute to climate change. The possibility of building its own wind turbine has already been rejected for reasons of space. As an alternative, the company is considering installing a photovoltaic system on one of its production halls. From initial discussions with the company, it has become clear that the current problem lies in the lack of knowledge about what potential such a plant has for the company and what aspects could represent a possible barrier. In addition, the question arises why more companies with high energy consumption rates do not rely on their own electricity production.

## 1.2 Scientific relevance

German scientists, as well as scientists worldwide, agree on one point: The energy transition is a central component to mitigate climate change. There is also agreement in the assessment that the current annual rates of expansion of renewable technologies are far from sufficient to achieve the German ambition of climate neutrality in the energy sector and thus the goal of the Paris Climate Agreement. Gerhards et al. (2021) emphasize that current electrification efforts in the mobility and heating sectors will increase Germany's total energy demand from 525 TWh/year to 875 TWh/year by 2030. In order to meet such an energy demand with renewable electricity, a huge increase in the annual growth of, among others, photovoltaic systems would be essential. In numbers, it requires an expansion of around 350GW in the field of photovoltaics.

In his study, Wirth (2022) also argues for the necessity of a significantly higher growth rate of PV systems than the current growth rate of 4.6 GW/year specified in the EEG2021. In this context, Wirth refers to the results of other studies that have dealt with the required increase in PV systems in the context of realizing German climate Gneutrality by the year 2045. Taking into account different boundary conditions such as acceptance, energy imports, and efficiency improvements, these studies indicate that a total installed PV capacity of about 300 to 450 GW will be needed on average by 2045. Based on the current total installed PV capacity, which is about 54 GW according to Breitkopf (2022a), this would mean an annual increase of 13 – 21 GW. This value exceeds the growth rate specified in the EEG2021 by 4.5 times.

Based on the above information and the fact that, at present, no concrete research exists on the potential PV power contribution of industrial companies such as osthaus & beckert GmbH, the scientific relevance of this work lies in demonstrating precisely this potential. Also relevant in this context is the identification of possible barriers that prevent companies such as osthaus & beckert GmbH from investing in their own PV system and thus also limit the potential performance contribution.

## 1.3 Social relevance

In order to achieve the growth rate of 13 – 21 GW/year described above, one thing is required above all: available installation areas. While most people associate the installation areas of PV systems with the roofs of private households, it is mainly the so-called PV ground-mounted systems (PV FFA), as illustrated in Figure 2, which make a large contribution to electricity production due to their size. According to a status report of the Bezirksregierung Düsseldorf (2020), the area required for PV-FFA plants has decreased from 3.5 MW/ha to 1.3 MW/ha since 2005 due to technological progress and the decreasing costs of the individual modules (unfavorable orientation of the plants is less important in the selection of areas). It is also stated that for 100 GW of newly installed capacity, only 1 % of the total area of Germany's 11,700,000 hectares of arable land would be taken up. Wirth (2022) believes that PV-FFA plants have a much smaller area requirement than they did a few years ago. Furthermore, he argues that new PV-FFA plants in the form of Agri-PV plants make it possible to simultaneously use and preserve agricultural land and produce solar energy.

*Figure 2 – Example of a PV-FFA plant (Wind Energie GmbH, 2020)*

Although the arguments of Wirth (2022) and the Bezirksregierung Düsseldorf (2020) sound plausible at first sight, in practice, conflicts of use often occur in the planning of PV-FFA plants. According to Stückemann (2021), when claiming the area to be used, project developers, citizens, and companies affected by the planning frequently clash. While landlords want to use the favor of the hour to generate high revenues, farmers who currently lease the area have to fear for their existence. Conservationists, as well as the residents of the areas to be utilized, also often view the development of the farmland critically and fight for the preservation of the natural areas.

Based on the presented facts, the social relevance of this research work lies mainly in the contribution to protect the interests of the directly affected citizens. By investigating the potential of PV systems on German industrial and commercial roofs, which is carried out in this research using the example of osthaus & beckert GmbH, an alternative to the space-intensive PV-FFA systems can be shown. This, in turn, protects natural areas from development with PV-FFA systems and, at the same time, promotes the expansion of renewable energies.

## 1.4 Economic relevance

In addition to the listed ecological and social aspects, which already provide the necessary relevance for this research work, the economic aspect must also be examined with regard to possible investments in company-owned PV systems.

As already made clear in the introduction, especially industrial companies like osthaus & beckert GmbH suffer from the constantly increasing electricity prices. The reason for this is that industrial companies which produce goods belong to the manufacturing sector. A study by the German Federal Statistical Office in 2018, in which the primary energy consumption of all German production sectors was examined, showed that the manufacturing industry has by far the largest primary energy demand with 42 % or 3.942 PJ (Umweltbundesamt, 2021a). At the same time, German industrial companies pay the highest price for electricity in a European comparison, averaging 17.81 cents/kWh (Figure 3) (Breitkopf, 2022b).

Therefore, the economic relevance of this research work lies in providing companies in the manufacturing sector with an insight into the example of osthaus & beckert GmbH as to whether a reduction in electricity costs and thus an economic added value can be realized through their own PV system. Confirming this fact would not only relieve the industrial companies in terms of costs but also strengthen their international competitive position.

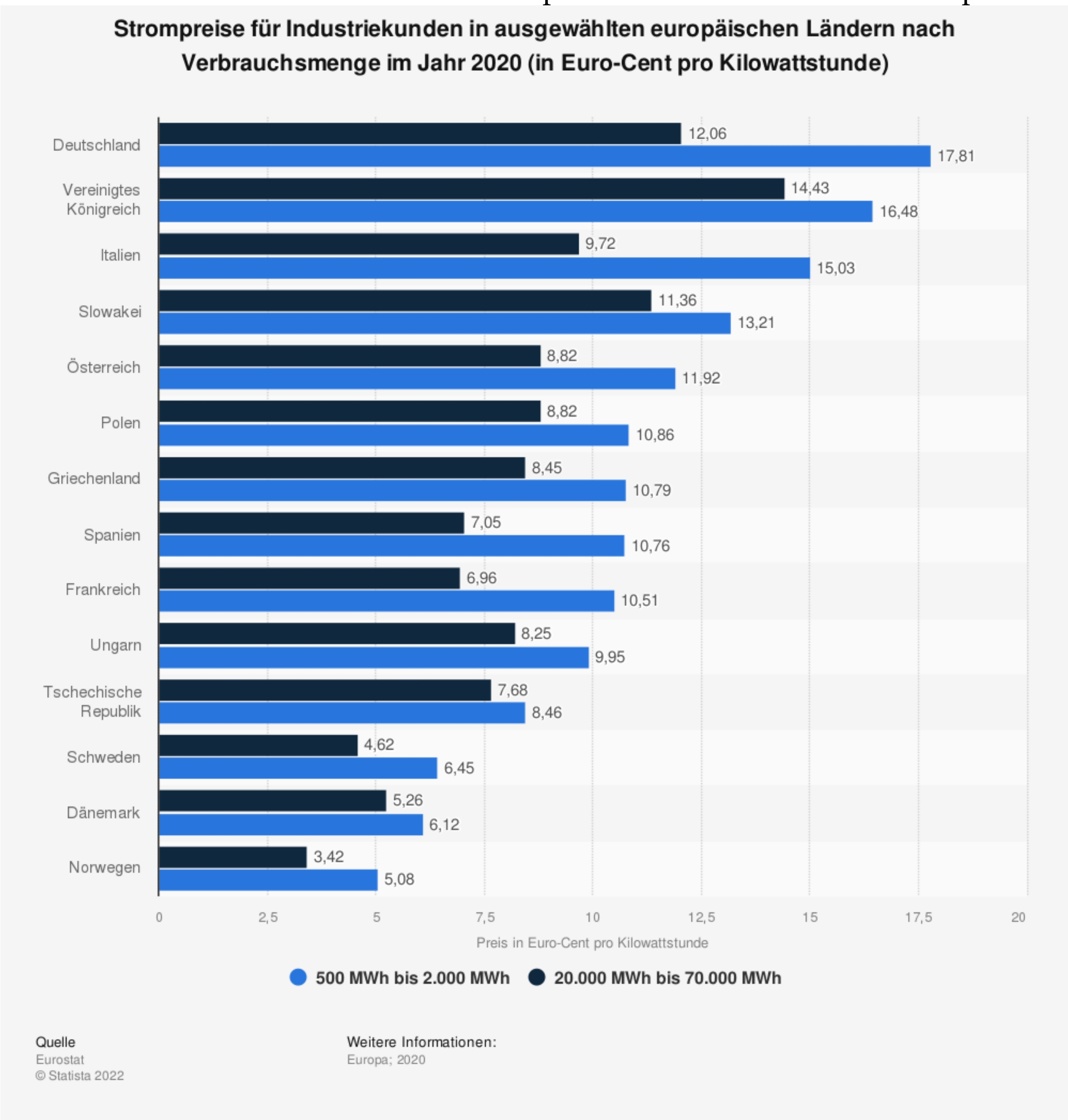



*Figure 3 – Electricity prices for industrial customers in selected European countries by consumption volume in 2020 (Breitkopf, 2022b)*

## 1.5 Main research question

Considering the research problem explained in the introduction and the background of osthaus & beckert GmbH, as well as the potential economic, environmental, and social relevance of this work, the main research question can be summarized as follows:

What potentials and barriers exist in Germany regarding the acquisition and commercial use of a photovoltaic system, and how do these barriers possibly impair sustainable use?

## 1.6 Secondary research questions

a) Are there barriers regarding the acquisition and commercial use of photovoltaic systems, and if so, what type of barriers are considered most relevant with respect to sustainable use?
b) Which photovoltaic system offers the greatest sustainable potential?
c) Does the installation of a PV system make economic sense for osthaus & beckert GmbH?

# 2 Theoretical framework

In this section, the theoretical framework for further investigation regarding the potentials and barriers to the sustainable use of company-owned PV systems is set. First, the reader is given a brief overview of a PV system's general structure and essential components. This part is crucial since several PV systems in which the components presented play a key role will be simulated later. Subsequently, based on literature research, different factors will be presented that can influence the sustainable use of a PV system and must be considered during the planning. Finally, the legal framework for using a photovoltaic system is examined in more detail. The main focus here is on the applicable building regulations for photovoltaic systems, taxes, and government subsidies for solar installations in Germany.

## 2.1 Design of a PV system

### PV-Module

The basic building block of any photovoltaic system is the solar cell, which is responsible for generating electricity. Almost 95 % of solar cells are made of silicon (Si), a semiconductor and the most abundant natural element on earth (Solaranlagen-ABC, 2016). These solar cells are distinguished between monocrystalline and polycrystalline cells. The difference between the two types of cells lies in their respective structural design. Polycrystalline solar cells have a non-uniform structure, as this is composed of countless individual silicon crystals. These types of solar cells are less expensive and better for the environmental footprint of the photovoltaic system because module production is less expensive, and there is less waste due to the square shape of the cell. They are often considered the best value solar cell of all solar cells. However, because less pure silicon is used, efficiency drops to about 15 %. The efficiency of monocrystalline solar cells is significantly higher. This is on average 20 %. The reason for this is that this type of solar cell consists of monocrystalline silicon, which means that the degree of purity is significantly higher than with polycrystalline solar cells. Due to the costly production, however, a higher financial cost must be paid for the purchase of monocrystalline solar cells. Despite this, monocrystalline solar cells are almost exclusively used today since the higher efficiency in conjunction with the system service life relativizes the acquisition costs (TRITEC, 2020).

Another type of solar cell is the thin-film cell, which belongs to the genus of amorphous solar cells. This cell type also uses silicon for production, but the silicon is additionally mixed with other materials. The mixture is then stamped as a very thin layer onto glass, for example, as the substrate material. The advantage of this cell type compared to the crystalline cell types described above is the significantly lower price. In addition, these cells are very flexible and can even be folded, depending on the substrate material. At the same time, the efficiency of five to seven percent is significantly lower than that of crystalline solar cells (Bröer, 2021).

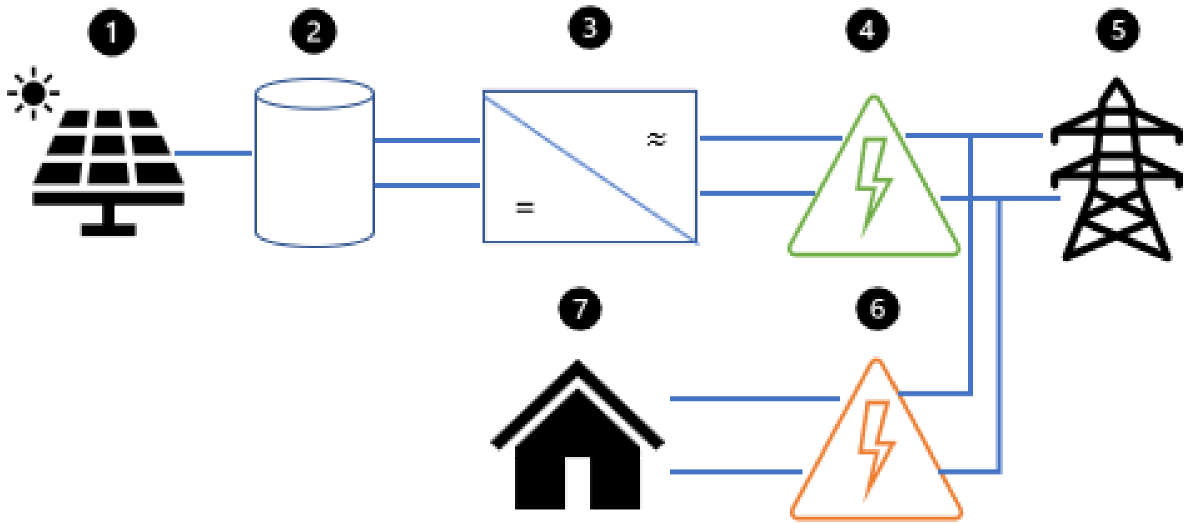
The last cell to be mentioned is the so-called Heterojunction with Intrinsic Thin-Layer cell (HIT cell). This is a solar cell in which a combination of crystalline and amorphous silicon is used. The HIT cell is characterized above all by the fact that it has a significantly lower temperature sensitivity, and the energy required for production is relatively low. In addition, HIT cells have a comparatively high efficiency of 25.6 % on average and can increase the yield by up to 10 % due to their double-sided light transmission (EnArgus, n.d.).

### Inverter

In addition to the solar cells installed on the roof, a PV system also consists of the so-called inverter, which, in addition to the solar modules, is also considered the heart of a PV system. The task of the inverter is manifold. On the one hand, it converts the direct current generated by the solar cells and passed on via the generator into alternating current so that this can be fed into the public grid. Furthermore, the inverter ensures that the current is permanently fed in synchronously with the grid frequency.

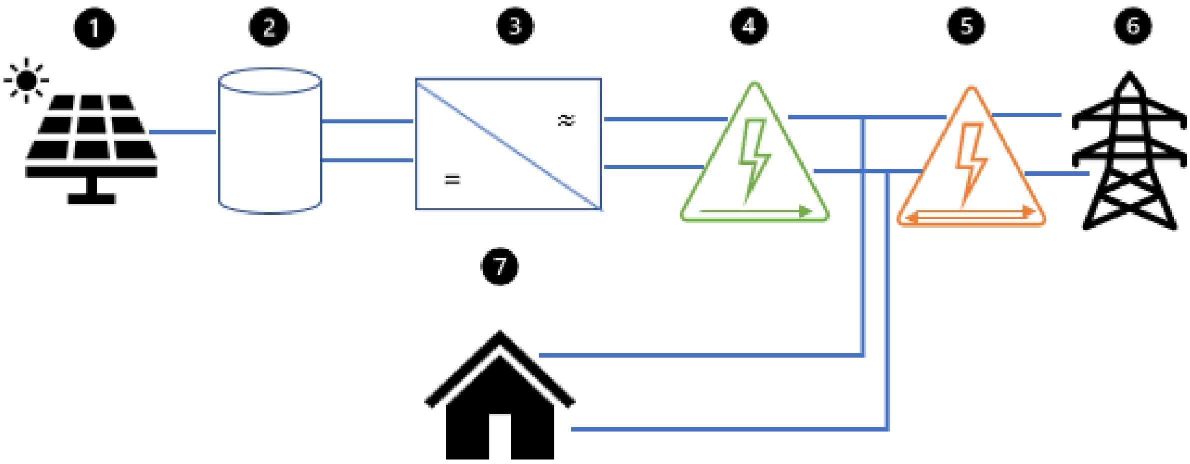
### Electricity meter

Another component of a PV system is the solar electricity meter. If the produced electricity is completely fed into the public grid (see chapter 2.2.1), the solar electricity meter is used to record the amount of electricity fed into the grid. In addition, the consumer also has a separate consumption meter, which records the electricity drawn from the public grid (Figure 4). If the owner of the PV system uses the surplus feed-in model instead (see chapter 2.2.1), the consumer meter is usually replaced by a bidirectional meter (Figure 5). This type of meter enables the simultaneous recording of electricity fed into the grid and electricity drawn from the public grid and additionally measures how much solar electricity was generated in total in a calendar year (Mertens, 2020).




| | | | |
|---|---|---|---|
| 1 | Solar cell | 5 | Public grid |
| 2 | Generator | 6 | Consumption meter |
| 3 | Inverter | 7 | Consumer |
| 4 | Solar electricity meter | | |

*Figure 4 – Structure of grid-connected PV system full feeder (illustrated by myself)*




| | | | |
|---|---|---|---|
| 1 | Solar cell | 5 | Bidirectional meter |
| 2 | Generator | 6 | Public grid |
| 3 | Inverter | 7 | Consumer |
| 4 | Solar electricity meter | | |

*Figure 5 – Structure of grid-connected PV system surplus feeder (illustrated by myself)*

## Storage Technology

In the course of presenting the surplus feed-in model, it was already discussed that battery storage can increase self-consumption and thus the economic potential of the PV system. As with solar cells and inverters, there are also different types of electricity storage systems. Since these differ in their technical specifications and price, the selection of the battery system plays a decisive role regarding the possible utilization potential of the PV system.

A distinction is made primarily between lead-based electricity storage systems and lithium-ion batteries. If lead-based power storage units are used for storing solar power, these are lead-acid or lead-gel batteries, as other lead batteries are unsuitable for use in the solar sector. The advantage of these electricity storage systems compared to lithium-ion storage systems is the significantly lower initial cost. This fact is mainly based on the fact that lead-acid/gel batteries have a lower depth of discharge, energy density, and shorter lifetime (1500 – 3000 charging cycles), which is again a disadvantage. Another disadvantage is that the installation site must have venting capabilities and be acid-resistant, as it is impossible to seal the lead-acid battery completely. In addition, lead-based electricity storage systems require a relatively large space (Energievoll, 2022).

Based on the disadvantages of lead-based electricity storage described, more and more solar electricity storage manufacturers are turning to lithium-ion technology. This convinces with an efficiency of up to 95 % and a lifetime of 5000-7000 charging cycles. At the same time, the depth of discharge of up to 100 % is also significantly higher than that of lead batteries, and the space requirement is significantly lower (Solarenergie, 2022).

## 2.2 Factors influencing the sustainable use of PV systems

After the main components of a PV system have been presented in the previous section, this section is about which factors should be considered within the planning process. In this respect, possible barriers and their effects on the potential of a PV system can already be identified, which can be compared with the data collected later in the research.

### Photovoltaic system utilization types

During a photovoltaic system's design and planning phase, it is crucial to consider the type of utilization as this significantly influences the system's potential. In Germany, there is a distinction between full feeders, surplus feeders, and stand-alone systems. The term "full feed-in" refers to a situation in which the entire amount of electricity generated by the photovoltaic system is put into the public grid and sold to an electricity company. Therefore, the electricity required is not used for the company's electricity needs. However, it must continue to be purchased from electricity companies. This method of employing photovoltaic systems was common a few years ago as a result of substantial tariff incentives (see chapter 2.3.2) (Next Kraftwerke GmbH, 2020).

While owners of older systems still benefit from the formerly high feed-in tariffs, new system owners are confronted with feed-in tariffs below the electricity purchase price of regular tariff customers. This circumstance reduces economic potential enormously. From an economic point of view, the idea is to consume as much of the generated electricity as possible and thus maintain the system's economic potential or keep it as high as possible (ibid.). Therefore, the operator model of surplus feed-in is increasingly used instead of full feed-in. Here, the PV system is still connected to the public grid, but the producer himself primarily uses the generated electricity. Only the excess energy, i.e., the energy that the electricity producer cannot immediately use for his consumption, is fed into the public grid (Solartechnik Brinkmeier, n.d.). The percentage of self-consumed solar electricity depends mainly on the size of the system, the annual consumption, and the times when the electricity is needed. Suppose the electricity is primarily used during the day (especially around noon when solar radiation is the highest). In that case, the percentage of self-generated and consumed solar electricity is more extensive than if the electricity is mainly used in the evening or at night (Hiltawsky-sonnenstrom, n.d.). Accordingly, the potential of a PV system is strongly dependent on the time of electricity consumption. For industrial companies with the highest electricity consumption during the day, a higher potential can be expected due to the self-use of the produced energy. In addition, the potential can be increased by using a battery storage system, which allows the owner of the PV system to temporarily store the excess electricity and then use it when the PV system produces no electricity. Thereby, selling unneeded electricity at low feed-in tariffs can be avoided. At the same time, further electricity costs can be saved as less cost-intensive electricity has to be purchased from the public grid (Mertens, 2020).

Stand-alone systems are not connected to the public power grid and provide power to one or more users via a locally constrained power grid. Instead of selling surplus energy, it is stored by different storage technologies for later use (Wesselak and Voswinckel, 2016). The potential of this operator model lies in the fact that the power purchase costs for electricity from the public grid are completely avoided. On the other hand, substantial deviations in electricity consumption can lead to an overload of the system, so there is not enough electricity available despite the expansion. Seen from the perspective of an industrial company, this would be tantamount to a loss of production and would therefore be rather unsuitable.

## Location

Concerning the possible performance potential of a PV system, the location is another crucial aspect that must be considered during the planning. According to Mertens (2020), irradiation values are assessed as sufficient everywhere in Germany. However, they differ considerably depending on the location. This circumstance is illustrated in Figure 6, which shows a map of Germany with the annual solar irradiation in kWh/m² and the annual energy that a 1 kWp system can generate with a performance ratio of 0.75 kWh/kWp. It is clear that both the irradiation values and the generatable energy are highest in the south of Germany. However, the values are much lower in the north and northwest of Germany. This circumstance is based on the respective distance to the equator. The closer a location is to the equator, the steeper the path of the sun and the shorter the distance the sun's rays travel through the earth's atmosphere (Solaranlage.eu, 2022). Assuming that two companies with exactly the same conditions operate a PV system, one located in the south and the other in the north of Germany, the one located in the south would have a larger electricity yield due to the higher radiation levels. Accordingly, the location in the north would limit the potential of the PV system and thus, represent a barrier regarding the optimal sustainable use of the system.

An additional aspect that must be considered is the division of global radiation into direct and diffuse radiation. As the name suggests, direct radiation is the solar radiation that hits the surface directly. Due to geographical location, air pollution, climatic conditions, etc., the ratio of direct radiation varies. The average share of direct radiation in total global radiation in Germany is about 50 % (Photovoltaik, 2022c). The remaining 50 % of global radiation is diffuse radiation. In contrast to direct radiation, the absorption and scattering of radiation prevent solar radiation from reaching the earth's surface directly. More precisely, aerosols and air molecules cause a reflection of radiation, diverting into opposite directions (Solaranlage.eu, n.d.). According to this, a PV system could only realize its full performance potential to a limited extent if it is located where air pollution and thus also diffuse radiation is higher.

Various models have been developed to determine diffuse radiation's effect on a PV system's yield. The most widely used model at present is the so-called Hofmann diffuse model. Following Hofmann *et al.* (2019), the advantage of this model over the other models is the low mean absolute deviation[1] (MAD) which is about 6 %/minute. Thus, it is the model with the lowest MAD and, accordingly, the most accurate in the calculation.

[1] The mean absolute deviation of a data set is the average distance between each measured value and the statistical average value. Thus, it allows an estimation about the variability of a data set (Frost, 2021).

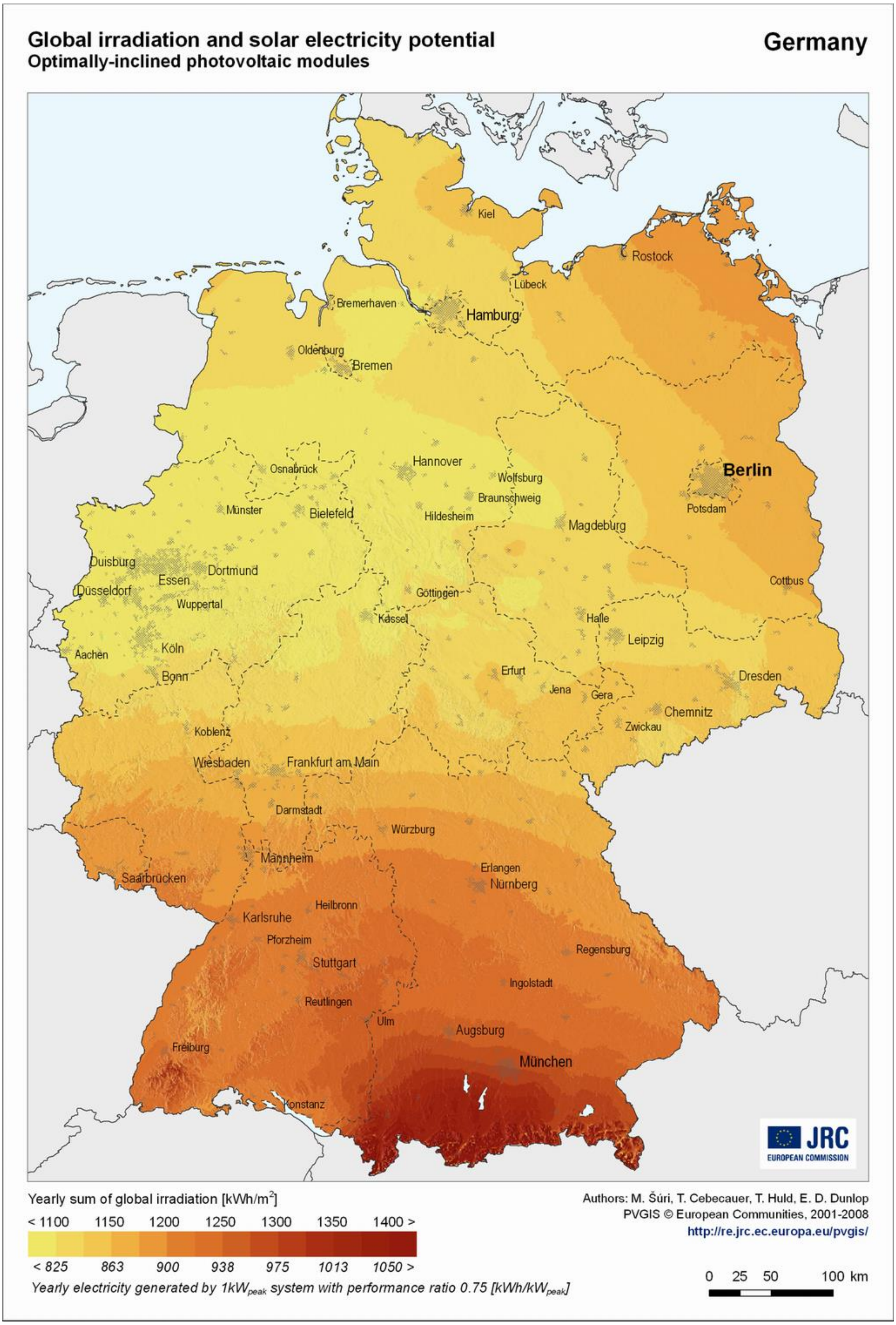



*Figure 6 – Yearly sum of irradiation (kWh/m²) in Germany (Solaranlage.eu, 2022)*

### Module inclination

In order to achieve high efficiency, the correct orientation of solar modules is often mentioned as an important factor. According to Doganay (2010), in addition to the angle of incidence to the sun, the so-called azimuth angle and the tilt angle are also crucial. The azimuth angle provides information about how high the deviation from the orientation to the south is. As can be seen in Figure 7, the azimuth angle is 0° for a pure south orientation. If the orientation of the plant deviates to the west, the azimuth angle changes in the form of plus values. With an exact west orientation, the azimuth angle would be 90°. If the system orientation deviates in an easterly direction, the change in the azimuth angle is precisely the opposite. Thus, with an exact east orientation, the azimuth angle would be -90°. However, calculations indicate that deviations of the compass direction of about 45 degrees result in no more than 5 percent yield losses. With an azimuth angle of 90 degrees, the yield reduction ranges from 6 % to 40 % (Photovoltaik, 2022a). The high fluctuations are due to the angle of inclination of the plant, which represents the horizontal deviation. The optimal orientation to achieve the best possible energy yields with a PV system in Germany and thus to use the full energy potential is considered to be surfaces tilted south by 30° to the horizontal. In Figure 7, this optimum is shown as a small black dot. According to Figure 7, the other extreme, i.e., the worst system orientation, would be a plant with an azimuth angle of 180° and a tilt angle of 90°. In this case, the annual irradiation would only be 30 %, meaning the energy yield would be significantly lower.

According to Konrad (2008), besides the orientation and the angle of inclination, the usable roof space of a building is also of high importance. He cites the following comparison as justification: For installing a PV system, a house with a 30° inclined gable roof is selected, oriented precisely to the south. In this case, one-half of the roof would meet the optimal requirements, but the other side of the roof would be practically unusable due to its north orientation. If, on the other hand, the same building with a gable roof is oriented in a west-east direction, only 70 - 87 percent of the yield can be expected due to the less favorable orientation, but the usable roof area is exceptionally high at up to 200 % compared to the base area. Thus, although the full performance potential of the system could not be used, the total output would be higher due to twice the usable space.

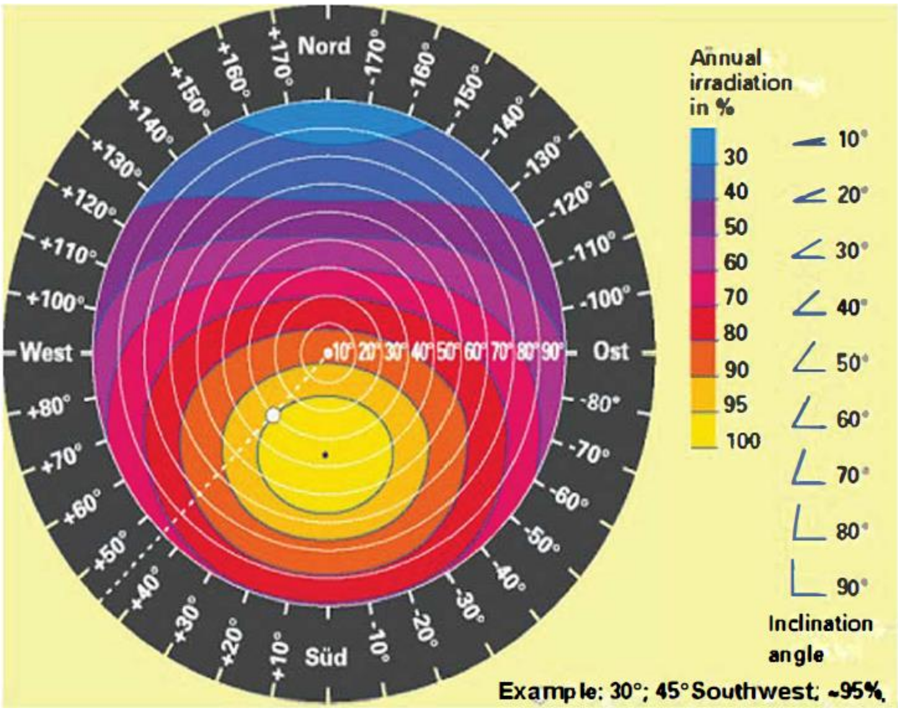



*Figure 7 - Azimuth and inclination angle (ing-büro-junge, 2017)*

## Service life

The service life of a PV system is usually 20 to 30 years. How long the PV system remains intact and what performance potential can be exploited depends in particular on the external influences acting on the system. Strong temperature fluctuations between summer and winter, for example, increase the probability of failure of the solder joints between the individual cells. Frequent high humidity causes the ethyl vinyl acetate (EVA) film, which serves to protect the solar cell from external influences, to dissolve more quickly. The UV rays of the sun, which are basically mandatory for electricity production using solar cells, also have a negative effect on the EVA film. The UV rays cause light-induced reactions in the film as well as reactions between the silicon and the chemicals in the glass, causing the latter to turn yellow-brown and thus affecting performance. On the other hand, shade can also lead to long-term performance degradation. To increase the overall voltage, solar cells are usually connected in series. If only some of the series-connected solar cells are in the shade, their behavior is comparable to a resistor, which heats up significantly. This phenomenon is called hotspots, which can permanently reduce performance or even break down the solar cell (Solaranlage Ratgeber, 2022a).

However, the lifetime and, therefore, the sustainable potential of a PV system does not only depend on the electricity-producing solar cell but on all solar modules mentioned in chapter 2.1.2. In this context, the module with the shortest lifetime is the inverter, which is usually between 10 to 15 years. With an average solar cell lifetime of 20 to 30 years, the inverter must therefore be replaced two to three times. This results in additional costs, which are particularly significant for large systems with several inverters. When considering the economic potential of a system, this aspect should be taken into account. An essential factor in achieving the longest possible life without significant loss of performance is the maintenance of all modules. Special attention should be paid to the correct configuration of the inverter to avoid performance losses.

Likewise, any wear and tear on the solar cells should be checked regularly (Abou Jieb and Hossain, 2022).

### Energy demand

As already mentioned within the presentation of the surplus feed model, the own consumption of the produced solar power is becoming increasingly attractive for future system owners. In this sense, it is necessary to consider the amount of energy to be generated to satisfy current demand before purchasing a PV system (Lützeler, 2019). A PV system with an energy yield that is too low could otherwise lead to the fact that much electricity must continue to be purchased from the public grid. This, in turn, weakens the economic potential of the system since, in addition to the investment costs for the PV system, high electricity costs must continue to be paid by the operator.

In this respect, it is also important to consider the availability of sufficient space. Since both private households and companies primarily use their roof area for the installation, its size and suitability must first be determined accordingly. As a rule, future system operators can refer to the building's construction plans. However, care should be taken to ensure that the plans are up to date, as otherwise, there may be undesirable complications in the implementation process. In addition, there may be deviations in the calculated maximum output if outdated data is used as the basis for the calculation (Lützeler, 2019).

### Amortization

The last and most relevant aspect for most future system operators is amortization, i.e., the point in time at which the system operator achieves economic profits with the PV system. This depends on the following factors (Solaranlage Ratgeber, 2022b):

- Investment costs
- Running costs
- Financing costs
- Feed-in revenue or market premium
- Electricity cost savings
- PV system output
- Electricity consumption
- Own consumption share

For a long time, the payback period for new PV systems was around 11 to 13 years (Klimaschutz- und Energieagentur Niedersachsen, n.d.). However, the payback period has increased significantly due to higher system prices and significantly lower feed-in tariffs. In 2021, the electricity production costs of a 10kW system averaged 11.05 cents per kWh, while the government-backed feed-in tariff was only 7.03 cents. Per kWh, the plant operator thus made a loss of 4.02 cents. Due to this fact, the payback period for a 10 kWh plant was already 18.3 years in 2021. In addition, due to the EEG degression mechanism (see chapter 2.3.2), the state-secured feed-in tariffs will continue to decrease in the coming years, further increasing the payback period. It is assumed that the payback period in 2023 will already be 21.6 years if there is no reform of the EEG degression mechanism. It is further argued that currently, the only way to shorten the payback period and, thus, to maintain the economic potential of an own plant is to maximize self-consumption. Furthermore, the cost of PV modules decreases as the number of modules increases so that a shorter payback period can be assumed for larger systems (Ammon and Bruns, 2021).

### 2.2.1 Selection criteria for PV-Modules

As already explained in chapter 2.1, the PV module is the basic component of every PV system. To achieve the highest possible benefit with the PV system, selecting the suitable PV module is highly significant. The most important criteria that must be considered when selecting the PV module are briefly described below.

**Efficiency**

The efficiency indicates how efficiently a PV module converts solar energy into electricity. The higher this value, the higher the electricity generation. The value given in the module datasheets always corresponds to the efficiency under laboratory conditions. Here, the so-called Standard Test Conditions (STC) are applied, assuming a temperature of 25°C and global radiation of 1000 W/m². Additionally, an air mass (AM) of 1.5 is assumed. In reality, this value is reached at a zenith angle[2] of 48.2° (Forchhammer, 2021). Looking at the prevailing climate in Germany, it is clear that these are not consistent with the STC. Germany lies almost entirely in the temperate climate zone. The annual average temperature is 8 °C, while the highest average temperature is 17 to 18 °C in July and the lowest is -0,5 °C in January (wetter-atlas, 2022). Based on the average temperatures mentioned, it can be assumed that the test conditions artificially produced in the laboratory are rarely reached in Germany. As described earlier in this chapter, the location of the PV system is crucial. Thus, the STCs are reached more frequently at some locations in Germany than at others. However, there are also locations where the STC are never reached (Energie-experten, 2022).

In addition to climatic conditions, shading from roof structures, trees, buildings, or similar can lead to significant performance losses of the PV modules and thus influence their efficiency. If only one module of a string is in the shade, the performance of all modules of this string is reduced equally. The associated voltage drop can also cause lasting damage to the modules and thus lead to further power losses (Solaranlage Ratgeber, 2021).

The efficiency of a PV module is, therefore, an essential factor in determining the performance potential, but the factors mentioned above must also be considered.

**Size and performance**

Another selection criterion significantly influencing the achievable energy potential is PV modules' size and associated power. If the installation area is a small and angled roof, the space can be better utilized by choosing smaller modules, thus increasing overall performance. On larger roofs, on the other hand, the use of larger modules could be beneficial. Thereby, choosing a large module with higher power output may result in not fully utilizing the roof space potential and, accordingly, achieving lower power output despite the higher power output of the individual module than if a smaller module with slightly worse performance is used. It should be noted, however, that modules larger than 2m² are not permitted for both roof-mounted and ground-mounted systems and, therefore, may not be installed (Forchhammer, 2021).

[2] When the sun is at its zenith and its rays fall perpendicularly on the earth's surface, the AM is 1 NREL (n.d.).

### Price-performance ratio

The ratio of module costs and achievable power also has an important role to consider when evaluating the economic potential of a PV system. Here, attention should be paid to how much power the respective PV module achieves per m² and whether the costs justify this (Schmitz, 2010). Furthermore, it should be taken into account that the costs per PV module decrease with increasing total quantity. If the roof areas are relatively large, as is the case with commercial enterprises, for example, the costs for the PV modules are significantly lower (Haustec, n.d.).

### Guarantees

About PV module warranties, a distinction is made between the product warranty and the performance warranty. The former refers to product defects, i.e., damage to the PV module. The second refers to the performance to be provided over a certain period of time. Usually, the buyer receives a promise of guaranteed performance of 90 % of the rated power for the first ten years. After fifteen years, the warranty is often 80 % of the actual output (Schmitz, 2010).

### Manufacturer

In connection with the guarantees just described, another purchase criterion is the manufacturer. The manufacturer should have been established on the market for a long time and be in an excellent financial position. Otherwise, there is a possibility that the manufacturer will become insolvent, and the guarantees will be invalidated (Märtel, 2021).

### Stress limits

Depending on the location, environmental influences such as snow and wind can significantly impact PV modules. For example, if the load of the snow is too great, micro-cracks will form in the glass of the solar module, significantly affecting performance. For this reason, care should also be taken here to ensure that the stress limits of a module are appropriate for the respective environmental circumstances (Forchhammer, 2021).

### Certificates

Another essential aspect when choosing a PV module is the certification regarding safety, quality, and durability requirements. In the European area, the following IEC certificates (International Electrotechnical Commission certificates) have become established for this purpose:

- IEC 61215 (Quality Lable)
- IEC 61646 (Test Norm for thin-film modules)
- IEC 61730 (Safety Standard, mandatory for PV modules in Europe)

In particular, the IEC 61730 certificate is of high importance. If the system operator uses a PV module without this certificate and installs it, the entire system must be retroactively dismantled during an inspection. This would mean that the full potential would be lost in every respect.

## 2.3 Legal framework

After the previous chapter already dealt with various factors that need to be considered when planning/acquiring a PV system, the legal framework regarding the possible installation of a PV system will now be examined in more detail.

### 2.3.1 Building permit

The installation of a PV system, like all construction projects in Germany, falls under the so-called building law. Building regulation is a matter for the federal states, i.e., it is not uniform but differs from each federal state. While a building permit is generally required for PV FFA systems, no building permit is required to install a PV system on a roof or facade. However, since building laws in Germany are not uniform, these regulations cannot be considered applicable universally. Many countries have restricted the permit exemption for PV systems in recent years by means of minor amendments and additional articles. In Lower Saxony, the federal state in which osthaus & beckert GmbH is located, only the construction of PV FFA systems was restricted by building law. Roof systems can still be built without special conditions. However, the roof's structural integrity must always be considered. Here it must be ensured that the additional load of the PV modules can be carried by the existing roof structure and that the structural safety is not impaired (Photovoltaik, 2022b).

### 2.3.2 Funding

In Germany, the promotion of renewable energy technologies such as solar power is governed by the EEG, which came into force on April 1, 2000, replacing the previous "Stromversorgungsgesetz" (Electricity Supply Act). Since the 1990s, the Electricity Supply Act has required grid operators to purchase electricity generated by operators of small wind or hydroelectric power plants. At that time, electricity from renewable sources was only remunerated at a low minimum rate, but this rate was not set by the legislature. This situation changed when the EEG came into force. The EEG aims to promote renewable energies in the form of hydropower, wind power, biomass, landfill, wastewater, mine gas, geothermal and solar energy. It aims to reduce dependence on fossil fuels and facilitate technological development. To achieve this goal, the EEG implies the feed-in tariff system, according to which grid operators must pay plant operators for renewable electricity according to fixed feed-in tariffs. The amount of feed-in tariff is guaranteed for 20 years. The result is that plant operators receive more planning security and can operate the respective system economically (Stadermann, 2021).

Since the introduction of the EEG in 2000, numerous adjustments have been made to regulations and subsequent implementation policies. Since this work refers to the renewable energy technology photovoltaics, any changes to other technologies are not considered. After the EEG-Amendment 2004, the EEG-Amendment 2009 represents the second adjustment or change of the EEG. In addition to adjustments regarding the obligation to report new PV systems and some other aspects, there were also changes regarding the feed-in tariffs. This was made in the form of the so-called sliding regression. The basic idea of the sliding regression is to reduce the remuneration per kWh in the following year, should the remuneration costs increase too much due to too high an increase in the number of PV systems. On the other hand, the tariff reduction is slowed down if the target for new installations is not reached. The aim of this measure was, on the one hand, to prevent overpriced system purchases and thus encourage economic activity on the part of system operators. In addition, it was intended to keep the cost of electricity within reasonable limits for all electricity customers since they are co-financing part of the expansion by means of the EEG surcharge (Erneuerbare-energien, 2022).

Three years after the entry into force of the EEG-Amendment 2009, further adjustments were made with the EEG-Amendment 2012. Regarding PV support, further extensive changes were made by the PV amendment 2012, which came into force retroactively to 01.04.2012. The most important changes are presented below (Erneuerbare-energien, 2012):

- Redesign of the remuneration classes and size limitation:
    - Instead of three, there are now four remuneration classes for roof systems (10kW, 40kW, 1000kW, < 1000kW)
    - Several open-space systems are counted as one system if they are erected within 24 months in the same municipality within a radius of 2km.
- One-time feed-in tariff reduction of 15 %, followed by "base degression" of 1 % per month (equivalent to 11.4 % per year).
- Total expansion target for subsidized photovoltaics in Germany is limited to 52 GW. An annual expansion corridor is set at 2.5 - 3.5 GW.
- Degression is controlled depending on expansion. If the expansion corridor is exceeded, the degression increases by between 1.4 % and 2.8 %. If the expansion corridor is not reached, the feed-in tariffs are increased.
- Introduction of the "market integration model and self-consumption bonus", according to which plants between 10 kW and 1000 kW per year will only be remunerated for 90 % of the total amount of electricity generated under the EEG from 2014.

Only two years after the last amendment of the EEG, the next updated edition, the EEG-Amendment 2014, was introduced. In this version, the focus of the amendments was again on the feed-in tariff, in addition to regulations on self-consumption. About self-consumption, it was stipulated that photovoltaic system owners who consume their own electricity must pay a share of 40 % (just under 1.9 cents/kWh) of the EEG levy from 2017. Only plants whose operation was already started before 01.08.2014 or whose maximum output does not exceed 10kW were exempted from this regulation. At the same time, the feed-in tariffs for new plants with 10 to 1000kW were increased by 0.3 cents. For new plants with 500kW installed capacity, the "mandatory direct marketing" was also introduced. This regulation obliges plant owners to sell their surplus solar power directly on the electricity exchange. As compensation for the resulting lower revenues, plant operators have since received a market premium of an additional 0.4 cents/kWh. The last change relates to the weakening of the base degression from 1 % to 0.5 % per month, designed for an annual expansion of 2.4 to 2.6 GW (pv-magazin, 2014).

The penultimate version of the EEG since then is the EEG-Amendment 2017. Concerning PV, only a few adjustments were made. One of the most significant changes is the introduction of the so-called tendering procedure. According to this procedure, the amount of remuneration per kWh of plants with a capacity of more than 750 kW is no longer based on the feed-in tariff set by the state but on the bids submitted during the tendering process. In addition to the introduction of the tendering procedure, the degression was again adjusted. To react more quickly to overruns or underruns of the expansion corridor, the reference period was reduced from 1 year to 6 months. In addition, a slightly accelerated increase in the feed-in tariffs was decided if the expansion target was not achieved for a longer period of time (Erneuerbare-energien, n.d.).

In 2021, the last and thus most current version of the EEG was adopted. After the introduction of the tendering procedure with the 2017 amendment to the EEG, the same underwent the first adjustment with the resolution of the 2021 amendment to the EEG. This amendment provides that ground-mounted systems and rooftop systems below 750 kW will no longer compete in the tendering process. In the course of this, two different segments were introduced. Plants below 750 kW fall under the first segment, while plants with a higher capacity fall under the second segment and continue to compete in the tenders. Further changes relate to plants for self-consumption (NATURSTROM AG, 2020). Another change relates to the market premium model introduced in 2014. Instead of the obligatory direct marketing for plants above 500 kWp defined in the EEG-Amendment 2014, this now applies to plants with an output above 100kWp commissioned after 01.06.2016 (Next Kraftwerke, 2022). In addition, the plant owner must use a so-called smart meter, enabling the direct marketer to remote control the plant. The direct marketer thus can retrieve the feed-in and regulate the feed-in power externally. The rationale for using the smart meter is that weather conditions can cause unpredictable deviations in electricity production, affecting the exchange electricity price. Without remote control, there would be the possibility of a negative exchange price, so that the marketed electricity could generate no revenue. The smart meter, therefore, serves to match the electricity fed into the grid with the actual consumption, thus creating a balance (Next Kraftwerke, n.d.). Finally, Table 1 shows the development of feed-in tariffs for PV systems since the introduction of the 2021 amendment to the EEG.

Shortly after the introduction of the EEG-Amendment 2021, work was already done on its revision. Concerning photovoltaics, the changes are mainly limited to its expansion target, the subsidy, and the EEG levy. With regard to the subsidy, a distinction will most likely be made between the remuneration for full feed-in and surplus feed-in. Accordingly, full-feed-in producers will receive a higher feed-in tariff than plant owners who also use the electricity produced for their own consumption. Furthermore, the degression of the feed-in tariff rates is to be suspended for 2022 and then only occur every six months in 2023. One change that has already been decided is that the EEG levy will be eliminated as of July 1, 2022. However, this change will not be included in the new EEG-Amendment but in a new EEG relief law. Here, the obligatory passing on of the savings to the consumers was also defined so that they benefit from the removal of the EEG surcharge (NATURSTROM AG, 2022).

*Table 1 - Feed-in tariffs since the introduction of the EEG-Novel 2021 by system type and nominal power of the PV system (Frahm, 2022)*

| **Commissioning of the system** | **System type** | **Nominal power of the PV system (kWp)** | **Feed-in tariff (Cent/kWh)** |
|---|---|---|---|
| Jan 21 | Installation on residential buildings, noise barriers, and buildings according to § 48 Abs. 3 EEG | <= 10<br>> 10 to 40<br>> 40 to 750<br><750 | 8,16<br>7,93<br>6,22<br>5,61 |
| Feb 21 | Installation on residential buildings, noise barriers, and buildings according to § 48 Abs. 3 EEG | <= 10<br>> 10 to 40<br>> 40 to 750<br><750 | 8,04<br>7,81<br>6,13<br>5,53 |
| Mar 21 | Installation on residential buildings, noise barriers, and buildings according to § 48 Abs. 3 EEG | <= 10<br>> 10 to 40<br>> 40 to 750<br><750 | 7,92<br>7,70<br>6,04<br>5,44 |
| Apr 21 | Installation on residential buildings, noise barriers, and buildings according to § 48 Abs. 3 EEG | <= 10<br>> 10 to 40<br>> 40 to 750<br><750 | 7,81<br>7,59<br>5,95<br>5,36 |
| May 21 | Installation on residential buildings, noise barriers, and buildings according to § 48 Abs. 3 EEG | <= 10<br>> 10 to 40<br>> 40 to 750<br><750 | 7,69<br>7,47<br>5,86<br>5,28 |
| Jun 21 | Installation on residential buildings, noise barriers, and buildings according to § 48 Abs. 3 EEG | <= 10<br>> 10 to 40<br>> 40 to 750<br><750 | 7,58<br>7,36<br>5,77<br>5,20 |
| Jul 21 | Installation on residential buildings, noise barriers, and buildings according to § 48 Abs. 3 EEG | <= 10<br>> 10 to 40<br>> 40 to 750<br><750 | 7,47<br>7,25<br>5,68<br>5,12 |

| | | | |
|---|---|---|---|
| Aug 21 | Installation on residential buildings, noise barriers, and buildings according to § 48 Abs. 3 EEG | <= 10<br>> 10 to 40<br>> 40 to 750<br><750 | 7,36<br>7,15<br>5,60<br>5,05 |
| Sep 21 | Installation on residential buildings, noise barriers, and buildings according to § 48 Abs. 3 EEG | <= 10<br>> 10 to 40<br>> 40 to 750<br><750 | 7,25<br>7,04<br>5,51<br>4,97 |
| Oct 21 | Installation on residential buildings, noise barriers, and buildings according to § 48 Abs. 3 EEG | <= 10<br>> 10 to 40<br>> 40 to 750<br><750 | 7,14<br>6,94<br>5,43<br>4,89 |
| Nov 21 | Installation on residential buildings, noise barriers, and buildings according to § 48 Abs. 3 EEG | <= 10<br>> 10 to 40<br>> 40 to 750<br><750 | 7,03<br>6,83<br>5,35<br>4,82 |
| Dec 21 | Installation on residential buildings, noise barriers, and buildings according to § 48 Abs. 3 EEG | <= 10<br>> 10 to 40<br>> 40 to 750<br><750 | 6,93<br>6,73<br>5,27<br>4,75 |
| Jan 22 | Installation on residential buildings, noise barriers, and buildings according to § 48 Abs. 3 EEG | <= 10<br>> 10 to 40<br>> 40 to 750<br><750 | 6,83<br>6,63<br>5,19<br>4,67 |
| Feb 22 | Installation on residential buildings, noise barriers, and buildings according to § 48 Abs. 3 EEG | <= 10<br>> 10 to 40<br>> 40 to 750<br><750 | 6,73<br>6,53<br>5,11<br>4,60 |
| Mar 22 | Installation on residential buildings, noise barriers, and buildings according to § 48 Abs. 3 EEG | <= 10<br>> 10 to 40<br>> 40 to 750<br><750 | 6,63<br>6,44<br>5,03<br>4,53 |

## 2.4 Corporate sustainability

The topic of sustainability is one of the central issues of the 21st century, given the advancing climate change and the shortage of important natural resources. Although everyone is now familiar with the term and can relate to it, the actual meaning of sustainability is often misunderstood. Because of this, the origin of the concept of sustainability and its definition and basic idea will be discussed in more detail below. Building on this, the extent to which sustainable development is promoted using photovoltaics will be discussed.

### 2.4.1 Origin and definition

The term "sustainable development" was introduced in 1987 by the United Nations' World Commission on Environment and Development (Heinberg and Lerch, 2010) and defined as follows:

“Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development, 1987).

Another seven years later, in 1994, increasing pressure on companies for their highly polluting practices led to the introduction of the so-called Triple Bottom Line Model of Sustainability. In addition to the economic aspect (1st dimension), the model also addresses the environmental aspect (2nd dimension) and the social aspect (3rd dimension). The basic idea behind the Triple Bottom Line Model is that the achievement of sustainable development can only be ensured if environmental, economic, and social goals are implemented simultaneously and on an equal footing. In this sense, it can be ensured that the economic, ecological, and social performance of society will endure today and in the future (Pufé, 2012).

### 2.4.2 Sustainable development using photovoltaic

Concerning corporate sustainability, the question arises as to what extent photovoltaics meets the requirements of sustainable development and whether it can contribute to ongoing sustainability in the company. The topic of amortization in the economic sense was already addressed in a previous section. It has already been shown that, from an economic point of view, the model of surplus feed-in, in particular, can bring great advantages in the form of cost savings for a company. Therefore, the entrepreneurial use of a PV system takes the economic dimension.

Regarding the ecological dimension, the energy payback time of a PV system must be considered. The energy payback time is the time it takes for the system to produce the amount of energy used for production, operation, and disposal. When using a monocrystalline module, between 43 and 64 grams of CO2 equivalent are produced per kWh (Umweltbundesamt, 2021c). For comparison, the use of fossil fuels emits approx. 485 grams of CO2 equivalent per kWh. On this basis, an average PV system lifetime of 30 years results in an energy payback time of one to two years in Germany (Umweltbundesamt, 2022).

Moreover, as described in Chapter 2.1, solar cells are made from silicon, the most abundant raw material on earth. Accordingly, overuse of raw materials seems very unlikely. The requirements of the ecological dimension of the Triple Bottom Line Model are therefore also fulfilled by the entrepreneurial use of photovoltaics.

Finally, the social dimension must be considered. Global society increasingly needs energy due to increasing material needs and individual mobility (Hillemeier, 2006). Particularly at present, when energy prices have risen significantly due to the war in Ukraine and the associated energy crisis in Europe (Schiffler, 2022), electricity generated by PV systems can make a significant social contribution. In this way, PV systems can increase the security of supply within the power grids and reduce the vulnerability of a country like Germany due to its dependence on energy imports (Dürrschmidt *et al.*, 2011). As described above, a high proportion of CO2 is also saved through PV systems. This saving not only has a positive effect on the environment but also on the health of the people living in it. In addition, unlike fossil fuel extraction systems, no additional space is required for the installation of rooftop PV systems, so natural areas are preserved, and people benefit from the preservation of ecosystem services (Berthold *et al.*, 2015). In this sense, photovoltaics also contributes to social sustainability.

# 3 Methodology

According to Yin (2014), research observations are considered reliable if they can be reproduced. In this sense, it must be ensured that other researchers investigating the same phenomenon using the same methods come to the same conclusions. To ensure that this is the case, this chapter will discuss the methodological approach, which consists of naming as well as describing the methods and sources used for data collection. In addition, the characteristics of the research context and the research approach are defined and described. Finally, the data analysis procedure will be explained.

## 3.1 Research approach

This study aims to identify and evaluate the potentials and barriers of a PV system in corporate use, taking osthaus & beckert GmbH as an example. It has been established that the number of company-owned PV systems has decreased significantly in the last year (Bundesverband Solarwirtschaft e.V., 2021). To identify and evaluate any potentials and barriers, it is necessary to gain a contextual understanding that enables the recording and investigation of any processes and interrelationships. To this end, a single case study was selected as the research approach. The choice of a case study is based on the theoretical basis, according to Yin (2014), after case studies are particularly suitable to explain a current issue. Furthermore, it is argued that focusing on a specific case while considering the context enables the understanding of complex phenomena. For example, the decision-making behavior of a company like osthaus & beckert GmbH can be analyzed under given conditions. Within the case study, a qualitative research approach was chosen. Qualitative research explores "a contextual understanding of phenomena, explains behavior and beliefs, identifies processes, and understands the context of people's experiences" (Hennink *et al.*, 2020). Unlike quantitative research, qualitative research is limited to a smaller group of participants. In particular, document review, expert interviews, and discussions are used as data collection methods here.

### 3.1.1 Case description

The osthaus & beckert was founded by Christian Osthaus and Andreas Beckert in 1994 and is located in the Osterholz-Scharmbeck region of Lower Saxony. The company is an industrial enterprise specializing in the processing of metals(osthaus & beckert GmbH, 2022b). The company's services cover a broad spectrum from engineering and design to think tanks and metrology for individual parts or prototypes to machine-optimized series production. The customers for this come from industry, trade, ship and yacht building, automotive, aerospace, and other sectors. In order to meet the unique customer requirements, the company has two large production halls and a constantly optimized machine park. This consists of equipment for laser cutting and welding, waterjet cutting, sawing, and press brakes, as well as swivel bending machines, a 4-roll CNC round bending machine, and turning and milling machines (osthaus & beckert GmbH, 2022a). According to the statements of the management, the operation of these machines implies a very high power consumption with simultaneously increasing electricity costs. By installing a PV system on the roof of one of the two production halls, the company hopes to cover its electricity requirements as far as possible by producing its own electricity. In this way, the company would act more sustainably, as it would reduce its own electricity costs on the one hand and make a contribution to the fight against climate change on the other.

### 3.1.2 Units of analysis

The research's unit of analysis is defined by the spatial boundaries, theoretical scope, and timeframe. The theoretical framework has already been discussed in chapter 2 in terms of a comprehensive literature review. In this way, it was already possible to determine which aspects need to be considered when planning a company-owned PV system. The spatial boundary is, on the one hand, the region of Osterholz-Scharmbeck in the federal state of Lower Saxony (Germany) (Figure 8), as osthaus & beckert GmbH has its company headquarters here. Furthermore, this spatial boundary was chosen due to the weather data required for the analysis, as these differ from region to region and only in this way is a representative result possible. Additionally, the roof area of the company's production hall forms another spatial boundary since this is the space where the PV-System should be installed. About the time frame, the investigation period extends over six months, from 01/01/2022 to 31/06/2022.

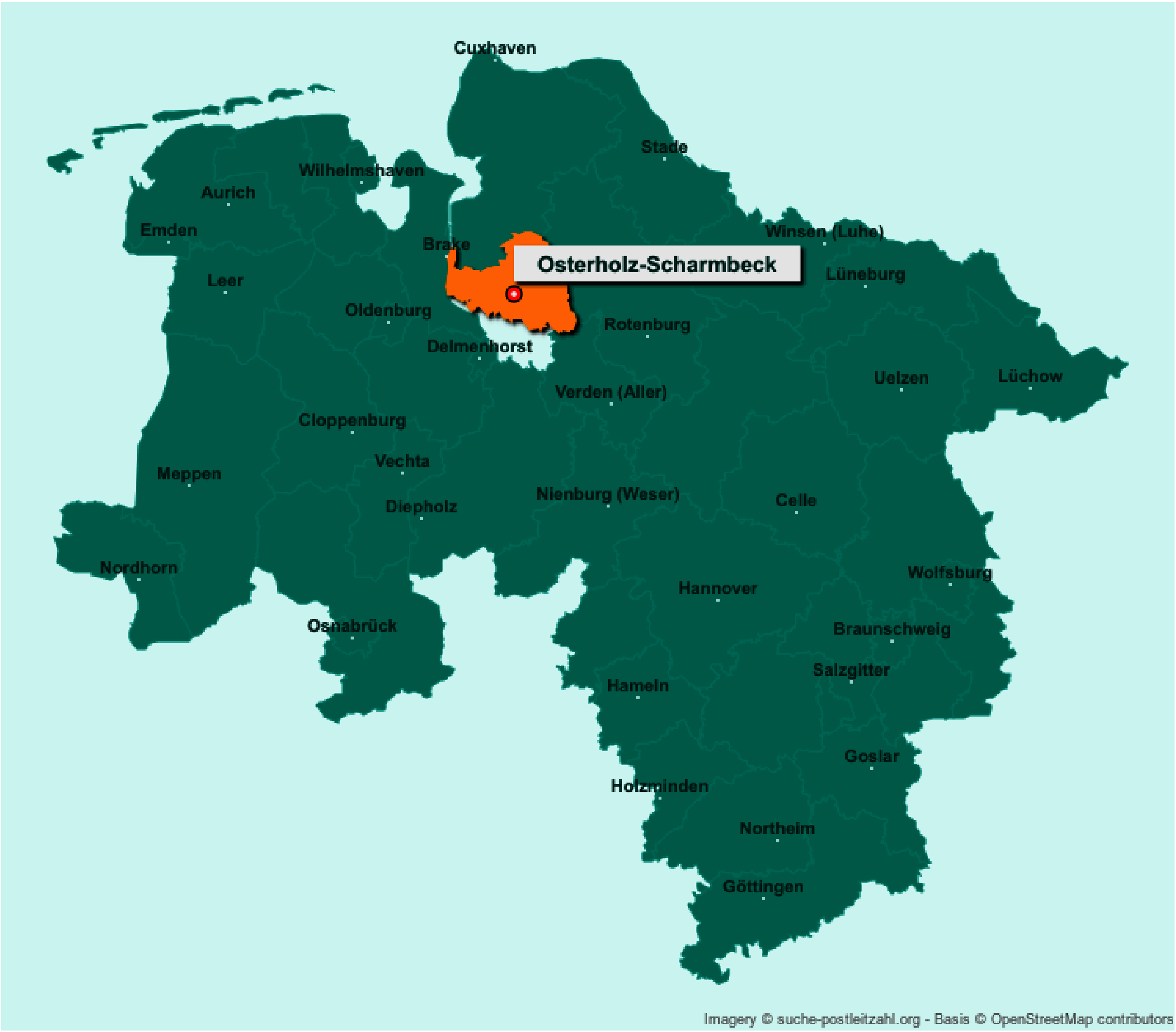



*Figure 8 - Osterholz-Scharmbeck in Lower Saxony, Germany (Postleitzahl, 2022)*

## 3.2 Data collection and storage

Yin (2014) argues that in addition to reliability, validity, i.e., the connection between the research results and the reality of research must be ensured. Moreover, meaningful results can only be obtained if as much information as possible is collected from different sources. For this purpose, several expert interviews are conducted first in this research. The aim was to gather expert opinions on potentials and barriers regarding the entrepreneurial use of photovoltaic systems. Furthermore, relevant data for the photovoltaic planning, as well as recommendations for the components of the PV systems to be used for the subsequent simulation, will be collected, considering the selected case. A document analysis supplements the collected data. This includes the analysis of osthaus & beckert GmbH's internal documents and the datasheets of the PV system components. The data collection is completed by the already mentioned simulation of several PV plants. For this purpose, the planning and simulation software PVSOL Premium 2022 R5 is used. Within the simulation, among other things, the data are used, which were already collected by the expert interviews and the document analysis. In addition, real data such as site-specific weather data are used. This step additionally underpins the link between research results and reality. In the following, the above-mentioned data collection methods and the procedure are specifically explained.

### 3.2.1 Expert Interview

The first step in data collection consisted of identifying data in the categories of potentials/barriers, building, energy, and company requirements (see Table 3). Since the last three categories mentioned are data that could only be answered by osthaus & beckert GmbH, an expert interview was selected as the data collection method. The managing directors Christian Osthaus and Andreas Becker were selected as interview partners, as they are most familiar with the company and the data required. In order to conduct the interviews, a decision had to be made in advance on the type of interview to be conducted. After some research, the choice was made for a semi-structured interview. This interview form was chosen because many questions cannot be answered with simple yes or no or predefined answer options. Instead, it requires the opportunity to receive an open-ended response from the interviewees. Furthermore, there is the possibility of asking unscheduled questions regarding the answers received. In this way, additional information can be gathered that would not be covered by the pre-defined questions. This allows the researcher to gain a deeper insight into the object of study. In preparation for the interview, an interview guide was created (Annex A) to guide the researcher during the interview. To ensure a smooth process, the interview guide was then already sent to the interview partners. The online platform "Microsoft Teams" and an office room in the company were available as locations for the interview. For time reasons, the online platform "Microsoft Teams" was selected. Before the interview began, the documentation method had to be clarified. Both Mr. Osthaus and Mr. Beckert gave their verbal consent to the researcher to record the entire audio of the interview using the software "Audacity" and to utilize it for the subsequent analysis.

Further semi-structured expert interviews were conducted with the "enerix Franchise GmbH & Co KG" as well as the "Memodo GmbH", which primarily served to collect data in the categories "Funding", "PV System", and "Potentials/Barriers". Again, an interview guide was prepared in advance (Annex A), which the researcher followed during the interview. Contact was made by calling the free service hotline.

After the researcher briefly described his concerns to the respective employee, they agreed to the further processing of the data collected during the telephone call within the research work.

### 3.2.2 Document analysis

The second data collection method of this study represents document analysis, which is particularly suitable for the inventory as well as the collection of information for further data collection (t2informatik GmbH, 2018). In the first step, the building plans of the investigated production hall provided by the management of osthaus & beckert GmbH in PDF form were analyzed. In this way, the researcher could determine the exact dimensions of the production hall, i.e., the height, width, and depth of the building and the roof. In addition, the dimensions of the roof structure could also be collected in this way, which could influence the performance potential in the later shadow analysis. This step was mandatory since this data could not be collected within the expert interview. However, the size of the roof area and possible shading by roof superstructures play a decisive role regarding the potential of a PV system. Another document analyzed is the last electricity bill of osthaus & beckert GmbH. By analyzing this document, the researcher determined the total electricity consumption and the current electricity costs of osthaus & beckert GmbH. Especially for the determination of the potential degree of self-sufficiency as well as for the profitability analysis, this data was necessary.

In order to determine which solar modules and battery storage units should be used within the later simulation, the next step was to collect and analyze product datasheets. The selection was based on the recommendations made by the experts during the interviews. The following manufacturers made the recommendations: SOLARWATT, SunPower, LONGI Solar, and Panasonic. According to the experts, the manufacturers SOLARWATT, Sun Power, and Panasonic are absolute premium manufacturers in the photovoltaic industry. All three convince by extremely high performance and resistant PV modules with product warranties between 25 and 40 years. In addition, all manufacturers have already been established on the market for a long time, so a high level of credibility is attributed to them. Unlike SOLARWATT and SunPower, Panasonic does not produce monocrystalline solar cells but focuses exclusively on HIT cells. In terms of price, all three manufacturers are in the upper price segment and are, therefore, somewhat more expensive than products from other manufacturers. According to the experts, the PV modules of the Chinese manufacturer LONGI Solar, the world leader in the production of monocrystalline solar modules, achieve similarly high performance. In addition, the modules are comparatively cheap.

Regarding battery storage, the experts argued in particular for the manufacturer VARTA AG. The company is a German energy storage manufacturer which has been in existence as a technology manufacturer for 130 years. In addition, according to the experts, storage systems have top values in battery efficiency and standby consumption. The warranty period of 10 years and the flexibility of the storage systems were listed as further positive aspects. According to the experts, it is possible to expand the storage capacity at any time and thus cover additional storage requirements uncomplicatedly.

Since the experts' recommendations did not refer to explicit PV modules or battery storage units but only to recommendable manufacturers, the initial selection of the modules and battery storage units to be compared was based exclusively on their efficiency or storage capacity. Three module datasheets were collected and compared for each manufacturer. The final selection was based on the selection criteria for solar modules defined in chapter 2.2.1. Concerning the battery storage, a total of only four datasheets were collected since only the manufacturer VARTA was considered. For the final selection, the respective storage capacity, number of cycles, lifetime, depth of discharge, and efficiency were compared. Finally, the researcher decided on the following PV modules and battery storage:

- PV-Module
  - SunPower SPR-MAX3-400 (monocrystalline)
  - SOLARWATT Panel classic H 2.0 pure, 405Wp (monocrystalline)
  - LONGI Solar LR4-60 HTH 400 M (monocrystalline)
  - Panasonic VBHN330SJ47 (HIT)
- Battery storage system
  - VARTA flex storage E 120kW/375kWh

After the selection of components was completed, internet research was carried out for price determination. The costs for the battery storage were determined by an inquiry at Varta AG.

### 3.2.3 PVSOL Premium

In addition to the expert interviews and the document analysis, the software PVSOL Premium 2022 R5 from Valentin Software GmbH was used for the data collection and the subsequent analysis. This is currently one of the most proven planning and simulation software for photovoltaic systems (Photovoltaik, 2021). The software enables the user to plan all common plant types in 2D and 3D. For this purpose, PVSOL Premium R5 has an extensive product database. This currently includes more than 21,900 PV modules, 2,600 battery systems, 5,500 inverters, as well as various electric vehicles, power optimizers, and much more. The technical data is also updated directly from the product manufacturers at regular intervals, ensuring that the data is always up to date. Another database integrated into the software is the climate database, which is used to determine the annual global radiation in the region to be analyzed (Valentin Software GmbH, 2022a). The data stored there originate from 8,350 weather stations worldwide and are provided on the one hand by the Swiss climate and weather data experts "Meteotest" and on the other hand by the German Weather Service (Valentin Software GmbH, 2020). Also integrated in the software is a database with the current feed-in tariffs (Valentin Software GmbH, 2022a).

The data to be collected was obtained using the simulation function of PVSOL Premium 2022 R5. In order to use this function, several steps had to be performed, and variables had to be entered within the software. In the following, the entire data collection process, including all steps performed in the software, is explained in detail. Additionally, for illustration purposes, Annex D contains some screenshots that were taken during the data analysis.

#### 3.2.3.1 System

To be able to use the software, the first step was to check the system requirements on the software side and to compare them with the system data of the computer used for the research. For this purpose, the software manual and the system info of the research computer were used. After successful verification, the next step was to purchase the software from the website https://valentin-software.com/produkte/pvsol-premium/ and install it on the research computer.

Instead of purchasing a single license, the researcher used the student offer. This allows students to use the full version of PVSOL Premium for 180 days at a moderate price of €71.

#### 3.2.3.2 Scenarios

In chapter 2.2, it was made clear that the potential of a PV system depends, in part, on the choice of components used. For this reason, the researcher decided to develop four scenarios, with each scenario differing in the components used. The components used in the scenarios correspond to the components identified within the document analysis. Regarding the determination of the economic potential, each scenario was additionally simulated with the operator model "Full Feeder" and "Surplus Feeder". Finally, the simulation results were compared. This procedure allows the researcher to highlight and compare the respective scenarios' potentials. An overview of the scenarios used is given in Table 2. Since the software has a function to select the optimal inverter automatically, these were determined for each scenario only during the software usage. For clarity, however, the inverters have already been included in Table 2.

*Table 2 - Scenarios used for the simulation in PVSOL Premium 2022 R5*

| Scenario | System Type | PV-Module | Inverter | Battery storage system |
| --- | --- | --- | --- | --- |
| 1 | Full Feeder | SunPower SPR-MAX3-400 | SUN2000-50KTL-M0 (400Vac) (v1) | VARTA flex storage E 120kW/375kWh |
| | Surplus Feeder | | | / |
| 2 | Full Feeder | SOLARWATT Panel classic H 2.0 pure, 405Wp | Huawei Technologies SUN2000-33KTL-A (v1) | VARTA flex storage E 120kW/375kWh |
| | Surplus Feeder | | Huawei Technologies SUN2000-30KTL-M3（440Vac）(v1) | / |
| 3 | Full Feeder | LONGI Solar LR4-60 HTH 400 M | Huawei Technologies SUN2000-40KTL-M3（ | VARTA flex storage E 120kW/375kWh |

| | | | | |
|---|---|---|---|---|
| | Surplus Feeder | | 440Vac) (v1)<br>Huawei Technologies SUN2000-20KTL-M0 (v2) | / |
| 4 | Full Feeder | Panasonic VBHN330SJ47 | Huawei Technologies SUN2000-215KTL-H0 (v1) | VARTA flex storage E 120kW/375kWh |
| | Surplus Feeder | | Huawei Technologies SUN2000-60KTL-M0 (400Vac) (v2) | / |

#### 3.2.3.3 Project Options

The first step within the software was to define the project options, on which the later calculations regarding the electricity yield, economic efficiency, and ecological footprint were based. Under the item "AC Mains", a mains voltage of 230V, as well as 3-phase (three-phase alternating current), was specified, as this is the general standard in Germany (Handwerkskammer für München und Oberbayern, 2007). Furthermore, a specific $CO_2$ saving through the use of PV energy of 485 g/kWh was defined. This was based on the data from the Federal Environment Agency on the average $CO_2$ emissions in the German electricity mix (Umweltbundesamt, 2022).

Next, the parameters for the simulation, configuration limits, automatic configuration, presentation, and simulation results were defined. Here, the default values provided by the software were retained.

#### 3.2.3.4 Project Data

The next step within the software was to enter the project data used for the title page in the later simulation reports. The following project data were entered:

- Offer Number: 123456
- Project Designer: Alexander Riedel
- Start of Operation: 01.07.2022
- Project Name: PV-Anlage osthaus & beckert GmbH
- Project Description: Planning of a company-owned PV system for osthaus & beckert GmbH
- Adress of Installation: Industriepark Brundorf 14, 28790 Schwanewede

In addition, a satellite image of the production hall from Google Maps was added as a project image.

Then the customer data was entered. The following data was entered here:

- Customer Number: 123456789
- Contact Person: Osthaus, Christian; Beckert, Andreas
- Company: osthaus & beckert GmbH
- Phone: 04795 95590
- E-Mail: andreas.beckert@osthaus-beckert.de; christian.osthaus@osthaus-beckert.de
- Adress: Industriepark Brundorf 14, 28790 Schwanewede

#### 3.2.3.5 System Type, Climate and Grid

After defining the project data, the system type, planning type, and climate data were defined on the software page "System Type, Climate, and Grid". Here, the system type "3D, Grid-connected PV System with Electrical Appliances and Battery System" and "3D, Grid-connected PV System" were selected according to the scenarios defined in Table 2.

To determine the specific climate data of the study area, the researcher used the climate data module MeteoSyn integrated into PVSOL Premium 2022 R5, which has access to the climate database already described. First, Germany was defined as the country where the study area is located. Then, by entering the postal code 27711 Osterholz-Scharmbeck, the climate data specific to the study area could be determined. Finally, the software provided the climate data in the form of the annual global radiation and the annual mean temperature.

#### 3.2.3.6 Consumption

In order to determine in the later simulation to what extent the PV system covers the daily electricity demand of osthaus & beckert, the next step was to define the electricity consumption (software page "Consumption"). For this, the load profile of osthaus & beckert first had to be created within the software. The following steps were carried out for this:

(1) Add consumption
(2) Load profiles / individual appliances
(3) New → Load profile (from measured values)
(4) Definition of properties of the Load Profile
   a. Name: osthaus & beckert GmbH Halle 3
   b. Comment: Load Profile of osthaus & beckert
   c. Time interval: 15 Min
   d. Number of days: 365
   e. Profile start day: 01.01.2021
   f. Number of values: 35040
   g. Units: kWh
   h. Number Format File: ####,##
   i. Table Format File: One value per line
   j. File: Import of the load profile of osthaus & beckert GmbH from the year 2021 provided by Mr. Beckert.
   k. Apply

#### 3.2.3.7 3D-Design

After successfully creating the load profile, the next step was creating a 3D model of the production hall on the "3D Design" software page. To do this, the "New 3D

System" menu was first opened via the "Edit" button. Then, the "Map Section" option was selected. This option allowed the researcher to use a satellite image of the study object provided by the map provider Google. An advantage of this option is that the geospatial data of the study object is taken directly from Google. This enables the exact determination of the solar radiation in the later simulation process. After the selection was confirmed by the researcher, a new planning window opened automatically. Within the "Object View" area, it would have been possible to create a 3D model from the 2D satellite image. However, since there were problems with the correct 3D representation of the roof structure, the researcher instead used the "Import" function to place a 3D model of the object under investigation created in the SketchUp Pro 2022 software. Building floor plans of the production hall served as the basis for this. Subsequently, the imported model was orientated to align with the structure's actual orientation. Another 3D model was created using the 3D Polygon Tool within PVSOL Premium 2022 R5. The 3D model is a 12-meter-high building located east of the object under investigation. Due to the significant height difference, this building casts a shadow on the roof of the study object at sunrise. This circumstance possibly leads to performance losses, which is why considering the building in the simulation was mandatory. According to Mr. Beckert, the remaining surrounding buildings and trees have either the same or a lower height than the object under investigation. Accordingly, the integration of further 3D models was not necessary.

The next step was to place the PV modules on the roof surface of the object under investigation. For this purpose, the researcher first switched to the "Module Coverage" area. In this area, the PV module "SunPower SPR-MAX3-400" from the American manufacturer "Maxeon" was selected first for roof coverage. This solar module belongs to the top class in the field of photovoltaics due to its very high quality and efficiency (Burkhardt, 2022). Subsequently, using the "cover" function, which allows for automatic roof area allocation, PV modules were first allocated to the roof area facing east and subsequently to the roof area facing west. When performing the subsequent string formation, a suitable inverter had to be selected first. Instead of a single inverter, the researcher selected only the manufacturers "SMA, Fronius, and Huawei". Here, the researcher again followed the recommendation of the interviewed experts. The software then automatically determined which inverters were compatible with the system created. The subsequent selection of the optimal inverter and the string formation also took place automatically. After confirming the suggestion, the steps described above were repeated for the modules on the west-facing roof surface. The last step within the 3D design was the wiring of the entire PV system. For this, a cable grommet was first placed on both sides of the roof. Subsequently, the "automatic wiring" function was used, whereby all modules were wired automatically. After closing the planning window, a window automatically opened in which the researcher started the shading analysis. This step was necessary to be able to determine the exact energy yield of the PV system during the later simulation since shade affects the actual electricity generation, as explained in Chapter 2.2.1. Finally, the power degradation of the individual modules was entered.

After the steps described in the further course were carried out within the software and a simulation result could be determined, the PV module and the inverter were replaced according to the scenarios listed in Table 2 and simulated.

### 3.2.3.8 Battery System

To complete the PV system, a battery system had to be selected following the 3D design. Here, the battery system "VARTA flex storage E 120kW/375kWh" from VARTA Storage GmbH was used. In making this choice, the researcher was guided by the findings from the expert interviews as well as the average energy consumption of osthaus & beckert GmbH. As can be seen in Table 2, the battery system was used in all four scenarios and accordingly did not need to be changed.

### 3.2.3.9 Financial Analysis

The last step before simulating the PV system was to define the parameters for calculating the economic efficiency. Calculating the economic efficiency of the PV systems, the software identifies the annual cumulative cash flow within the simulation. The annual cumulative cash flow is a comparison of the annual revenues or savings and the costs incurred. On the cost side are the operating costs, the self-financing share, taxes, loan repayments, and interest. Savings achieved through lower electricity purchases from the public grid (only in the case of the surplus feed-in model), tax refunds, and income generated through feed-ins are deducted from this. In collaboration with Mr. Beckert, the researcher first edited the "Financial Analysis Parameters" in the "Economic Parameters" section. The following is a brief overview of the input variables used:

(1) General Parameters
- a. Assessment Period: 20 Complete Years
- b. Annual Average return on capital employed: 1,00 %
- c. Value Added Sales Tax: All entries are net

(2) Income and expenditure
- a. Tax deductible Outgoing cost of system setup parts and labour:
  - i. Scenario 1: Surplus Feeder = €570,188.00; Full Feeder = €319,981.00
  - ii. Scenario 2: Surplus Feeder = €479,015.00; Full Feeder = €228,808.00
  - iii. Scenario 3: Surplus Feeder = €486,325.00; Full Feeder = €236,118.00
  - iv. Scenario 4: Surplus Feeder = €429,474.00; Full Feeder = €179,267.00
- b. Non-tax deductible Outgoing cost of system setup parts and labour: 0,00 €/kWp
- c. Incoming subsidies: €0.00
- d. Outgoing annual Operating Costs: €1,400.00
- e. Annual Consumption Costs: €0.00 per year
- f. Outgoing other annual costs: €0.00 per year
- g. Incoming other annual income/savings: €0.00 per year

(3) Financing
- a. Number on Loans: 1 Loan
- b. Loan Capital:
  - i. Scenario 1: Surplus Feeder = €500,000.00; Full Feeder = €250,000.00
  - ii. Scenario 2: Surplus Feeder = €400,000.00; Full Feeder = €150,000.00

iii. Scenario 3: Surplus Feeder = €400,000.00; Full Feeder = €150,000.00
iv. Scenario 4: Surplus Feeder = €300,000.00; Full Feeder = €100,000.00

c. Payment Instalment as % of Loan Capital: 100 %
d. Term: 10 Years
e. Repayment Free Initial Period: 0 Years
f. Loan Capital [ % of Investment]: Corresponds to the respective ratio of investment costs and loan amount
g. Instalment Loan
h. Loan Interest: 3,50 %
i. Repayment Period: quarterly

(4) Tax

a. Allow for Tax
b. Marginal Tax Rate for Income/Corporation Tax [ %]: 43,00
c. Depreciation Period [Years]: 20
d. Type of Depreciation: Linear

To specify the "Price of Electricity sold to Third Party", the next step was to determine the possible market premium. The simple use of the current feed-in tariff was not possible since the plant exceeds a maximum capacity of 100kWp. This has already been established in the occupation of the roof areas. As explained in chapter 2.3.2, direct marketing of surplus electricity is mandatory in this case. To determine the market premium, the Internet portal "Virtual Power Plant " was used. After the pre-determined value was entered, the last step was to define the "From-grid Tariff". For this, the researcher created the current electricity tariff of osthaus & beckert GmbH based on the last electricity bill and implemented this in the software.

#### 3.2.3.10 Results

After all the data had been entered into the software, the last step was to simulate the PV system. After the simulation was completed, the project presentations were exported, analyzed, and compared according to the categories listed in Table 3.

### 3.2.4 Overview of data collection

*Table 3 - Overview of the collected data*

| **Data collecting method** | **Category** | **Data** | **Input variables** |
|---|---|---|---|
| Expert interview osthaus & beckert GmbH | Building | - Roof area<br>- Building orientation<br>- Inclination roof area<br>- Statics<br>- Roof type<br>- Roof constructions | / |
| | Energy | - Energy usage times | / |

| | | | |
|---|---|---|---|
| | Company requirements | - PV operator model<br>- Share of own consumption<br>- PV module/inverter/electricity storage Preferences | / |
| | Potentials /Barriers | - Perceptions of potentials and barriers of an own PV-System | / |
| Expert interview enerix Franchise GmbH & Co KG / Memodo GmbH | PV-System | - Suitable PV Modules/PV Module Manufacturer<br>- Suitable Inverter/Manufacturer Inverter<br>- PV-module/inverter/battery storage selection criteria | / |
| | Funding | - Financing options | / |
| | Potentials /Barriers | - Potentials of a company-owned PV-System<br>- Barriers to the acquisition/use of a company-owned PV system. | / |
| Document analysis | Building | - Building construction plans<br>o Exact dimensioning of the object under examination | / |
| | Energy | - Electricity consumption (2021)<br>- Electricity costs | |
| | PV-Modules | - Type of module<br>- Performance<br>- Warranties<br>- Costs | Manufacturers recommended by the interviewed experts. |
| | Battery storage | - Technical data of battery storage<br>- Costs of battery storage | Manufacturers recommended by the interviewed experts. |

| | | | |
|---|---|---|---|
| PVSOL Premium 2022 R5 | Energy | - Production Forecast<br>o PV Generator Output<br>o Performance Ratio<br>o Yield reduction due to shading<br>o PV Generator Energy (AC grid)<br>▪ Direct own use<br>▪ Battery charge<br>▪ Grid feed-in<br>o Own power consumption<br>o Level of self-sufficiency | - Type of system<br>- Climate Data<br>- AC Mains (Voltage, Number of phases, cos Φ)<br>- 3D Model production hall 3 osthaus & beckert GmbH<br>- PV Module<br>- Inverter<br>- Battery system<br>- Cable Plan |

| | | | |
|---|---|---|---|
| | Economic | - Total investment costs<br>- Annual Cashflow<br>- Amortization period<br>- Return on equity | - Feed-in concept<br>- Price of electricity sold to third party<br>- Feed-in tariff<br>- From-grid tariff<br>- Assessment Period<br>- Annual Average return on capital employed<br>- Tax deductible outgoing cost of system setup parts and labour<br>- Outgoing annual operating costs<br>- Loans<br>- Tax |
| | Ecology | - $CO_2$ Emissions avoided | - Specific $CO_2$ saving through the use of PV energy |

## 3.3 Data analysis

The analysis of the collected data took place in three steps. First, the interviews were transcribed and translated into English since all interviews were conducted in German. To ensure a better analysis, the researcher also cleaned up the transcription in the sense that irrelevant sections were removed. For example, the greeting, as well as the preliminary discussion of conducting the interview, were considered irrelevant because this information did not add value to the research.

The next step consisted in coding the data. In qualitative data analysis, coding of data is a widely used technique (Gagnon, 2010). It involves assigning a code to a selected portion of the data, such as a part of an interview transcript, which serves as labels for questions, themes, or concepts in the data (Hennink *et al.*, 2020). They summarize sections of text in a few words and assist in describing, explaining, systematizing, and organizing data.

In this research, MAXQDA 2022 software was used to code the data from the interviews. The software is a computer-assisted data and text analysis software by VERBI, which was explicitly developed for qualitative research (MAXQDA, 2022). Prior to processing the interviews, the researcher developed deductive codes based on the data to be analyzed. During the coding of the interviews using MAXQDA 2022 software, additional data-driven inductive codes were developed based on the theory already researched in Chapter 2.

After the interview data were analyzed, the final step was to analyze the simulation reports. An Excel spreadsheet was created in which all scenarios and the categories to be analyzed were first entered. Tables 2 and 3 provide the basis for this. Then, the corresponding data from the simulation reports were filtered and entered into the excel spreadsheet. This step allowed the researcher to get an overview of the simulation results and compare them for further discussion.

# 4 Results

In this chapter, the results obtained from the analysis of the interviews and documents are presented. In doing so, the researcher is guided by the categories defined in Table 3. This is followed by the presentation of the simulation results for each scenario presented in Table 2.

## 4.1 Company requirements

In order to ensure the planning and simulation of a PV system tailored to the needs of osthaus & beckert GmbH, the company-specific requirements first had to be determined. Concerning the operator model, Mr. Osthaus and Mr. Beckert had the same opinion that the surplus feed-in model with as much self-consumption as possible should be aimed at. As a reason for this decision, the managing directors gave the low feed-in tariffs, which would reduce the economic added value of the system. In addition, a battery storage system is to be used to further increase self-consumption. However, the two managing directors assume that the storage system will only be needed on weekends, as energy consumption is very high on weekdays. In order to further increase consumption of own supply without reliance on energy providers for shortfall, osthaus & beckert GmbH is also pursuing the goal of using the stored energy to generate hydrogen. This can then be used for cutting machines. This would not only avoid possible feed-ins but, at the same time, save acquisition costs for the hydrogen.

Regarding the components to be used for the PV system, osthaus & beckert GmbH currently has no preferences. To his knowledge, Mr. Osthaus only remarked that the inverters from Huawei currently offer the best price-performance ratio. In addition, Unknown brands have not been considered since more established makes provide warranties during the product's service life.

The company has not set itself a specific budget limit. However, it is crucial to ensure that the ratio between investment costs and savings is optimized. Accordingly, the payback period is a decisive factor in the investment decision.

### Energy consumption and cost

In 2021, osthaus & beckert GmbH had an annual electricity consumption of 777,318 kWh. The monthly electricity consumption ranged between 53,000 kWh and 64,000 kWh from January to May. In June, the highest consumption was recorded, with almost 77,000 kWh. In the following months up to November, consumption always remained above 64,000 kWh, dropping to just under 60,000 kWh in December. Mr. Osthaus and Mr. Beckert cited the constantly changing order situation as the reason for the fluctuations in consumption. In addition, due to the Covid-19 pandemic, the number of orders had dropped sharply in the previous year and only slowly increased in 2021.

Figure 13 (Annex D) shows the load profile of osthaus & beckert GmbH, based on which it was analyzed that the company has a consumption of between 104,000 W and 260,000 W between 6 am and 11 pm. However, the highest consumption was recorded between 6 am and 3 pm. Mr. Beckert and Mr. Osthaus confirmed this result. According to their statements, from 3 pm onwards, almost exclusively laser work takes place, which causes the energy demand to drop. From 11 pm on, the consumption decreases further and ranges between 13,000 and 91,000 W. The management mentioned that electricity is still needed at night because the machines are never completely switched off and thus consume a certain amount of electricity even without a specific use.

Concerning electricity costs, it could be determined that osthaus & beckert GmbH pays 0.16236 €/kWh. According to Statista (2022), the average electricity costs of a German industrial company in April 2021 were 0.1694 €/kWh. This puts osthaus & beckert GmbH just below the average price. So far, the elimination of the EEG levy from 01.07.2022 has not been included in the electricity costs. From the last electricity cost statement of osthaus & beckert GmbH, it could be seen that the cost of the EEG levy is 0.03723 €/kWh. Less the EEG levy, the costs per kWh fall accordingly to 0.12513 €/kWh.

### Building

The roof of production hall 3 consists of a gable construction oriented east-west, with roof surfaces inclined at 7°. The roof is 75.02 m long and 28.75 m wide, providing a total area of 2156.825 m². Additionally, in the center of the roof is a roof structure in the form of a light band. The light band has a length of 60m, is 2.717 m wide, and 0.649 m high. Since an installation on the light band is not possible, its area had to be deducted from the total area. The result is a total area of 1993.805 m² for the installation of the PV system.

Regarding the structural suitability of the roof, Mr. Beckert could only state that the roof was already designed in such a way that a subsequent installation of a PV system would be possible.

## 4.2 Funding

Concerning the opportunities for funding photovoltaic systems, the experts interviewed mentioned the state feed-in tariff. At the same time, both the expert from enerix Franchise GmbH & Co KG and the expert from Memodo GmbH made it clear that the feed-in tariffs are currently too low to represent a significant benefit for a company. Another funding option is offered by the Kreditanstalt für Wiederaufbau (KfW) in the form of the "zinsgünstigen Kredit Erneuerbare Energien – Standard (270)". Within the framework of this subsidy program, private individuals, companies, and public institutions that meet the necessary conditions receive loans starting at an effective annual interest rate of 2.56 %. The amount of the actual effective annual interest rate depends on the term, the repayment-free years, and the fixed interest rate. Additionally, the applicant's creditworthiness and collateralization are checked by the applicant's bank (KfW, 2022a). Regarding creditworthiness, the applicant's bank assesses the risk of the 1-year probability of default and classifies the potential credit applicant into classes from one to seven. Class One, with a probability of 0.1 %, represents the class with the lowest default risk, while Class Seven, with >5.5 % to <=10 %, indicates the highest default risk. For collateral purposes, the loan applicant is classified into classes one through three. Class One represents value collateralization of >= 70 % and is the highest class. Class Three represents the worst collateral class with recoverable collateral of <= 40 %. Based on the assessment by the house bank, the loan applicant is classified into groups from A to I, whereby credit applicants in group A receive the lowest effective interest rate (KfW, 2022b).

According to the experts, making statements about other funding options is almost impossible. This is because subsidies are always limited in monetary terms. If the federal government, the states, or individual municipalities make grants available for photovoltaic systems, anyone who meets the eligibility requirements can apply for this grant. Once all available funds have been allocated, further applications are excluded. Therefore, it is worthwhile to inform oneself about and apply for possible subsidy programs at an early stage. According to the enerix Franchise GmbH & Co KG expert, prospective customers should not limit their research to the promotion of entire photovoltaic systems. In particular, the promotion of an electricity storage system is offered more frequently.

## 4.3 Potentials

### Economic potentials

Mr. Osthaus and Mr. Beckert see the greatest potential of their own PV system with regard to electricity costs. Both managing directors stated that they expect a significant reduction in electricity costs. By maximizing their self-consumption, the management also hopes to reduce their dependence on the electricity supplier.

The experts interviewed confirm the assumptions of osthaus & beckert GmbH. Both experts emphasize that roofs of commercial and industrial companies have enormous potential for installing PV systems. Even though companies obtain their electricity at a lower price than households, significant reductions in electricity costs can often be realized. In addition, companies can protect themselves from rising electricity prices. The prerequisite, however, is that they consume as much as possible of the electricity they produce themselves. Since companies generally have a more balanced electricity demand than simple households, these are optimal conditions for maximizing their self-consumption. According to the experts, integrating a battery storage system makes sense to increase the economic potential even further. This can prevent excess energy from being fed into the public grid at low prices. In addition, the stored energy can be used as an emergency generator. Thus, it can be avoided that expensive electricity must be purchased from the public grid in the event of a power outage. However, care should be taken here to ensure that the storage unit is matched as closely as possible to the size of the plant and the daily consumption. Otherwise, an oversized storage unit, for example, will result in high acquisition costs exceeding the actual benefit. On the other hand, a storage system that is too small will result in more electricity being fed into the grid than would be necessary. In both cases, the result would be a reduction in the economic potential of the PV system. The experts went on to say that in the course of maximizing self-consumption, it be useful to integrate charging stations for electric cars. This way, even more of the electricity produced can be used for the company's needs. The prerequisite for this is that the company itself or its employees already own electric cars.

The experts see further economic potential in using the PV system for marketing purposes. As people become increasingly aware of the consequences of climate change, a company’s environmental performance is an important decision-making criterion for customers. Thus, there is the possibility that new customers can be acquired more effectively if the company advertises the generation of its own electricity.

### Ecological potentials

According to the experts, when purchasing a PV system, most people think first and foremost of the economic benefit that can be achieved through electricity cost savings. However, the basic idea behind the development of PV technology was to create a climate-friendly energy source. Within the interviews, it was shown that today's PV modules fulfill this claim. The experts emphasized that significant progress has been made in PV system technology in recent years. Resource and energy efficiency in manufacturing, as well as the efficiency of the modules, have improved significantly in recent years. As a result, the energetic amortization of PV systems can be reached more quickly than a few years ago. According to the experts, the emissions caused by the production, operation, and disposal of monocrystalline PV modules currently average 43 to 63 grams of $CO_2$ equivalent/kWh. This results in an average energy payback time, i.e., the time until more energy has been generated than is required for production, use, and disposal, of between one and two years. According to the experts, it is impossible to give an exact, generally applicable figure for the energy payback period since a different electricity generation mix is used to produce the modules, depending on the production site. Additionally, the efficiency of the modules and the solar radiation at the respective operator location also influence the electricity production and, thus also the energy payback time. However, it could be said that high efficiency, as well as a high share of renewable energies in the electricity mix, simultaneously means a faster energetic amortization of the modules. In contrast, an energetic amortization of power generation plants with fossil fuels would not be possible because the energy input is larger than the usable energy.

Since self-consumption should be maximized from an economic point of view, the researcher asked to what extent the use of electricity storage impacts the life cycle assessment of a PV system. Both experts felt that electricity storage technology has also advanced significantly. According to the experts, current electricity storage systems can store and process an average of eighteen times as much energy as was used for production. It can also reduce additional electricity purchases from the public grid and, therefore, emissions from using fossil fuels to generate electricity. Thus, the frequent assumption that electricity storage systems significantly reduce the PV system's eco-balance is incorrect.

## 4.4 Barriers

In addition to the potentials of a company-owned PV system already mentioned, various legal, technical, and socio-economic barriers to such a project were identified during the expert interviews.

### Legal barriers

From a legal point of view, the **low EEG feed-in tariffs** mentioned several times in this study represent the first barrier. According to the experts, future system operators will no longer have an incentive to operate PV plants according to the full feed-in model. The only way to use a PV system in an economically viable way is to maximize self-consumption. To further increase self-consumption, additional cost-intensive battery storage units must be purchased, which extends the payback period of the entire PV system.

The experts see a further obstacle in the **mandatory direct marketing** for systems from 100kWp. To justify this opinion, the experts point to the fact that the yields per kWh are only just above the level of the state feed-in tariff, which means that the economic incentive of direct marketing is hardly present. In addition, the bureaucratic effort involved in direct marketing is significantly higher than in receiving the state feed-in tariffs. This circumstance, combined with a lack of knowledge on the part of future plant operators in direct marketing, often has a deterrent effect. The result is that companies that could contribute to the expansion of photovoltaics in

Germany through their large roof areas refrain from having their own PV system. The following quote from Mr. Osthaus, which he expressed in the context of the question of possible barriers, supports the experts' assumption:

"We as a company see the biggest barrier to having our own photovoltaic system in the regulatory frenzy of government agencies."

Mr. Osthaus went on to say that companies like osthaus & beckert GmbH could make a significant contribution to the much-needed energy transition. Regulations such as direct marketing would make it unnecessarily difficult for companies to enter the photovoltaic market and hinder the achievement of expansion targets.

According to the experts, the **mandatory tendering of PV systems** with a capacity of 750 kW or more represents a further barrier to the entrepreneurial use of a PV system. The requirements associated with the tendering process are significantly higher than those for a fixed tariff, which increases the time required for project implementation. In addition, self-consumption of electricity is not possible. The experts argue that companies may be unknowingly forced to tender their PV system by Paragraph 24 of the EEG, which states that several building-integrated photovoltaic systems are to be considered as one system if they are located "on the same property, the same building, the same business premises or otherwise in the immediate vicinity" (gesetze-im-internet, 2022: p. 33) and are commissioned within twelve consecutive calendar months. In this context, building-integrated systems refer to systems located on the building; rooftop systems are also included (gesetze-im-internet, 2022). For example, an imaginable scenario would be that company A commissions a plant with a capacity of 400 kWp. Company B, located on the same street, has simultaneously planned a plant with an output of 350 kWp. Since company A had commissioned the plant earlier, company B could be obliged to tender its plant due to the immediate vicinity.

In the context of direct marketing and tendering of PV plants, the last legal barrier mentioned was the **reduced remuneration**. Paragraph 48 (5) of the EEG amendment 2021 stated that plants with an installed capacity of more than 300 kW are only remunerated 50 % of the electricity generated (gesetze-im-internet, 2022). To receive the total remuneration, operators can alternatively participate in the previously described tendering procedure. According to the experts, this regulation either leads to operators deliberately undersizing their plants to receive the total remuneration, or the idea of owning a PV plant is completely discarded. The reduced compensation is, therefore, not only a barrier for the companies themselves but also to the government's ambitious goals regarding the energy transition and the associated expansion targets.

### Technical barriers

During the interviews, it was also possible to identify numerous technical barriers that jeopardize the project of a company-owned PV system. These included power losses due to shading, the location, the roof orientation and inclination, and selecting the right components. Because these barriers have already been discussed in the theoretical framework of this study, they will not be discussed again here, but only in chapter 5 in the context of osthaus & beckert GmbH.

One technical barrier mentioned by the experts that has not been discussed before is the **roof statics or the structural suitability of the roof truss** for the installation of a PV system. In the past, industrial halls, in particular, were often planned so that the lowest possible costs were incurred. Accordingly, the hall roofs often have little static reserves to carry the additional load of a PV system. A retrofit of the roof would therefore be necessary in many cases. The resulting additional costs, in turn, limit the economic viability of the PV system and extend its payback period.

**Grid compatibility** represents another possible barrier to the realization of a company-owned PV system. According to the experts, the grid operator must first check whether the local grid capacity is sufficient for the amount of electricity to be fed in. If the grid capacity is insufficient, the system owner is informed of the maximum possible amount of electricity to be fed into the grid, which may not be exceeded. In addition, paragraph 9 in the EEG 2021 stipulates that plant owners with an installed capacity of more than 25 kW are obliged to install a smart metering system and a controllable consumption device (gesetze-im-internet, 2022). Uncontrollable grid overloads are to be ruled out in this way. Hence, there is a risk of power regulation. This means that the network operator reduces the system output via the smart meter so that the network is not overloaded. The result is a loss of revenue for the plant operators.

#### Socio-economic barriers

In addition to the legal and technical barriers, socio-economic barriers were also identified during the interviews. The management of osthaus & beckert GmbH stated that **information deficits** regarding legal and technical basics in photovoltaics represent a decisive barrier. Planning offices could take over the system planning for the company, but it is hardly possible to assess the quality of the offer. The experts from Memodo GmbH and enerix Franchise GmbH & Co KG support this assumption. In addition, the experts argued that many entrepreneurs either have no interest in acquiring the necessary knowledge or lack the time and financial resources for doing so.

Lastly, the experts interviewed cited the lower willingness to take **risks for long-term investments** as a possible barrier. Although the PV system's component costs are much lower than a few years ago, purchasing one's own PV system is still a high-priced investment. Due to the low feed-in tariff, the amortization period of the systems has also increased significantly. Based on this, both the expert from Memodo GmbH and the expert from enerix Franchise GmbH & Co KG could imagine that older people, in particular, would avoid investing in their own photovoltaic system.

## 4.5 Scenarios

In the following, the simulation results of the four designed scenarios are presented. Furthermore, Annex E to L contains the detailed simulation reports for the respective scenarios.

### 4.5.1 PV system

All simulated PV systems consist of an east-facing and a west-facing system. The specific data on the components used can be found in Annex C.

#### Scenario 1

In scenario 1, the two plants comprise 1004 Maxeon SPR-MAX3-400 PV modules, which occupy a total area of 1774.8 m². The modules have an efficiency of 22.6 %, and the performance guarantee of the modules is 25 years. After the warranty period, the manufacturer guarantees a power output of 92 % of the original power. In addition to the PV modules, seven SUN2000-50KTL-M0 inverters from the manufacturer Huawei were installed. The system was completed by a VARTA flex storage E 120kW/375kWh (v3) commercial storage unit from Varta AG.

### Scenario 2

In scenario 2, the SOLARWATT panel classic H 2.0 pure, 405Wp (v1) PV module with an efficiency of 20.8 % and a performance guarantee of 84.8 % after 25 years was used. On the east side, 523 modules, and on the west side, 395 modules were installed. In total, the modules occupy a total area of 1778.00 m². In contrast to Scenario 1, the software determined different optimal inverters for the respective system in Scenario 2. On the one hand, the SUN2000-33-KTL-A (v1) for the west-facing system, and on the other hand, the SUN2000-30-KTL-M3 (440Vac) (v1) for the east-facing system. The system was also completed by a VARTA flex storage E 120kW/375kWh (v3) commercial storage from Varta AG.

### Scenario 3

The two plants simulated in Scenario 3 consist of a total of 1047 Panasonic VBHN330SJ47 (v1) modules, which occupy a total area of 1753.00m² and have a module efficiency of 19.7 % and a performance guarantee of 80 % after 25 years. As was the case in Scenario 2, the software determined two different optimal inverters. For the west-facing system, a total of three SUN2000-40KTL-M3 (440vac) (v1) inverters from Huawei Technologies were used. The modules of the east-facing system were interconnected by nine Huawei Technologies SUN2000-20KTL-M0 (v2) inverters. The system was also completed by a VARTA flex storage E 120kW/375kWh (v3) commercial storage unit from Varta AG.

### Scenario 4

In the last simulated scenario, 866 LONGI Solar LR4-66 HPH 420M (v1) modules with an efficiency of 21 % and a guaranteed output of 84.80 % after 25 years were installed on the two roof surfaces. This results in a PV generator area of 1729.5m². A total of three inverters from the manufacturer Huawei Technologies were used to interconnect the modules. The inverters are the SUN2000-215KTL-HO (v1) and SUN2000-60KTL-M0 (400vac) (v2) models. The former was used once for the east-facing system, while the latter was used twice for the west-facing system. The system was also completed by a VARTA flex storage E 120kW/375kWh (v3) commercial storage unit from Varta AG.

## 4.5.2 Energy

### Scenario 1

The two plants simulated in Scenario 1 achieve a PV generator output of 401.60 kWp. The PV generator energy (AC grid) is 351,129 kWh/year, so a system utilization rate of 88.85 % is achieved. This value includes the site-related global radiation, the module area, and module efficiency. In addition, losses due to shading were included in the calculation. In this case, the simulation showed that the annual yield reduction due to shading is 0.60 %/year. In the operator model of full feed-in, the generated energy is completely fed into the public grid. The situation is different for the surplus feed-in model. Here, based on the load profile data of osthaus & beckert GmbH, the simulation has shown that 237,339 kWh/year of the generated energy is directly consumed. In addition, 56,989 kWh/year are absorbed by the electricity storage system. Only 56,802 kWh/year are fed into the public grid. This results in a self-consumption share of 83.80 %. In relation to the total consumption of osthaus &

beckert GmbH, which is 777,484 kWh/year, including the standby consumption of the inverters, a degree of self-sufficiency of 37.40 % is achieved. The remaining 61.29 %, or 484,211 kWh/year, must still be drawn from the public grid.

Using the weather data selected in the software, it was also possible to determine that the PV systems generate the most energy in the months from April to August. In these months, the share of PV-generated energy in total consumption is significantly higher. On the other hand, the energy yield is meager in the first two months and the last two months of the year, which is why a large part of the energy must be obtained from the public grid (Figure 10). This circumstance applies to all scenarios and is not listed again in the following simulation results.

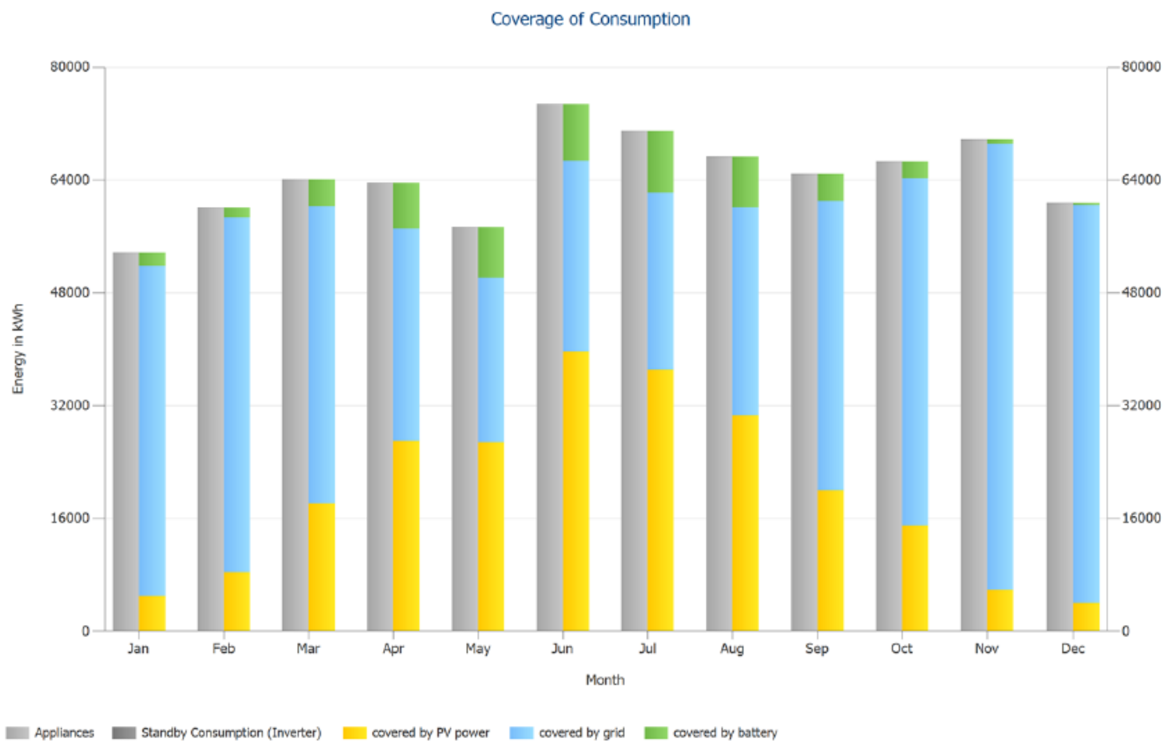



*Figure 9 - Coverage of energy consumption by PV systems by month*

## Scenario 2

A total of 918 monocrystalline PV modules achieve a PV generator output of 371.79 kWp. The annual yield reduction due to shading is 0.50 %/year, and the system utilization rate is 89.39 %. Under these circumstances, the system achieves a PV generator energy (AC grid) of 326,496 kWh/year. The simulation showed that 228,870 kWh/year of the generated energy is consumed directly within the surplus feed-in model. In addition, 51,506 kWh/year is stored in the Varta commercial storage, with battery energy to cover consumption reduced to 47,189 kWh/year due to losses during charging and discharging. Because of the limited absorption capacity of the commercial storage system and an intermittent imbalance between electricity production and consumption, 46,119 kWh/year are fed into the public grid. This results in a self-consumption share of 85.90 % and a degree of self-sufficiency of 35.60 %. To cover the entire electricity demand, including the standby consumption of the inverters (223 kW/year), osthaus & beckert GmbH must draw an additional 496,759 kWh/year from the public grid.

### Scenario 3

The PV system simulated in Scenario 3 achieves a PV generator capacity of 345.51 kWp. The PV generator energy (AC grid) is 294,286 kWh/year, corresponding to a system utilization rate of 86.40 %. The yield reduction due to shading is 0.60 %/year, as in Scenario 1. In the surplus feed-in model, 212,113 kWh/year of the PV generator energy is used for self-consumption. An additional 45,097 kWh/year is stored in the Varta commercial storage, with 4,533 kWh/year lost to charging and discharging operations. 37,075 kWh/year are fed into the public grid. Overall, the self-consumption share is thus 87.40 %. Measured against the total consumption of osthaus & beckert GmbH, which is 773,403 kWh/year, including the standby consumption of the inverters, a degree of self-sufficiency of 32.70 % is achieved. Thus, 520,387 kWh/year still has to be drawn from the public grid to cover the electricity demand.

### Scenario 4

In the fourth scenario, the simulation showed that a PV generator capacity of 363.72 kWp was achieved. The PV generator energy (AC grid) is 318,774 kWh/year, corresponding to a plant utilization rate of 89.08 %. The yield reduction due to shading calculated into the plant utilization rate is 0.40 %/year. Self-consumption within the surplus feed-in model is 225,666 kWh/year, with an additional 49,737 kWh/year stored in Varta commercial storage. From this, losses during charging and discharging are again subtracted, so the actual battery energy to cover consumption is 45,169 kWh/year. This results in a self-consumption share of 86.40 %. The total consumption, including the standby consumption of the inverters, is 773,356 kWh/year. This means that 502,520 kWh/year still has to be drawn from the public grid to cover electricity requirements, which corresponds to a degree of self-sufficiency of 35 %.

## 4.5.3 Economic efficiency

### Scenario 1

The investment costs, including all the components mentioned above in the text, amount to € 570,188.00 for the surplus feed-in model. In the first year, electricity costs of €46,396.39 are saved through self-consumption. Due to the power degradation of the modules, the savings decrease to €41,934.87 by the end of the systems' lifetime. Additional income is generated by feeding the surplus electricity into the grid. These amount to €2,961.37 in the first year and €1,987.30 at the end of the useful life. The cumulative cash flow is initially €-583,406.80. After 15.60 years, the assets have been amortized, i.e., the cumulative cash flow is €0.00. Over the remaining useful life, the cash flow increases to €430,699.03. This results in a return on equity of 8.26 %.

The investment costs and the cumulative cash flow are significantly lower for the full feed-in model. The investment costs are €319,981.00 due to the missing costs for the commercial storage, and the accumulated cash flow amounts to €-329,873.69. Through the complete direct marketing of the electricity, revenues of €18,308.91 are initially collected. This income is reduced by about 33 % by the end of the thirtieth year of use, corresponding to a feed-in revenue of €12,286.81. The result is a payback period of 25.20 years and a cash flow of €38,691.90 at the end of the useful life. The return on equity is 2.17 %.

### Scenario 2

The investment costs for both plants amount to €479,015.00 for the surplus feed-in model. Through self-consumption, annual electricity costs of around €44,457.00 are initially saved. At the end of the useful life, this amount is only €35,016.45. In addition, €2,403.96 is generated in the first year by feeding the surplus electricity into the grid. Over the entire useful life, the income from the feed-in steadily decreases so that after 30 years, only €1,413.41 is collected. The cumulative cash flow amounts to €-485,248.54 in the first year. After 14.60 years, the assets have been amortized, and after 30 years of use, the cumulative cash flow amounts to € 399,764.20. Overall, this results in a return on equity of 9.04 %.

In the full feed-in model, the investment costs are €228,808.00. Through the electricity fed into the grid, revenues of €17,183.62 can be generated at the beginning. At the end of the useful life, the income is only €12,859.71 due to the changing market premium. The accumulated cash flow amounts to €-230,833.60 in the first year. As was already the case in scenario 1, the payback period is significantly higher than in the surplus feed-in model. In this case, it amounts to 19.60 years. After 30 years, the cumulative cash flow reaches a value of €66,582.17. The return on equity is 3.74 %.

**Scenario 3**

In Scenario 3, the investment costs for surplus feed-in amount to €486,325.00. The self-consumption at the beginning saves almost 40,659 € in electricity costs. This amount is reduced to €30,730.91 after 30 years. In addition, €1,944.82 are generated in the first year by the electricity fed into the grid. At the end of the useful life, this amount is only €1,452.37. The cumulative cash flow in the first year is -€494,638.71. After 15.2 years, the assets have been amortized, and after 30 years of useful life, the cumulative cash flow is €387,691.74. Overall, this results in a return on equity of 7.33 %.

In the full feed-in model, the investment costs amount to €236,118.00. The feed-in tariff amounts to €15,367.37 in the first year and decreases to €8,623.23 by the thirtieth year of use. The cumulative cash flow is initially €-238,932.51 and is €35,300.31 at the end of the useful life. This results in a return on equity of 2.40 %. The amortization period corresponds to 23.40 years.

**Scenario 4**

In the fourth simulated scenario, the investment costs within the surplus feed-in model amount to €429,474.00. Through self-consumption, initial electricity costs of € 43,394.56 are saved. Additional revenue of €2,263.29 is generated in the first year from the directly marketed electricity. At the end of the useful life, the total feed-in tariff is only €1,373.19. The accumulated cash flow is €-426,717.03 in the first year and increases to €431,479.07 by the end of the useful life due to the previously mentioned revenues and savings. The result is a return on equity of 9.45 %. The payback period is 13.50 years.

In the full feed-in model, the investment amounts to €179,267.00. The total feed-in tariff in the first year is €16,640.06, decreasing to €10,096.54 by the thirtieth year of use. The accumulated cash flow is €-443,257.17 in the first year and is €96,947.47 at the end of the useful life. This results in a return on equity of 5.64 %. The amortization period is 16.40 years.

### 4.5.4 Ecology

**Scenario 1**

Based on the annual electricity consumption of osthaus & beckert GmbH of 773,318 kWh and the average CO2 emissions of 0.485 kg/kWh, it was determined that the company currently emits 376,999 kg $CO_2$/year through electricity consumption alone. The results of the simulation make it clear that emissions can be reduced by almost half through the use of PV systems. In numbers, the avoided $CO_2$ emissions for the surplus feed-in model total 167,601 kg $CO_2$/year. As Full-Feeder, osthaus & beckert could avoid the emission of 170,217.00 $CO_2$ per year. In addition, the module manufacturer has been awarded several sustainability certificates. Particularly noteworthy is the so-called Cradle to Cradle Bronze certificate awarded by the "Cradle to Cradle Products Innovation Institute" which "assesses products and materials safety to human and environmental health, design for future use cycles, and sustainable manufacturing" (Maxeon Solar Technologies, 2020: p.2).

### Scenario 2

Within the surplus feed-in model, the use of the PV system simulated in Scenario 2 results in an annual $CO_2$ emission saving of 156,653.00 kg. Within the surplus feed-in model, 158,242.00 kg of $CO_2$ emissions is avoided per year. Special certificates confirming the sustainable production of the solar cells or similar were not listed in the module datasheet.

### Scenario 3

The avoided $CO_2$ emissions by using the PV system simulated in Scenario 3 are 140,489 kg/year using the surplus feed-in model. Using the full feed-in model, a value of 142,687.00 kg of avoided $CO_2$ emissions is obtained. The module does not have a special sustainability certificate. However, it is certified according to the "Restriction of Certain Hazardous Substances" guidelines (RoHS guidelines). This type of certification means that the hazardous substances contained in the product that are harmful to the environment and difficult to dispose of do not exceed the prescribed maximum limit (OTT BLOG-TEAM, 2017).

### Scenario 4

Using the LONGI Solar PV module in conjunction with the surplus feed-in model, the emission of 152,207 kg/$CO_2$ per year is avoided. Using the full feed-in model, 154,587.00 kg $CO_2$ per year is saved. Special certificates indicating that the modules are manufactured in a particularly sustainable manner could not be taken from the module datasheet.

# 5 Discussion of the results

This chapter discusses the results presented in the previous chapter. The focus here is on answering the secondary research questions. To this end, the extent to which the simulation results support the findings from the expert interviews is discussed. In addition, the results are discussed in the context of osthaus & beckert GmbH.

## 5.1 Are there barriers regarding the acquisition and commercial use of photovoltaic systems, and if so, what type of barriers are considered most relevant with respect to sustainable use?

Within the interviews, it became clear that various barriers exist concerning the acquisition and commercial use of a PV system. In some cases, these considerably influence the sustainable use of PV systems. For example, in the interview with osthaus & beckert GmbH, it was determined that economic advantage is an essential criterion for acquiring and using a company-owned PV system. The simulation results of the four scenarios have clearly shown that this criterion is only fulfilled to a small extent in the full feed-in model. This is especially evident in the calculated returns on equity, which range from 2.17 % to 5.64 % for all scenarios. For companies whose goal is to feed the produced electricity into the grid to generate revenue, the low EEG remuneration as well as the low market premium for plants with a capacity of more than 100kW, thus, represent a significant barrier to sustainable use. In this context, the mandatory tendering regulated in Paragraph 24 EEG2021 has emerged as another significant barrier regarding the acquisition and sustainable use of a company-owned PV plant. In particular, the fact that the boundary for the immediate vicinity is not precisely defined is seen as highly problematic. Companies could be unknowingly forced to feed the generated energy into the grid due to a lack of information about plants that have already been built or are being planned in the same year. Under these circumstances, sustainable use of the plant would also not be feasible. A brief consultation with the management of osthaus & beckert GmbH revealed that apparently, no new plants were erected in the vicinity of the company in 2022. However, even if this circumstance is true, there is still the possibility that a nearby company is also currently planning a PV plant. Should this plant have a high capacity and be realized earlier than the plant of osthaus & beckert GmbH, this circumstance could force the company to tender for its own plant or lead to the cancellation of the project.

Irrelevant for osthaus & beckert GmbH is the legal barrier in the form of paragraph 48 (5) of the EEG 2021, according to which plants with an output of more than 300 kW will only be remunerated for 50 % of the electricity generated. As can be seen from the simulation results, each of the plants simulated in the scenarios exceeds this limit. However, at least 83.8 % of the generated energy is used for self-consumption, so a maximum of 16.2 % of the electricity must be remunerated. Nevertheless, if osthaus & beckert GmbH consider using the full feed-in model, this barrier would have a significant economic impact. After a short review, it could be determined that PVSOL Premium 2022 R5 did not consider the aspect of reduced remuneration in the simulation. Accordingly, the feed-in tariff shown in the results must be halved again, so the cumulative cash flow is even worse.

In addition to the legal barriers, several technical barriers were identified during the expert interviews. One of these barriers is related to the lack of static suitability of the roof truss for installing a PV system. The interview with osthaus & beckert GmbH revealed that a later installation of a PV system was already taken into account during the construction of the hall. Accordingly, this barrier is not classified as relevant in the case of osthaus & beckert GmbH. The same applies to the technical barrier "shading". From the simulation results, it could be seen that the annual yield reductions due to shading are a maximum of 0.6 %. The location of the company, on the other hand, based on the annual irradiation sum shown in Figure 6 (Chapter 2.2), can be regarded as a possible technical barrier concerning the maximum annual yield. Although no calculations are available, it can be assumed that a company location in the south of Germany would lead to a significant increase in electricity yields due to the higher irradiation values. However, the simulation results show that high annual electricity yields can be achieved despite the suboptimal location. The osthaus & beckert GmbH owes this fact primarily to the combination of an east-west roof orientation and a roof inclination of 7°. As can be seen from figure 9, such a roof orientation and inclination lead to a plant utilization rate of approximately 87 %. Simulation results confirm this estimated value. The utilization rates of plants simulated in Scenarios 1, 3, and 4 are about 2 % above this value. In the case of osthaus & beckert GmbH, the location, roof orientation, and roof inclination do not represent a barrier or exclusion criterion for the sustainable use of a company-owned PV system.

The last technical barriers identified were the selection of the wrong components and the lack of grid compatibility. In the case of the simulated scenarios, the researcher makes the assumption that the first mentioned barrier can be excluded due to the comprehensive research regarding the modules used as well as the automatic selection of the optimal inverter by PVSOL Premium 2022 R5. Regarding network compatibility, no information can be provided at this time.

Information deficits and a low willingness to take risks for long-term investments could be identified as barriers in the socio-economic area. The researcher suggests that barrier information deficits as highly relevant to a sustainable use of a PV system. As already shown in the results, choosing the wrong components can have a significant impact on the sustainable use of a PV system. Without in-house knowledge, offers from external system designers cannot be evaluated, and optimal sustainable use cannot be ensured. In this study, the researcher has found that knowledge acquisition requires a large investment of time. It is not expected that an entrepreneur will spend the same amount of time reviewing external bids to maximize sustainable use. The researcher suggests low willingness to take risks for long-term investments as less relevant in the entrepreneurial context. The experts' argument here related primarily to older people, for whom the benefits of owning a system may be lost in connection with the increased payback periods. As the simulations showed, the cumulative cash flow for the surplus feed-in model ranged from €381,691.74 to €481,015.49 after a thirty-year useful life. Thus, the plants increase the total enterprise value. Accordingly, the entrepreneur can benefit from the plant acquisition in any case. Either he uses the plant by himself over the entire useful life or he sells the company at a higher value. In both cases, the ongoing sustainable use of the plant is ensured.

## 5.2 Does the installation of a PV system make economic sense for osthaus & beckert GmbH?

Based on the simulation results presented in chapter 4 regarding economic efficiency, which are summarized in a truncated form in table 4, the installation of a PV system makes economic sense for osthaus & beckert GmbH, since a positive return on equity could be determined in all scenarios. At the same time, it could be shown that using the surplus feed-in model makes more economic sense, as the returns on equity were higher and the payback period significantly lower. In addition, a positive cumulative cash flow of between €381,691.74 and €481,015.49 was recorded in each scenario at the end of the useful life. This result confirms the statement of Ammon and Bruns (2021) described in chapter 2.2 that the payback period is significantly reduced by self-consumption and the economic potential is kept high. Furthermore, the modules are still functional after the indicated useful life and continue to generate electricity. Due to the aging process of the modules and the associated power degradation, the electricity yield will be lower, but electricity costs can still be saved. The economic added value, which is created by the installation of the system, therefore, does not simply stop at the end of the useful life but is merely reduced according to the remaining module performance.

Not mentioned in chapter 4, but included in the simulation reports, is that the installation costs, as well as other material costs (e.g., for cables), were not considered in the calculation of the investment costs. Also not considered were possible quantity discounts, reducing the costs per PV module. Due to this, it can be assumed that the actual investment costs deviate from the investment costs listed in chapter 4.

*Table 4 - Economic efficiency of each scenario simulated in PVSOL Premium 2022 R5*

| **Scenario** | **Operator model** | **Investment costs** | **Cashflow after 30 years** | **Amortization (years)** | **Return on equity** |
|---|---|---|---|---|---|
| 1 | Surplus Feeder | €570,188.00 | €430,699.03 | 15,60 | 8,26 % |
| | Full Feeder | €319,981.00 | €38,691.90 | 25,20 | 2,17 % |
| 2 | Surplus Feeder | €479,015.00 | €399,764.20 | 14,60 | 9,04 % |
| | Full Feeder | €228,808.00 | €66,582.17 | 19,60 | 3,74 % |
| 3 | Surplus Feeder | €486,325.00 | €318,368.84 | 16,00 | 7,33 % |
| | Full Feeder | €236,118.00 | €35,300.31 | 23,40 | 2,40 % |
| 4 | Surplus Feeder | €429,474.00 | €431,479.07 | 13,50 | 9,45 % |
| | Full Feeder | € 179,267.00 | €96,947.47 | 16,40 | 5,64 % |

## 5.3 Which photovoltaic system offers the greatest sustainable potential for osthaus & beckert GmbH?

### Social

Concerning the social factor, the simulated plants do not differ. All plants were installed on the hall roof of osthaus & beckert GmbH and therefore do not represent any impairment for social concerns and interests. Furthermore, a high level of CO2 emissions can be saved by means of each simulated plant. As described in chapter 2.4.2, this has a positive effect not only on the environment, but also on human health.

### Economic

From an economic point of view, the plants simulated in scenario 4 have the greatest potential. Using both the surplus feed-in model and the full feed-in model, the lowest investment costs are incurred here, the highest cumulative cash flow is achieved at the end of the useful life, the payback period is in some cases significantly shorter than for the other plants, and the return on equity is the highest at 9.45 % and 5.64 %. In addition, the fact that the plants simulated in scenario 4 are the only ones whose cumulative cash flow exceeds the acquisition costs after 30 years is particularly noteworthy.

In second place is the PV system simulated in Scenario 2, with payback periods of 14.60 and 19.60 years. The acquisition costs are lower than those of the systems simulated in Scenario 1 and 3. In addition, both the cumulative cash flow after 30 years and the return on equity are higher. Moreover, at 9.04 % for surplus feed-in, the return on equity is only slightly lower than the PV system in Scenario 1.

Although the PV system simulated in Scenario 1 has the second highest cumulative cash flow after 30 years, it only ranks third from an economic perspective. This fact is mainly due to the very high investment costs. These exceed the investment costs of the other simulated systems by around €90,000 to €140,000. The result is a return on equity of only 8.26 %. However, it is important to note at this point that the SunPower module used is the only module that, according to the datasheet, has a useful life of 40 years. However, to create a uniform framework, this aspect was not considered in the simulation. Therefore, it is likely that the profitability of the systems will be higher than what was determined in this research.

Scenario 3 represents the PV system with the lowest economic benefit. In The payback period exceeds that of the other simulated systems; in some cases significantly. In addition, it is the scenario with the lowest return on equity and the smallest cumulative cash flow after 30 years of service.

### Ecology

Regarding the reduction of the ecological footprint, the results have shown that in scenario 1 the most $CO_2$ emissions could be avoided. In addition, the SunPower module is the only module that has additional certificates related to environmental sustainability. In second place is the PV system simulated in Scenario 2. This is followed by the PV system from Scenario 4, with the PV system simulated in Scenario 3 performing worst.

The reason for the different $CO_2$ savings is clearly due to the generator power (AC grid). The higher the output, the less electricity has to be generated or purchased from fossil fuels. It is also noticeable that the avoided $CO_2$ emissions are always higher for the full feed-in model. The researcher speculates that this is related to the lack of electricity storage, as the production of the storage causes additional $CO_2$ emissions and thus affects the environmental footprint. Assuming that the researcher's hypothesis is correct, the fact that only 1.5 % fewer $CO_2$ emissions are avoided by using an electricity storage system would support the experts' statements regarding the life cycle assessment of electricity storage systems. However, no proof for this assumption can be provided from the available data.

## 5.4 Transferability of the results

The potentials and barriers of a company-owned PV system, which were determined during the expert interviews, can be regarded as generally valid in Germany and can therefore be transferred. The situation is different regarding the simulation results. Here, a large amount of specific company data was used by osthaus & beckert GmbH. The simulation results, therefore, relate specifically to the case of osthaus & beckert GmbH and cannot be transferred to any other company. However, taking into account the data used, it is possible that other companies can get a first impression of the potential of a company-owned PV system.

# 6 Conclusion

The aim of this study was to answer the following research question:

*What potentials and barriers exist in Germany regarding the acquisition and commercial use of a photovoltaic system, and how do these barriers possibly impair sustainable use?*

First, a theoretical framework was created in which the basic structure of a PV system and the subsidy system were discussed. In addition, the relevant literature was used to identify initial factors that influence the sustainable use of a PV system and should be taken into account during planning and acquisition. In the course of the qualitative data collection, the theoretical framework served primarily as the basis for the expert interviews conducted and the document analysis. The comprehensive literature review enabled the researcher to elaborate relevant questions, respond to the interviewed experts' answers, and ask in-depth follow-up questions. Based on the results of the aforementioned data collection methods, the researcher created the four scenarios presented in Chapter 3, which were simulated within the PVSOL Premium 2022 R5 planning and simulation software. The simulation results allowed the researcher to verify and evaluate the collected information regarding possible barriers and potentials of a company-owned PV plant related to osthaus & beckert GmbH under real conditions. Finally, the results presented in chapter 4 and discussed in chapter 5 are used in this section to answer the main research question. In addition, recommendations are made concerning future research.

## 6.1 Barriers in Germany regarding the acquisition and commercial use of a photovoltaic system

The data collection and analysis results have shown that legal, technical, and socio-economic barriers exist regarding the acquisition and sustainable entrepreneurial use of a PV system. Based on the simulation results, it could be determined that especially the legal barriers have a considerable influence on the economic potential and thus also on the sustainable entrepreneurial use of a PV system. The low EEG remuneration leads to the fact that new plants amortize themselves within the model of full feed-in only very late and the accumulated cash flow as well as the return on equity after a useful life of 30 years is only meager. In addition, only 50 % of the electricity generated by systems with a capacity of more than 300kW is remunerated. In order to derive greater economic benefit from a PV system, companies must accordingly resort to the surplus feed-in model. As the example of osthaus & beckert GmbH has shown, this can reduce the amortization period and increase the cumulative cash flow and return on equity. However, the legal barrier in the form of mandatory tendering for plants with an output of over 750kW could frustrate the entrepreneurial project, as this excludes self-consumption of the electricity produced. In this context, Paragraph 24 of the Renewable Energy Sources Act (EEG), which requires the aggregation of several plants, must be emphasized in particular. Consequently, even smaller plants can fall under the tendering obligation and thus reduce the sustainable potential of the company's own PV plant.

In the socio-economic field, a low willingness to take risks for long-term investments as well as information deficits could be identified as barriers for the acquisition and sustainable entrepreneurial use of a PV system. The latter in particular could be classified as highly relevant, measured by the amount of work required to gather information for the simulation in PVSOL 2022 R5 carried out in this study, as well as by the interview with the management of osthaus & beckert GmbH.

Insufficient static suitability of the roof truss, roof orientation and pitch, shading, grid compatibility, and location could be identified as technical barriers. Apart from the static suitability of the roof truss, each of these technical barriers can lead to significant performance losses of the PV system and thus reduce the sustainability potential of a PV system. The extent to which these barriers affect the sustainable use of a PV system could only be determined to a limited extent in this study. This is mainly because a comparison with a reference company, which has different prerequisites than osthaus & beckert GmbH, did not occur. Based on the results, it can only be summarized at this point that the existing conditions in the case of osthaus & beckert GmbH have only slightly impaired the sustainable use of a PV system.

## 6.2 Potentials in Germany regarding the acquisition and commercial use of a photovoltaic system

In addition to the identification of possible barriers, another part of the research question was to determine potentials regarding the acquisition and entrepreneurial use of a PV system. One of these potentials is the economic potential. Based on the simulation results, it could be shown that acquiring a PV system is economically profitable for osthaus & beckert GmbH, both using the full feed-in model and the surplus feed-in model. At the same time, it could be shown that the achievable economic advantage is significantly higher due to a high self-consumption share of the produced electricity. This circumstance could be attributed to the significant difference between the income from the directly marketed electricity and the savings from the electricity not drawn from the public grid. For example, in Scenario 1, with the full feed-in model, the feed-in revenue in the first year was €18,30.91. On the other hand, using the surplus feed-in model saved electricity costs of €46,396.39 in the first year.

Another potential is the ecological potential, which refers to the avoidance of CO2 emissions. It has been shown that a considerable amount of CO2 emissions can be prevented by generating electricity through a PV system. This circumstance is, among other things, due to the energy payback time of PV modules, which has been significantly reduced over the last few years due to improved resource and energy efficiency in manufacturing. How high the avoided CO2 emissions actually turn out to be depends largely on the installed PV power. The higher the PV system's output, the more electricity can be generated, and CO2 emissions avoided. Accordingly, the ecological potential of a company-owned PV system lies in the fact that lower CO2 emissions improve the eco-balance of a company, and the environment is less affected.

## 6.3 Recommendation for further research

At this point, the researcher points out that further research is needed despite comprehensive results. Here, the researcher refers in particular to a possible project implementation by osthaus & beckert GmbH. The results presented in chapter 4 have shown that the company already considered the possibility of a subsequent installation of a PV system during the construction of the production hall and designed the roof structure accordingly. Despite this, it is necessary to check the actual load capacity of the roof truss before realizing a PV plant according to the specific plant data. Furthermore, osthaus & beckert GmbH should check the possibility of funding before the project implementation. Due to the short-lived funding offers, this research could not give precise information. Additional research is also required concerning the investment costs, as the costs for installation and other materials were not taken into account within the profitability calculation. Furthermore, as shown in chapter 2.2.1, there is the possibility that the price per PV module is lower than assumed in this study due to the high number of modules. Moreover, osthaus & beckert GmbH should check as best as possible whether and to what extent a PV system has been installed in the vicinity in the last 12 months. The same applies to possible planned installations. This way, the risk of an involuntary mandatory tender can be minimized.

Finally, the researcher points out again that the EEG amendment from 2021 served as the basis for the legal barriers shown. Future research could come to different results due to an updated EEG amendment and the accompanying legal changes.

# 7 Reflection

This section briefly reflects on the research question in conjunction with the results as well as the research process.

In retrospect, the research question turned out to be too broad. While the results from the expert interviews basically reflect the existing state of research and can be related to Germany as a whole, the simulation results relate to the specific conditions of osthaus & beckert GmbH. Although it was possible to verify the potentials and barriers practically in this way, the results cannot be transferred to every other German industrial company. Thus, the research question could not be answered to the full extent. In retrospect, a research question that is more specific to osthaus & beckert GmbH seems more appropriate to the researcher.

Concerning the research process and in particular the data collection process, it has become apparent in retrospect that the researcher underestimated the time required at the beginning of the study. Especially the use of the software PVSOL Premium 2022 R5 was associated with significantly higher learning and time effort than was initially assumed. New information and incorrect inputs led to the fact that the time-consuming simulations had to be repeated more often.

Finally, the researcher emphasizes that this study was based on the great interest in renewable energy planning in Germany. The heavy workload and time pressure did not diminish this interest. Instead, this research has contributed that the interest has increased even more, and the desire for a profession in this field has been strengthened.

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# Annex

## Annex A: Interview guides

These interview guides are translated from the original German versions used in the interviews.

### Interview osthaus & beckert GmbH

**Building**

- Which of the two halls is to be used for the installation of the PV system?
- How large is the roof area of the hall?
- What type of roof is it?
- Are there any superstructures on the roof?
- What is the slope of the roof surface of the hall?
- What is the orientation of the hall?
- What is the height of the building and are there any surrounding buildings or the like that cast a shadow on their roof area?

**Energy data**

- What was your energy consumption in 2021?
- How much euros do you currently pay per kWh?
- At what times/days do you need the energy?

**Company requirements**

- Which operator model are you aiming for?
- Do you already have preferences regarding the PV module to be used?
- How do you feel about the use of an electricity storage system?
- Do you have a specific budget for the PV system?

**Potentials and Barriers**

- What potentials/improvements do you hope for from your own PV system?
- Where do you currently see the greatest barriers to your own PV system?

## Interview Memodo GmbH & enerix Franchise GmbH & Co KG

**PV System**

- Are there certain photovoltaic modules or basically manufacturers that you can recommend for a commercial photovoltaic system?
- Are there certain inverter or basically manufacturers that you can recommend?
- Which electricity storage systems or manufacturers of electricity storage systems would you recommend for commercial use?

**Funding**

- What funding opportunities are offered to companies regarding their own PV system?

**Potentials and Barriers**

- What potential do you see for a company in the industrial sector regarding its own PV system?
- Which factors possibly limit these potentials and could be seen as barriers?

## Annex B: Coding scheme

| Umbrella Code | Deductive Codes | Additional data-driven inductive codes |
|---|---|---|
| Potentials | Economic potentials<br>Ecological potentials | Marketing purposes<br>Electricity cost savings<br>Dependence on electricity supplier<br>Resource and energy efficiency<br>Life cycle assessment of electricity storage<br>Technological progress |
| Barriers | Legal barriers<br>Technical barriers<br>Socioeconomic barriers | Low feed-in tariff<br>Mandatory direct marketing<br>Mandatory tendering<br>Reduced remuneration<br>Roof statics<br>Shading<br>Grid compatibility<br>Location<br>Roof orientation<br>Roof inclination<br>Information deficits<br>Risk long-term investments |
| Funding | Feed-in tariff<br>Funding program | |
| Building | Roof area<br>Building orientation<br>Inclination roof area<br>Statics<br>Roof type<br>Roof constructions | |

| | | |
|---|---|---|
| Energy | Usage time | |

## Annex C: Datasheets

### PV Modules

| Module: | Available at: |
|---|---|
| SunPower SPR-MAX3-400 (v1) | https://www.photovoltaikforum.com/mdb/pv-modul/112286-spr-max3-400/#datenblatt |
| SOLARWATT Panel classic H 2.0 pure, 405Wp (v1) | https://www.photovoltaikforum.com/mdb/pv-modul/132703-panel-classic-h-2-0-pure-405-glas-folie/ |
| Panasonic VBHN330SJ47 (v1) | https://www.photovoltaikforum.com/mdb/pv-modul/101634-vbhn330sj47/ |
| LONGI Solar LR4-66 HPH 420 M (v1) | https://www.photovoltaikforum.com/mdb/pv-modul/133237-lr4-66hph-420m/ |

### Inverter

| Inverter: | Available at: |
|---|---|
| SUN2000-50KTL-M0 (400Vac) (v1) | https://solar.huawei.com/en/download?p=%2F-%2Fmedia%2FSolar%2Fattachment%2Fpdf%2Fau%2Fdatasheet%2FSUN2000-50KTL-M0.pdf |
| Huawei Technologies SUN2000-33KTL-A (v1) | https://solar.huawei.com/de-DE/download?p=%2F-%2Fmedia%2FSolar%2Fattachment%2Fpdf%2Feu%2Fdatasheet%2FSUN2000-33KTL-A.pdf |
| Huawei Technologies SUN2000-30KTL-M3（440Vac）(v1) | https://solar.huawei.com/de-DE/download?p=%2F-%2Fmedia%2FSolar%2Fattachment%2Fpdf%2Feu%2Fdatasheet%2FSUN2000-30-40KTL-M3.pdf |
| Huawei Technologies SUN2000-40KTL-M3（440Vac）(v1) | https://solar.huawei.com/de-DE/download?p=%2F-%2Fmedia%2FSolar%2Fattachment%2Fpdf%2Feu%2Fdatasheet%2FSUN2000-30-40KTL-M3.pdf |

| | |
|---|---|
| Huawei Technologies SUN2000-20KTL-M0 (v2) | https://solar.huawei.com/de-DE/download?p=%2F-%2Fmedia%2FSolar%2Fattachment%2Fpdf%2Feu%2Fdatasheet%2FSUN2000-12-20KTL-M0.pdf |
| Huawei Technologies SUN2000-215KTL-H0 (v1) | https://solar.huawei.com/de-DE/download?p=%2F-%2Fmedia%2FSolar%2Fattachment%2Fpdf%2Fde%2Fdatasheet%2FSUN2000-215KTL-H0.pdf |
| Huawei Technologies SUN2000-60KTL-M0 (400Vac) (v2) | https://solar.huawei.com/de-DE/download?p=%2F-%2Fmedia%2FSolar%2Fattachment%2Fpdf%2Feu%2Fdatasheet%2FSUN2000-60KTL-M0.pdf |

### Battery storage system

| **Battery storgage system:** | **Available at:** |
|---|---|
| VARTA flex storage E 120kW/375kWh | https://www.varta-ag.com/fileadmin/varta/consumer/downloads/energy-storage/varta-flex-storage/Datasheet_VARTA_Flex_storage_E_dach_en_2.pdf |

## Annex D: Screenshots of the data analysis in PVSOL Premium 2022 R5

The following screenshots were taken in the data analysis for Scenario 1.

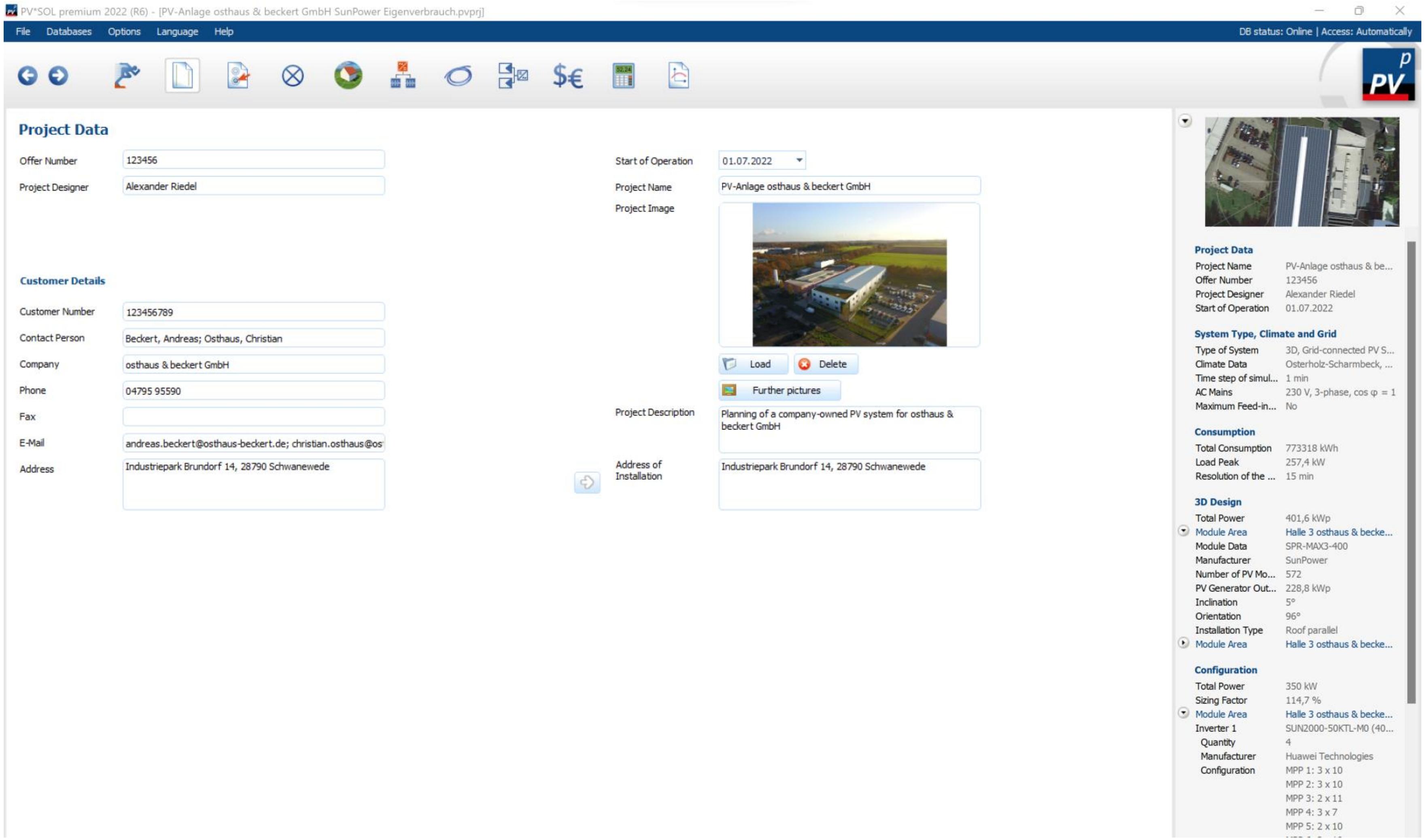



*Figure 10 - Screenshot of the software page "Project Data" (Valentin Software GmbH, 2022b)*

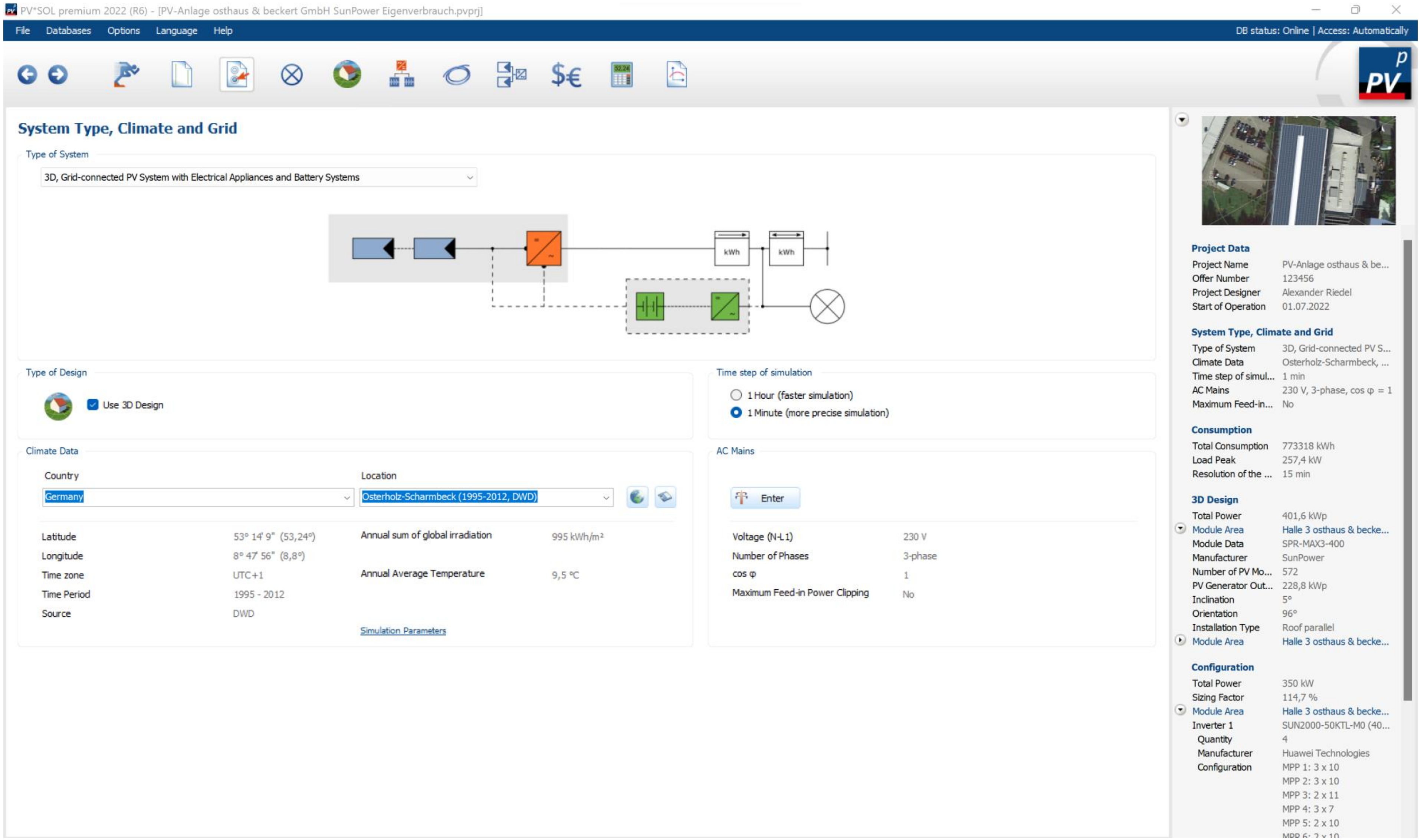



*Figure 11 - Screenshot of the software page "System Type, Climate and Grid" (Valentin Software GmbH, 2022b)*

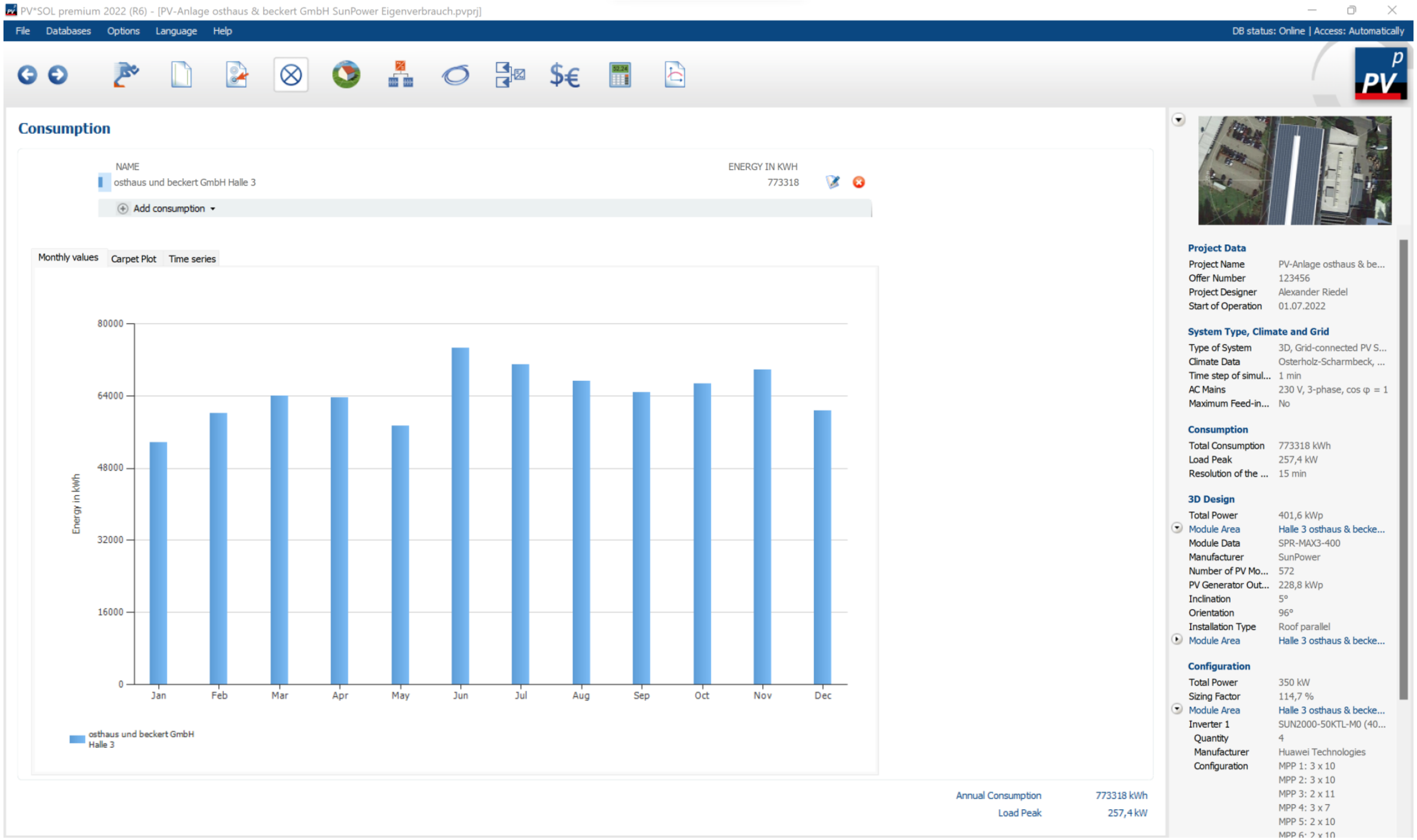



*Figure 12 - Screenshot of the software page "Consumption" (Valentin Software GmbH, 2022b)*

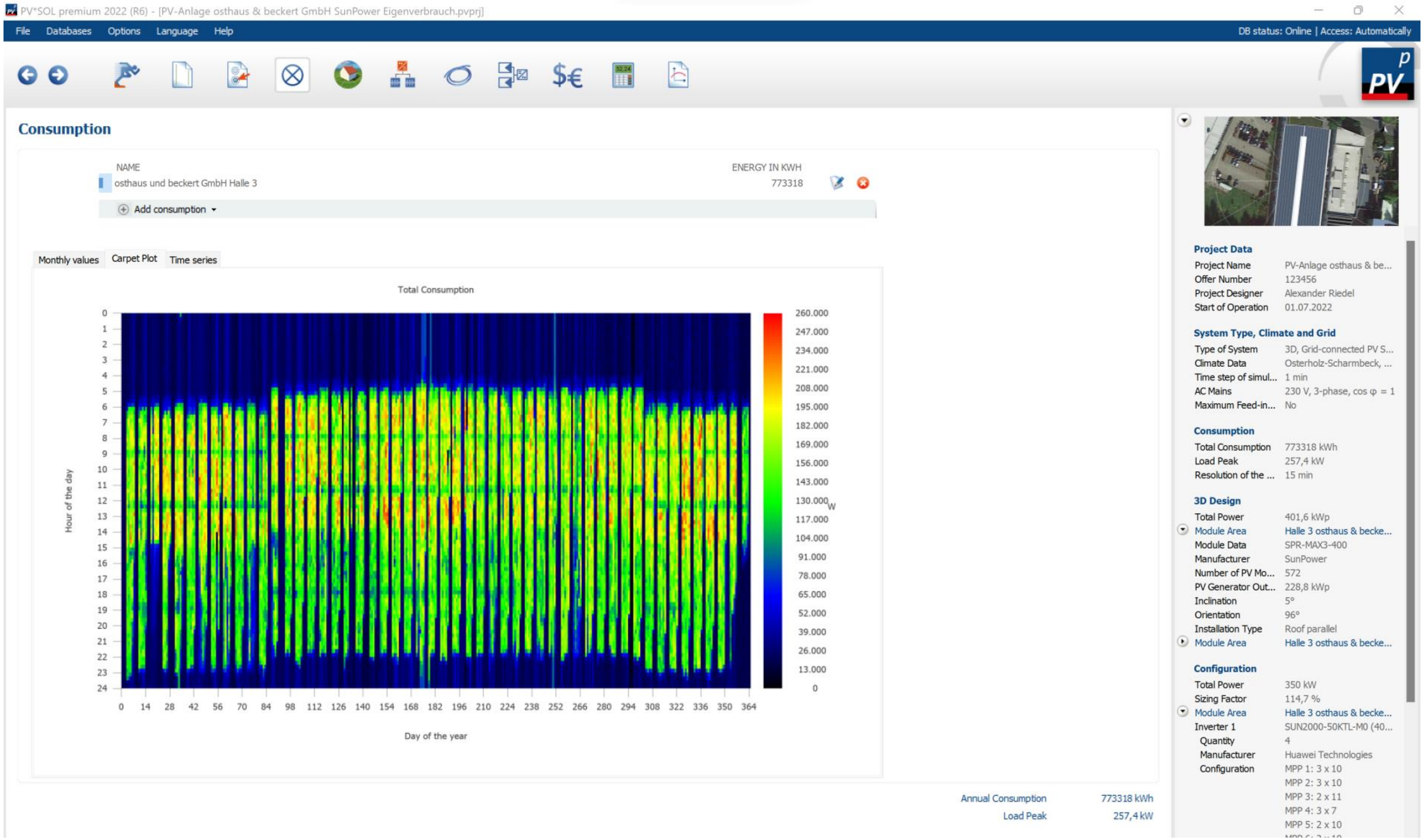



*Figure 13 - Screenshot of the software page "Consumption (Carpet Plot)" (Valentin Software GmbH, 2022b)*

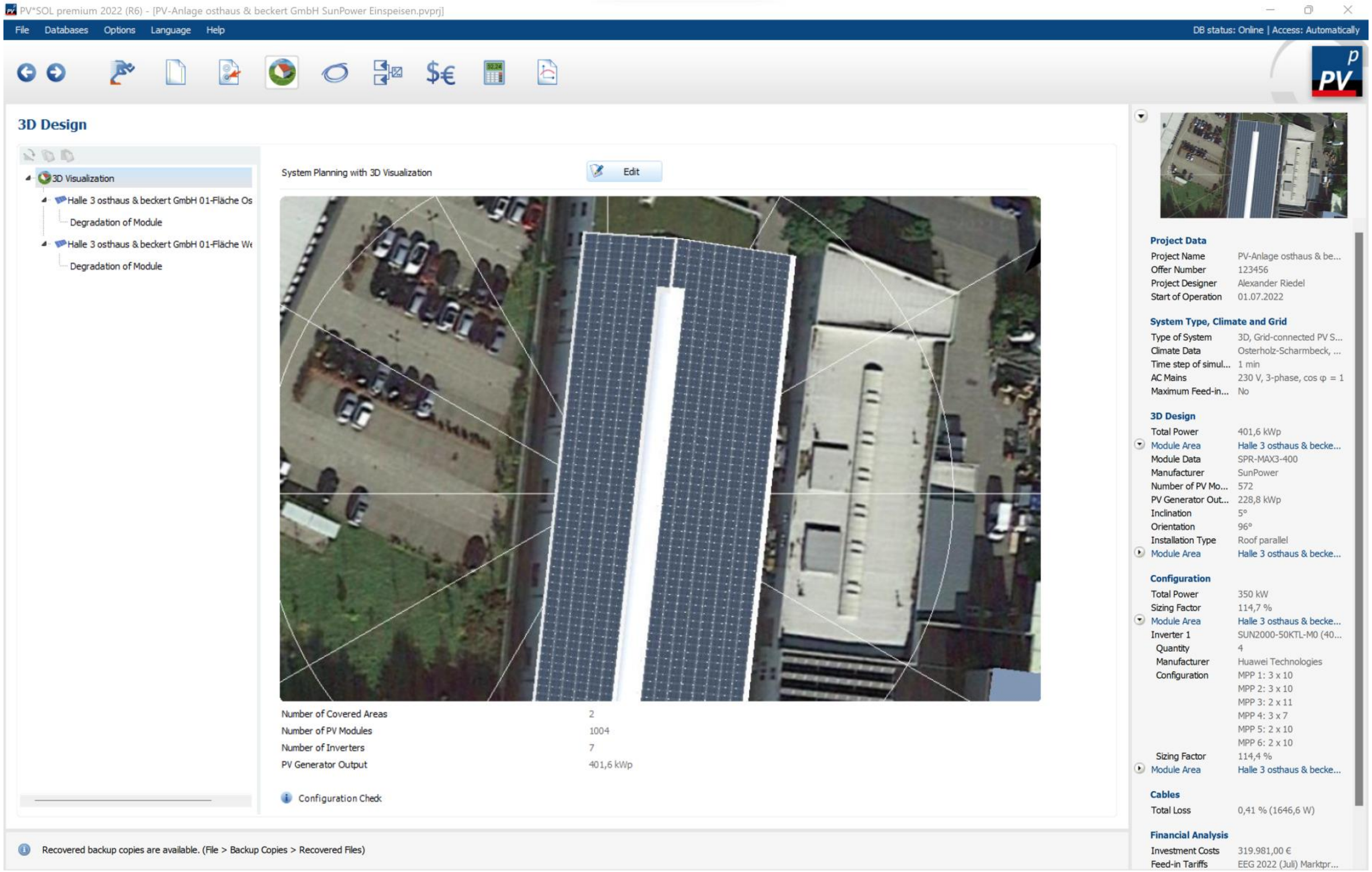



*Figure 14 - Screenshot of the software page "3D Design" (Valentin Software GmbH, 2022b)*

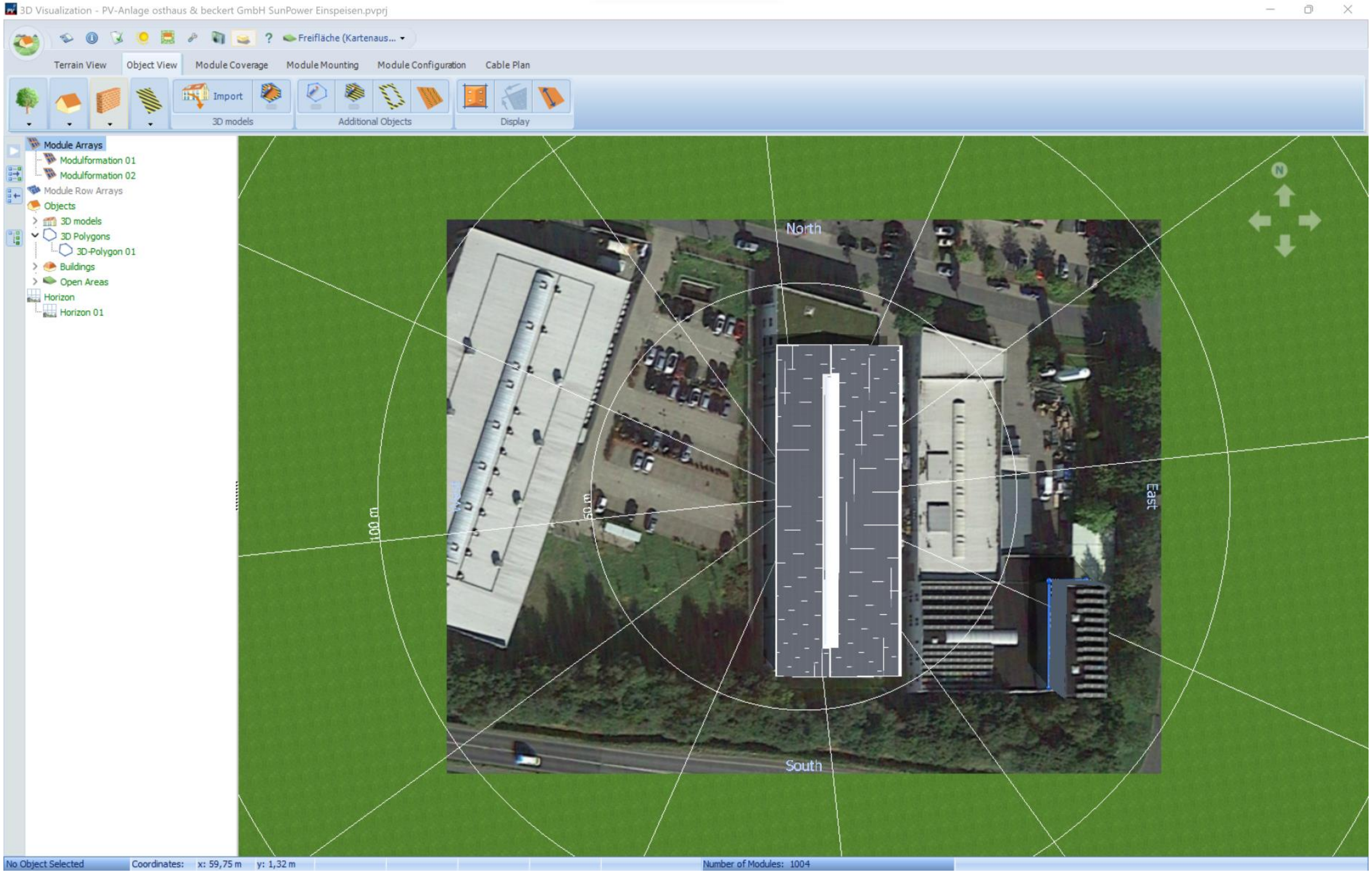



*Figure 15 - Screenshot of the software page "3D Design (Edit)" (Valentin Software GmbH, 2022b)*

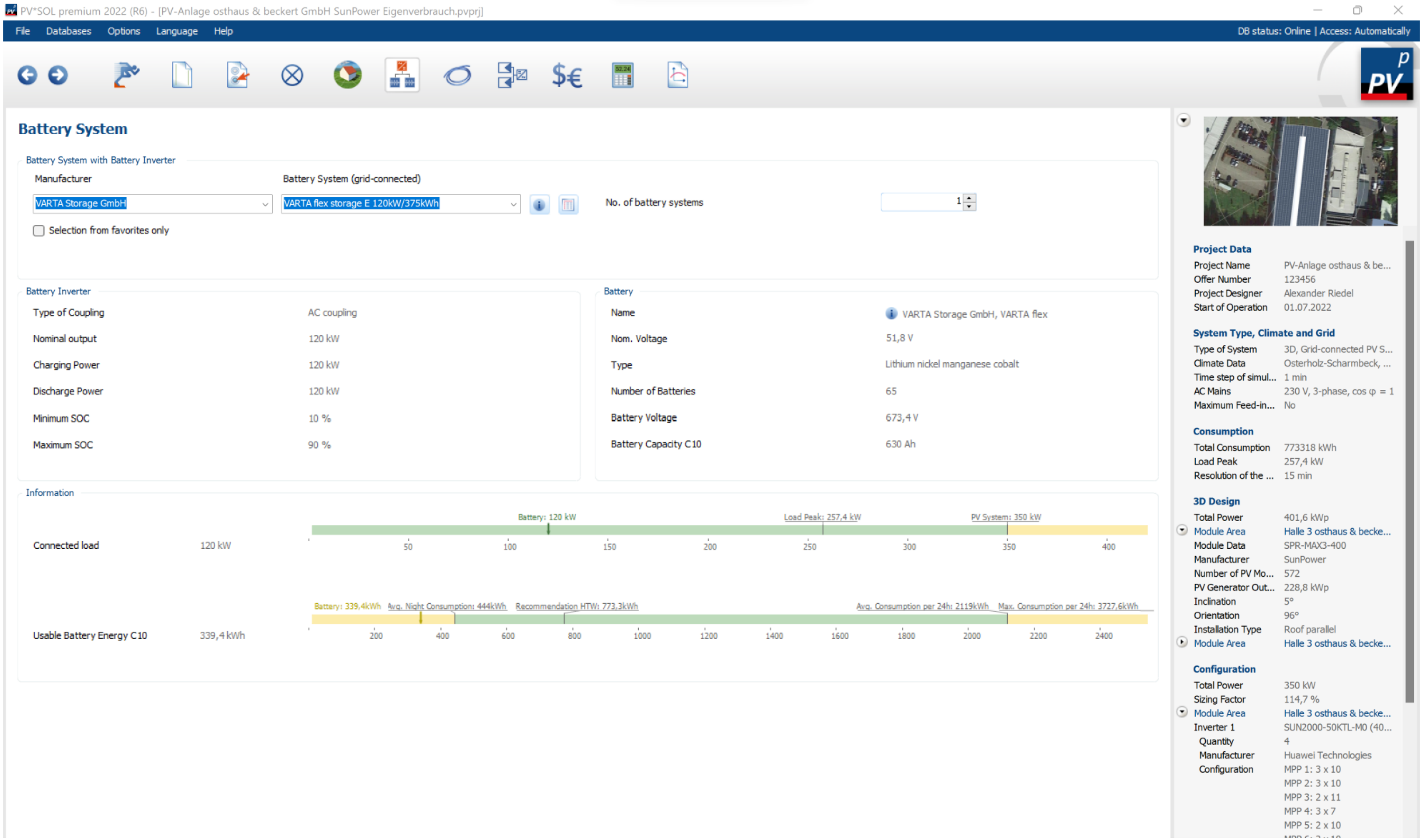



*Figure 16 - Screenshot of the software page "Battery System" (Valentin Software GmbH, 2022b)*

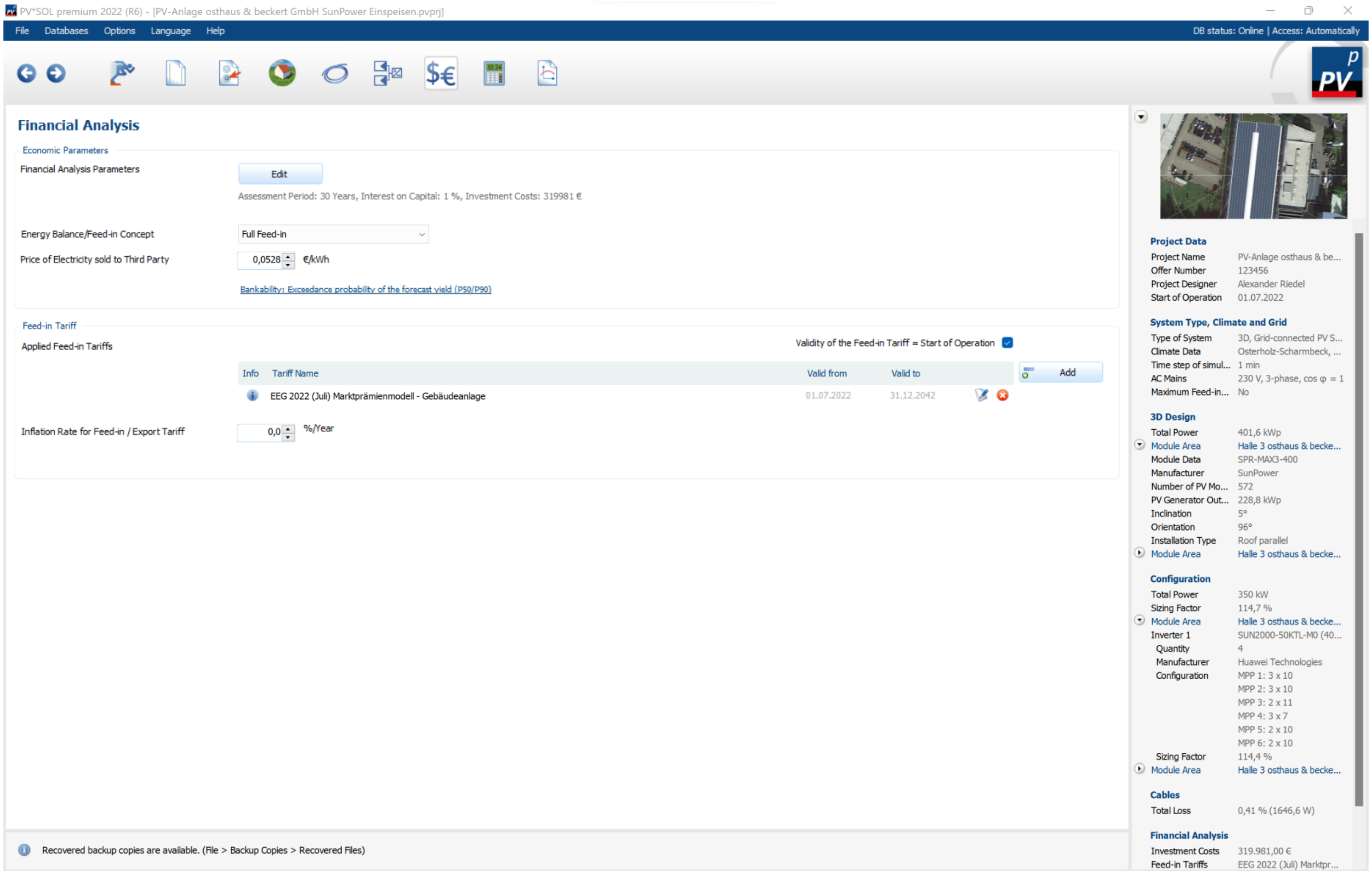



*Figure 17 - Screenshot of the software page "Financial Analysis" (Valentin Software GmbH, 2022b)*

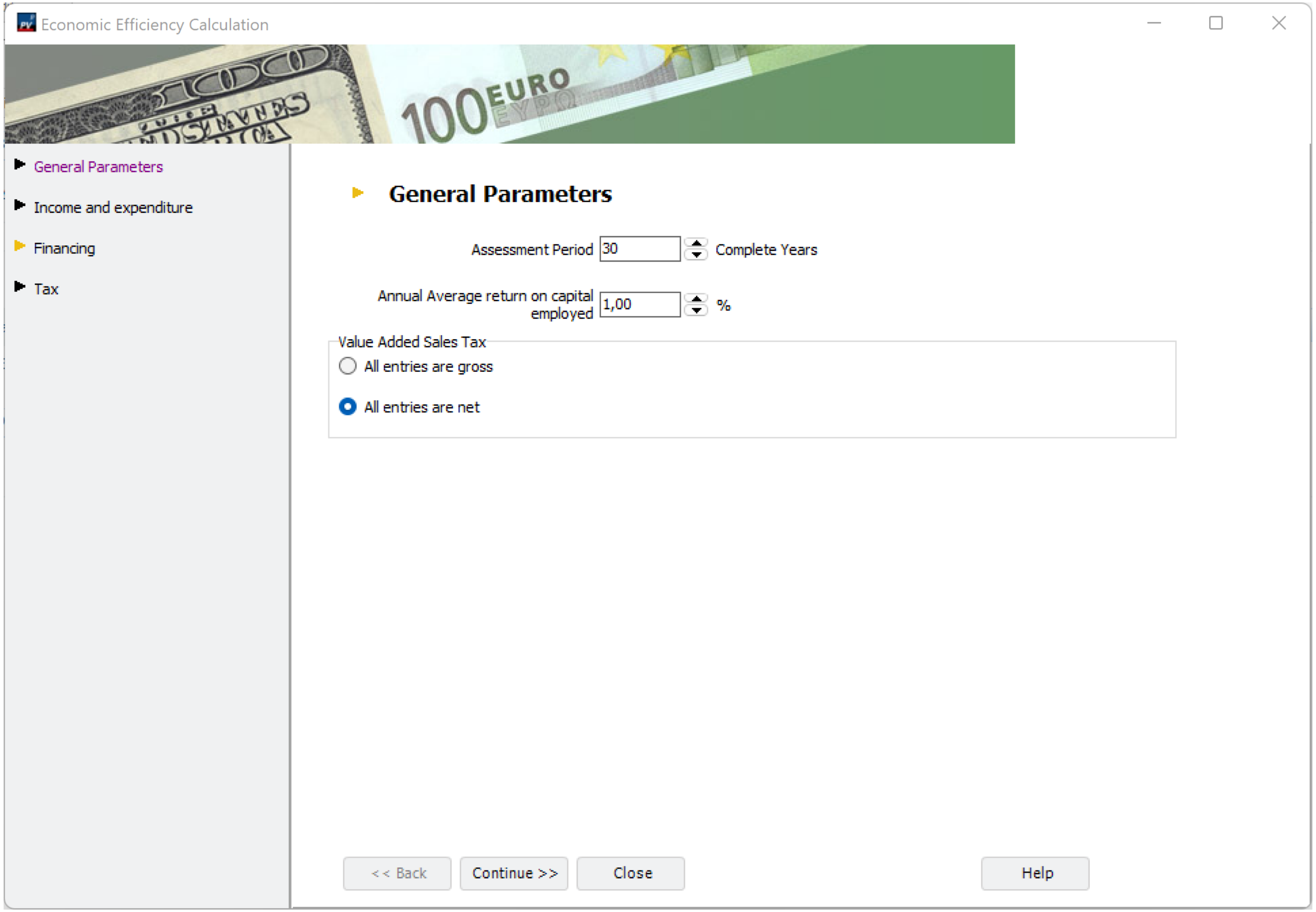



*Figure 18 - Screenshot of the software page "Financial Analysis (Edit)" (Valentin Software GmbH, 2022b)*

## Annex E: Simulation report Scenario 1 (Surplus Feeder)

**osthaus & beckert GmbH**
Beckert, Andreas; Osthaus, Christian
Industriepark Brundorf 14, 28790
Schwanewede

**Customer No.:** 123456789
**Project Name:** PV-Anlage osthaus & beckert GmbH
**Offer no.:** 123456

09.08.2022

# Your PV system

### Address of Installation

Industriepark Brundorf 14, 28790 Schwanewede


Project Description:

Planning of a company-owned PV system for osthaus & beckert GmbH

# Project Overview

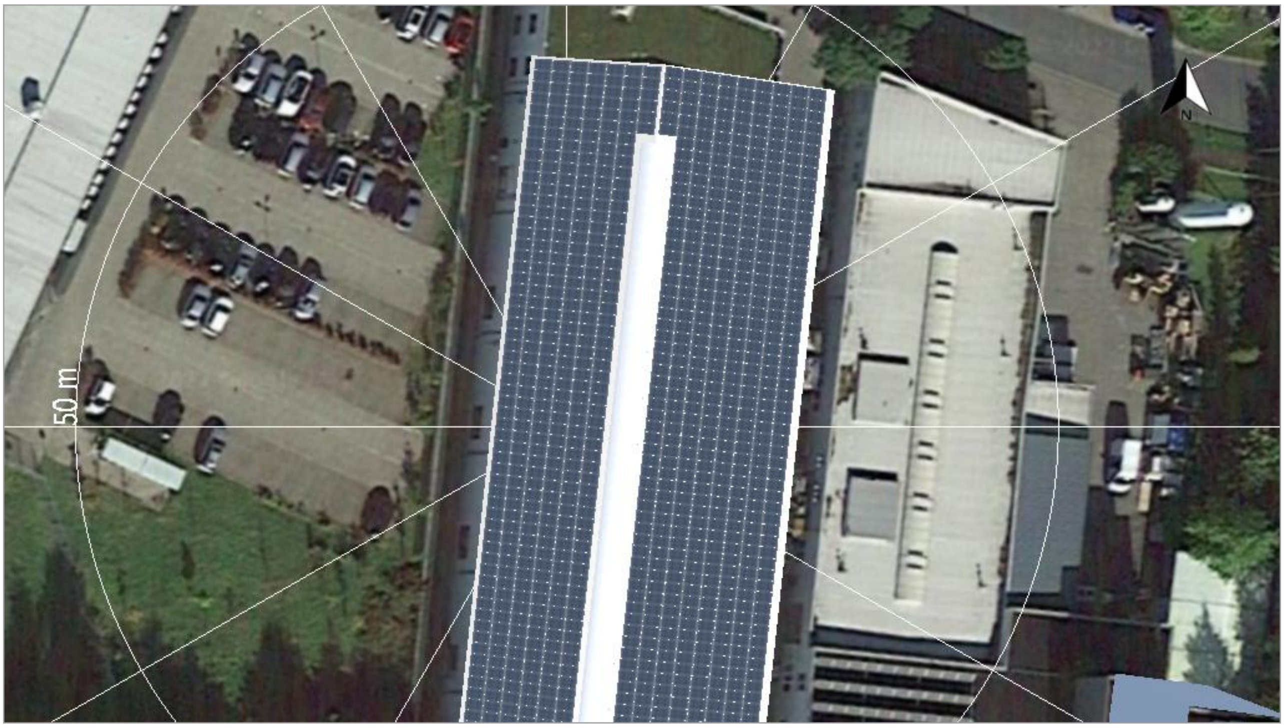



Figure: Overview Image, 3D Design

## PV System

3D, Grid-connected PV System with Electrical Appliances and Battery Systems

| | | |
|---|---|---|
| Climate Data | Osterholz-Scharmbeck, DEU (1995 - 2012) | |
| Values source | DWD | |
| PV Generator Output | 401,6 | kWp |
| PV Generator Surface | 1.774,8 | m² |
| Number of PV Modules | 1004 | |
| Number of Inverters | 7 | |
| No. of battery systems | 1 | |

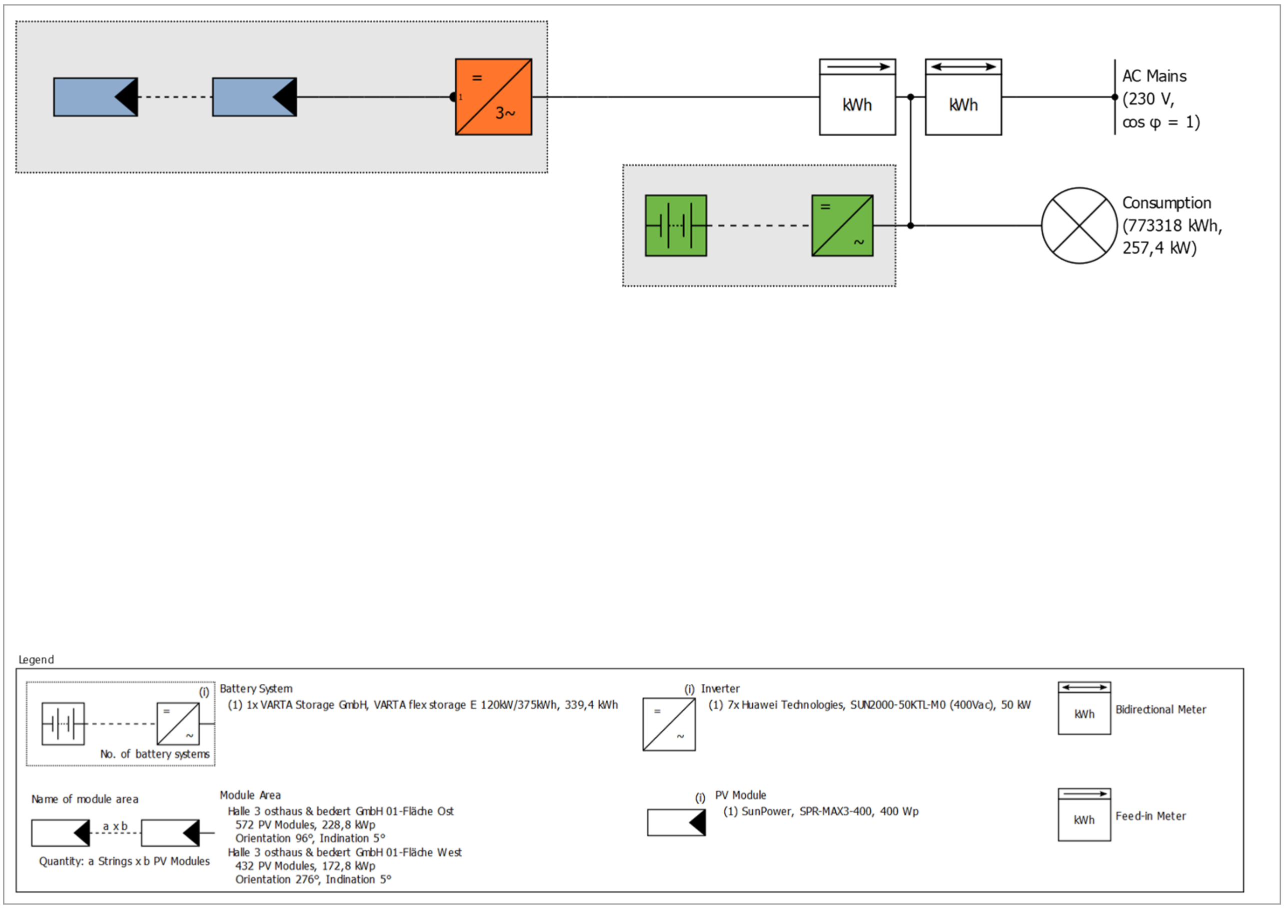



Figure: Schematic diagram

# Production Forecast

| Production Forecast | | |
|---|---|---|
| PV Generator Output | 401,60 | kWp |
| Spec. Annual Yield | 873,91 | kWh/kWp |
| Performance Ratio (PR) | 88,85 | % |
| Yield Reduction due to Shading | 0,6 | %/Year |
| | | |
| PV Generator Energy (AC grid) | 351.129 | kWh/Year |
| Direct Own Use | 237.339 | kWh/Year |
| Battery Charge | 56.989 | kWh/Year |
| Down-regulation at Feed-in Point | 0 | kWh/Year |
| Grid Feed-in | 56.802 | kWh/Year |
| | | |
| Own Power Consumption | 83,8 | % |
| | | |
| $CO_2$ Emissions avoided | 167.601 | kg / year |
| | | |
| Level of Self-sufficiency | 37,4 | % |

# Financial Analysis

## Your Gain

| | |
|---|---|
| Total investment costs | 570.188,00 € |
| Internal Rate of Return of Capital Resources | 8,26 % |
| Amortization Period | 15,6 Years |
| Electricity Production Costs | 0,0716 €/kWh |
| Energy Balance/Feed-in Concept | Surplus Feed-in |

The results have been calculated with a mathematical model calculation from Valentin Software GmbH (PV*SOL algorithms). The actual yields from the solar power system may differ as a result of weather variations, the efficiency of the modules and inverter, and other factors.

# Set-up of the System

## Overview

### System Data

| | |
|---|---|
| Type of System | 3D, Grid-connected PV System with Electrical Appliances and Battery Systems |

### Climate Data

| | |
|---|---|
| Location | Osterholz-Scharmbeck, DEU (1995 - 2012) |
| Values source | DWD |
| Resolution of the data | 1 min |
| Simulation models used: | |
| - Diffuse Irradiation onto Horizontal Plane | Hofmann |
| - Irradiance onto tilted surface | Hay & Davies |

### Consumption

| | |
|---|---|
| Total Consumption | 773318 kWh |
| osthaus und beckert GmbH Halle 3 | 773318 kWh |
| Load Peak | 257,4 kW |

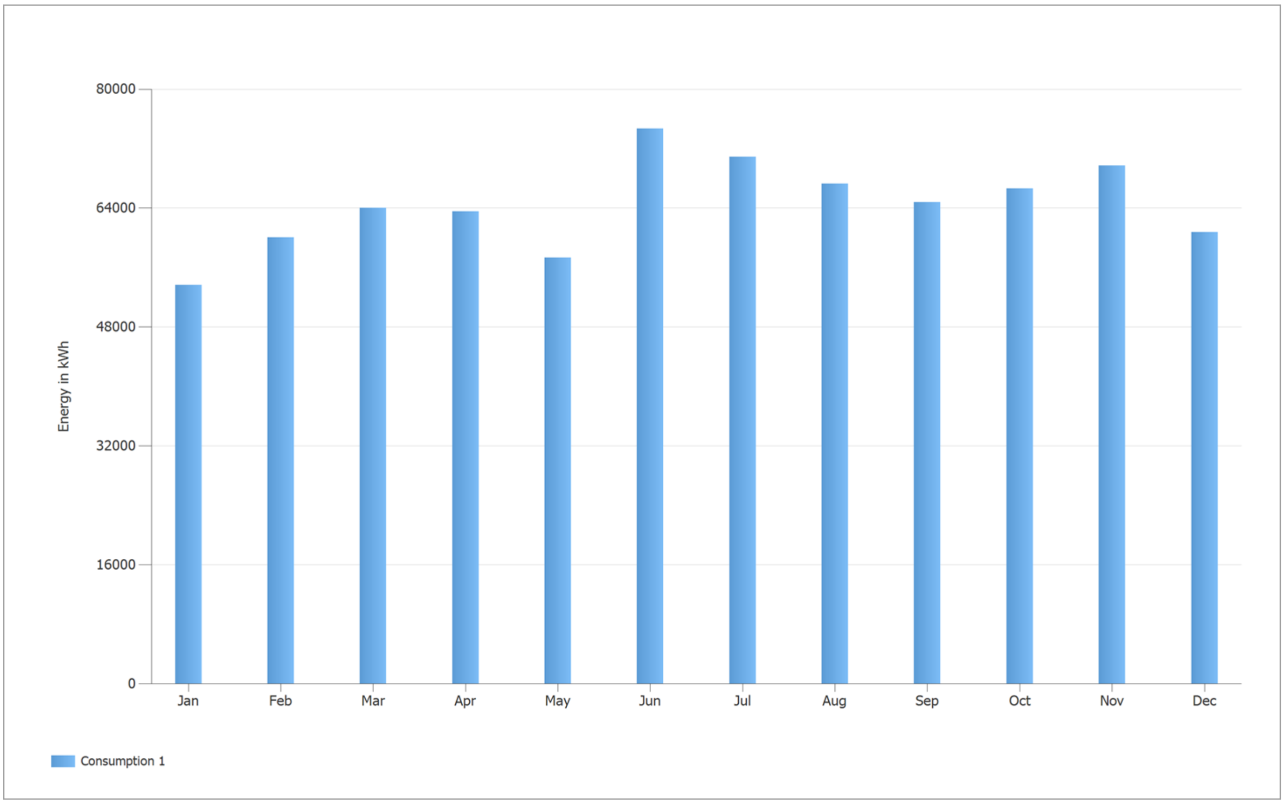



Figure: Consumption

# Module Areas

## 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost

### PV Generator, 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost

| | | |
|---|---|---|
| Name | Halle 3 osthaus & beckert GmbH 01-Fläche Ost | |
| PV Modules | 572 x SPR-MAX3-400 (v1) | |
| Manufacturer | SunPower | |
| Inclination | 5 | ° |
| Orientation | East 96 | ° |
| Installation Type | Roof parallel | |
| PV Generator Surface | 1.011,1 | m² |

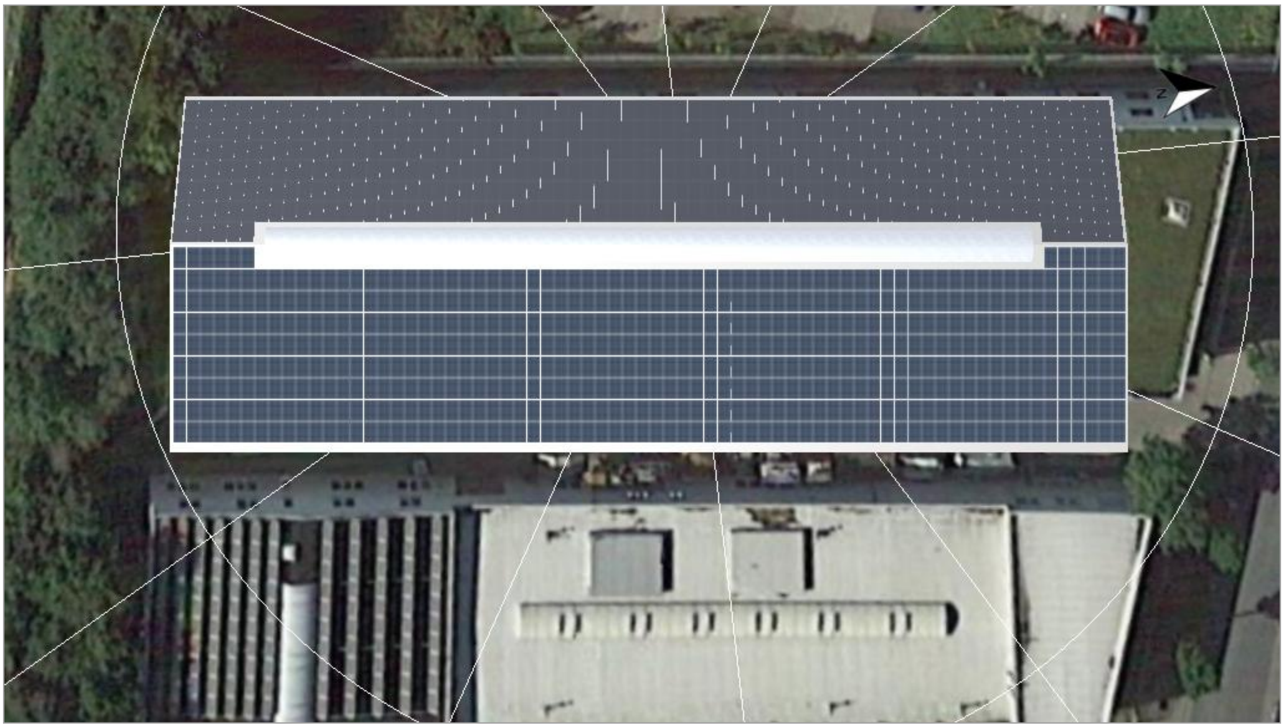


Figure: 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost

## *2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West*

### PV Generator, 2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West

| | |
|---|---|
| Name | Halle 3 osthaus & beckert GmbH 01-Fläche West |
| PV Modules | 432 x SPR-MAX3-400 (v1) |
| Manufacturer | SunPower |
| Inclination | 5 ° |
| Orientation | West 276 ° |
| Installation Type | Roof parallel |
| PV Generator Surface | 763,7 m² |

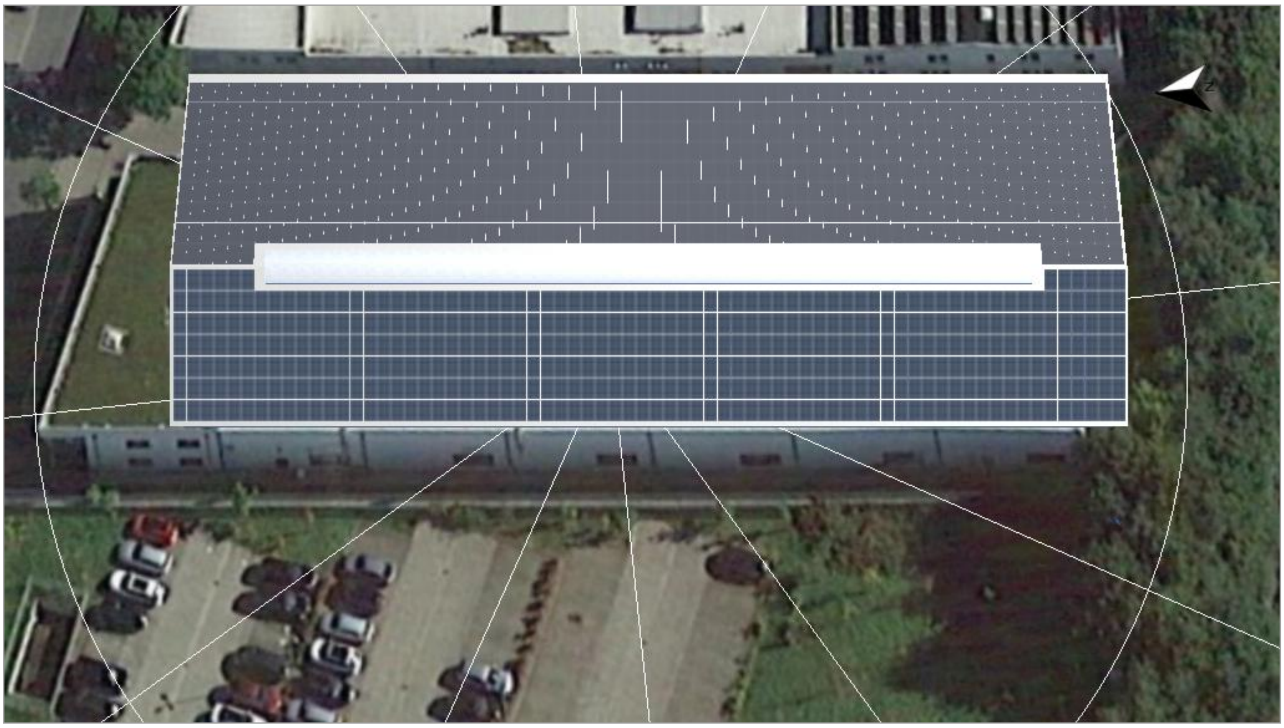


Figure: 2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West

# Horizon Line, 3D Design

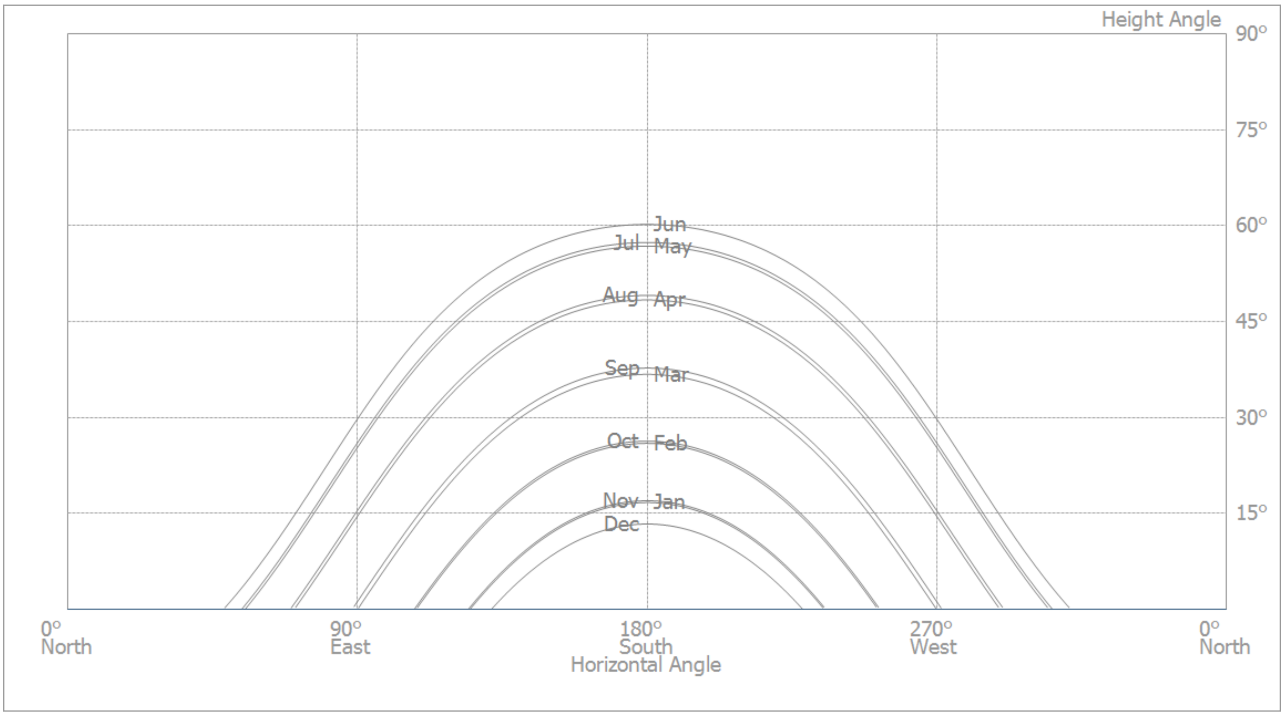



Figure: Horizon (3D Design)

# Inverter configuration

## Configuration 1

| | |
|---|---|
| Module Area | Halle 3 osthaus & beckert GmbH 01-Fläche Ost |
| Inverter 1 | |
| Model | SUN2000-50KTL-M0 (400Vac) (v1) |
| Manufacturer | Huawei Technologies |
| Quantity | 4 |
| Sizing Factor | 114,4 % |
| Configuration | MPP 1: 3 x 10 |
| | MPP 2: 3 x 10 |
| | MPP 3: 2 x 11 |
| | MPP 4: 3 x 7 |
| | MPP 5: 2 x 10 |
| | MPP 6: 2 x 10 |

## Configuration 2

| | |
|---|---|
| Module Area | Halle 3 osthaus & beckert GmbH 01-Fläche West |
| Inverter 1 | |
| Model | SUN2000-50KTL-M0 (400Vac) (v1) |
| Manufacturer | Huawei Technologies |
| Quantity | 3 |
| Sizing Factor | 115,2 % |
| Configuration | MPP 1+2+3+4+5+6: 16 x 9 |

# AC Mains

| AC Mains | | |
|---|---|---|
| Number of Phases | 3 | |
| Mains voltage between phase and neutral | 230 | V |
| Displacement Power Factor (cos phi) | +/- 1 | |

# Battery Systems

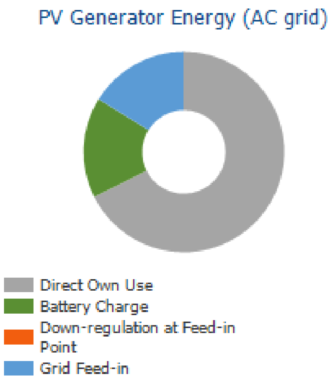
| Battery System | | |
|---|---|---|
| Model | VARTA flex storage E 120kW/375kWh (v3) | |
| Manufacturer | VARTA Storage GmbH | |
| Quantity | 1 | |
| Battery Inverter | | |
| Type of Coupling | AC coupling | |
| Nominal output | 120 | kW |
| Battery | | |
| Manufacturer | VARTA Storage GmbH | |
| Model | VARTA flex storage E BM (v1) | |
| Quantity | 65 | |
| Battery Energy | 339,4 | kWh |
| Battery Type | Lithium nickel manganese cobalt oxide/graphite | |

# Simulation Results

## Results Total System

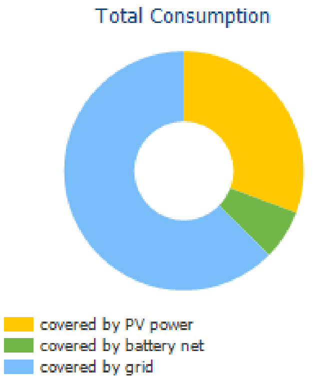
### PV System

| | | |
|---|---|---|
| PV Generator Output | 401,60 | kWp |
| Spec. Annual Yield | 873,91 | kWh/kWp |
| Performance Ratio (PR) | 88,85 | % |
| Yield Reduction due to Shading | 0,6 | %/Year |
| PV Generator Energy (AC grid) | 351.129 | kWh/Year |
| Direct Own Use | 237.339 | kWh/Year |
| Battery Charge | 56.989 | kWh/Year |
| Down-regulation at Feed-in Point | 0 | kWh/Year |
| Grid Feed-in | 56.802 | kWh/Year |
| Own Power Consumption | 83,8 | % |
| $CO_2$ Emissions avoided | 167.601 | kg / year |



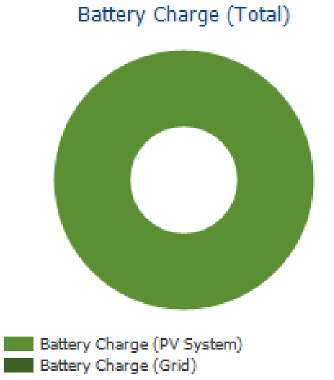

### Appliances

| | | |
|---|---|---|
| Appliances | 773.318 | kWh/Year |
| Standby Consumption (Inverter) | 166 | kWh/Year |
| Total Consumption | 773.484 | kWh/Year |
| covered by PV power | 237.339 | kWh/Year |
| covered by battery net | 51.934 | kWh/Year |
| covered by grid | 484.211 | kWh/Year |
| Solar Fraction | 37,4 | % |




### Battery System

| | | |
|---|---|---|
| Charge at beginning | 339 | kWh |
| Battery Charge (Total) | 56.989 | kWh/Year |
| Battery Charge (PV System) | 56.989 | kWh/Year |
| Battery Charge (Grid) | 0 | kWh/Year |
| Battery Energy for the Covering of Consumption | 51.934 | kWh/Year |
| Losses due to charging/discharging | 5.381 | kWh/Year |
| Losses in Battery | 12 | kWh/Year |
| Cycle Load | 2,8 | % |
| Service Life | >20 | Years |




### Level of Self-sufficiency

| | | |
|---|---|---|
| Total Consumption | 773.484 | kWh/Year |
| covered by grid | 484.211 | kWh/Year |
| Level of Self-sufficiency | 37,4 | % |

## Energy Flow Graph

Project: PV-Anlage osthaus & beckert GmbH

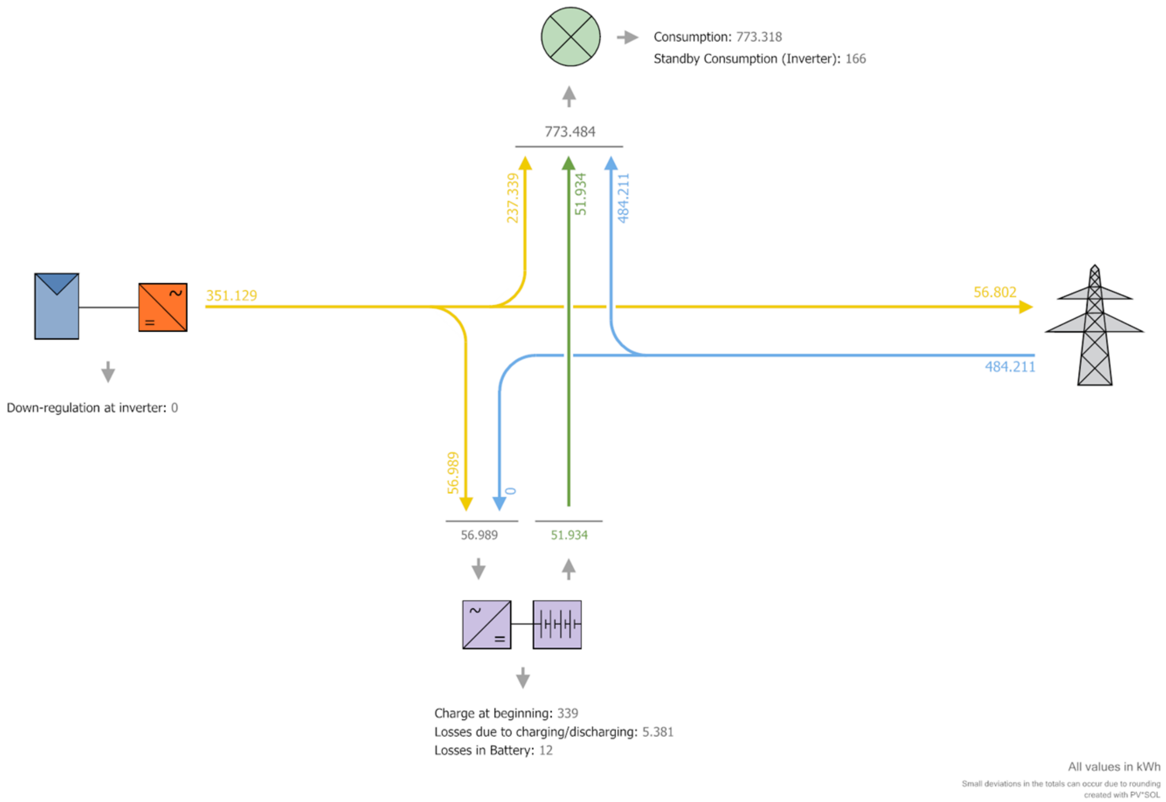



Figure: Energy flow

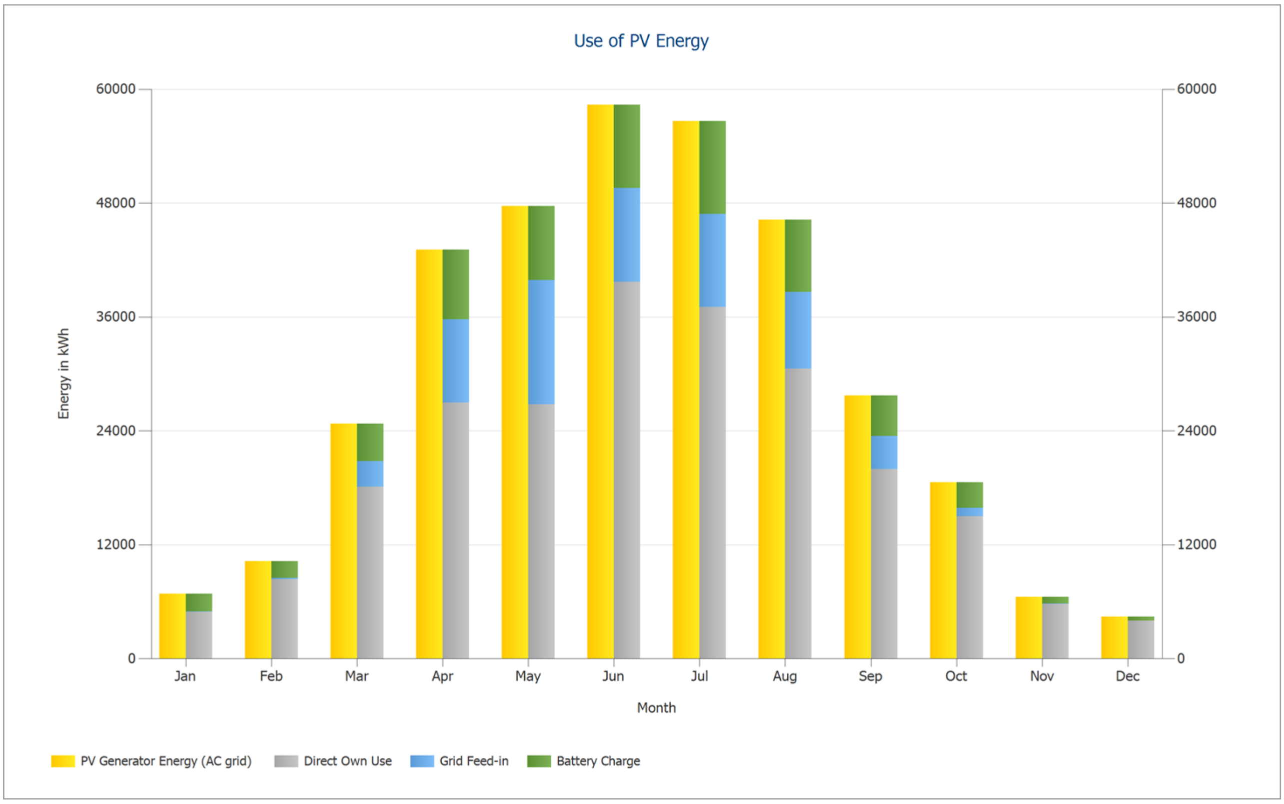



Figure: Use of PV Energy

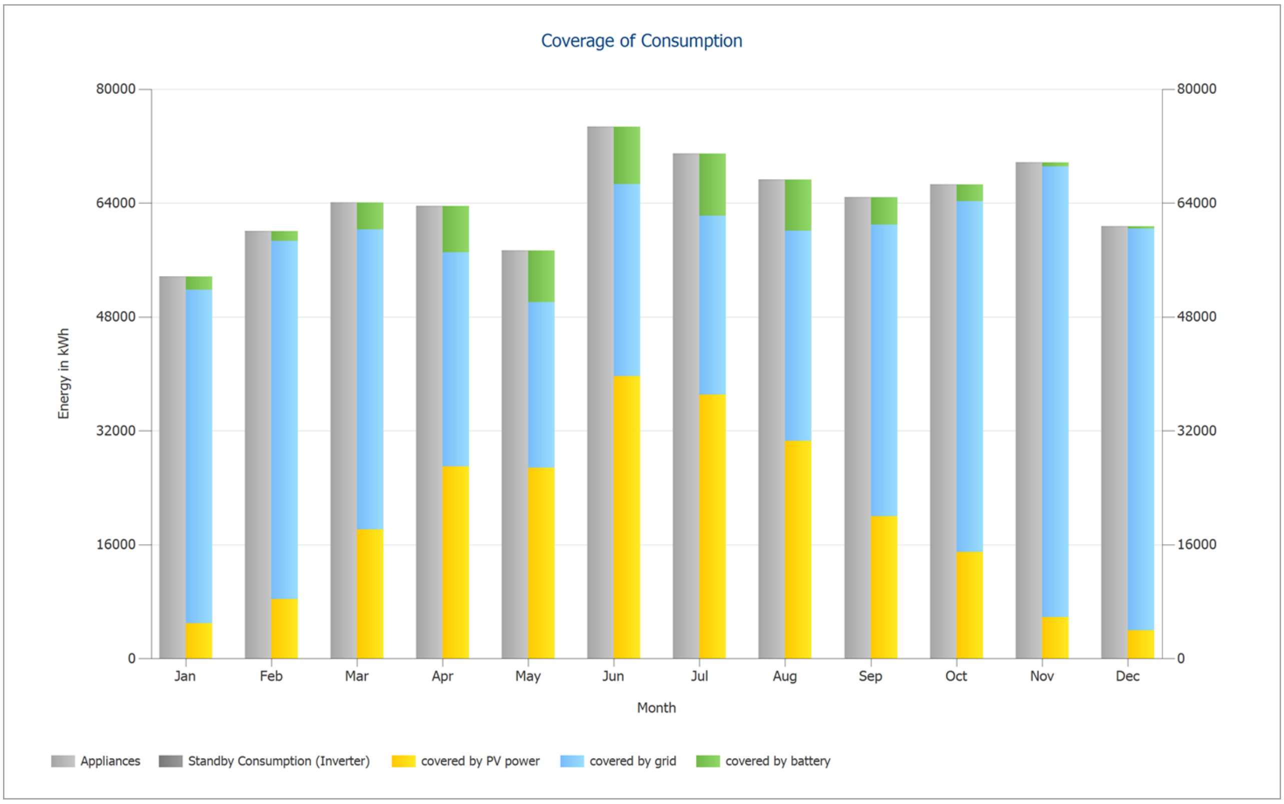



Figure: Coverage of Consumption

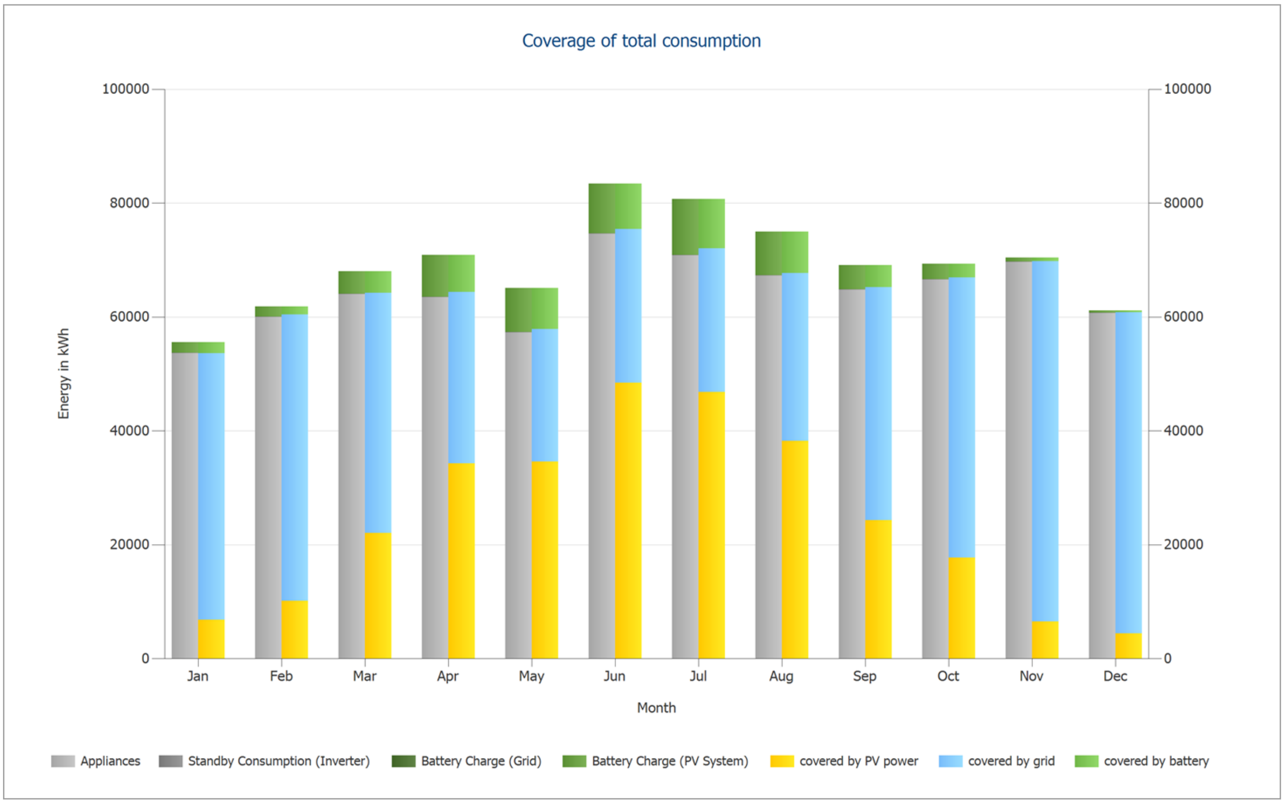



Figure: Coverage of total consumption

# Yield for EnEV

## Yield in accordance with DIN 15316-4-6

| | |
|---|---|
| January | 5227 kWh |
| February | 7163,2 kWh |
| March | 17483,5 kWh |
| April | 32967 kWh |
| May | 39833,6 kWh |
| June | 42037,2 kWh |
| July | 37851 kWh |
| August | 32443,7 kWh |
| September | 22152,4 kWh |
| October | 13878,7 kWh |
| November | 5407,3 kWh |
| December | 3064,1 kWh |
| **Annual Value** | **259.508,8 kWh** |

Boundary Conditions:
Climate Data according to DIN V 18599-10
HALLE 3 OSTHAUS & BECKERT GMBH 01-FLÄCHE OST
System Power Factor: 0.75
Peak Power Coefficient: 0.182
Orientation: East
Inclination: 0°

HALLE 3 OSTHAUS & BECKERT GMBH 01-FLÄCHE WEST
System Power Factor: 0.75
Peak Power Coefficient: 0.182
Orientation: West
Inclination: 0°

# Financial Analysis

## Overview

### System Data

| | | |
|---|---|---|
| Grid Feed-in in the first year (incl. module degradation) | 56.691 | kWh/Year |
| PV Generator Output | 401,6 | kWp |
| Start of Operation of the System | 01.07.2022 | |
| Assessment Period | 30 | Years |
| Interest on Capital | 1 | % |

### Economic Parameters

| | | |
|---|---|---|
| Internal Rate of Return of Capital Resources | 8,26 | % |
| Accrued Cash Flow (Cash Balance) | 430.699,03 | € |
| Amortization Period | 15,6 | Years |
| Electricity Production Costs | 0,0716 | €/kWh |

### Payment Overview

| | | |
|---|---|---|
| Specific Investment Costs | 1.419,79 | €/kWp |
| Investment Costs | 570.188,00 | € |
| One-off Payments | 0,00 | € |
| Incoming Subsidies | 0,00 | € |
| Annual Costs | 1.400,00 | €/Year |
| Other Revenue or Savings | 0,00 | €/Year |

### Loans

| **Reference** | **Loan 1** | |
|---|---|---|
| Loan Capital | 500.000,00 | € |
| Payment Installment | 100,00 | % |
| Credit type | Installment Loan | |
| Term | 10,00 | Years |
| Grace period | 0,00 | Years |
| Interest | 3,50 | |
| Repayment Period | quarterly | |

### Remuneration and Savings

| | | |
|---|---|---|
| Total Payment from Utility in First Year | 2.990,98 | €/Year |
| First year savings | 46.860,35 | €/Year |
| | | |
| EEG 2022 (Juli) Marktprämienmodell - Gebäudeanlage | | |
| Validity | 01.07.2022 - | 31.12.2042 |
| Specific feed-in / export Remuneration | 0,0528 | €/kWh |
| Feed-in / Export Tariff | 2990,9837 | €/Year |
| | | |
| Tarif oshaus & beckert GmbH (Wattline) | | |
| Energy Price | 0,1624 | €/kWh |
| Inflation Rate for Energy Price | 1 | %/Year |

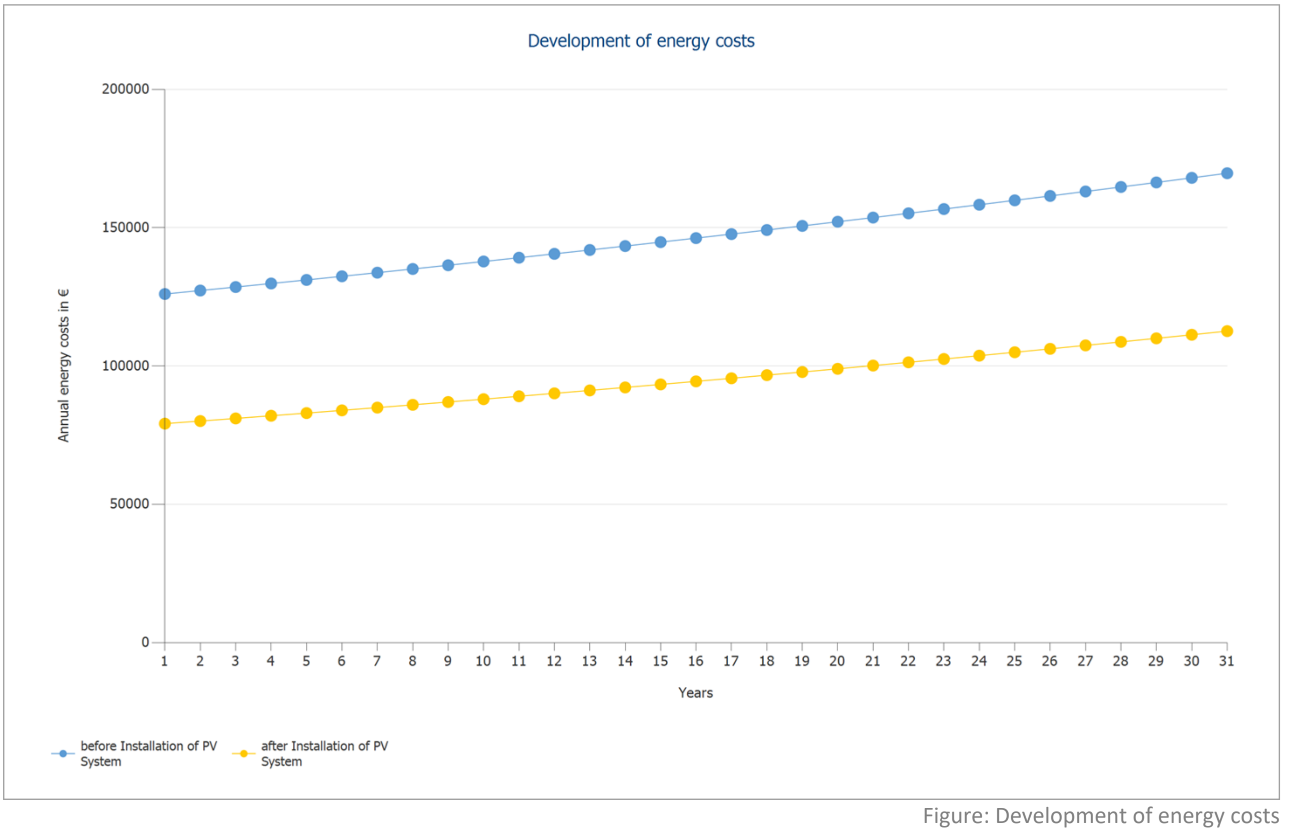



Figure: Development of energy costs

# Cash flow

## Cash flow

| | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| Operating costs | -1.386,14 € | -1.372,41 € | -1.358,83 € | -1.345,37 € | -1.332,05 € |
| Depreciation | -28.227,13 € | -27.947,65 € | -27.670,94 € | -27.396,97 € | -27.125,72 € |
| Self-Financing | -70.188,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 2.961,37 € | 2.922,65 € | 2.884,40 € | 2.846,63 € | 2.809,32 € |
| Electricity Savings | 46.396,39 € | 46.247,67 € | 46.098,95 € | 45.950,24 € | 45.801,52 € |
| Loan repayments | -49.504,95 € | -49.014,80 € | -48.529,51 € | -48.049,02 € | -47.573,28 € |
| Loan Interest | -16.676,98 € | -14.796,34 € | -12.951,31 € | -11.141,37 € | -9.365,99 € |
| Results before Tax | 3.067,51 € | 5.053,91 € | 7.002,28 € | 8.913,15 € | 10.787,08 € |
| Tax Refund | -1.319,03 € | -2.173,18 € | -3.010,98 € | -3.832,66 € | -4.638,44 € |
| Results after Tax | 1.748,48 € | 2.880,73 € | 3.991,30 € | 5.080,50 € | 6.148,64 € |
| **Annual Cash Flow** | **-89.717,34 €** | **-18.186,42 €** | **-16.867,27 €** | **-15.571,55 €** | **-14.298,93 €** |
| Accrued Cash Flow (Cash Balance) | -89.717,34 € | -107.903,76 € | -124.771,03 € | -140.342,58 € | -154.641,51 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -583.406,80 € | -537.782,08 € | -493.168,52 € | -449.549,69 € | -406.909,35 € |

## Cash flow

| | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 |
|---|---|---|---|---|---|
| Operating costs | -1.318,86 € | -1.305,81 € | -1.292,88 € | -1.280,08 € | -1.267,40 € |
| Depreciation | -26.857,14 € | -26.591,23 € | -26.327,95 € | -26.067,28 € | -25.809,19 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 2.772,47 € | 2.736,08 € | 2.700,13 € | 2.664,63 € | 2.629,56 € |
| Electricity Savings | 45.652,80 € | 45.504,08 € | 45.355,35 € | 45.206,66 € | 45.057,92 € |
| Loan repayments | -47.102,26 € | -46.635,90 € | -46.174,16 € | -45.716,99 € | -45.264,35 € |
| Loan Interest | -7.624,68 € | -5.916,93 € | -4.242,25 € | -2.600,15 € | -990,16 € |
| Results before Tax | 12.624,58 € | 14.426,19 € | 16.192,40 € | 17.923,78 € | 19.620,74 € |
| Tax Refund | -5.428,57 € | -6.203,26 € | -6.962,73 € | -7.707,23 € | -8.436,92 € |
| Results after Tax | 7.196,01 € | 8.222,93 € | 9.229,67 € | 10.216,55 € | 11.183,82 € |
| **Annual Cash Flow** | **-13.049,10 €** | **-11.821,74 €** | **-10.616,54 €** | **-9.433,16 €** | **-8.271,34 €** |
| Accrued Cash Flow (Cash Balance) | -167.690,61 € | -179.512,36 € | -190.128,90 € | -199.562,06 € | -207.833,40 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -365.231,51 € | -324.500,42 € | -284.700,55 € | -245.816,56 € | -207.833,40 € |

Cash flow

| | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 |
|---|---|---|---|---|---|
| Operating costs | -1.254,85 € | -1.242,43 € | -1.230,13 € | -1.217,95 € | -1.205,89 € |
| Depreciation | -25.553,65 € | -25.300,64 € | -25.050,14 € | -24.802,12 € | -24.556,56 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 2.594,93 € | 2.560,73 € | 2.526,95 € | 2.493,59 € | 2.460,64 € |
| Electricity Savings | 44.909,21 € | 44.760,48 € | 44.611,78 € | 44.463,05 € | 44.314,34 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 20.695,64 € | 20.778,14 € | 20.858,46 € | 20.936,57 € | 21.012,53 € |
| Tax Refund | -8.899,12 € | -8.934,60 € | -8.969,14 € | -9.002,72 € | -9.035,39 € |
| Results after Tax | 11.796,51 € | 11.843,54 € | 11.889,32 € | 11.933,84 € | 11.977,14 € |
| **Annual Cash Flow** | **37.350,16 €** | **37.144,18 €** | **36.939,46 €** | **36.735,97 €** | **36.533,70 €** |
| Accrued Cash Flow (Cash Balance) | -170.483,23 € | -133.339,05 € | -96.399,58 € | -59.663,62 € | -23.129,92 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -170.483,23 € | -133.339,05 € | -96.399,58 € | -59.663,62 € | -23.129,92 € |

Cash flow

| | Year 16 | Year 17 | Year 18 | Year 19 | Year 20 |
|---|---|---|---|---|---|
| Operating costs | -1.193,95 € | -1.182,13 € | -1.170,42 € | -1.158,84 € | -1.147,36 € |
| Depreciation | -24.313,42 € | -24.072,70 € | -23.834,35 € | -23.598,37 € | -23.364,72 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 2.428,10 € | 2.395,96 € | 2.364,22 € | 2.332,87 € | 2.301,92 € |
| Electricity Savings | 44.165,63 € | 44.016,92 € | 43.868,18 € | 43.719,46 € | 43.570,76 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 21.086,35 € | 21.158,06 € | 21.227,62 € | 21.295,13 € | 21.360,59 € |
| Tax Refund | -9.067,13 € | -9.097,96 € | -9.127,88 € | -9.156,90 € | -9.185,05 € |
| Results after Tax | 12.019,22 € | 12.060,09 € | 12.099,74 € | 12.138,22 € | 12.175,54 € |
| **Annual Cash Flow** | **36.332,64 €** | **36.132,79 €** | **35.934,09 €** | **35.736,59 €** | **35.540,26 €** |
| Accrued Cash Flow (Cash Balance) | 13.202,72 € | 49.335,51 € | 85.269,61 € | 121.006,20 € | 156.546,46 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 13.202,72 € | 49.335,51 € | 85.269,61 € | 121.006,20 € | 156.546,46 € |

## Cash flow

| | Year 21 | Year 22 | Year 23 | Year 24 | Year 25 |
|---|---|---|---|---|---|
| Operating costs | -1.136,00 € | -1.124,75 € | -1.113,62 € | -1.102,59 € | -1.091,68 € |
| Depreciation | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 2.272,40 € | 2.242,87 € | 2.213,03 € | 2.183,56 € | 2.154,46 € |
| Electricity Savings | 43.422,04 € | 43.273,32 € | 43.124,61 € | 42.975,89 € | 42.827,18 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 44.558,44 € | 44.391,44 € | 44.224,02 € | 44.056,85 € | 43.889,96 € |
| Tax Refund | -19.160,13 € | -19.088,32 € | -19.016,33 € | -18.944,45 € | -18.872,68 € |
| Results after Tax | 25.398,31 € | 25.303,12 € | 25.207,69 € | 25.112,41 € | 25.017,28 € |
| **Annual Cash Flow** | **25.398,31 €** | **25.303,12 €** | **25.207,69 €** | **25.112,41 €** | **25.017,28 €** |
| Accrued Cash Flow (Cash Balance) | 181.944,77 € | 207.247,89 € | 232.455,58 € | 257.567,98 € | 282.585,26 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 181.944,77 € | 207.247,89 € | 232.455,58 € | 257.567,98 € | 282.585,26 € |

## Cash flow

| | Year 26 | Year 27 | Year 28 | Year 29 | Year 30 |
|---|---|---|---|---|---|
| Operating costs | -1.080,87 € | -1.070,17 € | -1.059,57 € | -1.049,08 € | -1.038,69 € |
| Depreciation | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 2.125,71 € | 2.097,33 € | 2.069,30 € | 2.041,62 € | 2.014,29 € |
| Electricity Savings | 42.678,45 € | 42.529,72 € | 42.381,02 € | 42.232,30 € | 42.083,59 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 43.723,30 € | 43.556,89 € | 43.390,75 € | 43.224,84 € | 43.059,18 € |
| Tax Refund | -18.801,02 € | -18.729,46 € | -18.658,02 € | -18.586,68 € | -18.515,45 € |
| Results after Tax | 24.922,28 € | 24.827,43 € | 24.732,73 € | 24.638,16 € | 24.543,73 € |
| **Annual Cash Flow** | **24.922,28 €** | **24.827,43 €** | **24.732,73 €** | **24.638,16 €** | **24.543,73 €** |
| Accrued Cash Flow (Cash Balance) | 307.507,54 € | 332.334,97 € | 357.067,70 € | 381.705,86 € | 406.249,59 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 307.507,54 € | 332.334,97 € | 357.067,70 € | 381.705,86 € | 406.249,59 € |

## Cash flow

| | Year 31 |
|---|---|
| Operating costs | -1.028,41 € |
| Depreciation | 0,00 € |
| Self-Financing | 0,00 € |
| Feed-in / Export Tariff | 1.987,30 € |
| Electricity Savings | 41.934,87 € |
| Loan repayments | 0,00 € |
| Loan Interest | 0,00 € |
| Results before Tax | 42.893,75 € |
| Tax Refund | -18.444,31 € |
| Results after Tax | 24.449,44 € |
| **Annual Cash Flow** | **24.449,44 €** |
| Accrued Cash Flow (Cash Balance) | 430.699,03 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 430.699,03 € |

Degradation and inflation rates are applied on a monthly basis over the entire observation period. This is done in the first year.

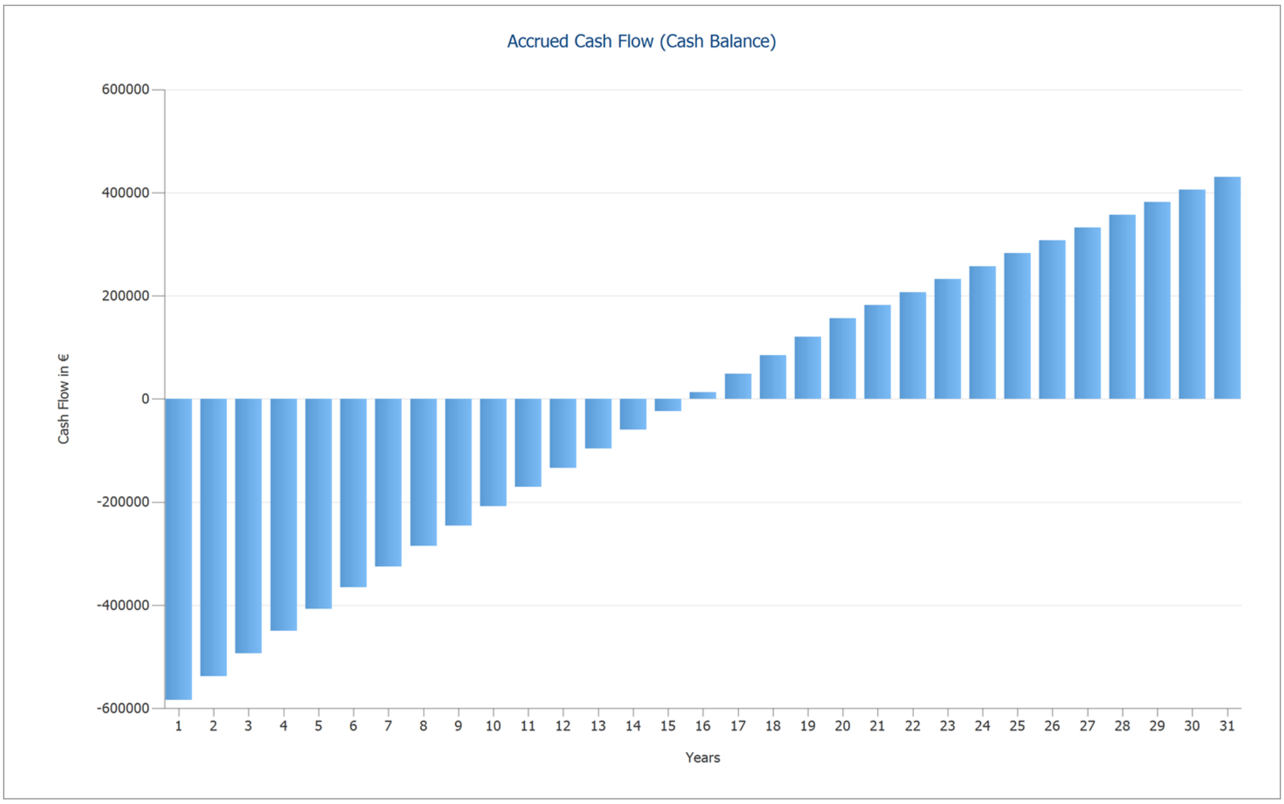



Figure: Accrued Cash Flow (Cash Balance)

# Plans and parts list

## Circuit Diagram

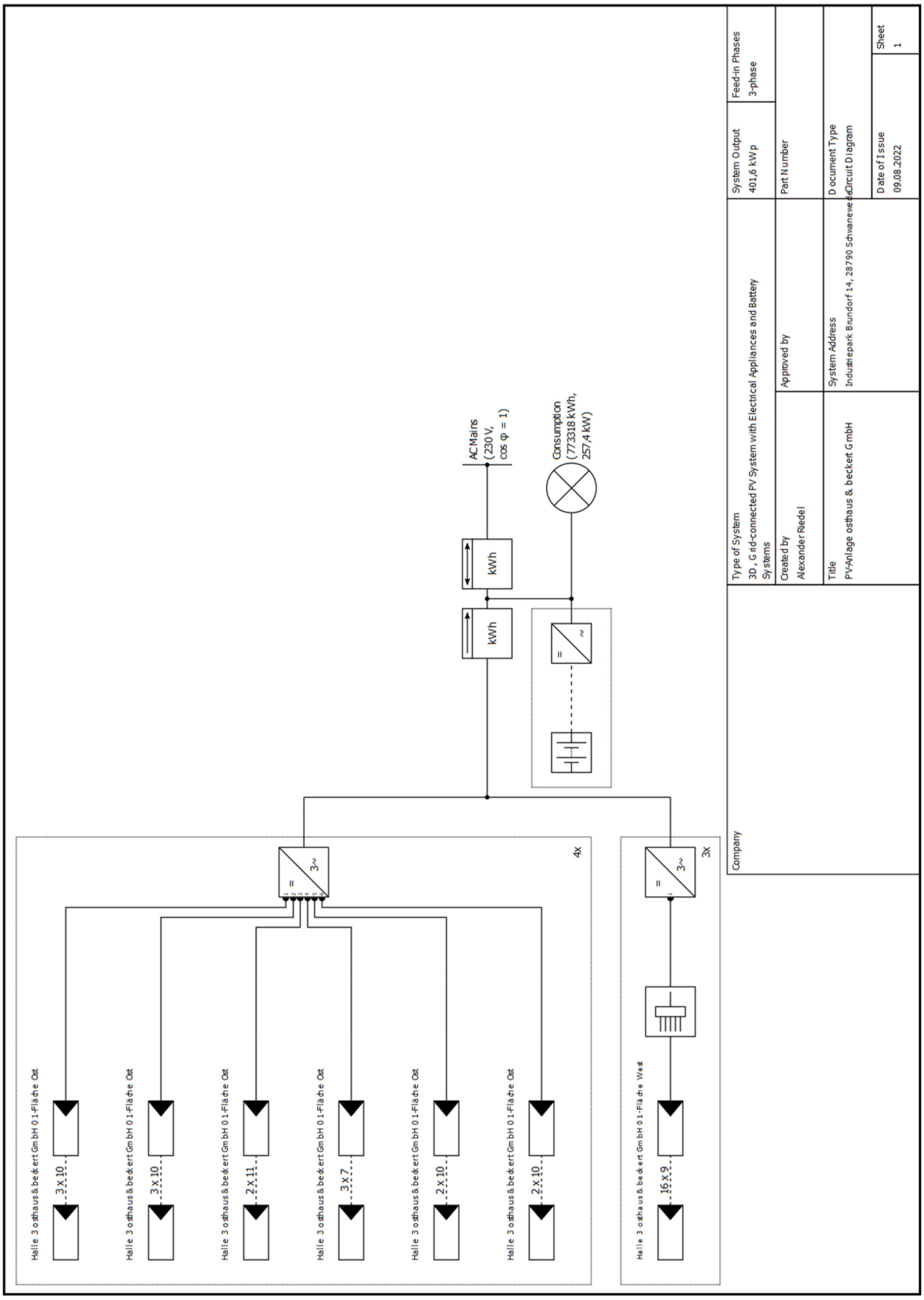



Figure: Circuit Diagram

# Overview plan

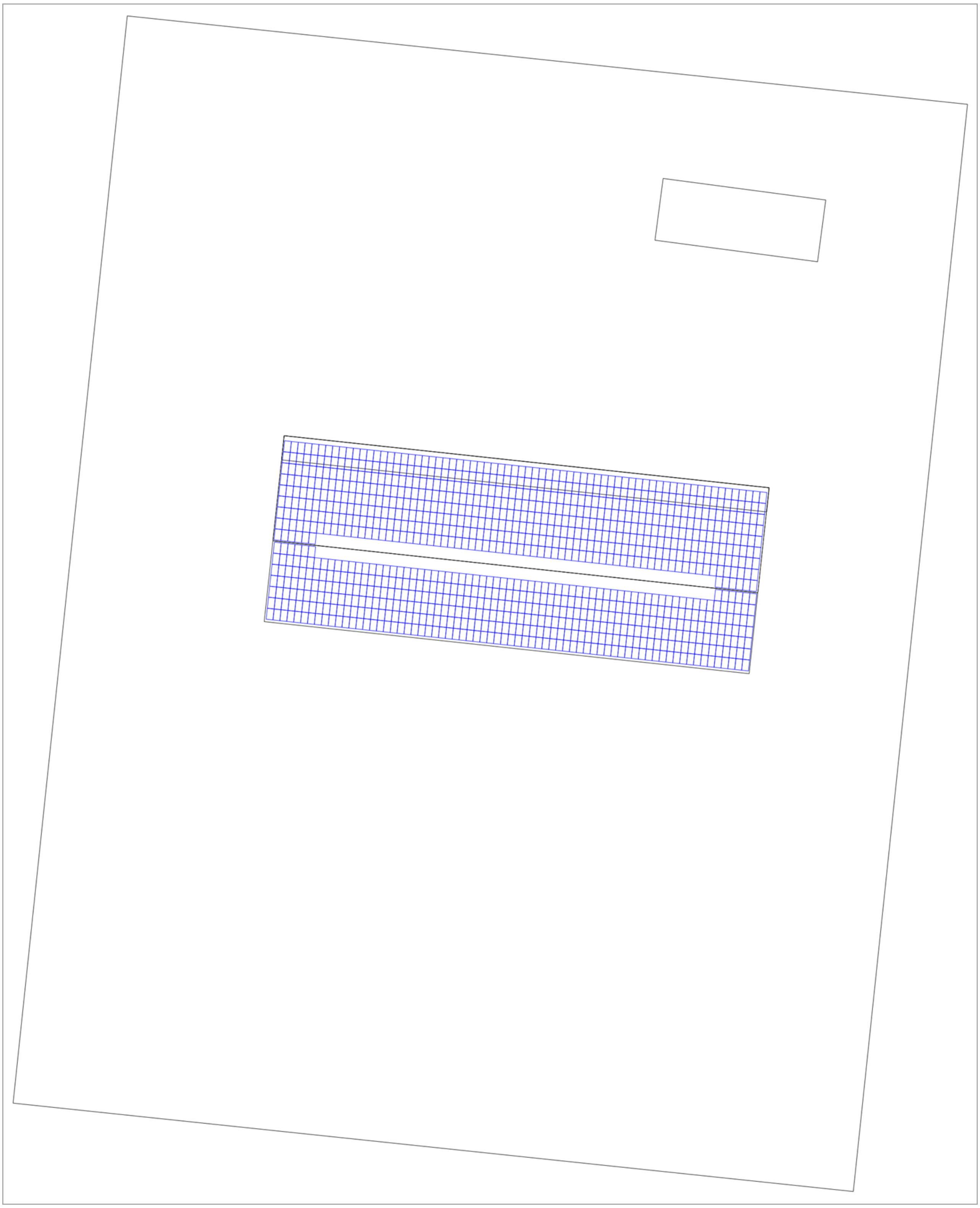


Figure: Overview plan

# Dimensioning Plan

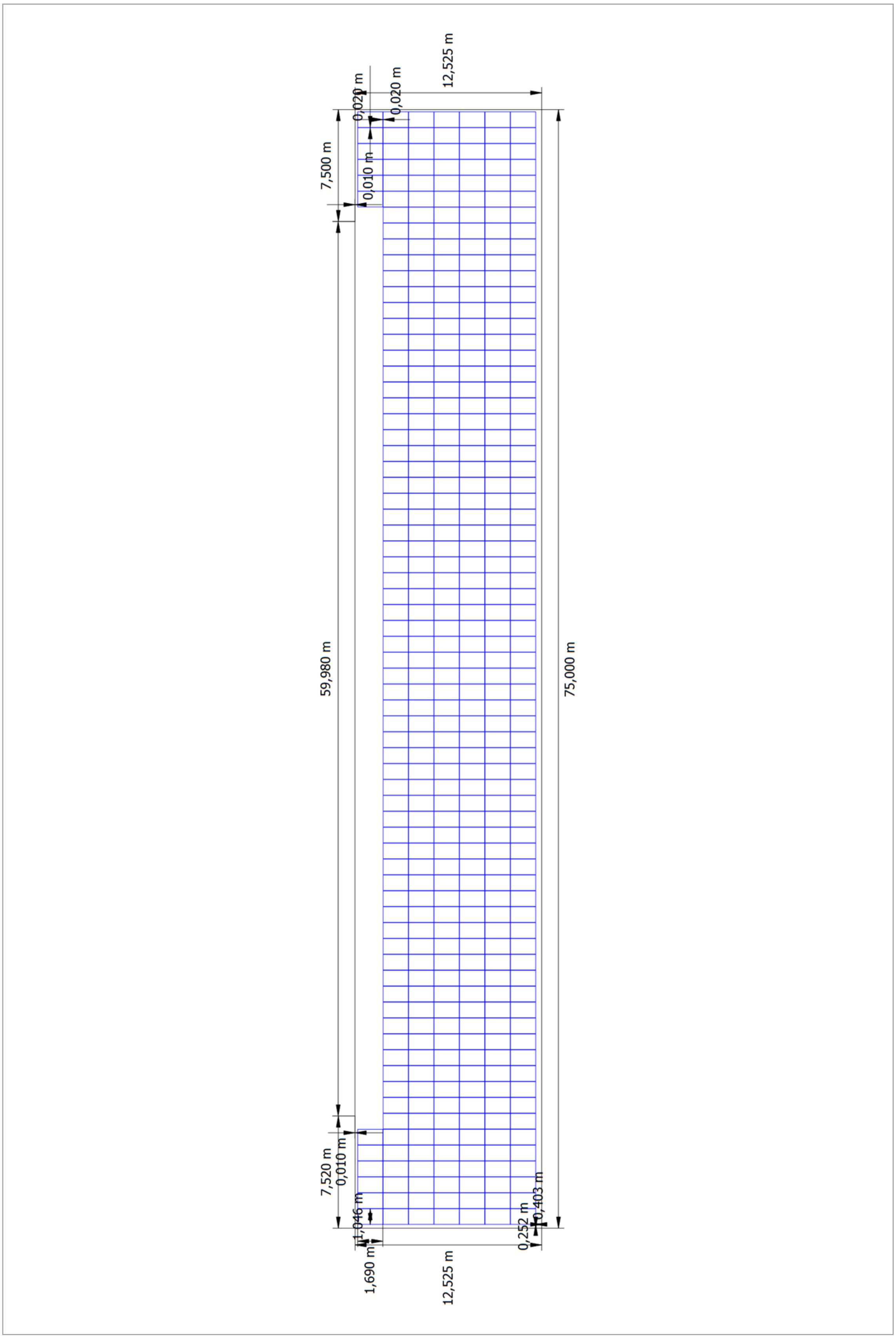



Figure: Halle 3 osthaus & beckert GmbH 01-Fläche West

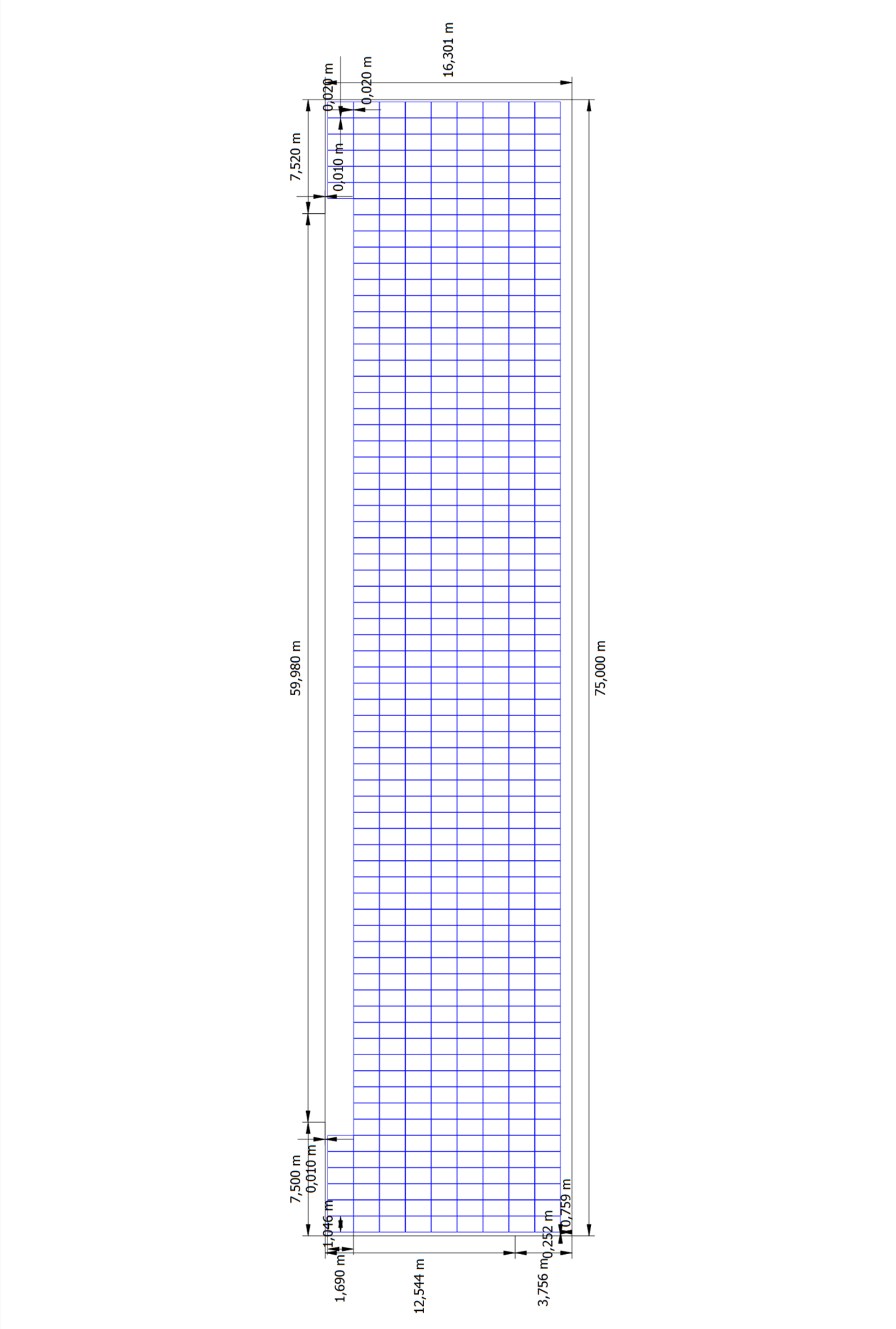



Figure: Halle 3 osthaus & beckert GmbH 01-Fläche Ost

# String Plan

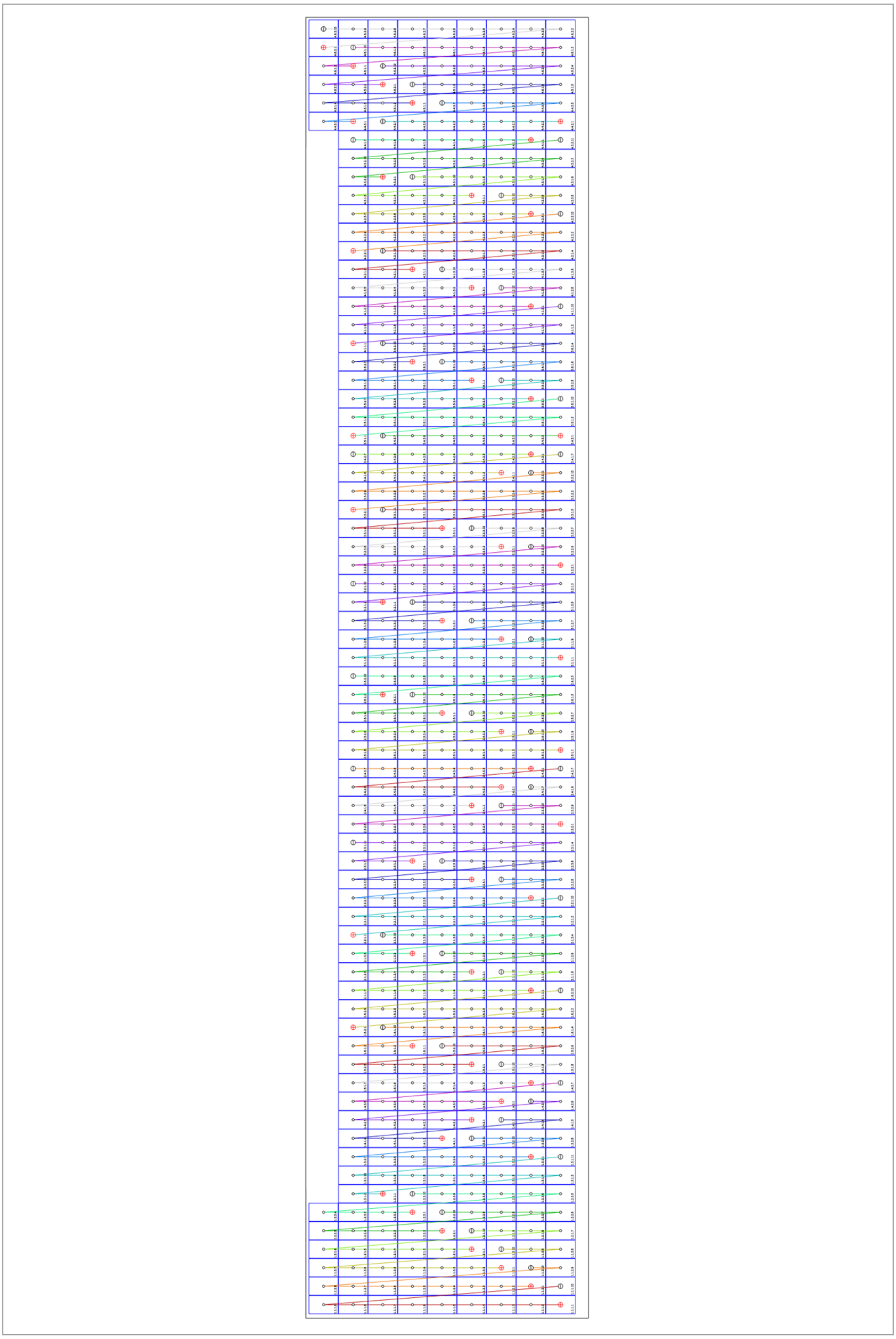


Figure: Halle 3 osthaus & beckert GmbH 01-Fläche Ost

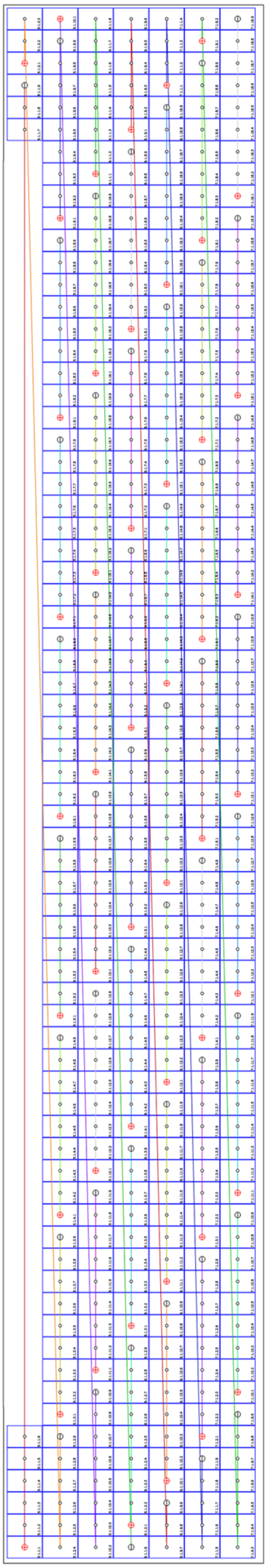


Figure: Halle 3 osthaus & beckert GmbH 01-Fläche West

# Parts list

## Parts list

| # | Type | Item number | Manufacturer | Name | Quantity | Unit |
|---|---|---|---|---|---|---|
| 1 | PV Module | | SunPower | SPR-MAX3-400 | 1004 | Piece |
| 2 | Inverter | | Huawei Technologies | SUN2000-50KTL-M0 (400Vac) | 7 | Piece |
| 3 | Battery System | | VARTA Storage GmbH | VARTA flex storage E 120kW/375kWh | 1 | Piece |
| 4 | Components | | | Feed-in Meter | 1 | Piece |
| 5 | Components | | | Bidirectional Meter | 1 | Piece |

## Annex F: Simulation report Scenario 1 (Full Feeder)

**osthaus & beckert GmbH**
Beckert, Andreas; Osthaus, Christian
Industriepark Brundorf 14, 28790
Schwanewede

**Customer No.:** 123456789
**Project Name:** PV-Anlage osthaus & beckert GmbH
**Offer no.:** 123456

09.08.2022

# Your PV system

### Address of Installation

Industriepark Brundorf 14, 28790 Schwanewede


Project Description:
Planning of a company-owned PV system for osthaus & beckert GmbH

# Project Overview

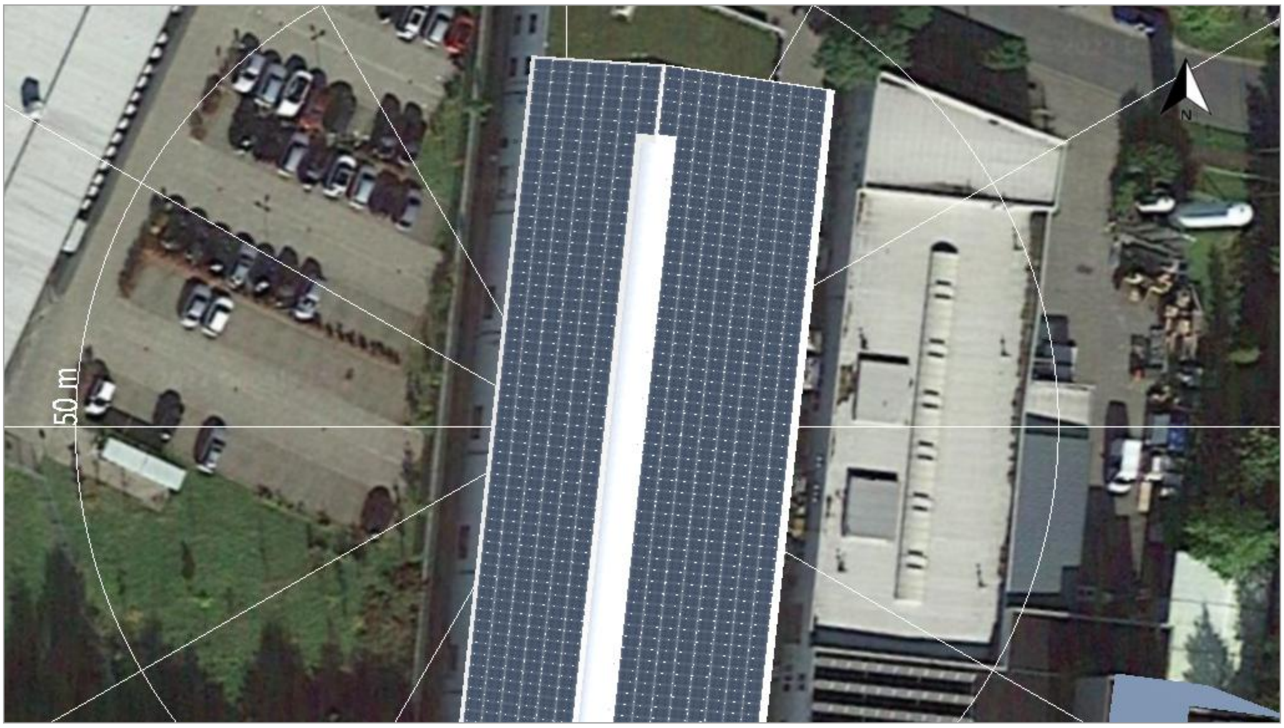



Figure: Overview Image, 3D Design

## PV System

3D, Grid-connected PV System

| | | |
|---|---|---|
| Climate Data | Osterholz-Scharmbeck, DEU (1995 - 2012) | |
| Values source | DWD | |
| PV Generator Output | 401,6 | kWp |
| PV Generator Surface | 1.774,8 | m² |
| Number of PV Modules | 1004 | |
| Number of Inverters | 7 | |

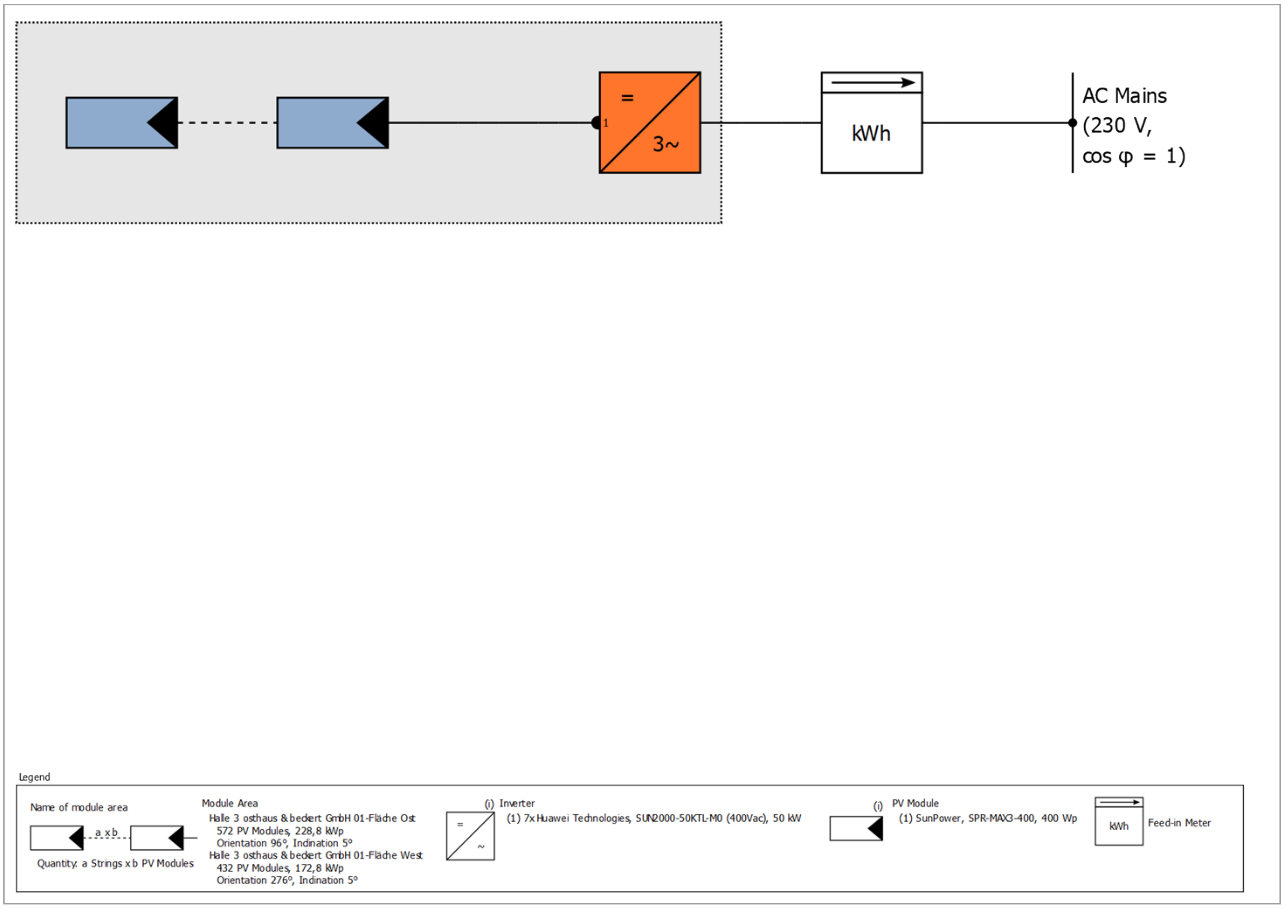



Figure: Schematic diagram

# Production Forecast

| Production Forecast | | |
|---|---|---|
| PV Generator Output | 401,60 | kWp |
| Spec. Annual Yield | 873,91 | kWh/kWp |
| Performance Ratio (PR) | 88,85 | % |
| Yield Reduction due to Shading | 0,6 | %/Year |
| | | |
| Grid Feed-in | 351.129 | kWh/Year |
| Grid Feed-in in the first year (incl. module degradation) | 350.496 | kWh/Year |
| Standby Consumption (Inverter) | 166 | kWh/Year |
| | | |
| $CO_2$ Emissions avoided | 170.217 | kg / year |

# Financial Analysis

| Your Gain | | |
|---|---|---|
| Total investment costs | 319.981,00 | € |
| Internal Rate of Return of Capital Resources | 2,17 | % |
| Amortization Period | 25,2 | Years |
| Electricity Production Costs | 0,0416 | €/kWh |
| Energy Balance/Feed-in Concept | Full Feed-in | |

The results have been calculated with a mathematical model calculation from Valentin Software GmbH (PV*SOL algorithms). The actual yields from the solar power system may differ as a result of weather variations, the efficiency of the modules and inverter, and other factors.

# Set-up of the System

## Overview

| System Data | |
|---|---|
| Type of System | 3D, Grid-connected PV System |

| Climate Data | |
|---|---|
| Location | Osterholz-Scharmbeck, DEU (1995 - 2012) |
| Values source | DWD |
| Resolution of the data | 1 min |
| Simulation models used: | |
| - Diffuse Irradiation onto Horizontal Plane | Hofmann |
| - Irradiance onto tilted surface | Hay & Davies |

## Module Areas

### 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost

| PV Generator, 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost | | |
|---|---|---|
| Name | Halle 3 osthaus & beckert GmbH 01-Fläche Ost | |
| PV Modules | 572 x SPR-MAX3-400 (v1) | |
| Manufacturer | SunPower | |
| Inclination | 5 | ° |
| Orientation | East 96 | ° |
| Installation Type | Roof parallel | |
| PV Generator Surface | 1.011,1 | m² |

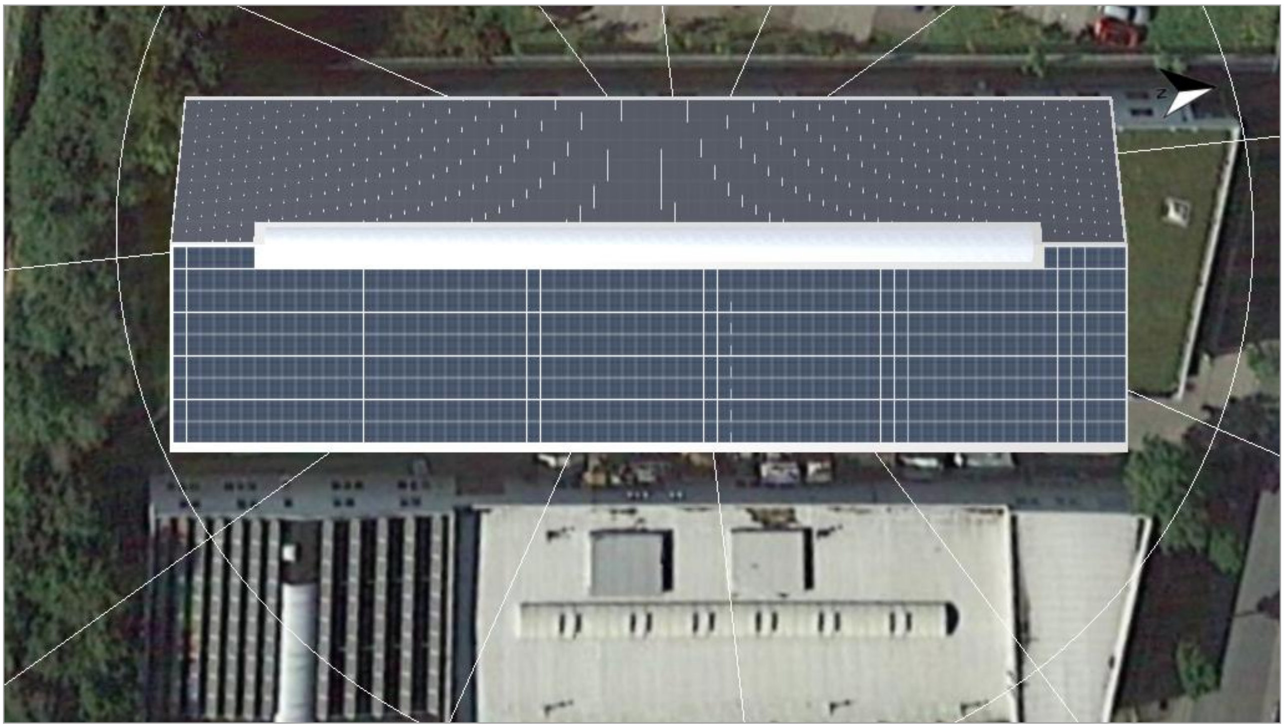


Figure: 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost

## *2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West*

### PV Generator, 2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West

| | |
|---|---|
| Name | Halle 3 osthaus & beckert GmbH 01-Fläche West |
| PV Modules | 432 x SPR-MAX3-400 (v1) |
| Manufacturer | SunPower |
| Inclination | 5 ° |
| Orientation | West 276 ° |
| Installation Type | Roof parallel |
| PV Generator Surface | 763,7 m² |

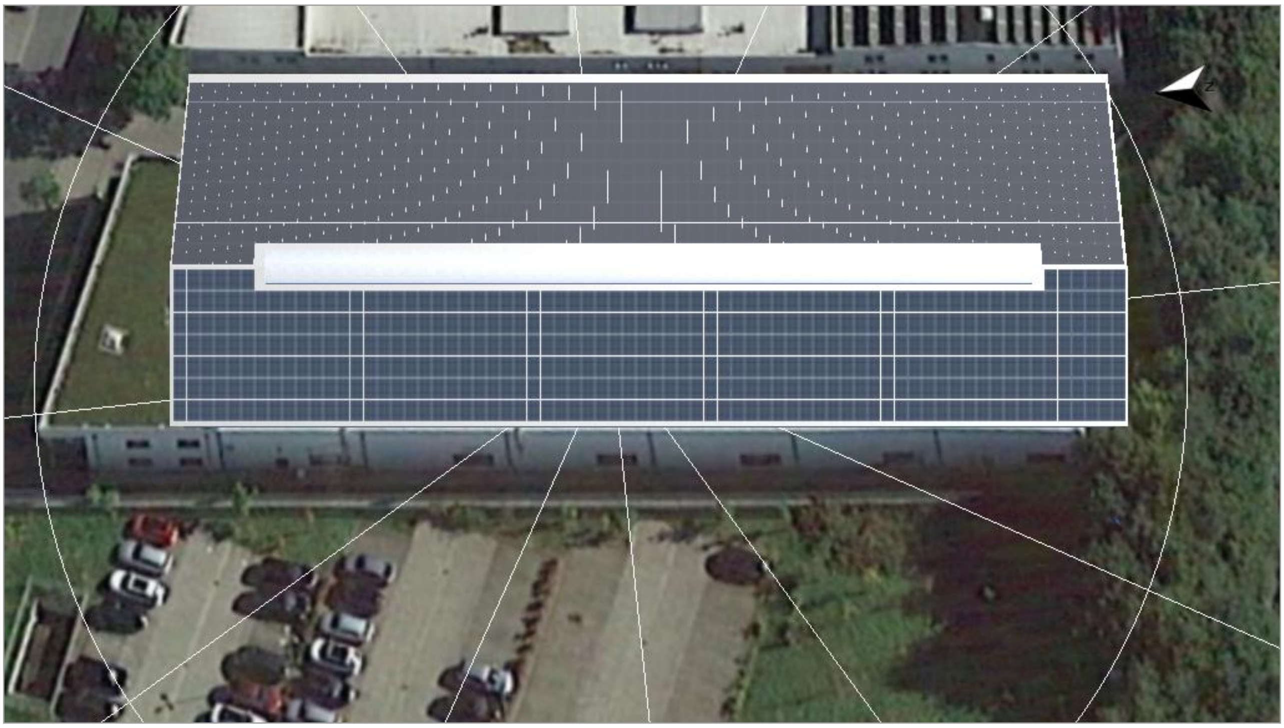


Figure: 2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West

# Horizon Line, 3D Design

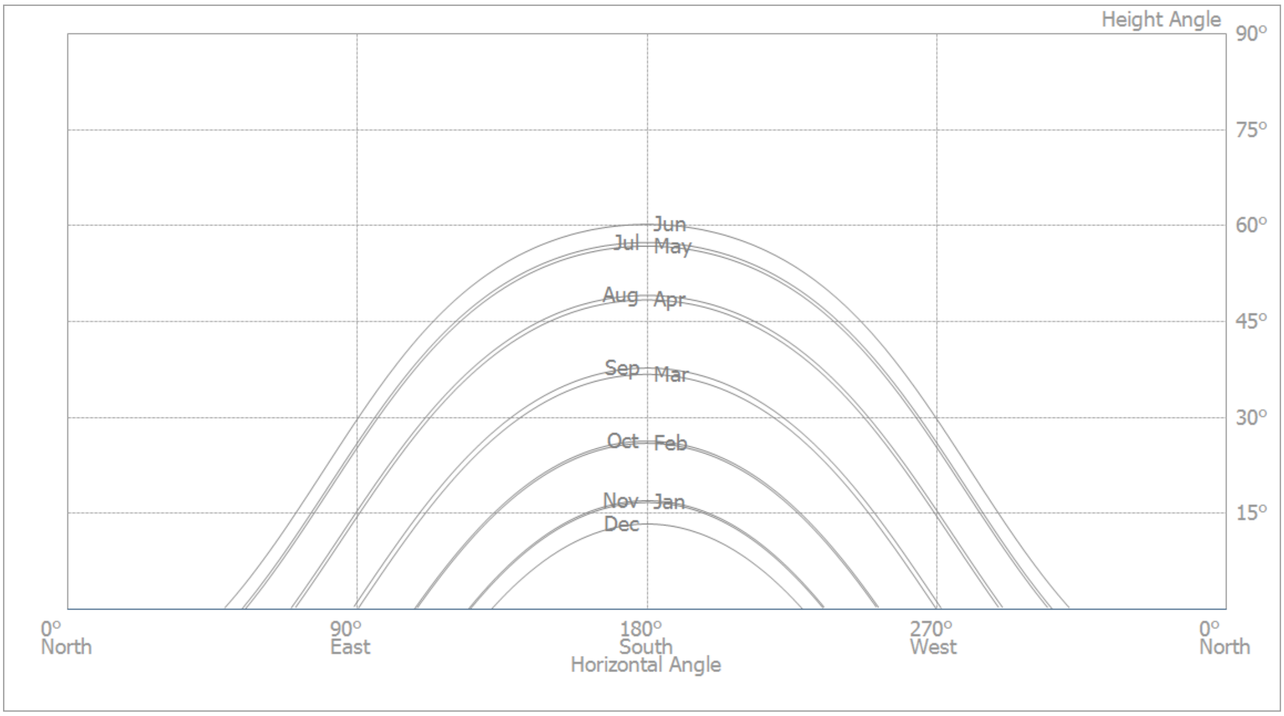



Figure: Horizon (3D Design)

# Inverter configuration

## Configuration 1

| | |
|---|---|
| Module Area | Halle 3 osthaus & beckert GmbH 01-Fläche Ost |
| Inverter 1 | |
| Model | SUN2000-50KTL-M0 (400Vac) (v1) |
| Manufacturer | Huawei Technologies |
| Quantity | 4 |
| Sizing Factor | 114,4 % |
| Configuration | MPP 1: 3 x 10 |
| | MPP 2: 3 x 10 |
| | MPP 3: 2 x 11 |
| | MPP 4: 3 x 7 |
| | MPP 5: 2 x 10 |
| | MPP 6: 2 x 10 |

## Configuration 2

| | |
|---|---|
| Module Area | Halle 3 osthaus & beckert GmbH 01-Fläche West |
| Inverter 1 | |
| Model | SUN2000-50KTL-M0 (400Vac) (v1) |
| Manufacturer | Huawei Technologies |
| Quantity | 3 |
| Sizing Factor | 115,2 % |
| Configuration | MPP 1+2+3+4+5+6: 16 x 9 |

# AC Mains

## AC Mains

| | |
|---|---|
| Number of Phases | 3 |
| Mains voltage between phase and neutral | 230 V |
| Displacement Power Factor (cos phi) | +/- 1 |

# Simulation Results

## Results Total System

### PV System

| | |
|---|---|
| PV Generator Output | 401,60 kWp |
| Spec. Annual Yield | 873,91 kWh/kWp |
| Performance Ratio (PR) | 88,85 % |
| Yield Reduction due to Shading | 0,6 %/Year |
| Grid Feed-in | 351.129 kWh/Year |
| Grid Feed-in in the first year (incl. module degradation) | 350.496 kWh/Year |
| Standby Consumption (Inverter) | 166 kWh/Year |
| $CO_2$ Emissions avoided | 170.217 kg / year |

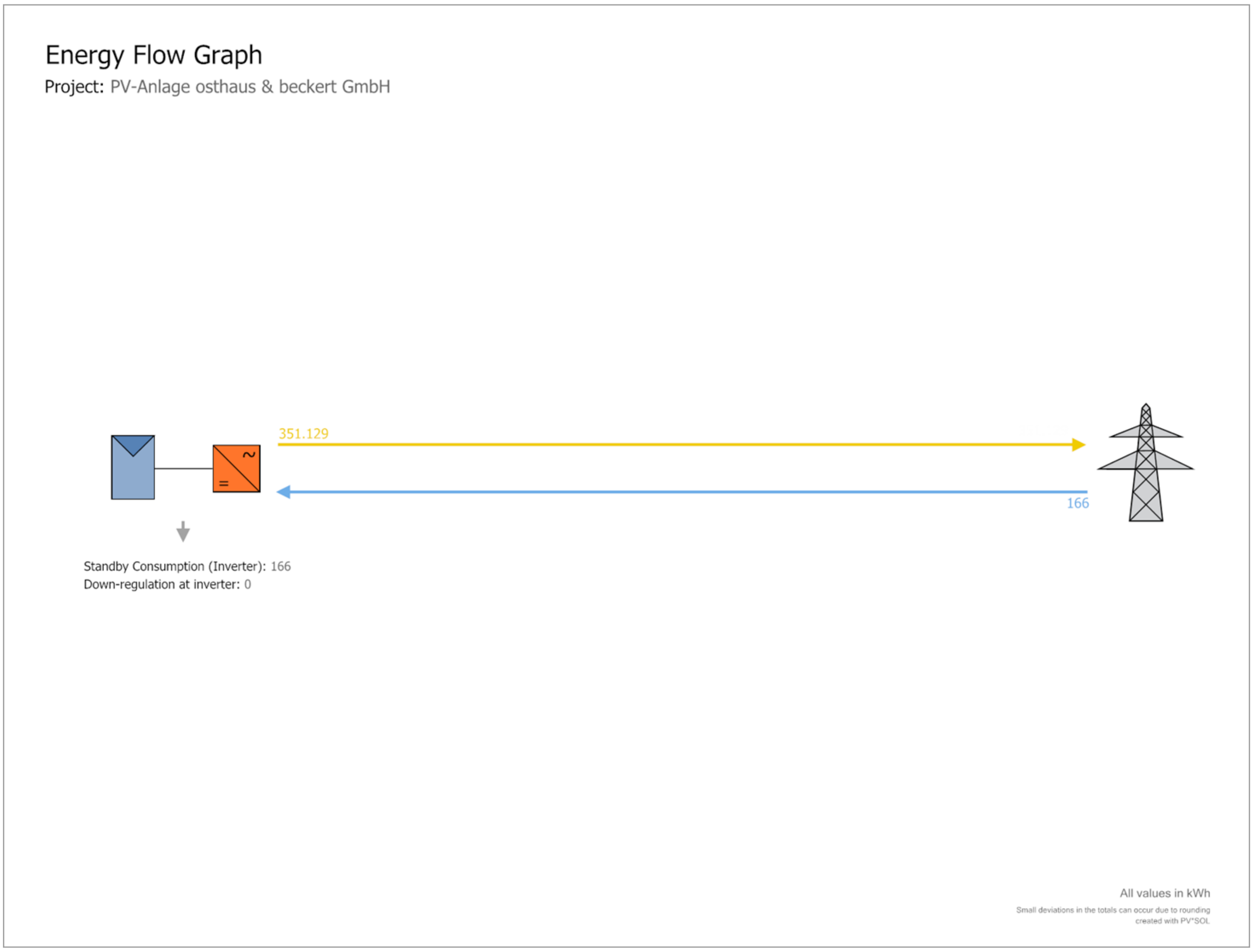



Figure: Energy flow

# Yield for EnEV

## Yield in accordance with DIN 15316-4-6

| | |
|---|---|
| January | 5227 kWh |
| February | 7163,2 kWh |
| March | 17483,5 kWh |
| April | 32967 kWh |
| May | 39833,6 kWh |
| June | 42037,2 kWh |
| July | 37851 kWh |
| August | 32443,7 kWh |
| September | 22152,4 kWh |
| October | 13878,7 kWh |
| November | 5407,3 kWh |
| December | 3064,1 kWh |
| **Annual Value** | **259.508,8 kWh** |

Boundary Conditions:
Climate Data according to DIN V 18599-10
HALLE 3 OSTHAUS & BECKERT GMBH 01-FLÄCHE OST
System Power Factor: 0.75
Peak Power Coefficient: 0.182
Orientation: East
Inclination: 0°

HALLE 3 OSTHAUS & BECKERT GMBH 01-FLÄCHE WEST
System Power Factor: 0.75
Peak Power Coefficient: 0.182
Orientation: West
Inclination: 0°

# Financial Analysis

## Overview

### System Data

| | | |
|---|---|---|
| Grid Feed-in in the first year (incl. module degradation) | 350.496 | kWh/Year |
| PV Generator Output | 401,6 | kWp |
| Start of Operation of the System | 01.07.2022 | |
| Assessment Period | 30 | Years |
| Interest on Capital | 1 | % |

### Economic Parameters

| | | |
|---|---|---|
| Internal Rate of Return of Capital Resources | 2,17 | % |
| Accrued Cash Flow (Cash Balance) | 38.691,90 | € |
| Amortization Period | 25,2 | Years |
| Electricity Production Costs | 0,0416 | €/kWh |

### Payment Overview

| | | |
|---|---|---|
| Specific Investment Costs | 796,77 | €/kWp |
| Investment Costs | 319.981,00 | € |
| One-off Payments | 0,00 | € |
| Incoming Subsidies | 0,00 | € |
| Annual Costs | 1.400,00 | €/Year |
| Other Revenue or Savings | 0,00 | €/Year |

### Loans

| **Reference** | **Loan 1** | |
|---|---|---|
| Loan Capital | 250.000,00 | € |
| Payment Installment | 100,00 | % |
| Credit type | Installment Loan | |
| Term | 10,00 | Years |
| Grace period | 0,00 | Years |
| Interest | 3,50 | |
| Repayment Period | quarterly | |

### Remuneration and Savings

| | | |
|---|---|---|
| Total Payment from Utility in First Year | 18.492,00 | €/Year |
| | | |
| EEG 2022 (Juli) Marktprämienmodell - Gebäudeanlage | | |
| Validity | 01.07.2022 - 31.12.2042 | |
| Specific feed-in / export Remuneration | 0,0528 | €/kWh |
| Feed-in / Export Tariff | 18492,003 | €/Year |

# Cash flow

## Cash flow

| | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| Operating costs | -1.386,14 € | -1.372,41 € | -1.358,83 € | -1.345,37 € | -1.332,05 € |
| Depreciation | -15.840,64 € | -15.683,81 € | -15.528,52 € | -15.374,77 € | -15.222,55 € |
| Self-Financing | -69.981,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 18.308,91 € | 18.069,52 € | 17.833,08 € | 17.599,55 € | 17.368,89 € |
| Loan repayments | -24.752,48 € | -24.507,40 € | -24.264,75 € | -24.024,51 € | -23.786,64 € |
| Loan Interest | -8.338,49 € | -7.398,17 € | -6.475,66 € | -5.570,68 € | -4.683,00 € |
| Results before Tax | -7.256,36 € | -6.384,87 € | -5.529,92 € | -4.691,28 € | -3.868,70 € |
| Tax Refund | 3.120,23 € | 2.745,49 € | 2.377,87 € | 2.017,25 € | 1.663,54 € |
| Results after Tax | -4.136,12 € | -3.639,37 € | -3.152,06 € | -2.674,03 € | -2.205,16 € |
| **Annual Cash Flow** | **-83.028,96 €** | **-12.462,97 €** | **-11.888,29 €** | **-11.323,77 €** | **-10.769,26 €** |
| Accrued Cash Flow (Cash Balance) | -83.028,96 € | -95.491,93 € | -107.380,22 € | -118.703,98 € | -129.473,24 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -329.873,69 € | -310.431,08 € | -291.578,96 € | -273.307,54 € | -255.607,16 € |

## Cash flow

| | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 |
|---|---|---|---|---|---|
| Operating costs | -1.318,86 € | -1.305,81 € | -1.292,88 € | -1.280,08 € | -1.267,40 € |
| Depreciation | -15.071,83 € | -14.922,60 € | -14.774,85 € | -14.628,57 € | -14.483,73 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 17.141,07 € | 16.916,07 € | 16.693,84 € | 16.474,35 € | 16.257,57 € |
| Loan repayments | -23.551,13 € | -23.317,95 € | -23.087,08 € | -22.858,50 € | -22.632,17 € |
| Loan Interest | -3.812,34 € | -2.958,47 € | -2.121,13 € | -1.300,08 € | -495,08 € |
| Results before Tax | -3.061,96 € | -2.270,80 € | -1.495,02 € | -734,37 € | 11,36 € |
| Tax Refund | 1.316,64 € | 976,45 € | 642,86 € | 315,78 € | -4,88 € |
| Results after Tax | -1.745,32 € | -1.294,36 € | -852,16 € | -418,59 € | 6,47 € |
| **Annual Cash Flow** | **-10.224,62 €** | **-9.689,71 €** | **-9.164,39 €** | **-8.648,52 €** | **-8.141,97 €** |
| Accrued Cash Flow (Cash Balance) | -139.697,86 € | -149.387,56 € | -158.551,95 € | -167.200,47 € | -175.342,44 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -238.468,30 € | -221.881,59 € | -205.837,77 € | -190.327,72 € | -175.342,44 € |

## Cash flow

| | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 |
|---|---|---|---|---|---|
| Operating costs | -1.254,85 € | -1.242,43 € | -1.230,13 € | -1.217,95 € | -1.205,89 € |
| Depreciation | -14.340,33 € | -14.198,34 € | -14.057,77 € | -13.918,58 € | -13.780,77 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 16.043,47 € | 15.832,01 € | 15.623,17 € | 15.416,91 € | 15.213,21 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 448,29 € | 391,24 € | 335,28 € | 280,39 € | 226,55 € |
| Tax Refund | -192,76 € | -168,23 € | -144,17 € | -120,57 € | -97,42 € |
| Results after Tax | 255,52 € | 223,01 € | 191,11 € | 159,82 € | 129,13 € |
| **Annual Cash Flow** | **14.595,85 €** | **14.421,35 €** | **14.248,88 €** | **14.078,40 €** | **13.909,91 €** |
| Accrued Cash Flow (Cash Balance) | -160.746,59 € | -146.325,23 € | -132.076,36 € | -117.997,96 € | -104.088,05 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -160.746,59 € | -146.325,23 € | -132.076,36 € | -117.997,96 € | -104.088,05 € |

## Cash flow

| | Year 16 | Year 17 | Year 18 | Year 19 | Year 20 |
|---|---|---|---|---|---|
| Operating costs | -1.193,95 € | -1.182,13 € | -1.170,42 € | -1.158,84 € | -1.147,36 € |
| Depreciation | -13.644,33 € | -13.509,24 € | -13.375,48 € | -13.243,05 € | -13.111,93 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 15.012,03 € | 14.813,34 € | 14.617,11 € | 14.423,32 € | 14.231,93 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 173,75 € | 121,97 € | 71,20 € | 21,43 € | -27,37 € |
| Tax Refund | -74,71 € | -52,45 € | -30,62 € | -9,21 € | 11,77 € |
| Results after Tax | 99,04 € | 69,52 € | 40,59 € | 12,22 € | -15,60 € |
| **Annual Cash Flow** | **13.743,37 €** | **13.578,76 €** | **13.416,07 €** | **13.255,27 €** | **13.096,33 €** |
| Accrued Cash Flow (Cash Balance) | -90.344,69 € | -76.765,92 € | -63.349,86 € | -50.094,59 € | -36.998,25 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -90.344,69 € | -76.765,92 € | -63.349,86 € | -50.094,59 € | -36.998,25 € |

## Cash flow

| | Year 21 | Year 22 | Year 23 | Year 24 | Year 25 |
|---|---|---|---|---|---|
| Operating costs | -1.136,00 € | -1.124,75 € | -1.113,62 € | -1.102,59 € | -1.091,68 € |
| Depreciation | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 14.048,77 € | 13.866,87 € | 13.682,38 € | 13.500,19 € | 13.320,27 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 12.912,76 € | 12.742,12 € | 12.568,77 € | 12.397,60 € | 12.228,59 € |
| Tax Refund | -5.552,49 € | -5.479,11 € | -5.404,57 € | -5.330,97 € | -5.258,29 € |
| Results after Tax | 7.360,27 € | 7.263,01 € | 7.164,20 € | 7.066,63 € | 6.970,30 € |
| **Annual Cash Flow** | **7.360,27 €** | **7.263,01 €** | **7.164,20 €** | **7.066,63 €** | **6.970,30 €** |
| Accrued Cash Flow (Cash Balance) | -29.637,98 € | -22.374,97 € | -15.210,78 € | -8.144,14 € | -1.173,85 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -29.637,98 € | -22.374,97 € | -15.210,78 € | -8.144,14 € | -1.173,85 € |

## Cash flow

| | Year 26 | Year 27 | Year 28 | Year 29 | Year 30 |
|---|---|---|---|---|---|
| Operating costs | -1.080,87 € | -1.070,17 € | -1.059,57 € | -1.049,08 € | -1.038,69 € |
| Depreciation | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 13.142,58 € | 12.967,10 € | 12.793,82 € | 12.622,69 € | 12.453,70 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 12.061,71 € | 11.896,94 € | 11.734,25 € | 11.573,61 € | 11.415,00 € |
| Tax Refund | -5.186,54 € | -5.115,68 € | -5.045,73 € | -4.976,65 € | -4.908,45 € |
| Results after Tax | 6.875,18 € | 6.781,26 € | 6.688,52 € | 6.596,96 € | 6.506,55 € |
| **Annual Cash Flow** | **6.875,18 €** | **6.781,26 €** | **6.688,52 €** | **6.596,96 €** | **6.506,55 €** |
| Accrued Cash Flow (Cash Balance) | 5.701,33 € | 12.482,58 € | 19.171,10 € | 25.768,06 € | 32.274,61 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 5.701,33 € | 12.482,58 € | 19.171,10 € | 25.768,06 € | 32.274,61 € |

## Cash flow

| | Year 31 |
|---|---|
| Operating costs | -1.028,41 € |
| Depreciation | 0,00 € |
| Self-Financing | 0,00 € |
| Feed-in / Export Tariff | 12.286,81 € |
| Loan repayments | 0,00 € |
| Loan Interest | 0,00 € |
| Results before Tax | 11.258,40 € |
| Tax Refund | -4.841,11 € |
| Results after Tax | 6.417,29 € |
| **Annual Cash Flow** | **6.417,29 €** |
| Accrued Cash Flow (Cash Balance) | 38.691,90 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 38.691,90 € |

Degradation and inflation rates are applied on a monthly basis over the entire observation period. This is done in the first year.

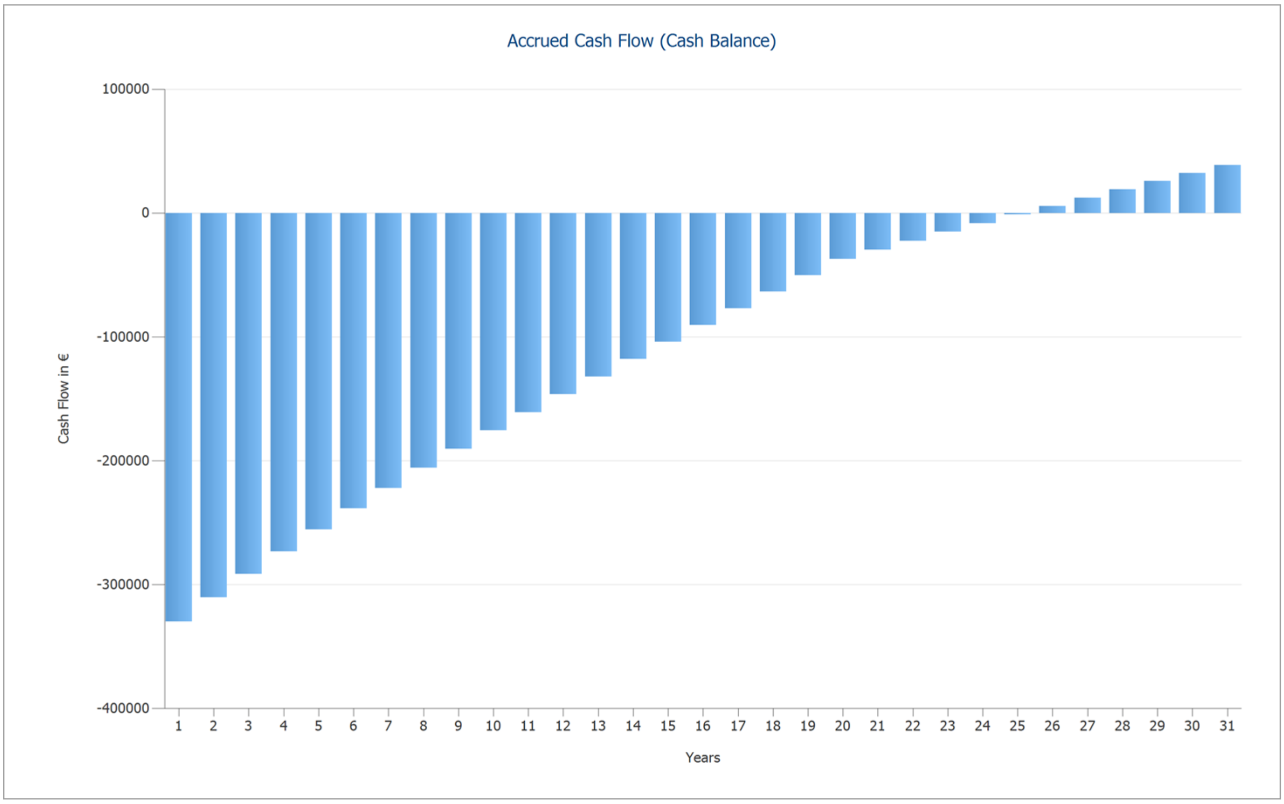



Figure: Accrued Cash Flow (Cash Balance)

# Plans and parts list

## Circuit Diagram

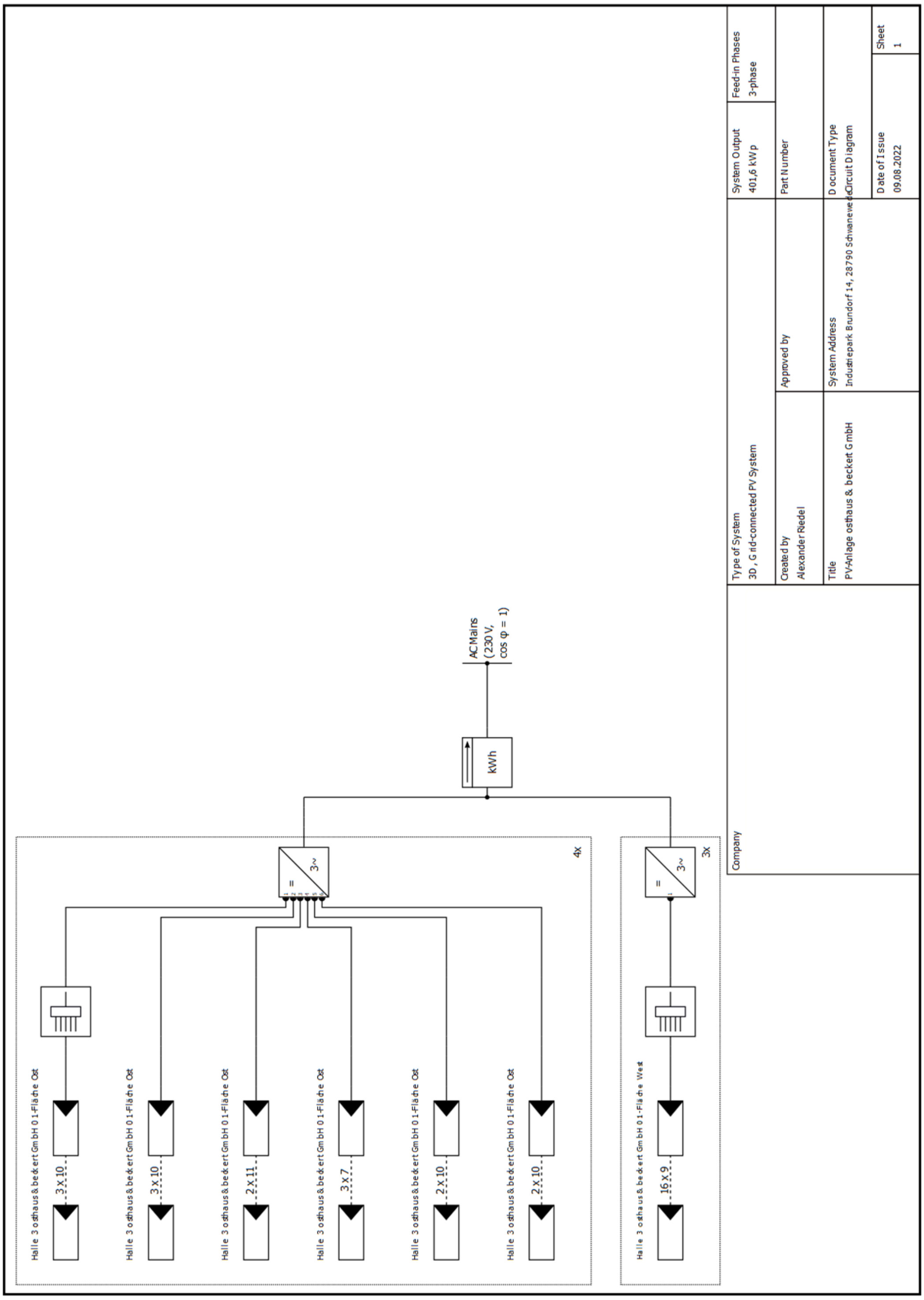



Figure: Circuit Diagram

# Overview plan

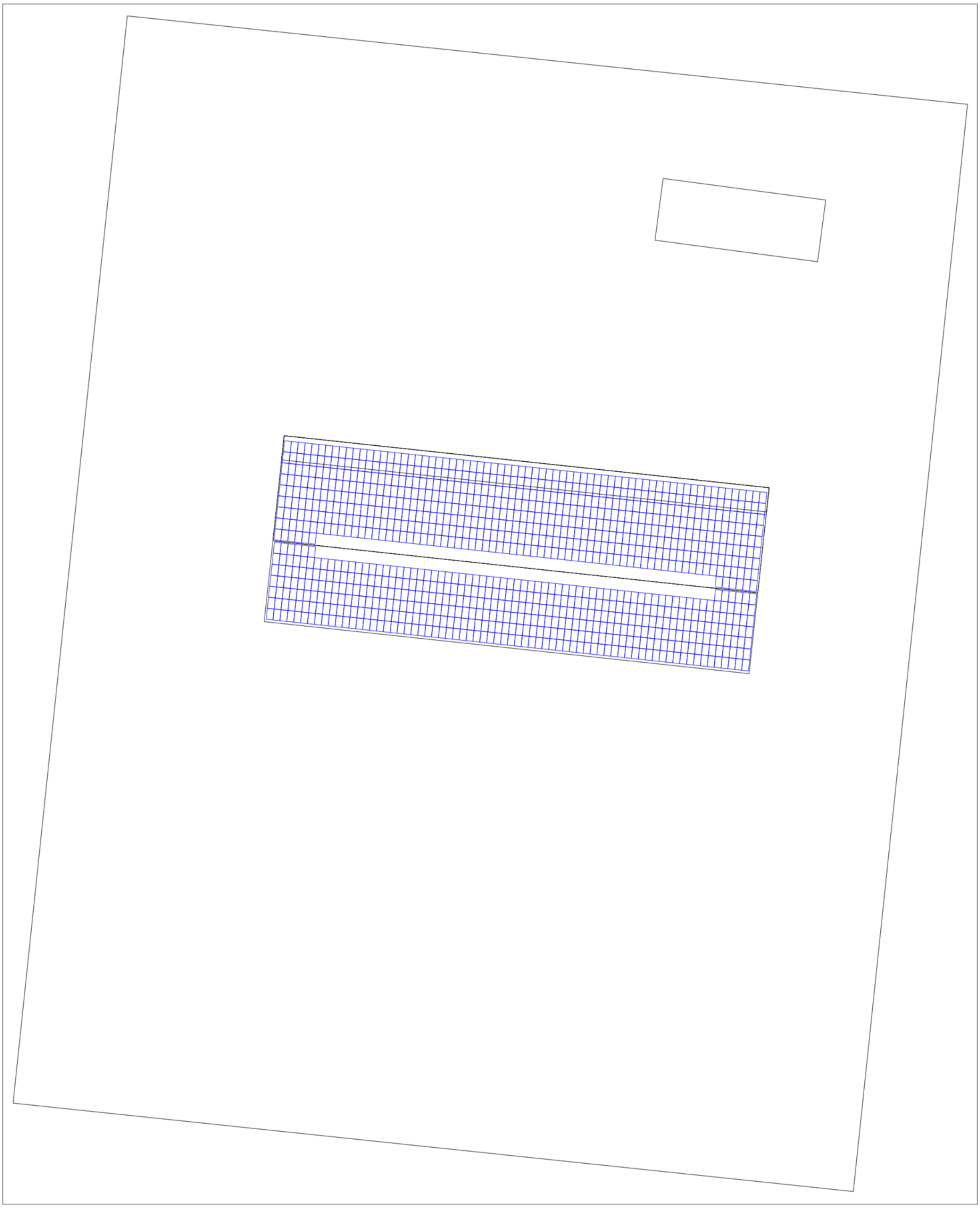


Figure: Overview plan

# Dimensioning Plan

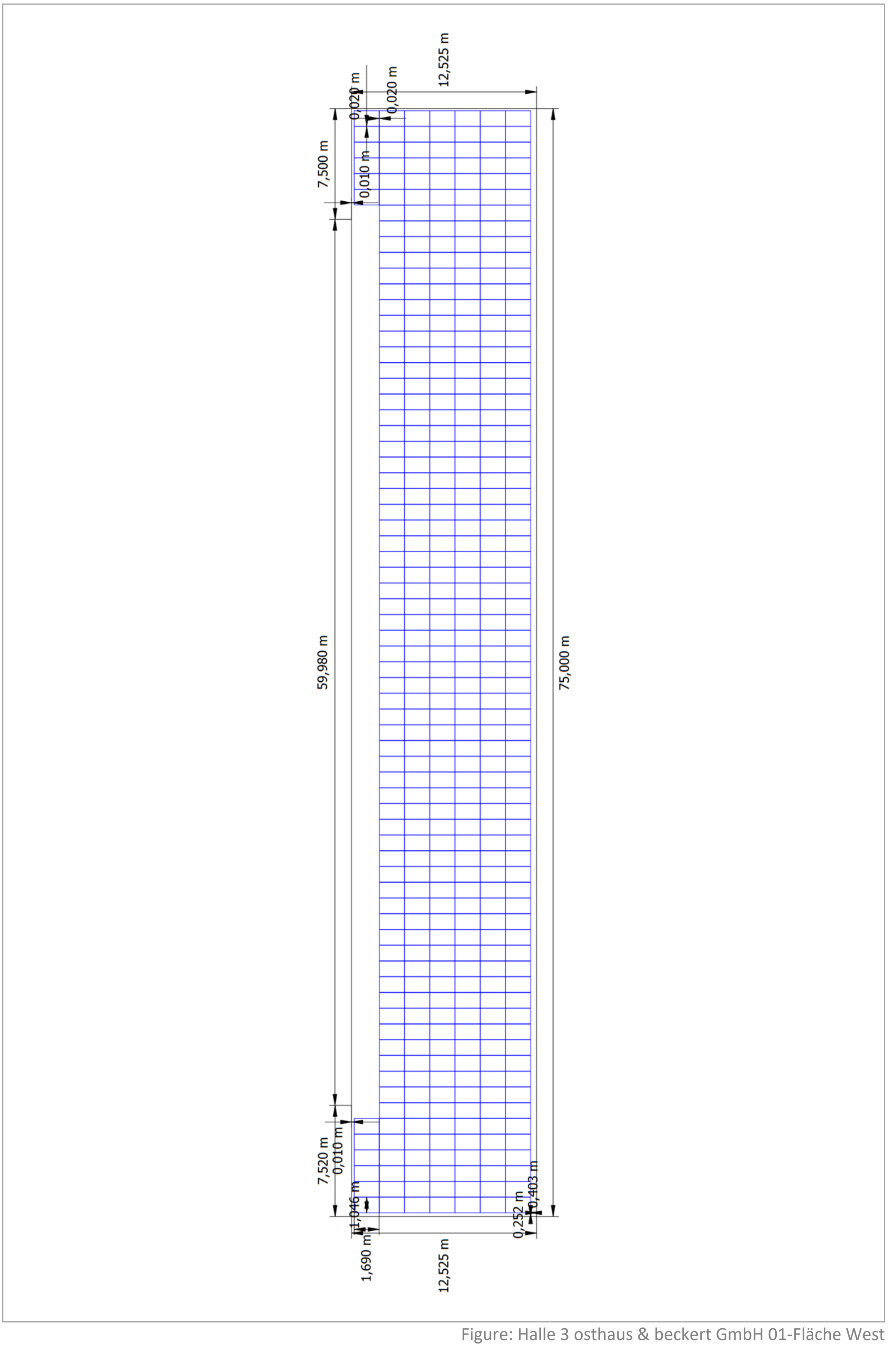



Figure: Halle 3 osthaus & beckert GmbH 01-Fläche West

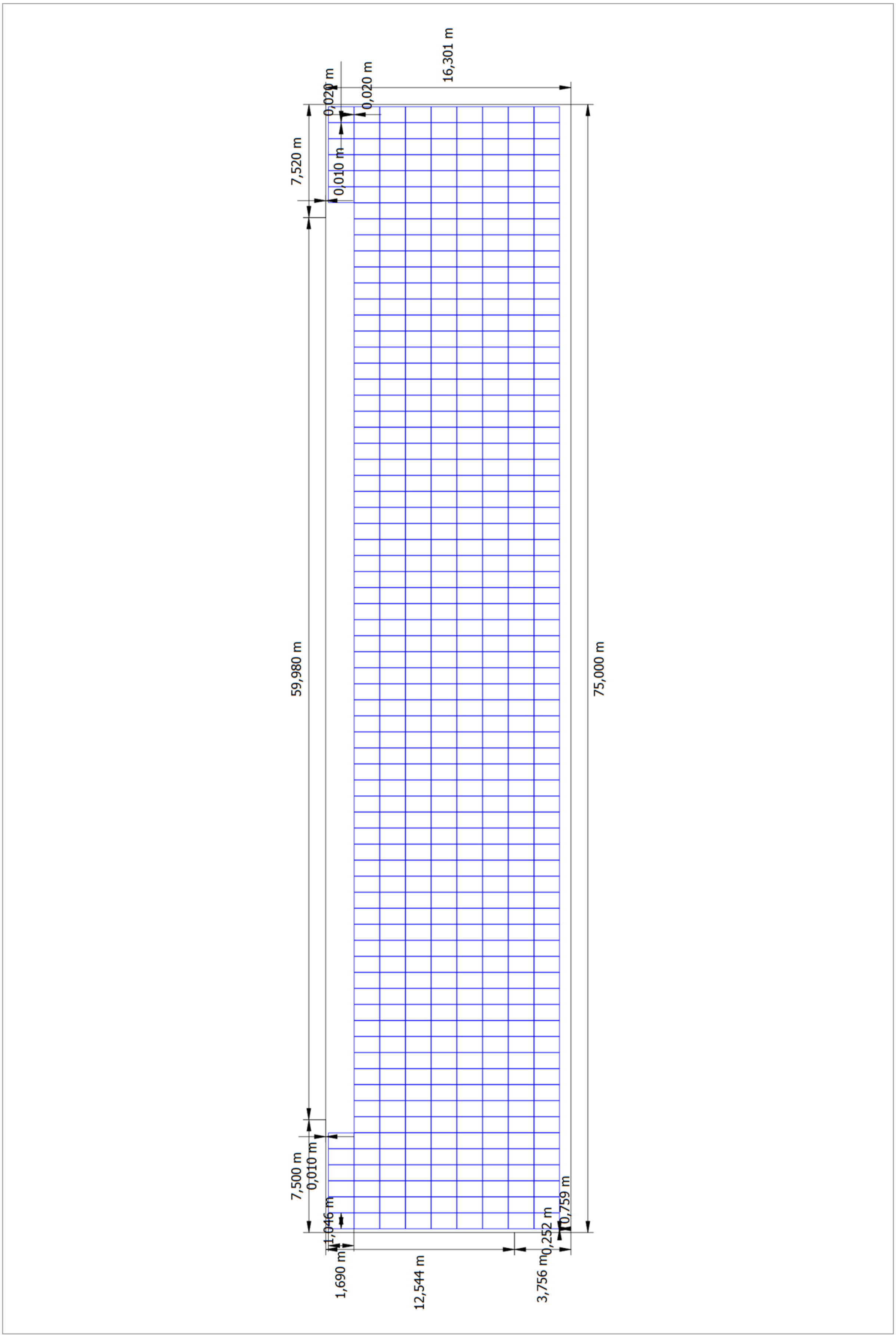



Figure: Halle 3 osthaus & beckert GmbH 01-Fläche Ost

# String Plan

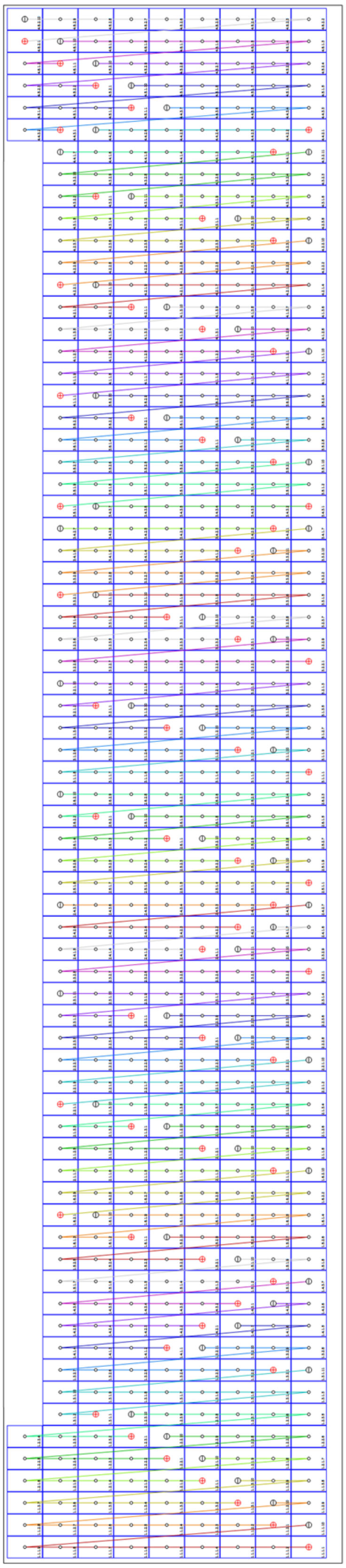


Figure: Halle 3 osthaus & beckert GmbH 01-Fläche Ost

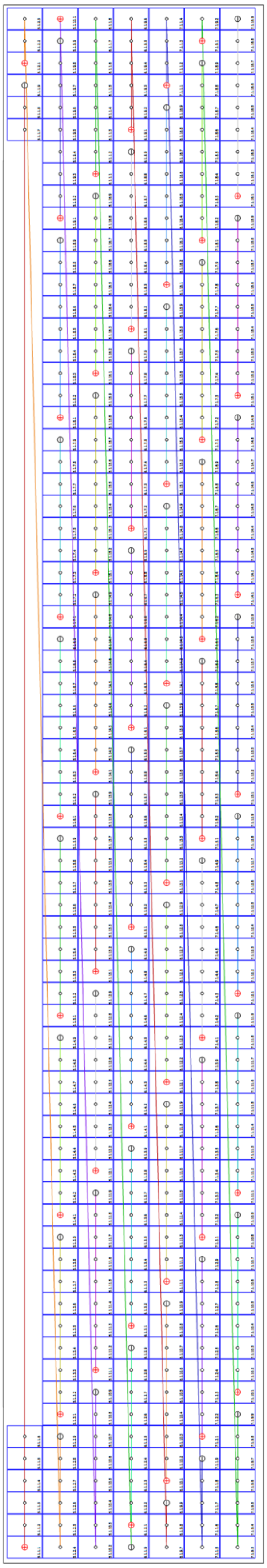


Figure: Halle 3 osthaus & beckert GmbH 01-Fläche West

# Parts list

Parts list

| # | Type | Item number | Manufacturer | Name | Quantity | Unit |
|---|---|---|---|---|---|---|
| 1 | PV Module | | SunPower | SPR-MAX3-400 | 1004 | Piece |
| 2 | Inverter | | Huawei Technologies | SUN2000-50KTL-M0 (400Vac) | 7 | Piece |
| 3 | Components | | | Feed-in Meter | 1 | Piece |

## Annex G: Simulation report Scenario 2 (Surplus Feeder)

**osthaus & beckert GmbH**
Beckert, Andreas; Osthaus, Christian
Industriepark Brundorf 14, 28790
Schwanewede

**Customer No.:** 123456789
**Project Name:** PV-Anlage osthaus & beckert GmbH
**Offer no.:** 123456

09.08.2022

# Your PV system

### Address of Installation

Industriepark Brundorf 14, 28790 Schwanewede


Project Description:

Planning of a company-owned PV system for osthaus & beckert GmbH

# Project Overview

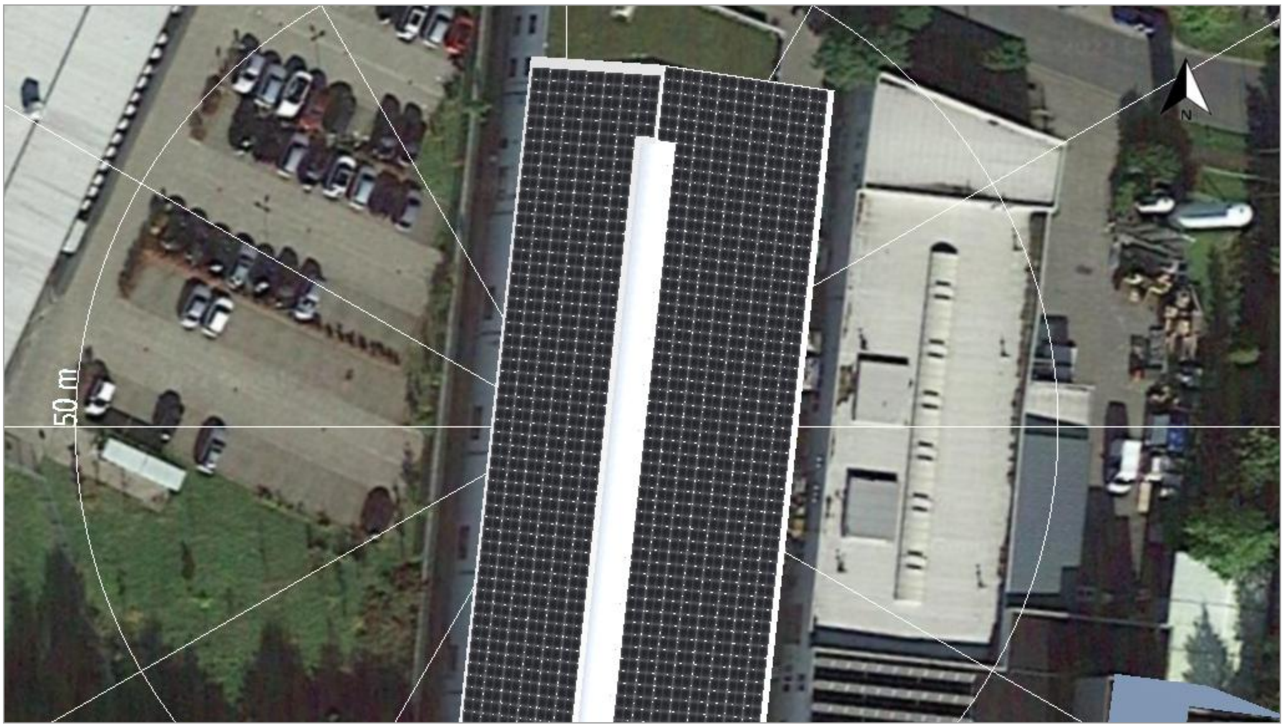



Figure: Overview Image, 3D Design

## PV System

3D, Grid-connected PV System with Electrical Appliances and Battery Systems

| | | |
|---|---|---|
| Climate Data | Osterholz-Scharmbeck, DEU (1995 - 2012) | |
| Values source | DWD | |
| PV Generator Output | 371,79 | kWp |
| PV Generator Surface | 1.778,0 | m² |
| Number of PV Modules | 918 | |
| Number of Inverters | 11 | |
| No. of battery systems | 1 | |

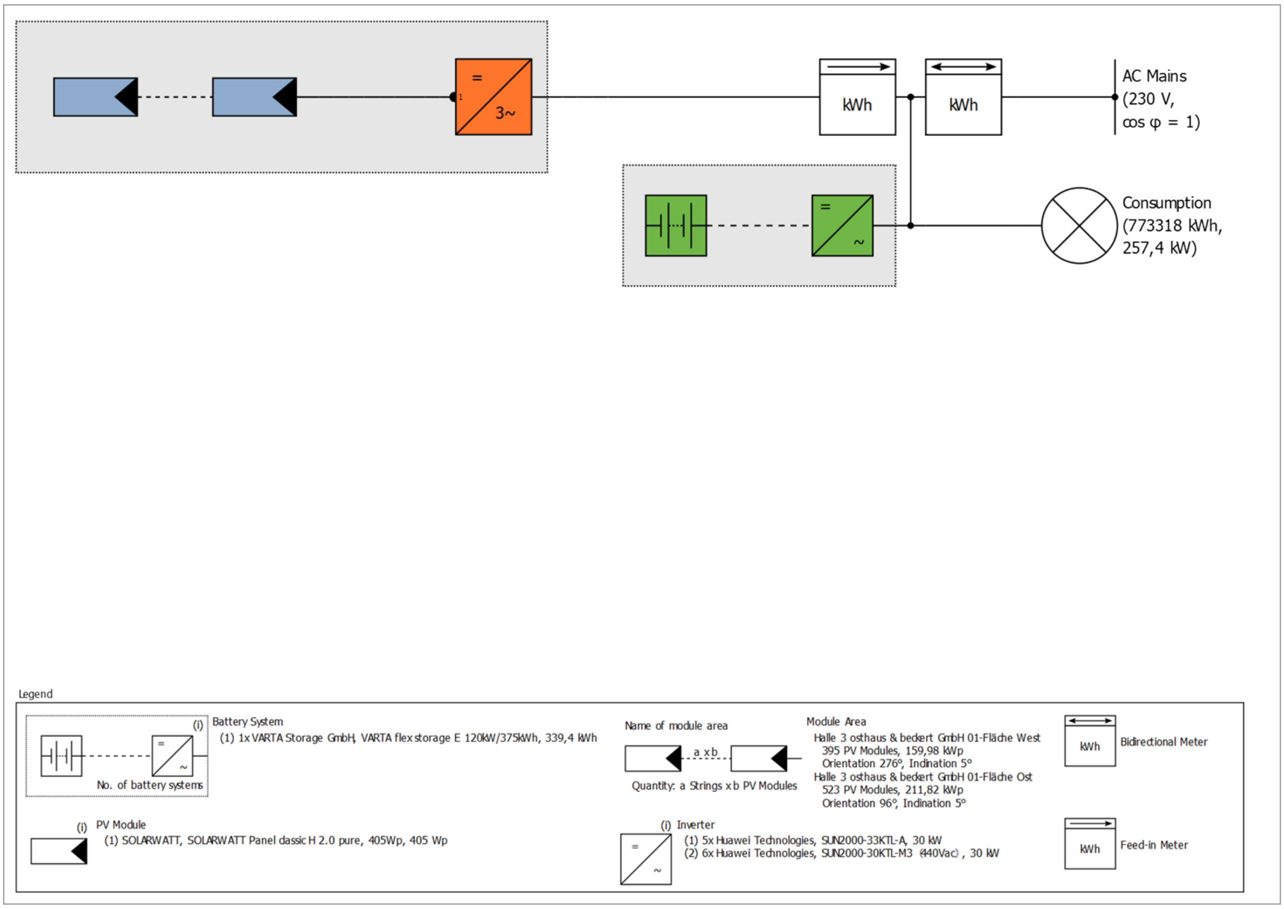



Figure: Schematic diagram

# Production Forecast

| Production Forecast | |
|---|---|
| PV Generator Output | 371,79 kWp |
| Spec. Annual Yield | 877,57 kWh/kWp |
| Performance Ratio (PR) | 89,39 % |
| Yield Reduction due to Shading | 0,5 %/Year |
| | |
| PV Generator Energy (AC grid) | 326.496 kWh/Year |
| Direct Own Use | 228.870 kWh/Year |
| Battery Charge | 51.506 kWh/Year |
| Down-regulation at Feed-in Point | 0 kWh/Year |
| Grid Feed-in | 46.119 kWh/Year |
| | |
| Own Power Consumption | 85,9 % |
| | |
| $CO_2$ Emissions avoided | 155.802 kg / year |
| | |
| Level of Self-sufficiency | 35,6 % |

# Financial Analysis

## Your Gain

| | |
|---|---|
| Total investment costs | 479.015,00 € |
| Internal Rate of Return of Capital Resources | 9,04 % |
| Amortization Period | 14,6 Years |
| Electricity Production Costs | 0,0651 €/kWh |
| Energy Balance/Feed-in Concept | Surplus Feed-in |

The results have been calculated with a mathematical model calculation from Valentin Software GmbH (PV*SOL algorithms). The actual yields from the solar power system may differ as a result of weather variations, the efficiency of the modules and inverter, and other factors.

# Set-up of the System

## Overview

### System Data

| | |
|---|---|
| Type of System | 3D, Grid-connected PV System with Electrical Appliances and Battery Systems |

### Climate Data

| | |
|---|---|
| Location | Osterholz-Scharmbeck, DEU (1995 - 2012) |
| Values source | DWD |
| Resolution of the data | 1 min |
| Simulation models used: | |
| - Diffuse Irradiation onto Horizontal Plane | Hofmann |
| - Irradiance onto tilted surface | Hay & Davies |

### Consumption

| | |
|---|---|
| Total Consumption | 773318 kWh |
| osthaus und beckert GmbH Halle 3 | 773318 kWh |
| Load Peak | 257,4 kW |

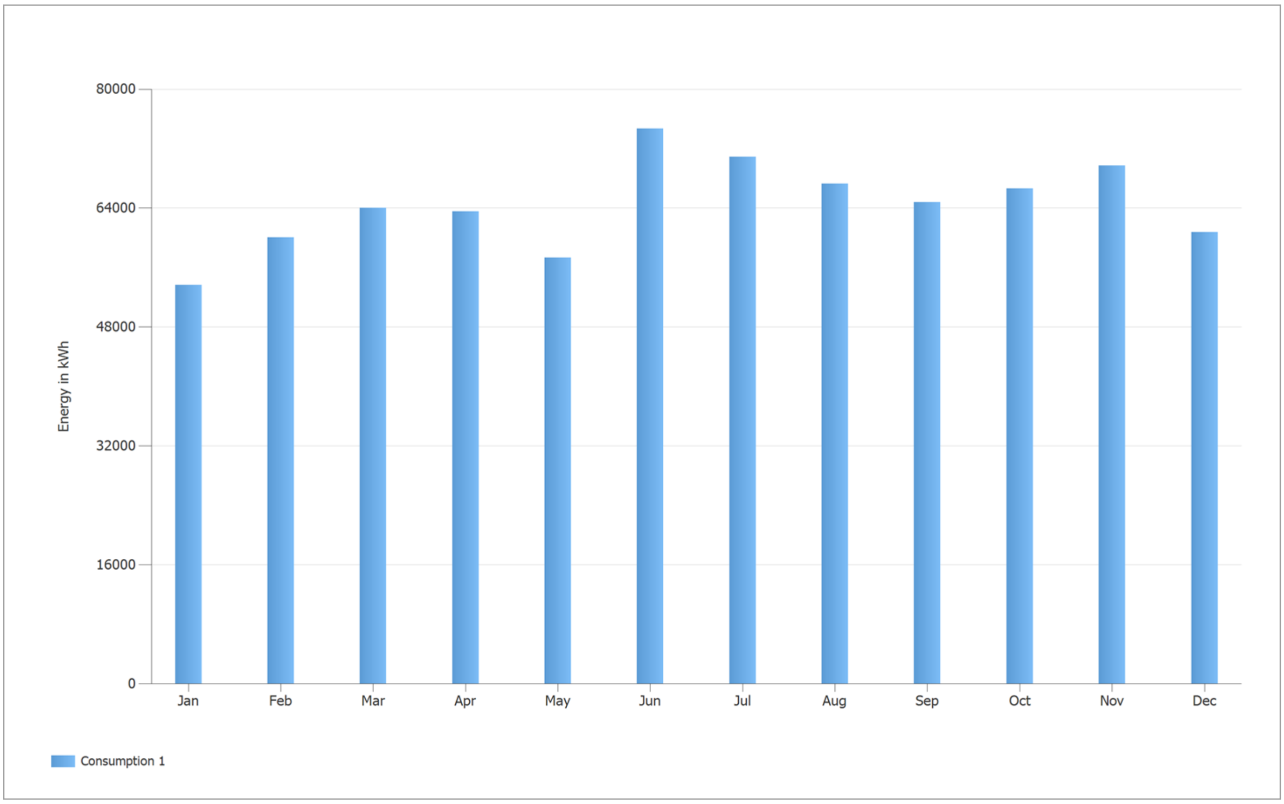



Figure: Consumption

# Module Areas

## 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West

### PV Generator, 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West

| | | |
|---|---|---|
| Name | Halle 3 osthaus & beckert GmbH 01-Fläche West | |
| PV Modules | 395 x SOLARWATT Panel classic H 2.0 pure, 405Wp (v1) | |
| Manufacturer | SOLARWATT | |
| Inclination | 5 | ° |
| Orientation | West 276 | ° |
| Installation Type | Roof parallel | |
| PV Generator Surface | 765,1 | m² |

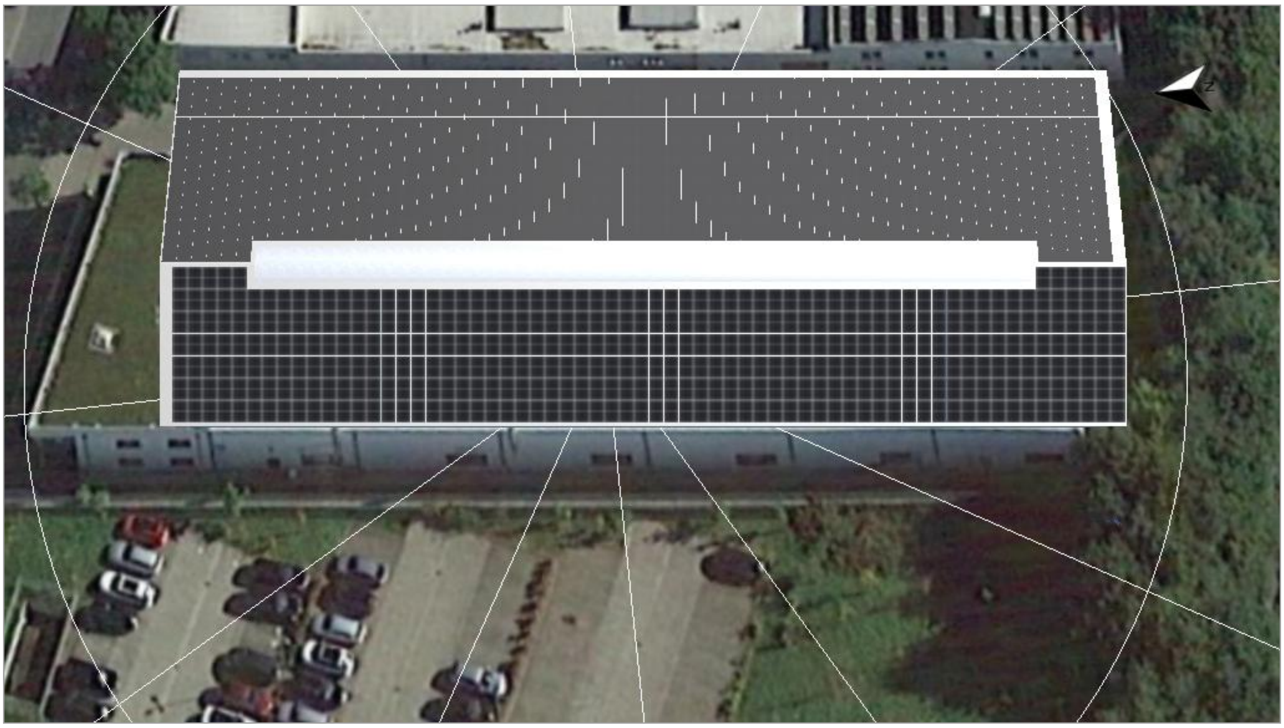


Figure: 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West

## *2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost*

### PV Generator, 2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost

| | | |
|---|---|---|
| Name | Halle 3 osthaus & beckert GmbH 01-Fläche Ost | |
| PV Modules | 523 x SOLARWATT Panel classic H 2.0 pure, 405Wp (v1) | |
| Manufacturer | SOLARWATT | |
| Inclination | 5 | ° |
| Orientation | East 96 | ° |
| Installation Type | Roof parallel | |
| PV Generator Surface | 1.013,0 | m² |

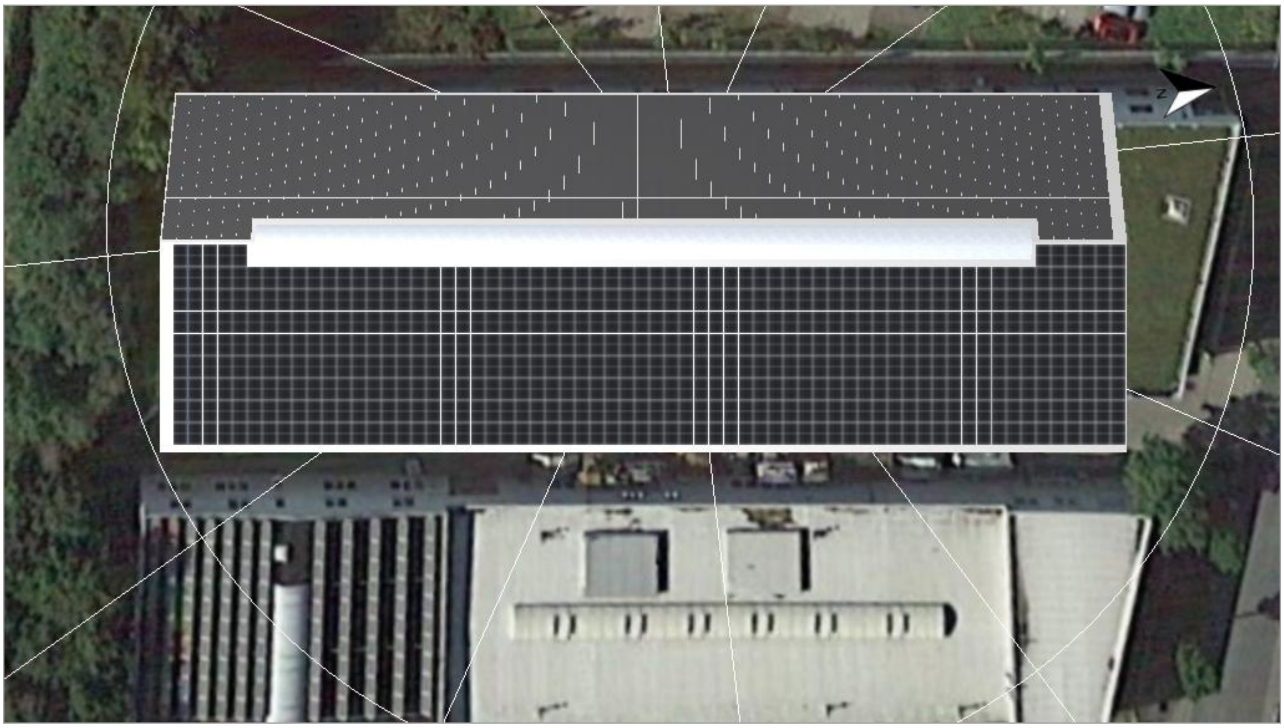


Figure: 2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost

# Horizon Line, 3D Design

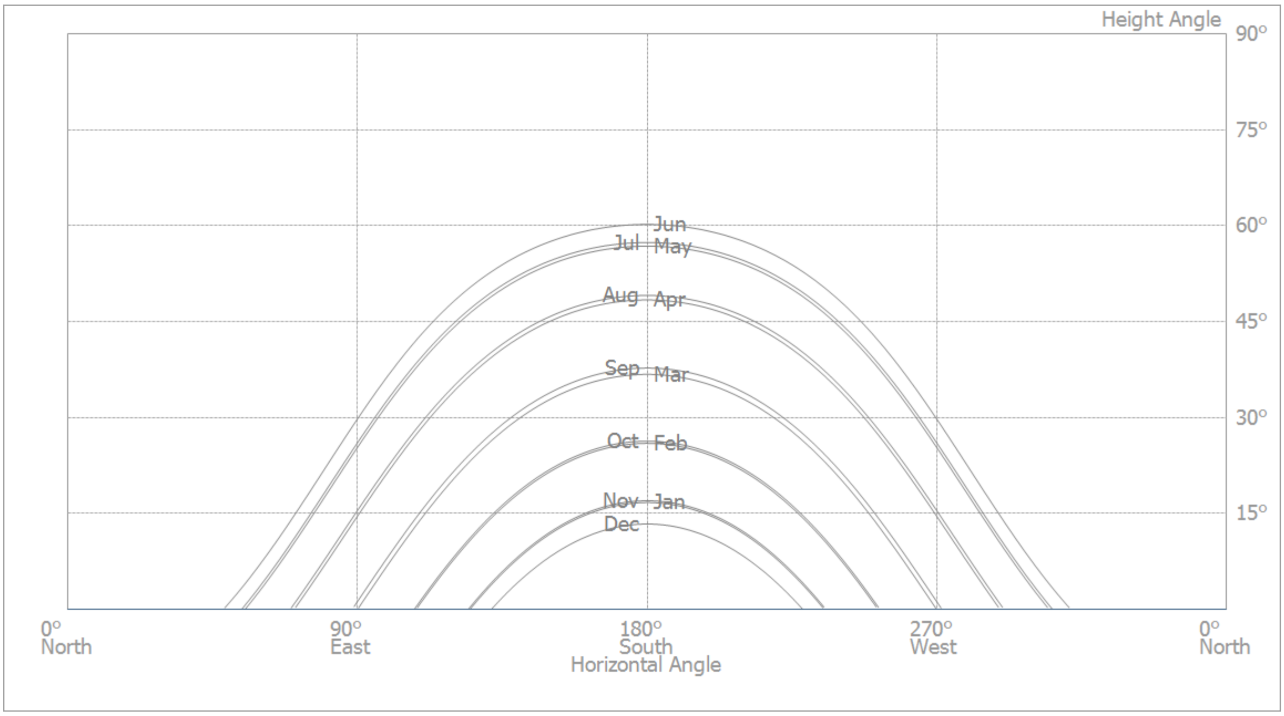



Figure: Horizon (3D Design)

# Inverter configuration

Configuration 1

| | |
|---|---|
| Module Area | Halle 3 osthaus & beckert GmbH 01-Fläche West |
| Inverter 1 | |
| Model | SUN2000-33KTL-A (v1) |
| Manufacturer | Huawei Technologies |
| Quantity | 5 |
| Sizing Factor | 106,7 % |
| Configuration | MPP 1: 1 x 20 |
| | MPP 2: 1 x 20 |
| | MPP 3: 1 x 20 |
| | MPP 4: 1 x 19 |

Configuration 2

| | |
|---|---|
| Module Area | Halle 3 osthaus & beckert GmbH 01-Fläche Ost |
| Inverter 1 | |
| Model | SUN2000-30KTL-M3（440Vac） (v1) |
| Manufacturer | Huawei Technologies |
| Quantity | 5 |
| Sizing Factor | 117,5 % |
| Configuration | MPP 1: 1 x 22 |
| | MPP 2: 1 x 22 |
| | MPP 3: 1 x 22 |
| | MPP 4: 1 x 21 |
| Inverter 2 | |
| Model | SUN2000-30KTL-M3（440Vac） (v1) |
| Manufacturer | Huawei Technologies |
| Quantity | 1 |
| Sizing Factor | 118,8 % |
| Configuration | MPP 1: 1 x 22 |
| | MPP 2: 1 x 22 |
| | MPP 3: 1 x 22 |
| | MPP 4: 1 x 22 |

# AC Mains

AC Mains

| | | |
|---|---|---|
| Number of Phases | 3 | |
| Mains voltage between phase and neutral | 230 | V |
| Displacement Power Factor (cos phi) | +/- 1 | |

# Battery Systems

Battery System

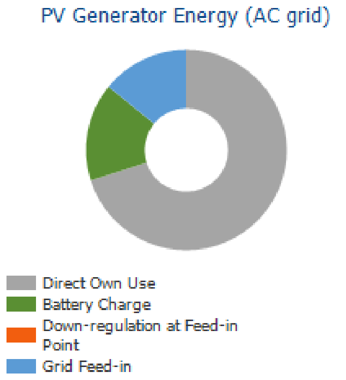
| | | |
|---|---|---|
| Model | VARTA flex storage E 120kW/375kWh (v3) | |
| Manufacturer | VARTA Storage GmbH | |
| Quantity | 1 | |
| Battery Inverter | | |
| Type of Coupling | AC coupling | |
| Nominal output | 120 | kW |
| Battery | | |
| Manufacturer | VARTA Storage GmbH | |
| Model | VARTA flex storage E BM (v1) | |
| Quantity | 65 | |
| Battery Energy | 339,4 | kWh |
| Battery Type | Lithium nickel manganese cobalt oxide/graphite | |

# Simulation Results

## Results Total System

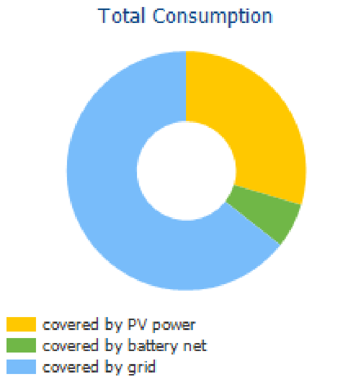
### PV System

| | | |
|---|---|---|
| PV Generator Output | 371,79 | kWp |
| Spec. Annual Yield | 877,57 | kWh/kWp |
| Performance Ratio (PR) | 89,39 | % |
| Yield Reduction due to Shading | 0,5 | %/Year |
| PV Generator Energy (AC grid) | 326.496 | kWh/Year |
| Direct Own Use | 228.870 | kWh/Year |
| Battery Charge | 51.506 | kWh/Year |
| Down-regulation at Feed-in Point | 0 | kWh/Year |
| Grid Feed-in | 46.119 | kWh/Year |
| Own Power Consumption | 85,9 | % |
| $CO_2$ Emissions avoided | 155.802 | kg / year |



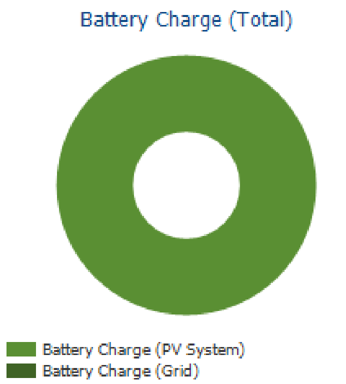

### Appliances

| | | |
|---|---|---|
| Appliances | 773.318 | kWh/Year |
| Standby Consumption (Inverter) | 224 | kWh/Year |
| Total Consumption | 773.542 | kWh/Year |
| covered by PV power | 228.870 | kWh/Year |
| covered by battery net | 46.815 | kWh/Year |
| covered by grid | 497.856 | kWh/Year |
| Solar Fraction | 35,6 | % |




### Battery System

| | | |
|---|---|---|
| Charge at beginning | 339 | kWh |
| Battery Charge (Total) | 51.506 | kWh/Year |
| Battery Charge (PV System) | 51.506 | kWh/Year |
| Battery Charge (Grid) | 0 | kWh/Year |
| Battery Energy for the Covering of Consumption | 46.815 | kWh/Year |
| Losses due to charging/discharging | 5.025 | kWh/Year |
| Losses in Battery | 5 | kWh/Year |
| Cycle Load | 2,6 | % |
| Service Life | >20 | Years |




### Level of Self-sufficiency

| | | |
|---|---|---|
| Total Consumption | 773.542 | kWh/Year |
| covered by grid | 497.856 | kWh/Year |
| Level of Self-sufficiency | 35,6 | % |

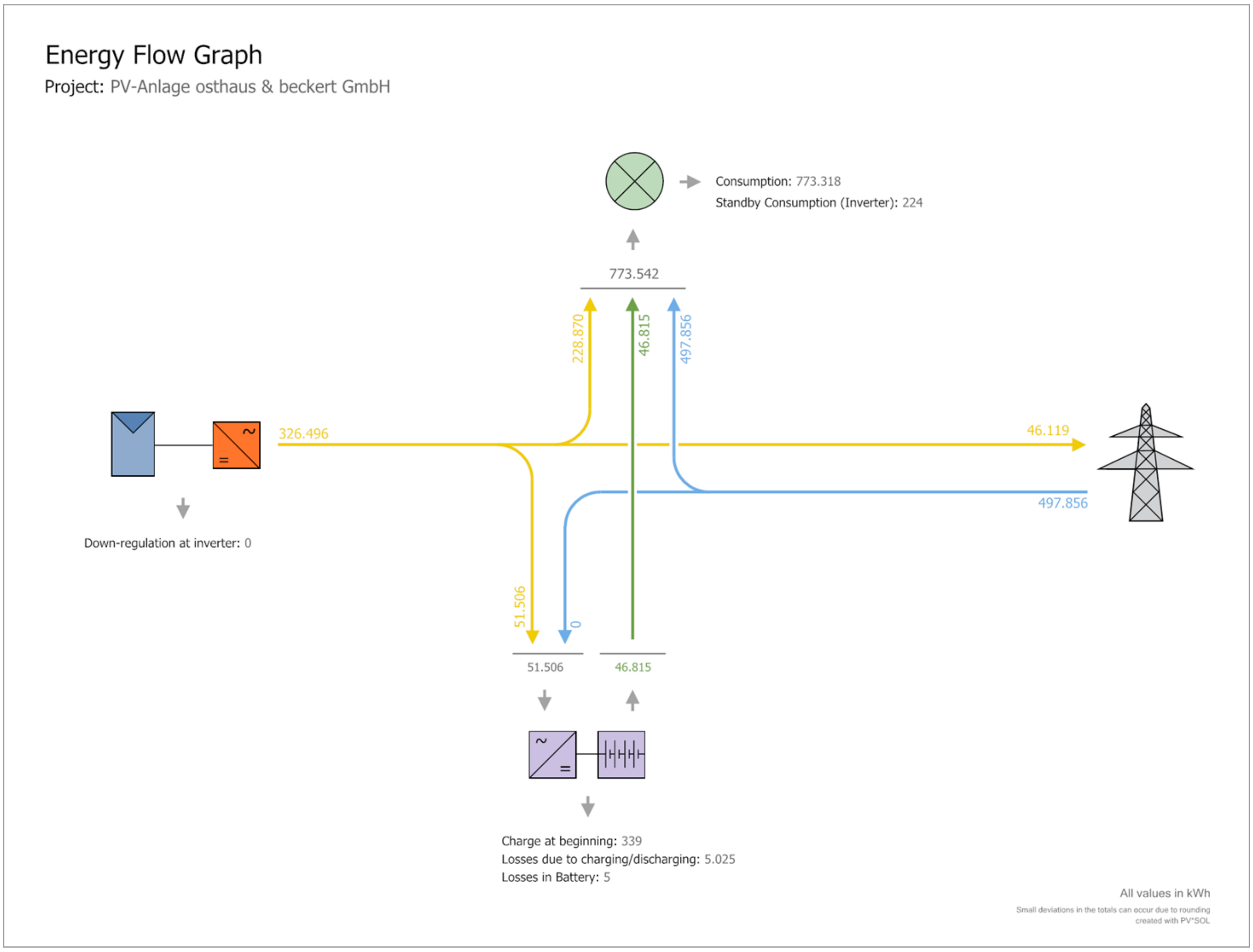



Figure: Energy flow

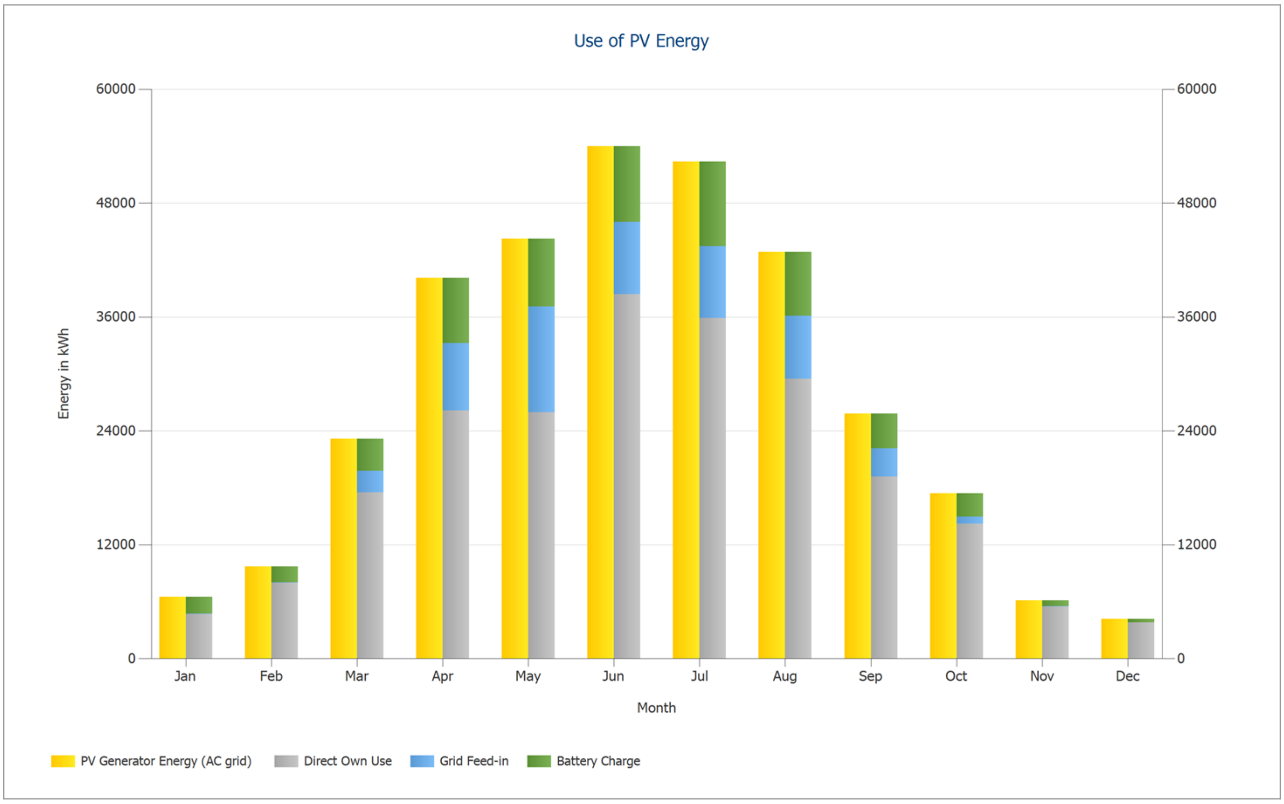



Figure: Use of PV Energy

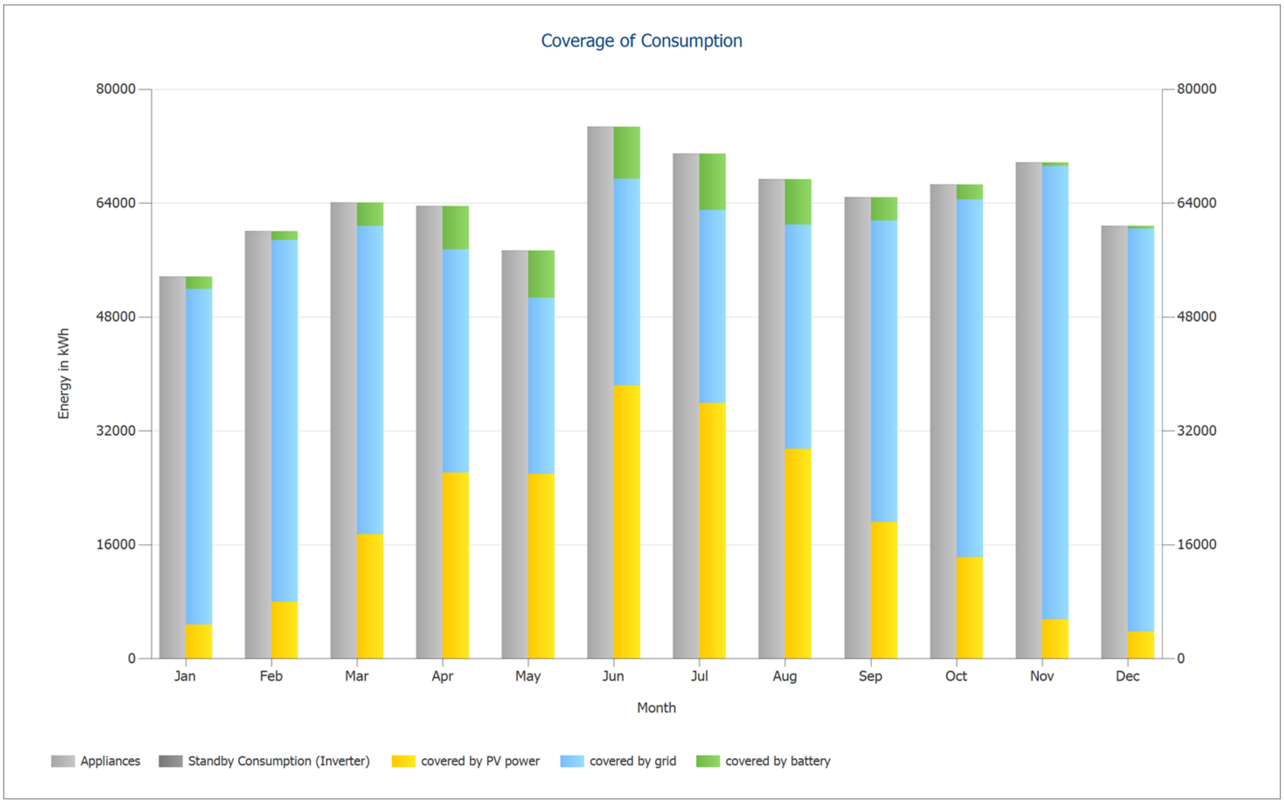



Figure: Coverage of Consumption

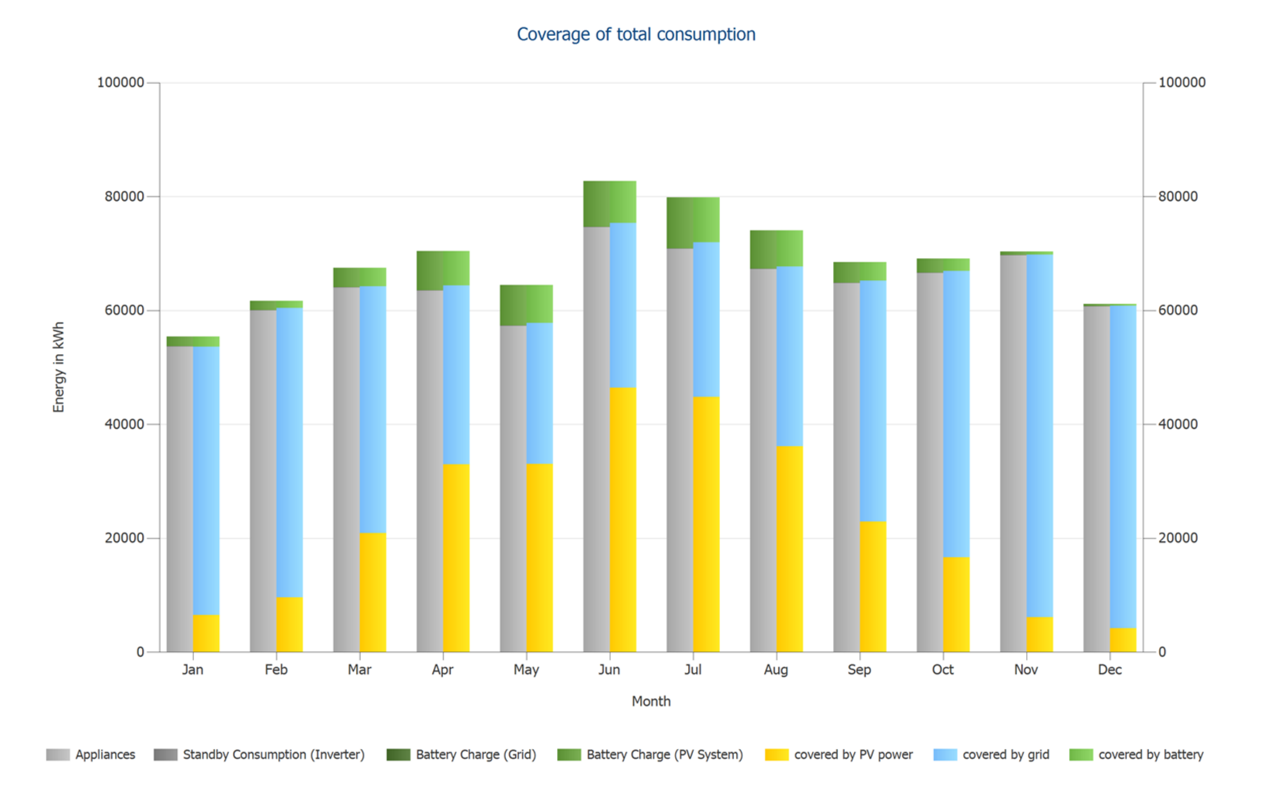



Figure: Coverage of total consumption

# Yield for EnEV

| Yield in accordance with DIN 15316-4-6 | | |
|---|---|---|
| January | 5236,6 | kWh |
| February | 7176,3 | kWh |
| March | 17515,4 | kWh |
| April | 33027,1 | kWh |
| May | 39906,3 | kWh |
| June | 42113,9 | kWh |
| July | 37920 | kWh |
| August | 32502,9 | kWh |
| September | 22192,8 | kWh |
| October | 13904 | kWh |
| November | 5417,1 | kWh |
| December | 3069,7 | kWh |
| **Annual Value** | **259.982,2** | **kWh** |

Boundary Conditions:
Climate Data according to DIN V 18599-10
HALLE 3 OSTHAUS & BECKERT GMBH 01-FLÄCHE WEST
System Power Factor: 0.75
Peak Power Coefficient: 0.182
Orientation: West
Inclination: 0°

HALLE 3 OSTHAUS & BECKERT GMBH 01-FLÄCHE OST
System Power Factor: 0.75
Peak Power Coefficient: 0.182
Orientation: East
Inclination: 0°

# Financial Analysis

## Overview

### System Data

| | | |
|---|---|---|
| Grid Feed-in in the first year (incl. module degradation) | 45.925 | kWh/Year |
| PV Generator Output | 371,8 | kWp |
| Start of Operation of the System | 01.07.2022 | |
| Assessment Period | 30 | Years |
| Interest on Capital | 1 | % |

### Economic Parameters

| | | |
|---|---|---|
| Internal Rate of Return of Capital Resources | 9,04 | % |
| Accrued Cash Flow (Cash Balance) | 399.764,20 | € |
| Amortization Period | 14,6 | Years |
| Electricity Production Costs | 0,0651 | €/kWh |

### Payment Overview

| | | |
|---|---|---|
| Specific Investment Costs | 1.288,40 | €/kWp |
| Investment Costs | 479.015,00 | € |
| One-off Payments | 0,00 | € |
| Incoming Subsidies | 0,00 | € |
| Annual Costs | 1.400,00 | €/Year |
| Other Revenue or Savings | 0,00 | €/Year |

### Loans

| **Reference** | **Loan 1** | |
|---|---|---|
| Loan Capital | 400.000,00 | € |
| Payment Installment | 100,00 | % |
| Credit type | Installment Loan | |
| Term | 10,00 | Years |
| Grace period | 0,00 | Years |
| Interest | 3,50 | |
| Repayment Period | quarterly | |

### Remuneration and Savings

| | | |
|---|---|---|
| Total Payment from Utility in First Year | 2.428,00 | €/Year |
| First year savings | 44.563,47 | €/Year |
| | | |
| EEG 2022 (Juli) Marktprämienmodell - Gebäudeanlage | | |
| Validity | 01.07.2022 | - 31.12.2042 |
| Specific feed-in / export Remuneration | 0,0529 | €/kWh |
| Feed-in / Export Tariff | 2427,9976 | €/Year |
| | | |
| Tarif oshaus & beckert GmbH (Wattline) | | |
| Energy Price | 0,1624 | €/kWh |
| Inflation Rate for Energy Price | 1 | %/Year |

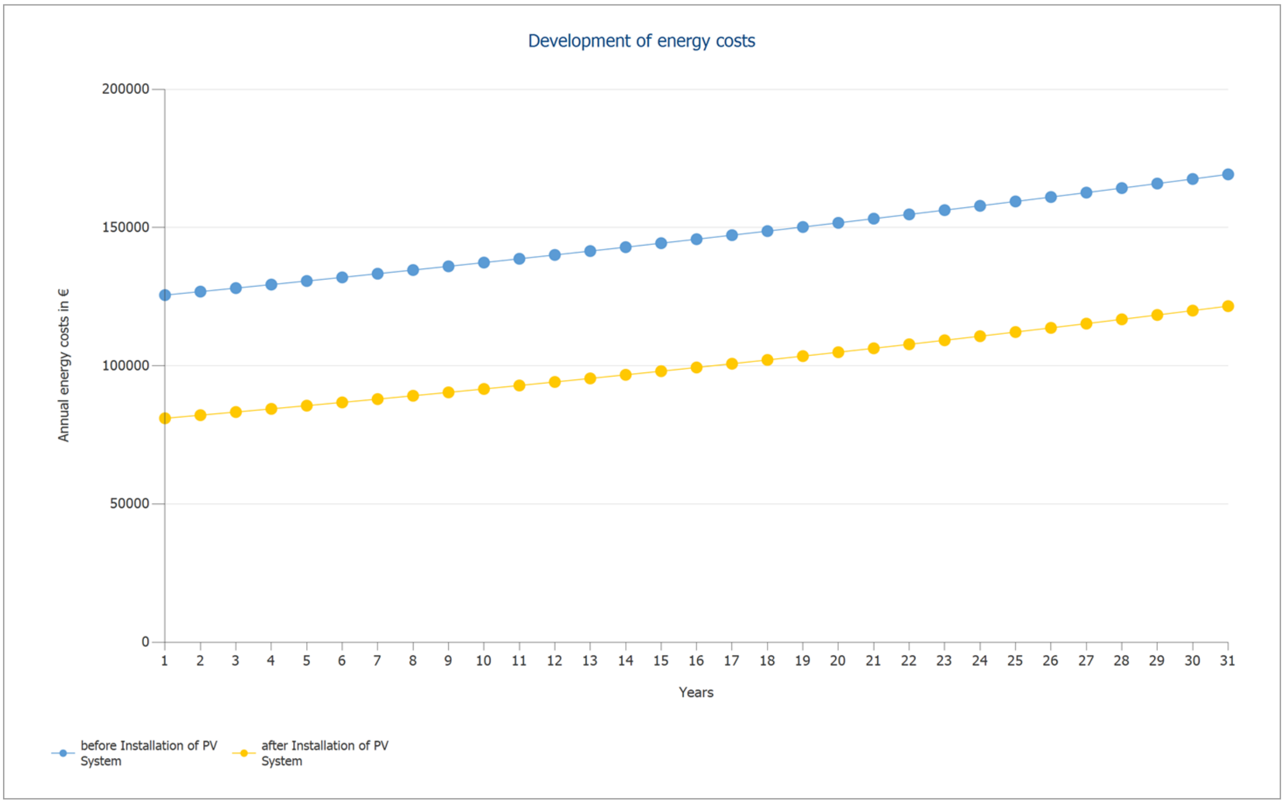



Figure: Development of energy costs

# Cash flow

## Cash flow

| | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| Operating costs | -1.386,14 € | -1.372,41 € | -1.358,83 € | -1.345,37 € | -1.332,05 € |
| Depreciation | -23.713,61 € | -23.478,83 € | -23.246,36 € | -23.016,20 € | -22.788,32 € |
| Self-Financing | -79.015,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 2.403,96 € | 2.363,77 € | 2.324,15 € | 2.285,08 € | 2.246,55 € |
| Electricity Savings | 44.122,25 € | 43.818,72 € | 43.515,19 € | 43.211,67 € | 42.908,14 € |
| Loan repayments | -39.603,96 € | -39.211,84 € | -38.823,61 € | -38.439,21 € | -38.058,63 € |
| Loan Interest | -13.341,58 € | -11.837,07 € | -10.361,05 € | -8.913,09 € | -7.492,79 € |
| Results before Tax | 8.084,87 € | 9.494,18 € | 10.873,10 € | 12.222,08 € | 13.541,53 € |
| Tax Refund | -3.476,49 € | -4.082,50 € | -4.675,43 € | -5.255,49 € | -5.822,86 € |
| Results after Tax | 4.608,37 € | 5.411,68 € | 6.197,67 € | 6.966,58 € | 7.718,67 € |
| **Annual Cash Flow** | **-90.296,97 €** | **-10.321,34 €** | **-9.379,58 €** | **-8.456,43 €** | **-7.551,64 €** |
| Accrued Cash Flow (Cash Balance) | -90.296,97 € | -100.618,31 € | -109.997,88 € | -118.454,31 € | -126.005,95 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -485.248,54 € | -444.520,96 € | -404.715,88 € | -365.820,00 € | -327.820,22 € |

## Cash flow

| | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 |
|---|---|---|---|---|---|
| Operating costs | -1.318,86 € | -1.305,81 € | -1.292,88 € | -1.280,08 € | -1.267,40 € |
| Depreciation | -22.562,69 € | -22.339,30 € | -22.118,12 € | -21.899,12 € | -21.682,30 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 2.208,56 € | 2.171,11 € | 2.134,18 € | 2.097,76 € | 2.061,86 € |
| Electricity Savings | 42.604,61 € | 42.301,08 € | 41.997,55 € | 41.694,05 € | 41.390,50 € |
| Loan repayments | -37.681,81 € | -37.308,72 € | -36.939,33 € | -36.573,59 € | -36.211,48 € |
| Loan Interest | -6.099,74 € | -4.733,54 € | -3.393,80 € | -2.080,12 € | -792,13 € |
| Results before Tax | 14.831,88 € | 16.093,54 € | 17.326,93 € | 18.532,49 € | 19.710,53 € |
| Tax Refund | -6.377,71 € | -6.920,22 € | -7.450,58 € | -7.968,97 € | -8.475,53 € |
| Results after Tax | 8.454,17 € | 9.173,32 € | 9.876,35 € | 10.563,52 € | 11.235,00 € |
| **Annual Cash Flow** | **-6.664,95 €** | **-5.796,11 €** | **-4.944,86 €** | **-4.110,95 €** | **-3.294,17 €** |
| Accrued Cash Flow (Cash Balance) | -132.670,90 € | -138.467,01 € | -143.411,87 € | -147.522,83 € | -150.817,00 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -290.703,62 € | -254.457,46 € | -219.069,19 € | -184.526,43 € | -150.817,00 € |

## Cash flow

| | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 |
|---|---|---|---|---|---|
| Operating costs | -1.254,85 € | -1.242,43 € | -1.230,13 € | -1.217,95 € | -1.205,89 € |
| Depreciation | -21.467,63 € | -21.255,07 € | -21.044,63 € | -20.836,27 € | -20.629,97 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 2.026,47 € | 1.991,57 € | 1.957,17 € | 1.923,25 € | 1.889,81 € |
| Electricity Savings | 41.086,98 € | 40.783,44 € | 40.479,93 € | 40.176,39 € | 39.872,87 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 20.390,97 € | 20.277,51 € | 20.162,34 € | 20.045,43 € | 19.926,83 € |
| Tax Refund | -8.768,12 € | -8.719,33 € | -8.669,81 € | -8.619,53 € | -8.568,54 € |
| Results after Tax | 11.622,85 € | 11.558,18 € | 11.492,53 € | 11.425,89 € | 11.358,29 € |
| **Annual Cash Flow** | **33.090,48 €** | **32.813,26 €** | **32.537,16 €** | **32.262,16 €** | **31.988,26 €** |
| Accrued Cash Flow (Cash Balance) | -117.726,52 € | -84.913,27 € | -52.376,11 € | -20.113,95 € | 11.874,31 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -117.726,52 € | -84.913,27 € | -52.376,11 € | -20.113,95 € | 11.874,31 € |

## Cash flow

| | Year 16 | Year 17 | Year 18 | Year 19 | Year 20 |
|---|---|---|---|---|---|
| Operating costs | -1.193,95 € | -1.182,13 € | -1.170,42 € | -1.158,84 € | -1.147,36 € |
| Depreciation | -20.425,71 € | -20.223,47 € | -20.023,24 € | -19.824,99 € | -19.628,70 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 1.856,85 € | 1.824,35 € | 1.792,32 € | 1.760,74 € | 1.729,61 € |
| Electricity Savings | 39.569,35 € | 39.265,83 € | 38.962,28 € | 38.658,75 € | 38.355,24 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 19.806,54 € | 19.684,58 € | 19.560,93 € | 19.435,66 € | 19.308,78 € |
| Tax Refund | -8.516,81 € | -8.464,37 € | -8.411,20 € | -8.357,34 € | -8.302,78 € |
| Results after Tax | 11.289,73 € | 11.220,21 € | 11.149,73 € | 11.078,33 € | 11.006,01 € |
| **Annual Cash Flow** | **31.715,44 €** | **31.443,69 €** | **31.172,97 €** | **30.903,32 €** | **30.634,71 €** |
| Accrued Cash Flow (Cash Balance) | 43.589,75 € | 75.033,44 € | 106.206,41 € | 137.109,73 € | 167.744,44 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 43.589,75 € | 75.033,44 € | 106.206,41 € | 137.109,73 € | 167.744,44 € |

## Cash flow

| | Year 21 | Year 22 | Year 23 | Year 24 | Year 25 |
|---|---|---|---|---|---|
| Operating costs | -1.136,00 € | -1.124,75 € | -1.113,62 € | -1.102,59 € | -1.091,68 € |
| Depreciation | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 1.697,58 € | 1.666,51 € | 1.636,73 € | 1.607,38 € | 1.578,45 € |
| Electricity Savings | 38.051,71 € | 37.748,19 € | 37.444,67 € | 37.141,14 € | 36.837,62 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 38.613,29 € | 38.289,95 € | 37.967,78 € | 37.645,92 € | 37.324,40 € |
| Tax Refund | -16.603,71 € | -16.464,68 € | -16.326,15 € | -16.187,75 € | -16.049,49 € |
| Results after Tax | 22.009,57 € | 21.825,27 € | 21.641,63 € | 21.458,18 € | 21.274,91 € |
| **Annual Cash Flow** | **22.009,57 €** | **21.825,27 €** | **21.641,63 €** | **21.458,18 €** | **21.274,91 €** |
| Accrued Cash Flow (Cash Balance) | 189.754,02 € | 211.579,28 € | 233.220,92 € | 254.679,10 € | 275.954,00 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 189.754,02 € | 211.579,28 € | 233.220,92 € | 254.679,10 € | 275.954,00 € |

## Cash flow

| | Year 26 | Year 27 | Year 28 | Year 29 | Year 30 |
|---|---|---|---|---|---|
| Operating costs | -1.080,87 € | -1.070,17 € | -1.059,57 € | -1.049,08 € | -1.038,69 € |
| Depreciation | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 1.549,94 € | 1.521,83 € | 1.494,13 € | 1.466,83 € | 1.439,92 € |
| Electricity Savings | 36.534,08 € | 36.230,55 € | 35.927,03 € | 35.623,51 € | 35.319,98 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 37.003,15 € | 36.682,21 € | 36.361,60 € | 36.041,26 € | 35.721,21 € |
| Tax Refund | -15.911,36 € | -15.773,35 € | -15.635,49 € | -15.497,74 € | -15.360,12 € |
| Results after Tax | 21.091,80 € | 20.908,86 € | 20.726,11 € | 20.543,52 € | 20.361,09 € |
| **Annual Cash Flow** | **21.091,80 €** | **20.908,86 €** | **20.726,11 €** | **20.543,52 €** | **20.361,09 €** |
| Accrued Cash Flow (Cash Balance) | 297.045,80 € | 317.954,66 € | 338.680,77 € | 359.224,29 € | 379.585,38 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 297.045,80 € | 317.954,66 € | 338.680,77 € | 359.224,29 € | 379.585,38 € |

**Offer Number:** 123456

## Cash flow

| | Year 31 |
|---|---|
| Operating costs | -1.028,41 € |
| Depreciation | 0,00 € |
| Self-Financing | 0,00 € |
| Feed-in / Export Tariff | 1.413,41 € |
| Electricity Savings | 35.016,45 € |
| Loan repayments | 0,00 € |
| Loan Interest | 0,00 € |
| Results before Tax | 35.401,45 € |
| Tax Refund | -15.222,62 € |
| Results after Tax | 20.178,83 € |
| **Annual Cash Flow** | **20.178,83 €** |
| Accrued Cash Flow (Cash Balance) | 399.764,20 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 399.764,20 € |

Degradation and inflation rates are applied on a monthly basis over the entire observation period. This is done in the first year.

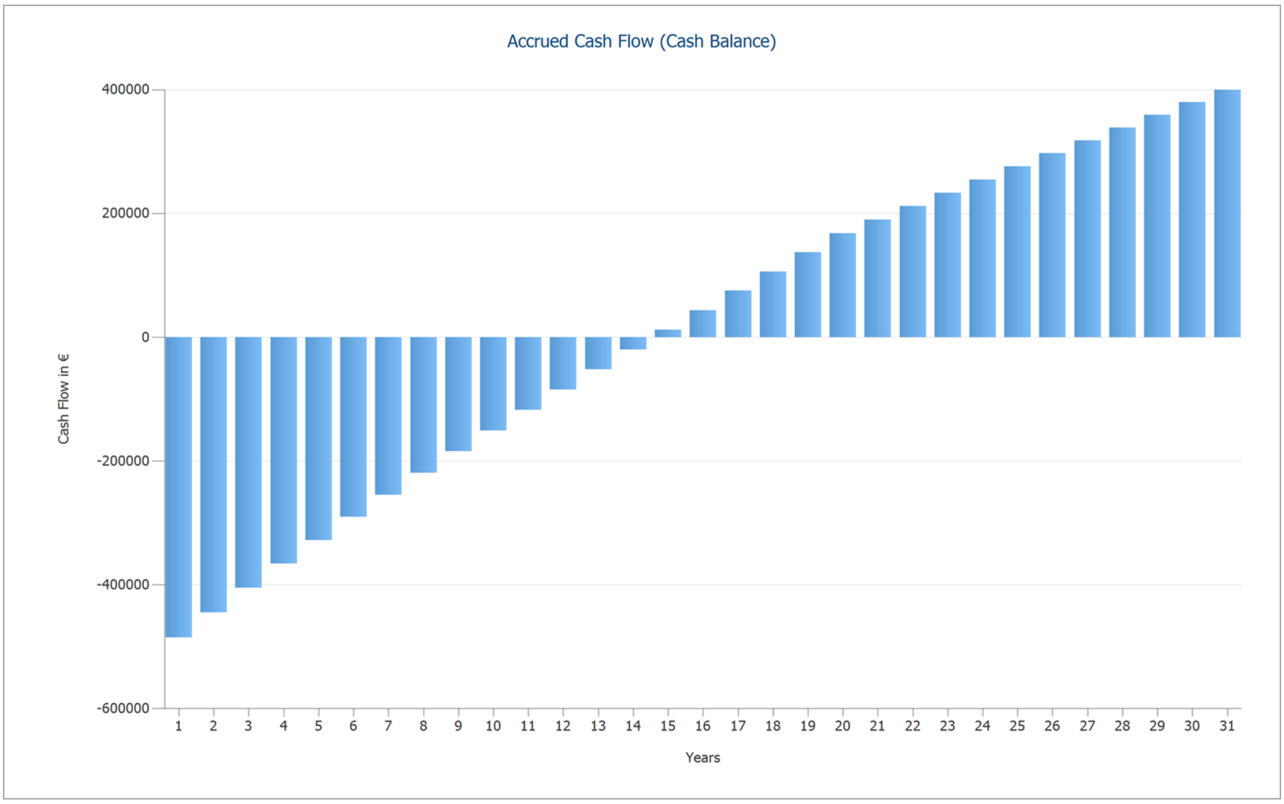



Figure: Accrued Cash Flow (Cash Balance)

# Plans and parts list

## Circuit Diagram

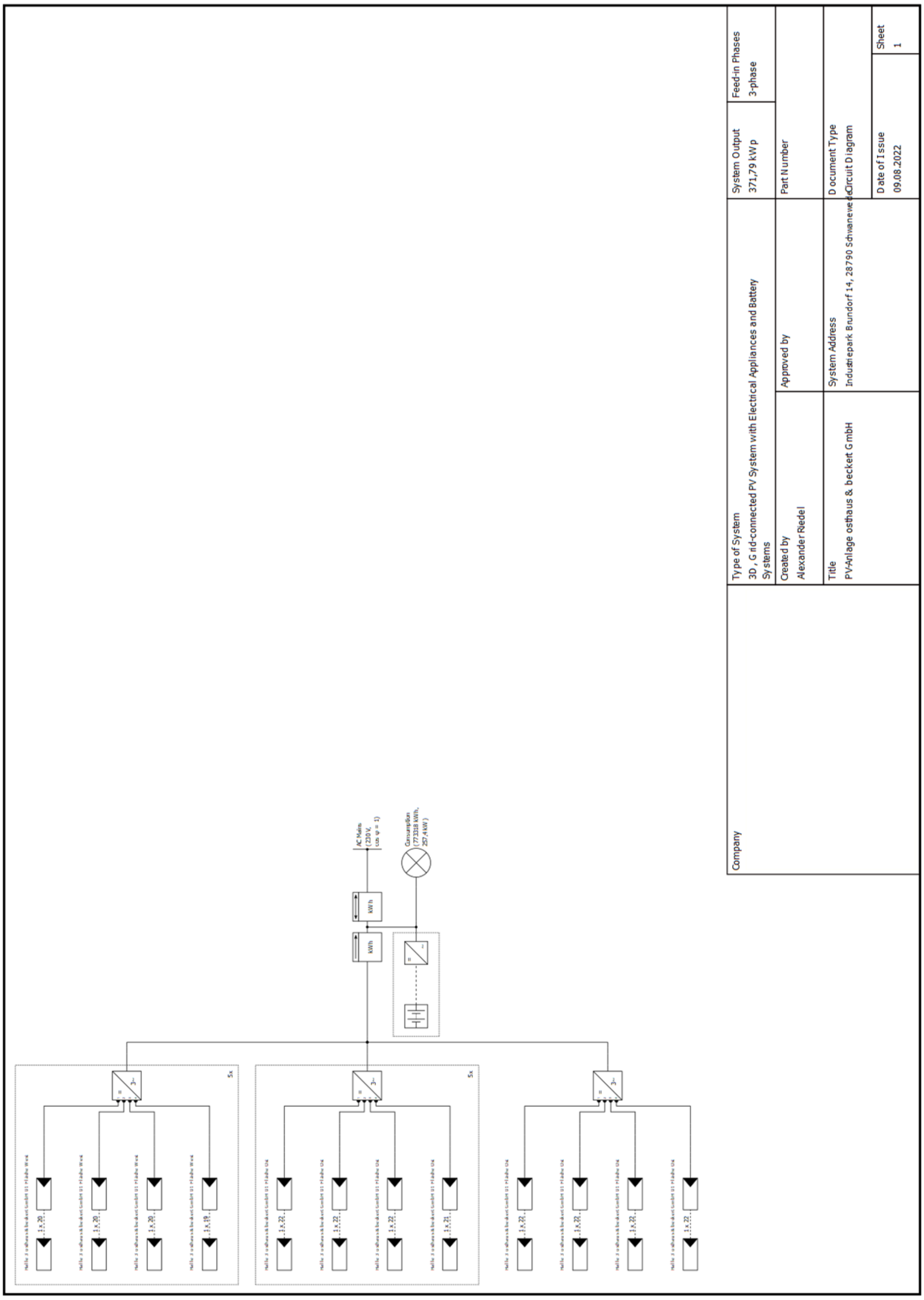



Figure: Circuit Diagram

# Overview plan

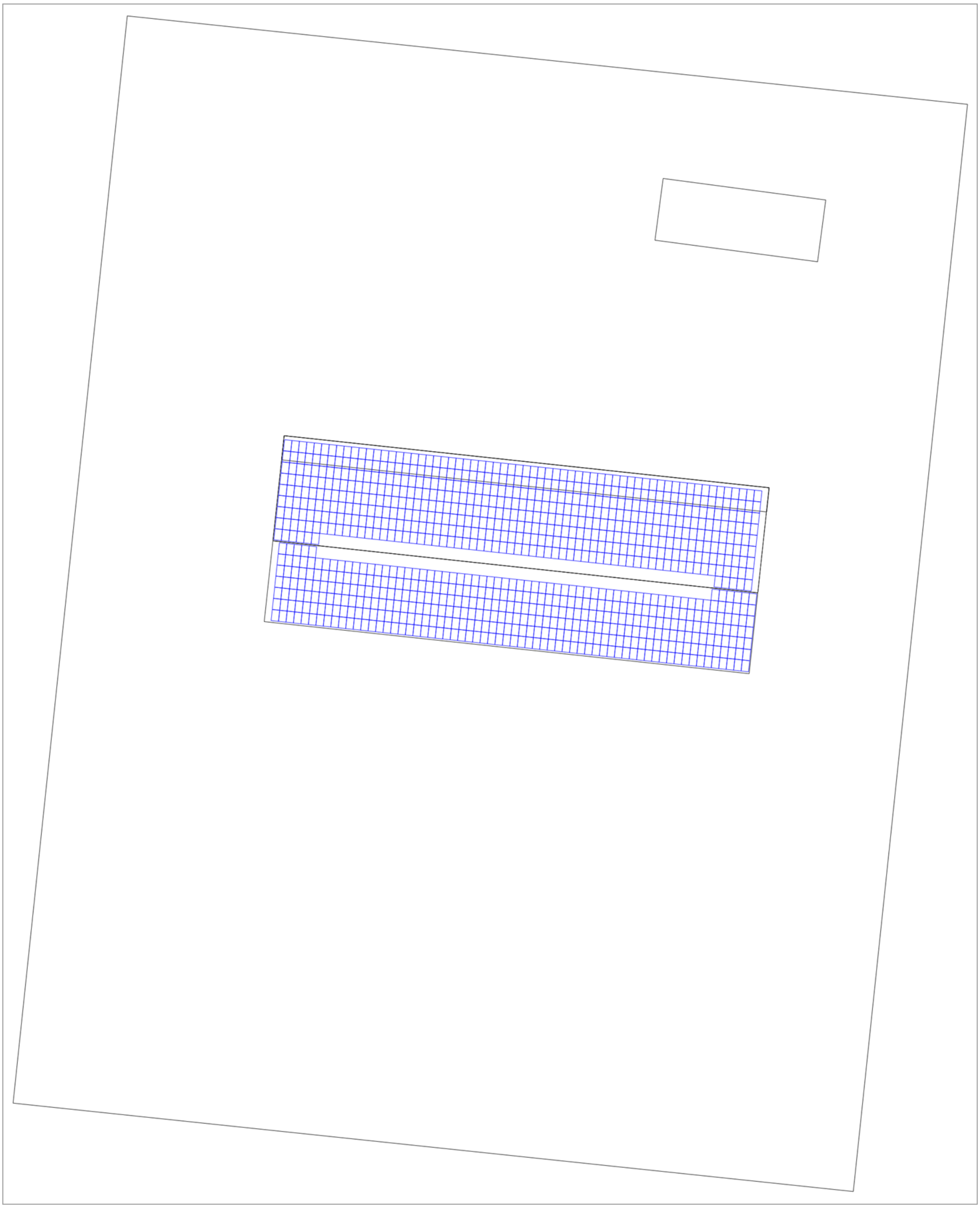


Figure: Overview plan

# Dimensioning Plan

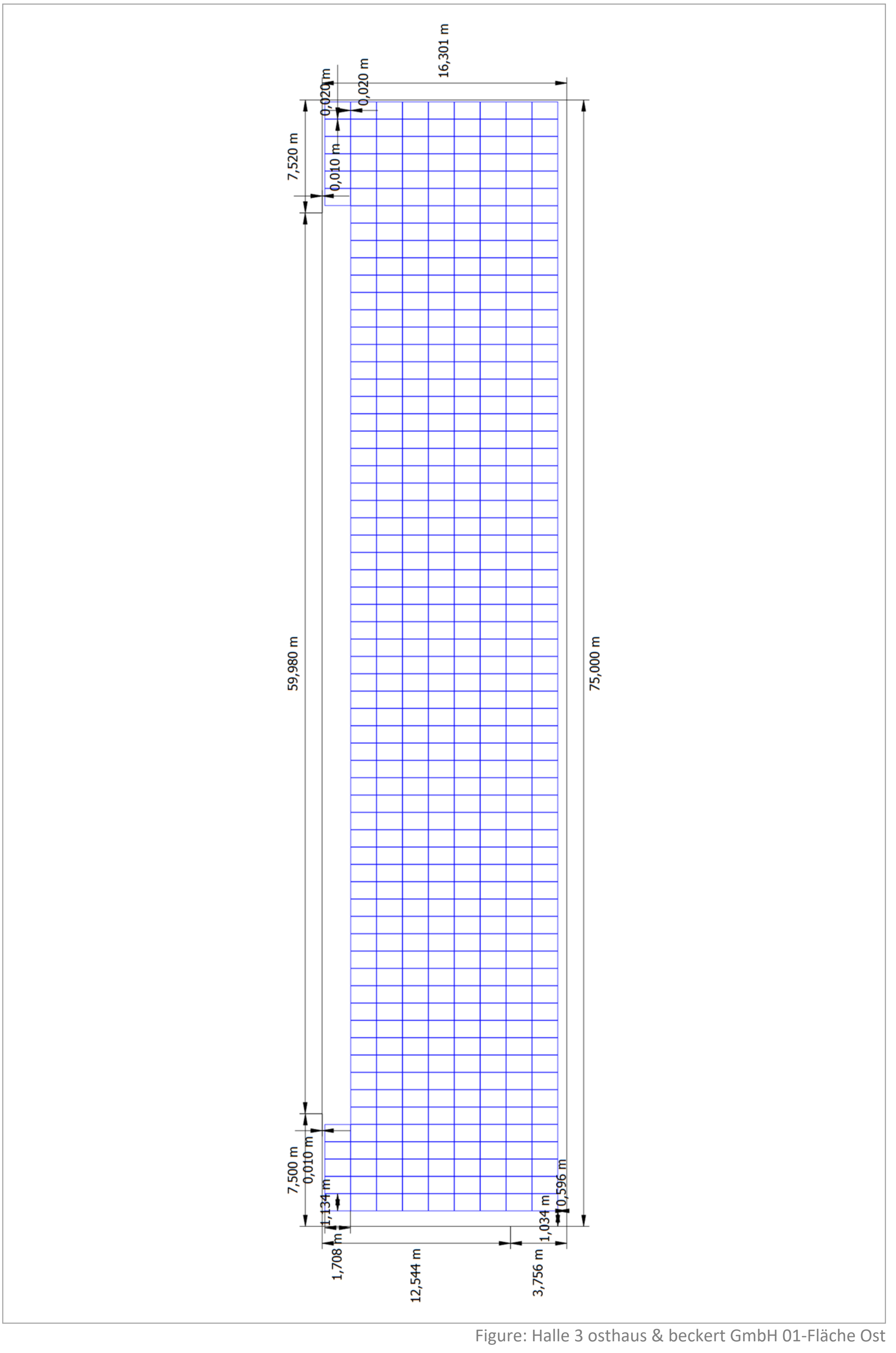



Figure: Halle 3 osthaus & beckert GmbH 01-Fläche Ost

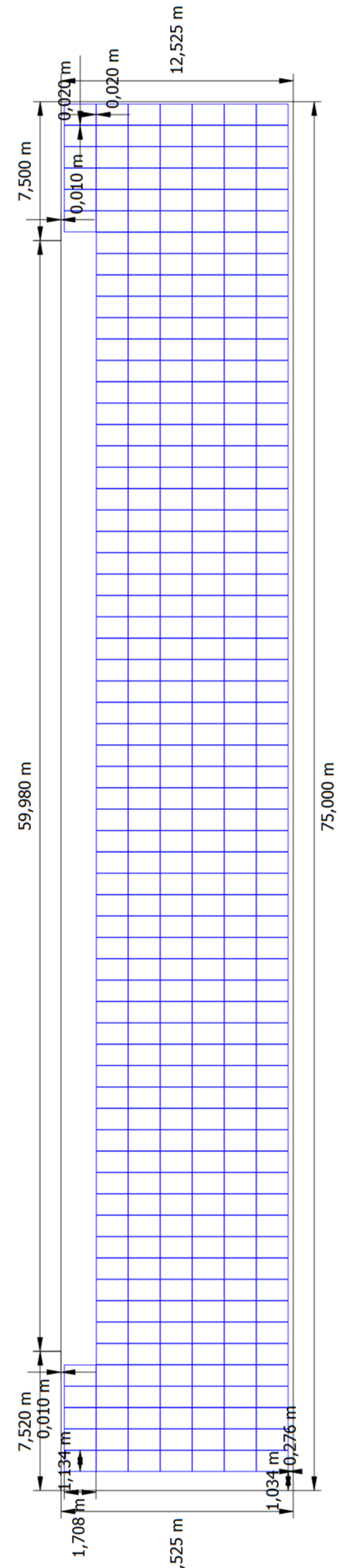



Figure: Halle 3 osthaus & beckert GmbH 01-Fläche West

# String Plan

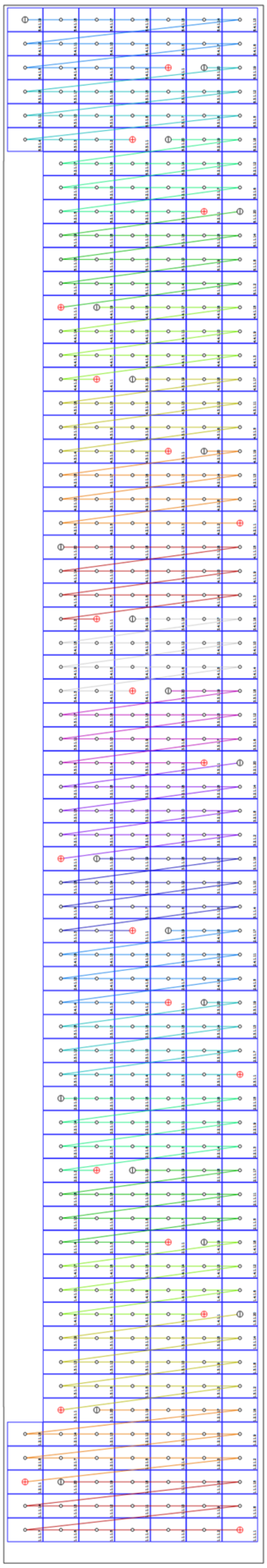


Figure: Halle 3 osthaus & beckert GmbH 01-Fläche West

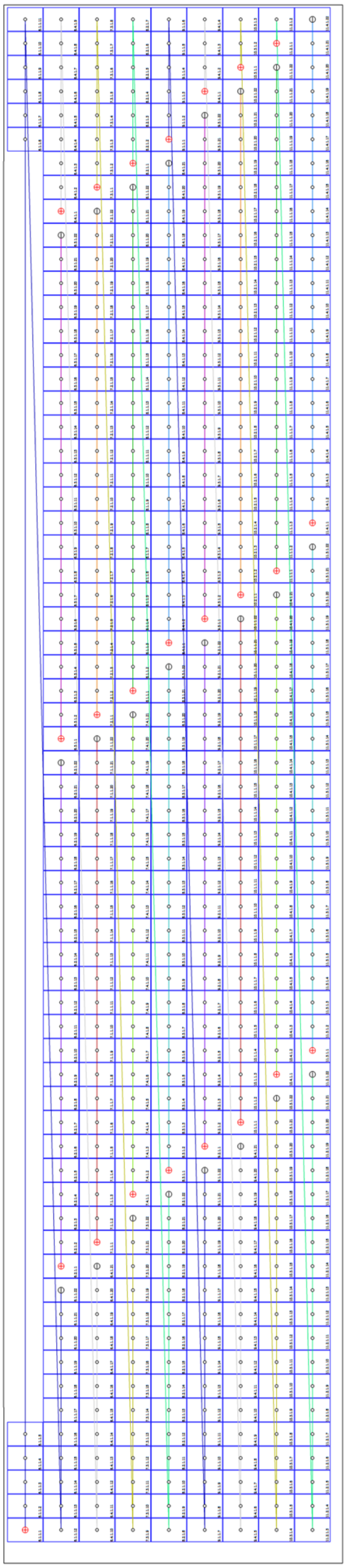


Figure: Halle 3 osthaus & beckert GmbH 01-Fläche Ost

# Parts list

## Parts list

| # | Type | Item number | Manufacturer | Name | Quantity | Unit |
|---|---|---|---|---|---|---|
| 1 | PV Module | | SOLARWATT | SOLARWATT Panel classic H 2.0 pure, 405Wp | 918 | Piece |
| 2 | Inverter | | Huawei Technologies | SUN2000-33KTL-A | 5 | Piece |
| 3 | Inverter | | Huawei Technologies | SUN2000-30KTL-M3 （440Vac） | 6 | Piece |
| 4 | Battery System | | VARTA Storage GmbH | VARTA flex storage E 120kW/375kWh | 1 | Piece |
| 5 | Components | | | Feed-in Meter | 1 | Piece |
| 6 | Components | | | Bidirectional Meter | 1 | Piece |

## Annex H: Simulation report Scenario 2 (Full Feeder)

**osthaus & beckert GmbH**
Beckert, Andreas; Osthaus, Christian
Industriepark Brundorf 14, 28790
Schwanewede

**Customer No.:** 123456789
**Project Name:** PV-Anlage osthaus & beckert GmbH
**Offer no.:** 123456

02.08.2022

# Your PV system

### Address of Installation

Industriepark Brundorf 14, 28790 Schwanewede


Project Description:
Planning of a company-owned PV system for osthaus & beckert GmbH

# Project Overview

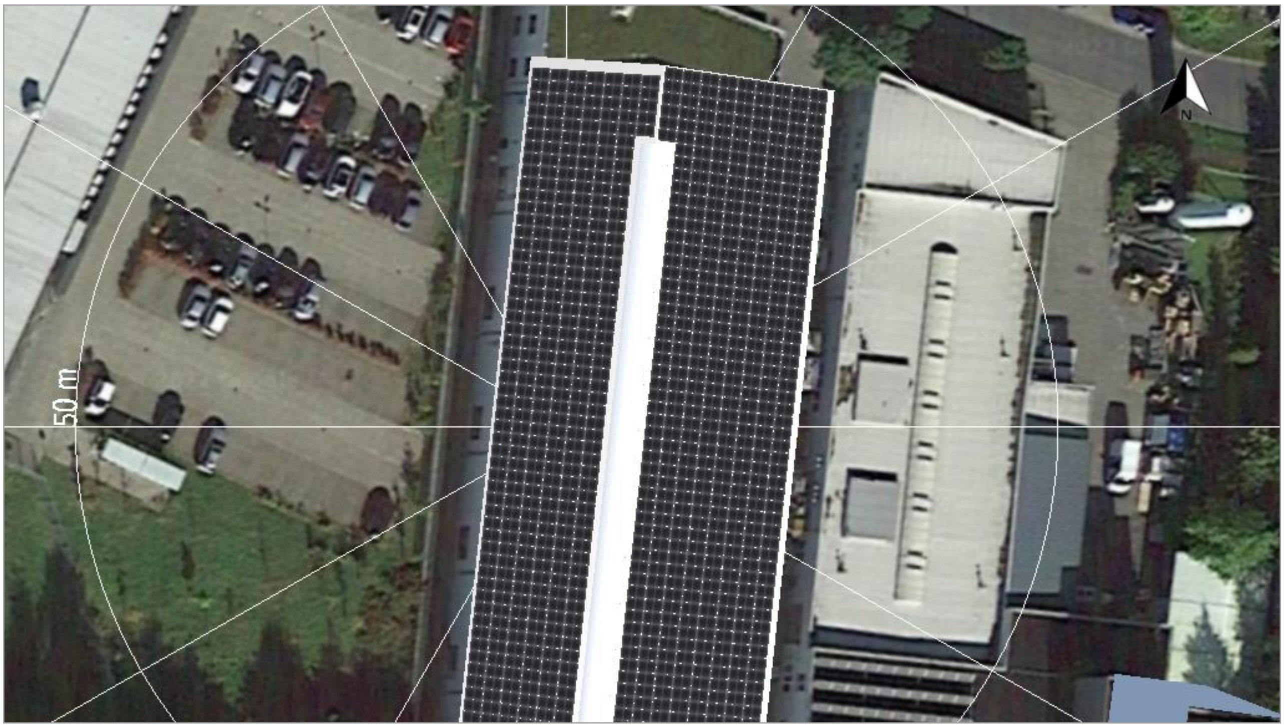



Figure: Overview Image, 3D Design

## PV System

### 3D, Grid-connected PV System

| | | |
|---|---|---|
| Climate Data | Osterholz-Scharmbeck, DEU (1995 - 2012) | |
| Values source | DWD | |
| PV Generator Output | 371,79 | kWp |
| PV Generator Surface | 1.778,0 | m² |
| Number of PV Modules | 918 | |
| Number of Inverters | 11 | |

**Offer Number:** 123456

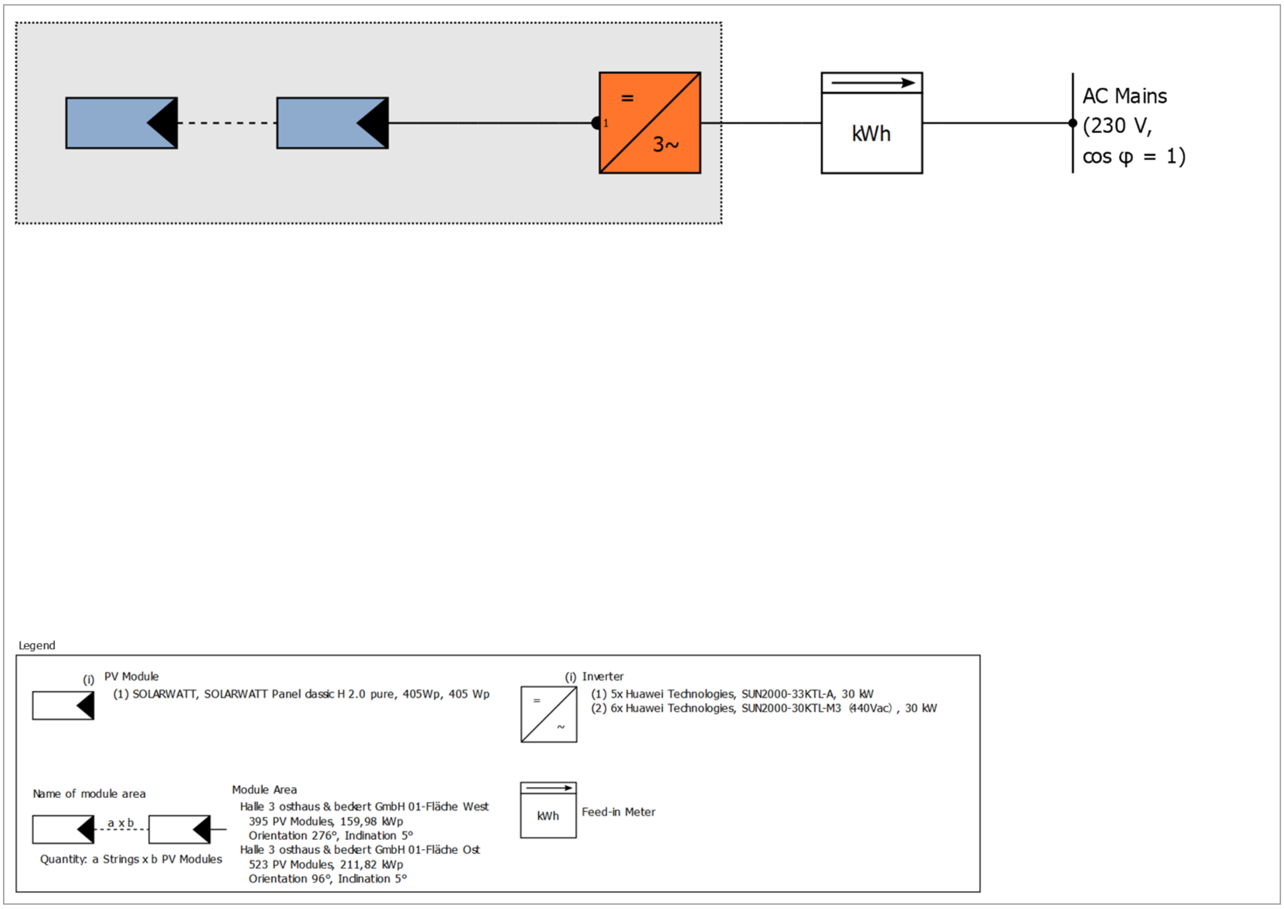



Figure: Schematic diagram

# Production Forecast

| Production Forecast | |
|---|---|
| PV Generator Output | 371,79 kWp |
| Spec. Annual Yield | 877,57 kWh/kWp |
| Performance Ratio (PR) | 89,39 % |
| Yield Reduction due to Shading | 0,5 %/Year |
| | |
| Grid Feed-in | 326.495 kWh/Year |
| Grid Feed-in in the first year (incl. module degradation) | 325.234 kWh/Year |
| Standby Consumption (Inverter) | 224 kWh/Year |
| | |
| $CO_2$ Emissions avoided | 158.242 kg / year |

# Financial Analysis

| Your Gain | |
|---|---|
| Total investment costs | 228.808,00 € |
| Internal Rate of Return of Capital Resources | 3,74 % |
| Amortization Period | 19,6 Years |
| Electricity Production Costs | 0,0328 €/kWh |
| Energy Balance/Feed-in Concept | Full Feed-in |

The results have been calculated with a mathematical model calculation from Valentin Software GmbH (PV*SOL algorithms). The actual yields from the solar power system may differ as a result of weather variations, the efficiency of the modules and inverter, and other factors.

# Set-up of the System

## Overview

| System Data | |
|---|---|
| Type of System | 3D, Grid-connected PV System |

| Climate Data | |
|---|---|
| Location | Osterholz-Scharmbeck, DEU (1995 - 2012) |
| Values source | DWD |
| Resolution of the data | 1 min |
| Simulation models used: | |
| - Diffuse Irradiation onto Horizontal Plane | Hofmann |
| - Irradiance onto tilted surface | Hay & Davies |

## Module Areas

### 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West

| PV Generator, 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West | | |
|---|---|---|
| Name | Halle 3 osthaus & beckert GmbH 01-Fläche West | |
| PV Modules | 395 x SOLARWATT Panel classic H 2.0 pure, 405Wp (v1) | |
| Manufacturer | SOLARWATT | |
| Inclination | 5 | ° |
| Orientation | West 276 | ° |
| Installation Type | Roof parallel | |
| PV Generator Surface | 765,1 | m² |

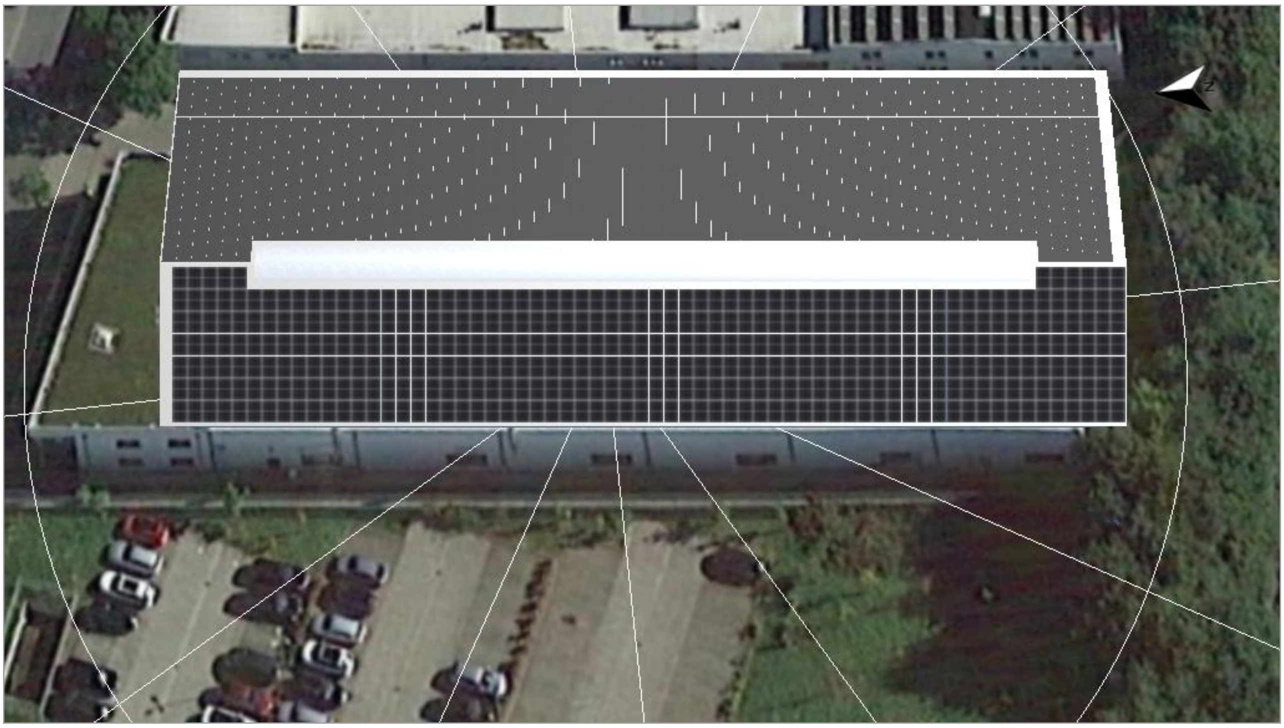


Figure: 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West

## *2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost*

### PV Generator, 2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost

| | | |
|---|---|---|
| Name | Halle 3 osthaus & beckert GmbH 01-Fläche Ost | |
| PV Modules | 523 x SOLARWATT Panel classic H 2.0 pure, 405Wp (v1) | |
| Manufacturer | SOLARWATT | |
| Inclination | 5 | ° |
| Orientation | East 96 | ° |
| Installation Type | Roof parallel | |
| PV Generator Surface | 1.013,0 | m² |

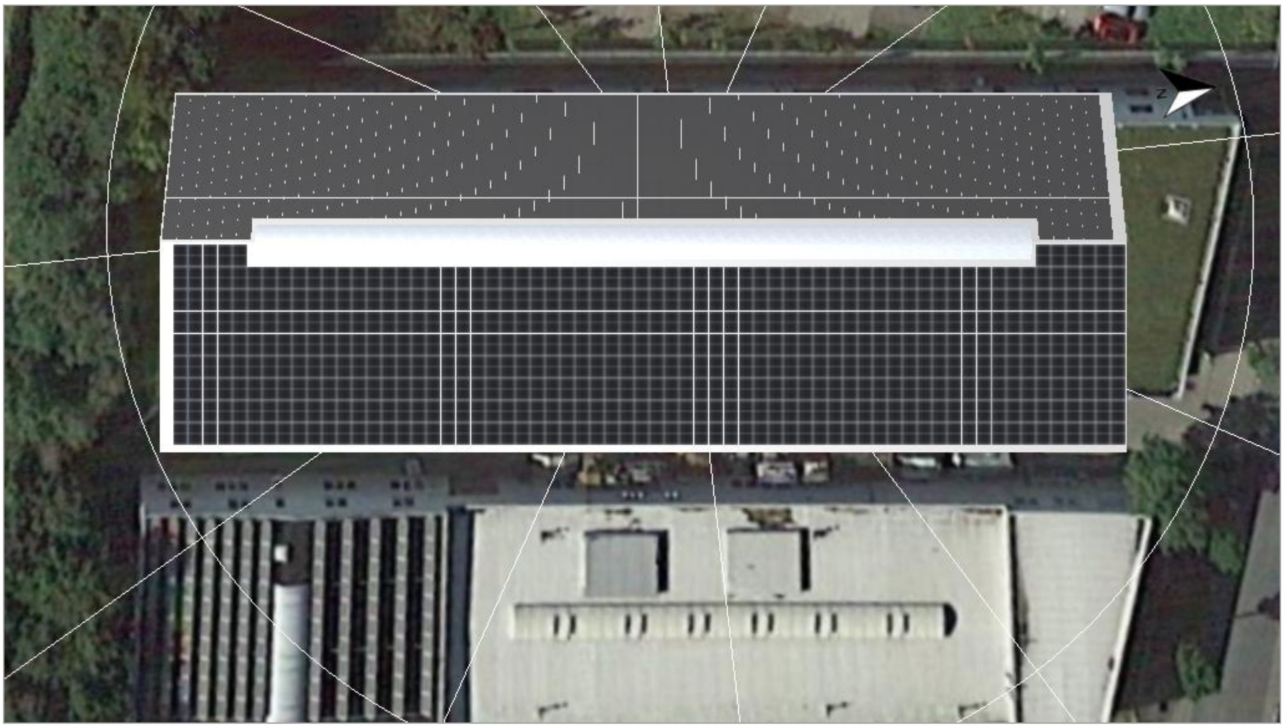


Figure: 2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost

# Horizon Line, 3D Design

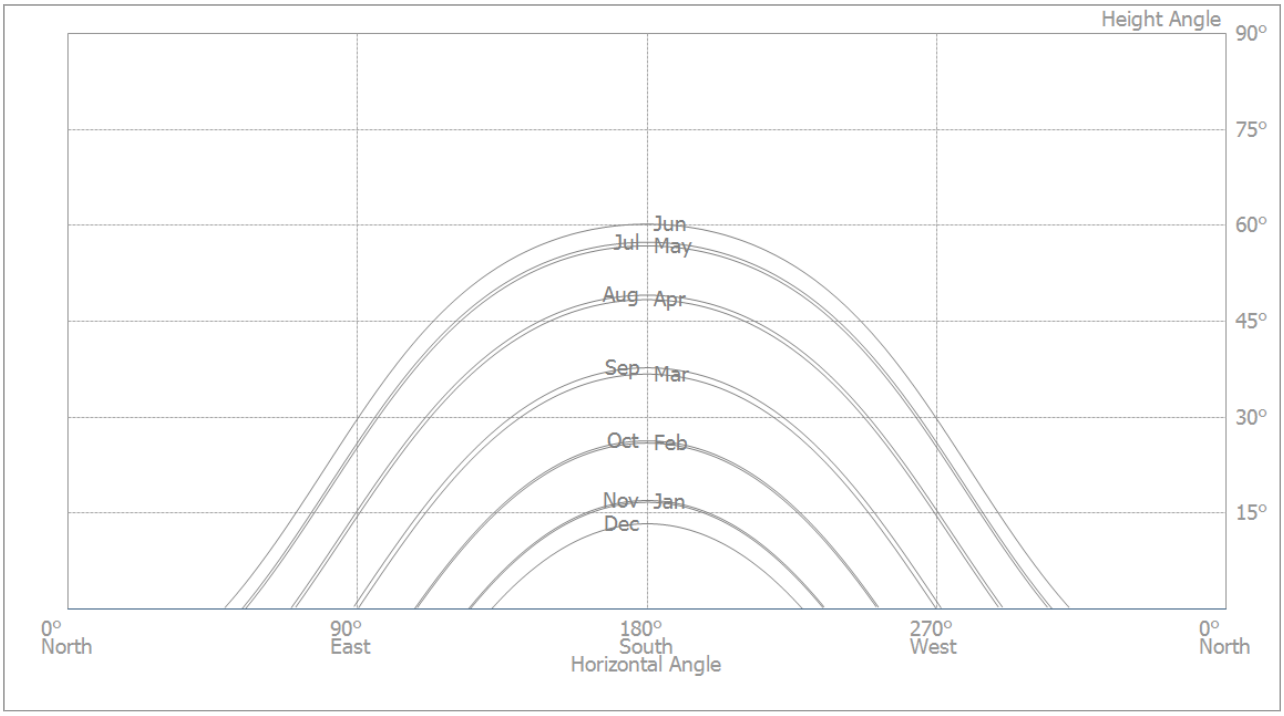



Figure: Horizon (3D Design)

# Inverter configuration

Configuration 1

| | |
|---|---|
| Module Area | Halle 3 osthaus & beckert GmbH 01-Fläche West |
| Inverter 1 | |
| Model | SUN2000-33KTL-A (v1) |
| Manufacturer | Huawei Technologies |
| Quantity | 5 |
| Sizing Factor | 106,7 % |
| Configuration | MPP 1: 1 x 20 |
| | MPP 2: 1 x 20 |
| | MPP 3: 1 x 20 |
| | MPP 4: 1 x 19 |

### Configuration 2

| | |
|---|---|
| Module Area | Halle 3 osthaus & beckert GmbH 01-Fläche Ost |
| Inverter 1 | |
| Model | SUN2000-30KTL-M3（440Vac） (v1) |
| Manufacturer | Huawei Technologies |
| Quantity | 5 |
| Sizing Factor | 117,5 % |
| Configuration | MPP 1: 1 x 22 |
| | MPP 2: 1 x 22 |
| | MPP 3: 1 x 22 |
| | MPP 4: 1 x 21 |
| Inverter 2 | |
| Model | SUN2000-30KTL-M3（440Vac） (v1) |
| Manufacturer | Huawei Technologies |
| Quantity | 1 |
| Sizing Factor | 118,8 % |
| Configuration | MPP 1: 1 x 22 |
| | MPP 2: 1 x 22 |
| | MPP 3: 1 x 22 |
| | MPP 4: 1 x 22 |

# AC Mains

### AC Mains

| | |
|---|---|
| Number of Phases | 3 |
| Mains voltage between phase and neutral | 230 V |
| Displacement Power Factor (cos phi) | +/- 1 |

# Simulation Results

## Results Total System

| PV System | | |
|---|---:|---|
| PV Generator Output | 371,79 | kWp |
| Spec. Annual Yield | 877,57 | kWh/kWp |
| Performance Ratio (PR) | 89,39 | % |
| Yield Reduction due to Shading | 0,5 | %/Year |
| | | |
| Grid Feed-in | 326.495 | kWh/Year |
| Grid Feed-in in the first year (incl. module degradation) | 325.234 | kWh/Year |
| Standby Consumption (Inverter) | 224 | kWh/Year |
| | | |
| $CO_2$ Emissions avoided | 158.242 | kg / year |

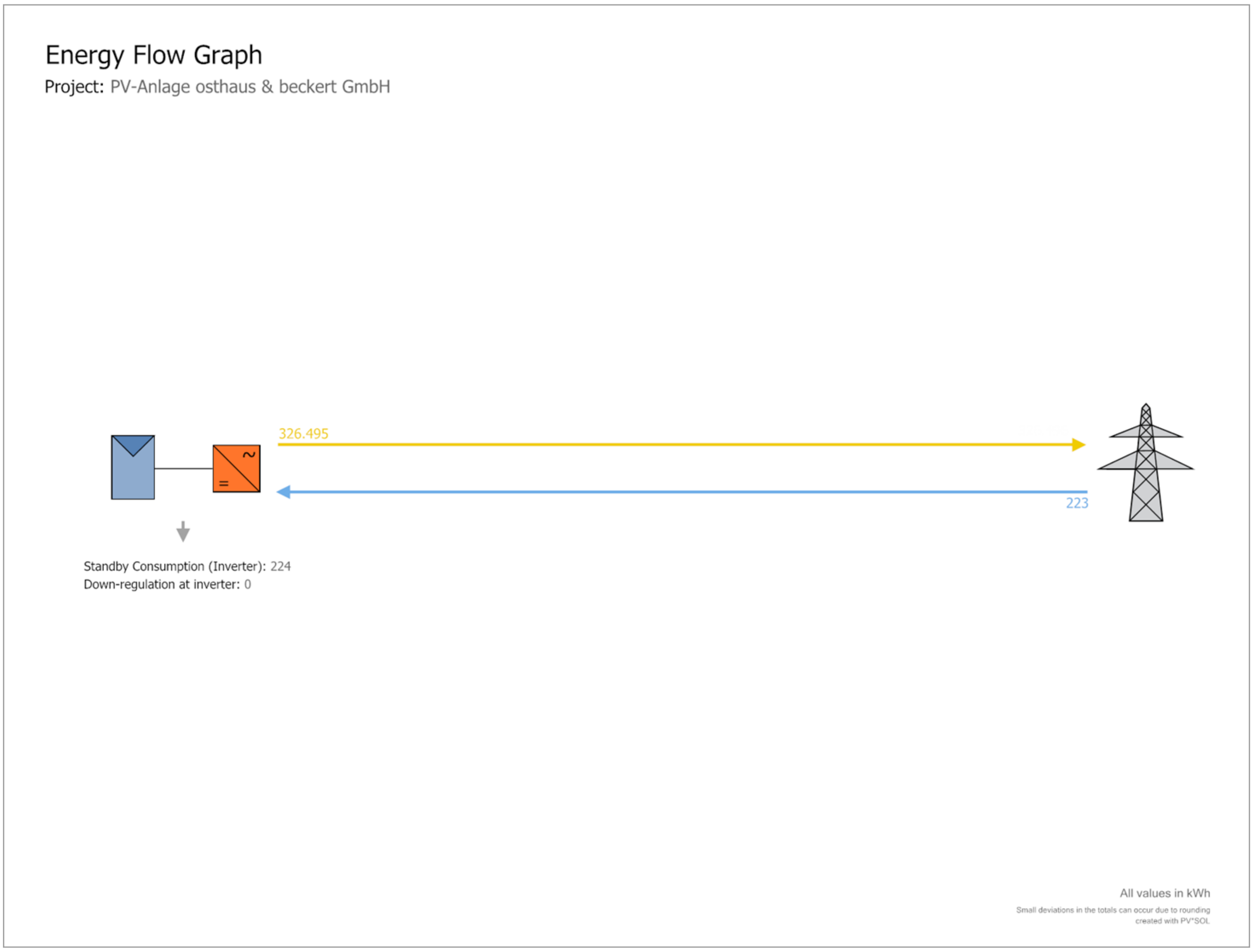



Figure: Energy flow

# Yield for EnEV

## Yield in accordance with DIN 15316-4-6

| | | |
|---|---|---|
| January | 5236,6 | kWh |
| February | 7176,3 | kWh |
| March | 17515,4 | kWh |
| April | 33027,1 | kWh |
| May | 39906,3 | kWh |
| June | 42113,9 | kWh |
| July | 37920 | kWh |
| August | 32502,9 | kWh |
| September | 22192,8 | kWh |
| October | 13904 | kWh |
| November | 5417,1 | kWh |
| December | 3069,7 | kWh |
| **Annual Value** | **259.982,2** | **kWh** |

Boundary Conditions:
Climate Data according to DIN V 18599-10
HALLE 3 OSTHAUS & BECKERT GMBH 01-FLÄCHE WEST
System Power Factor: 0.75
Peak Power Coefficient: 0.182
Orientation: West
Inclination: 0°

HALLE 3 OSTHAUS & BECKERT GMBH 01-FLÄCHE OST
System Power Factor: 0.75
Peak Power Coefficient: 0.182
Orientation: East
Inclination: 0°

# Financial Analysis

## Overview

### System Data

| | | |
|---|---|---|
| Grid Feed-in in the first year (incl. module degradation) | 325.234 | kWh/Year |
| PV Generator Output | 371,8 | kWp |
| Start of Operation of the System | 01.07.2022 | |
| Assessment Period | 30 | Years |
| Interest on Capital | 1 | % |

### Economic Parameters

| | | |
|---|---|---|
| Internal Rate of Return of Capital Resources | 3,74 | % |
| Accrued Cash Flow (Cash Balance) | 66.582,17 | € |
| Amortization Period | 19,6 | Years |
| Electricity Production Costs | 0,0328 | €/kWh |

### Payment Overview

| | | |
|---|---|---|
| Specific Investment Costs | 615,42 | €/kWp |
| Investment Costs | 228.808,00 | € |
| One-off Payments | 0,00 | € |
| Incoming Subsidies | 0,00 | € |
| Annual Costs | 1.400,00 | €/Year |
| Other Revenue or Savings | 0,00 | €/Year |

### Loans

| **Reference** | **Loan 1** | |
|---|---|---|
| Loan Capital | 150.000,00 | € |
| Payment Installment | 100,00 | % |
| Credit type | Installment Loan | |
| Term | 10,00 | Years |
| Grace period | 0,00 | Years |
| Interest | 3,50 | |
| Repayment Period | quarterly | |

### Remuneration and Savings

| | | |
|---|---|---|
| Total Payment from Utility in First Year | 17.194,66 | €/Year |
| | | |
| EEG 2022 (Juli) Marktprämienmodell - Gebäudeanlage | | |
| Validity | 01.07.2022 - | 31.12.2042 |
| Specific feed-in / export Remuneration | 0,0529 | €/kWh |
| Feed-in / Export Tariff | 17194,6585 | €/Year |

# Cash flow

## Cash flow

| | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| Operating costs | -1.386,14 € | -1.372,41 € | -1.358,83 € | -1.345,37 € | -1.332,05 € |
| Depreciation | -11.327,13 € | -11.214,98 € | -11.103,94 € | -10.994,00 € | -10.885,15 € |
| Self-Financing | -78.808,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 17.024,41 € | 16.739,87 € | 16.459,29 € | 16.182,62 € | 15.909,82 € |
| Loan repayments | -14.851,49 € | -14.704,44 € | -14.558,85 € | -14.414,71 € | -14.271,99 € |
| Loan Interest | -5.003,09 € | -4.438,90 € | -3.885,39 € | -3.342,41 € | -2.809,80 € |
| Results before Tax | -691,95 € | -286,43 € | 111,13 € | 500,84 € | 882,82 € |
| Tax Refund | 297,54 € | 123,16 € | -47,78 € | -215,36 € | -379,61 € |
| Results after Tax | -394,41 € | -163,26 € | 63,34 € | 285,48 € | 503,21 € |
| **Annual Cash Flow** | **-82.726,77 €** | **-3.652,73 €** | **-3.391,57 €** | **-3.135,23 €** | **-2.883,63 €** |
| Accrued Cash Flow (Cash Balance) | -82.726,77 € | -86.379,49 € | -89.771,06 € | -92.906,29 € | -95.789,92 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -230.833,60 € | -215.342,99 € | -200.290,31 € | -185.668,42 € | -171.470,27 € |

## Cash flow

| | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 |
|---|---|---|---|---|---|
| Operating costs | -1.318,86 € | -1.305,81 € | -1.292,88 € | -1.280,08 € | -1.267,40 € |
| Depreciation | -10.777,37 € | -10.670,67 € | -10.565,02 € | -10.460,41 € | -10.356,84 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 15.640,84 € | 15.375,62 € | 15.114,12 € | 14.856,29 € | 14.602,08 € |
| Loan repayments | -14.130,68 € | -13.990,77 € | -13.852,25 € | -13.715,10 € | -13.579,30 € |
| Loan Interest | -2.287,40 € | -1.775,08 € | -1.272,68 € | -780,05 € | -297,05 € |
| Results before Tax | 1.257,19 € | 1.624,07 € | 1.983,55 € | 2.335,75 € | 2.680,79 € |
| Tax Refund | -540,59 € | -698,35 € | -852,93 € | -1.004,37 € | -1.152,74 € |
| Results after Tax | 716,60 € | 925,72 € | 1.130,62 € | 1.331,38 € | 1.528,05 € |
| **Annual Cash Flow** | **-2.636,70 €** | **-2.394,39 €** | **-2.156,61 €** | **-1.923,30 €** | **-1.694,41 €** |
| Accrued Cash Flow (Cash Balance) | -98.426,62 € | -100.821,01 € | -102.977,61 € | -104.900,92 € | -106.595,33 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -157.688,89 € | -144.317,42 € | -131.349,11 € | -118.777,27 € | -106.595,33 € |

## Cash flow

| | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 |
|---|---|---|---|---|---|
| Operating costs | -1.254,85 € | -1.242,43 € | -1.230,13 € | -1.217,95 € | -1.205,89 € |
| Depreciation | -10.254,30 € | -10.152,77 € | -10.052,25 € | -9.952,72 € | -9.854,18 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 14.351,46 € | 14.104,36 € | 13.860,75 € | 13.620,58 € | 13.383,81 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 2.842,30 € | 2.709,16 € | 2.578,37 € | 2.449,91 € | 2.323,74 € |
| Tax Refund | -1.222,19 € | -1.164,94 € | -1.108,70 € | -1.053,46 € | -999,21 € |
| Results after Tax | 1.620,11 € | 1.544,22 € | 1.469,67 € | 1.396,45 € | 1.324,53 € |
| **Annual Cash Flow** | **11.874,41 €** | **11.696,99 €** | **11.521,92 €** | **11.349,17 €** | **11.178,71 €** |
| Accrued Cash Flow (Cash Balance) | -94.720,91 € | -83.023,92 € | -71.502,00 € | -60.152,82 € | -48.974,11 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -94.720,91 € | -83.023,92 € | -71.502,00 € | -60.152,82 € | -48.974,11 € |

## Cash flow

| | Year 16 | Year 17 | Year 18 | Year 19 | Year 20 |
|---|---|---|---|---|---|
| Operating costs | -1.193,95 € | -1.182,13 € | -1.170,42 € | -1.158,84 € | -1.147,36 € |
| Depreciation | -9.756,62 € | -9.660,02 € | -9.564,37 € | -9.469,68 € | -9.375,92 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 13.150,39 € | 12.920,29 € | 12.693,44 € | 12.469,83 € | 12.249,40 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 2.199,83 € | 2.078,14 € | 1.958,65 € | 1.841,32 € | 1.726,12 € |
| Tax Refund | -945,93 € | -893,60 € | -842,22 € | -791,77 € | -742,23 € |
| Results after Tax | 1.253,90 € | 1.184,54 € | 1.116,43 € | 1.049,55 € | 983,89 € |
| **Annual Cash Flow** | **11.010,52 €** | **10.844,56 €** | **10.680,80 €** | **10.519,23 €** | **10.359,80 €** |
| Accrued Cash Flow (Cash Balance) | -37.963,59 € | -27.119,03 € | -16.438,23 € | -5.919,00 € | 4.440,80 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -37.963,59 € | -27.119,03 € | -16.438,23 € | -5.919,00 € | 4.440,80 € |

## Cash flow

| | Year 21 | Year 22 | Year 23 | Year 24 | Year 25 |
|---|---|---|---|---|---|
| Operating costs | -1.136,00 € | -1.124,75 € | -1.113,62 € | -1.102,59 € | -1.091,68 € |
| Depreciation | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 12.023,64 € | 11.802,59 € | 11.591,74 € | 11.383,91 € | 11.179,06 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 10.887,63 € | 10.677,84 € | 10.478,12 € | 10.281,32 € | 10.087,38 € |
| Tax Refund | -4.681,68 € | -4.591,47 € | -4.505,59 € | -4.420,97 € | -4.337,57 € |
| Results after Tax | 6.205,95 € | 6.086,37 € | 5.972,53 € | 5.860,35 € | 5.749,81 € |
| **Annual Cash Flow** | **6.205,95 €** | **6.086,37 €** | **5.972,53 €** | **5.860,35 €** | **5.749,81 €** |
| Accrued Cash Flow (Cash Balance) | 10.646,75 € | 16.733,12 € | 22.705,65 € | 28.566,00 € | 34.315,81 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 10.646,75 € | 16.733,12 € | 22.705,65 € | 28.566,00 € | 34.315,81 € |

**Offer Number:** 123456

## Cash flow

| | Year 26 | Year 27 | Year 28 | Year 29 | Year 30 |
|---|---|---|---|---|---|
| Operating costs | -1.080,87 € | -1.070,17 € | -1.059,57 € | -1.049,08 € | -1.038,69 € |
| Depreciation | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 10.977,14 € | 10.778,13 € | 10.581,99 € | 10.388,67 € | 10.198,14 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 9.896,28 € | 9.707,97 € | 9.522,42 € | 9.339,59 € | 9.159,45 € |
| Tax Refund | -4.255,40 € | -4.174,43 € | -4.094,64 € | -4.016,02 € | -3.938,56 € |
| Results after Tax | 5.640,88 € | 5.533,54 € | 5.427,78 € | 5.323,56 € | 5.220,88 € |
| **Annual Cash Flow** | **5.640,88 €** | **5.533,54 €** | **5.427,78 €** | **5.323,56 €** | **5.220,88 €** |
| Accrued Cash Flow (Cash Balance) | 39.956,68 € | 45.490,22 € | 50.918,00 € | 56.241,57 € | 61.462,45 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 39.956,68 € | 45.490,22 € | 50.918,00 € | 56.241,57 € | 61.462,45 € |

## Cash flow

| | Year 31 |
|---|---|
| Operating costs | -1.028,41 € |
| Depreciation | 0,00 € |
| Self-Financing | 0,00 € |
| Feed-in / Export Tariff | 10.010,37 € |
| Loan repayments | 0,00 € |
| Loan Interest | 0,00 € |
| Results before Tax | 8.981,96 € |
| Tax Refund | -3.862,24 € |
| Results after Tax | 5.119,72 € |
| **Annual Cash Flow** | **5.119,72 €** |
| Accrued Cash Flow (Cash Balance) | 66.582,17 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 66.582,17 € |

Degradation and inflation rates are applied on a monthly basis over the entire observation period. This is done in the first year.

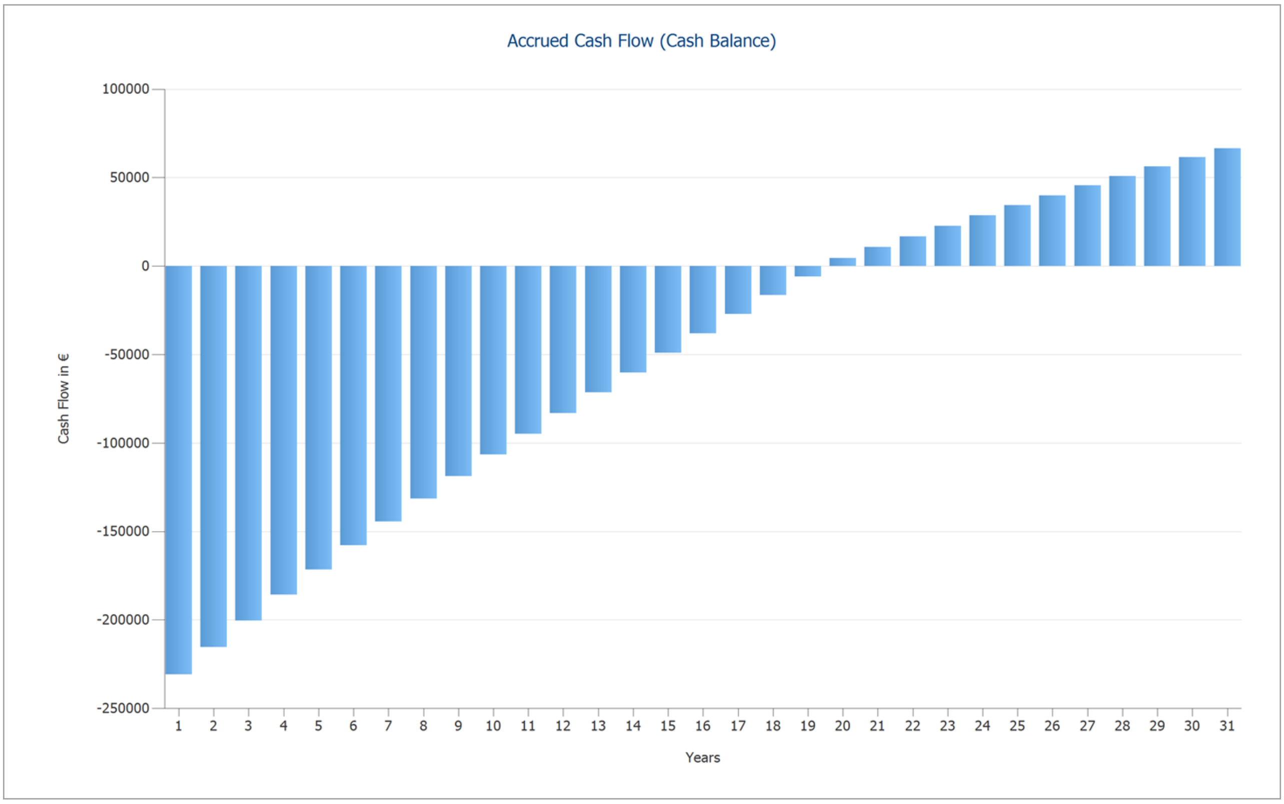



Figure: Accrued Cash Flow (Cash Balance)

# Plans and parts list

## Circuit Diagram

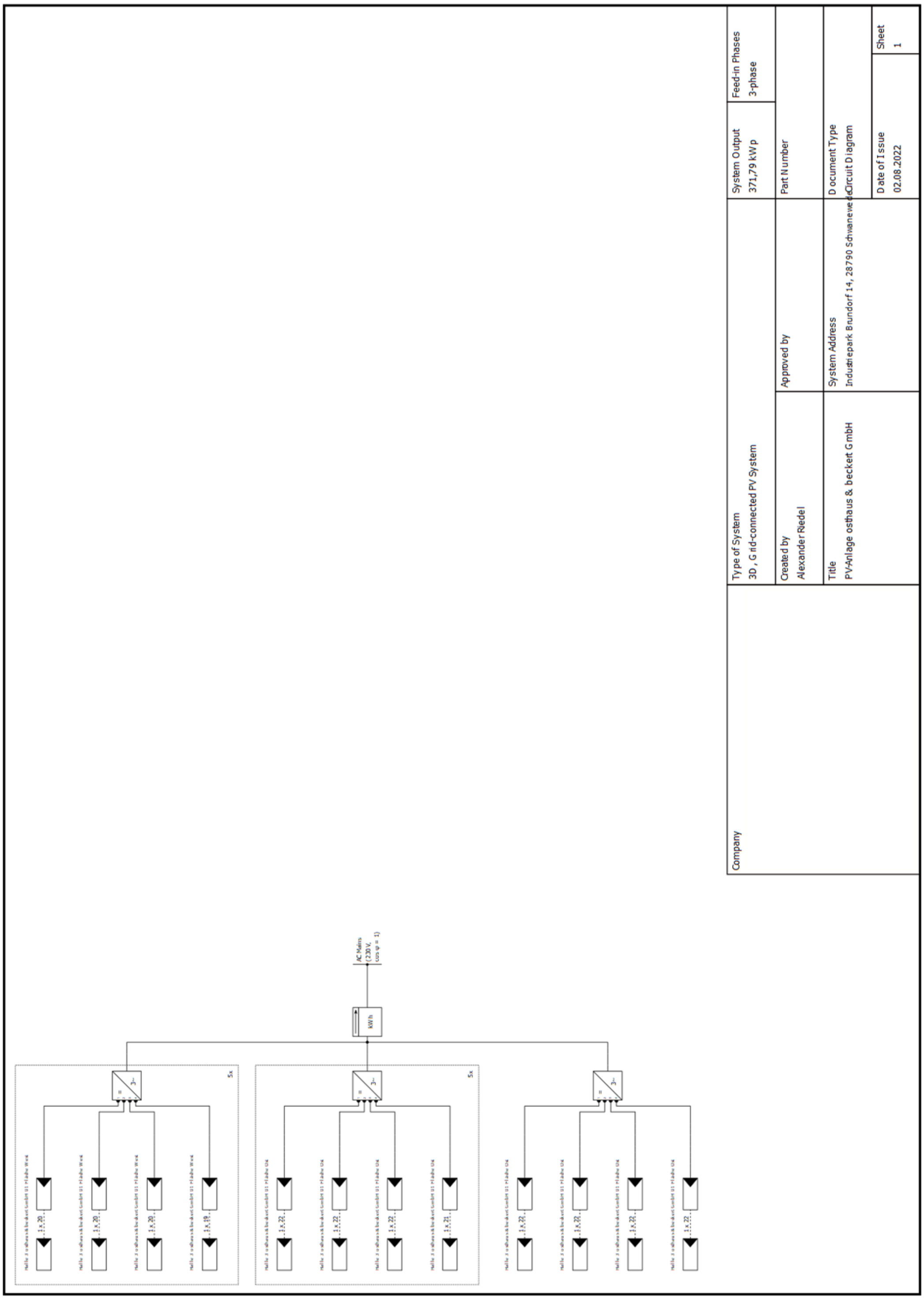



Figure: Circuit Diagram

# Overview plan

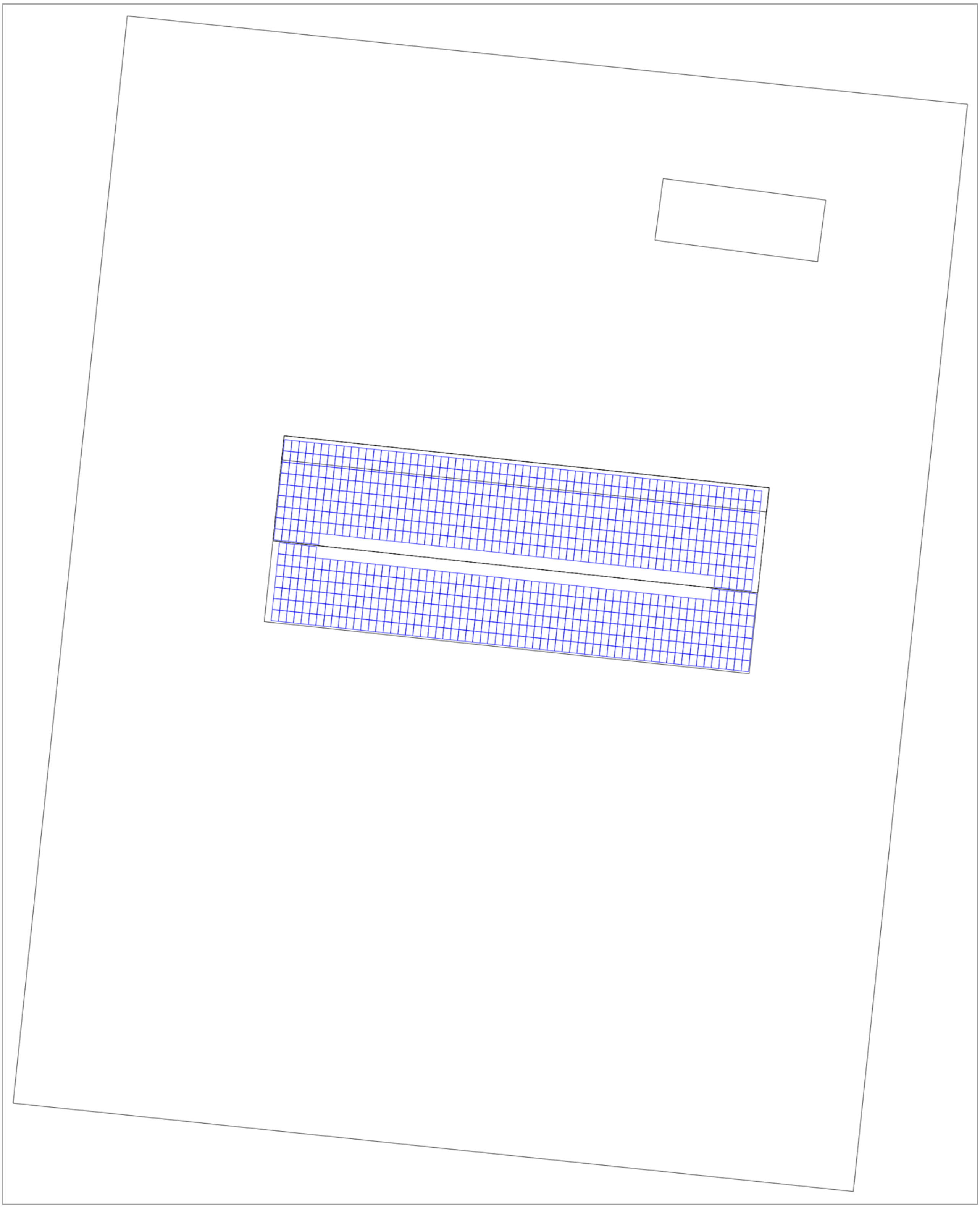


Figure: Overview plan

# Dimensioning Plan

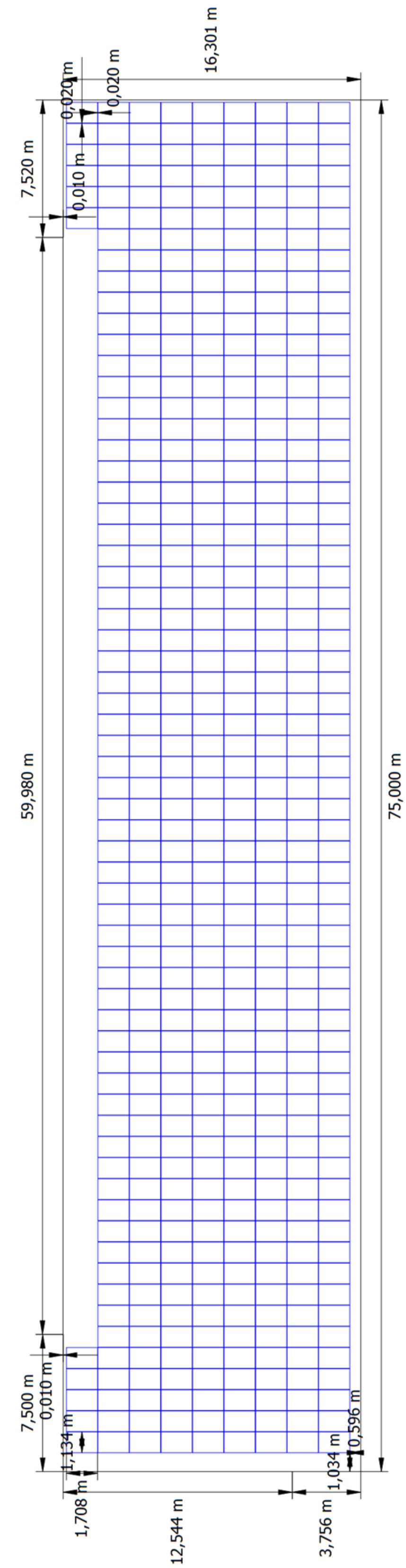



Figure: Halle 3 osthaus & beckert GmbH 01-Fläche Ost

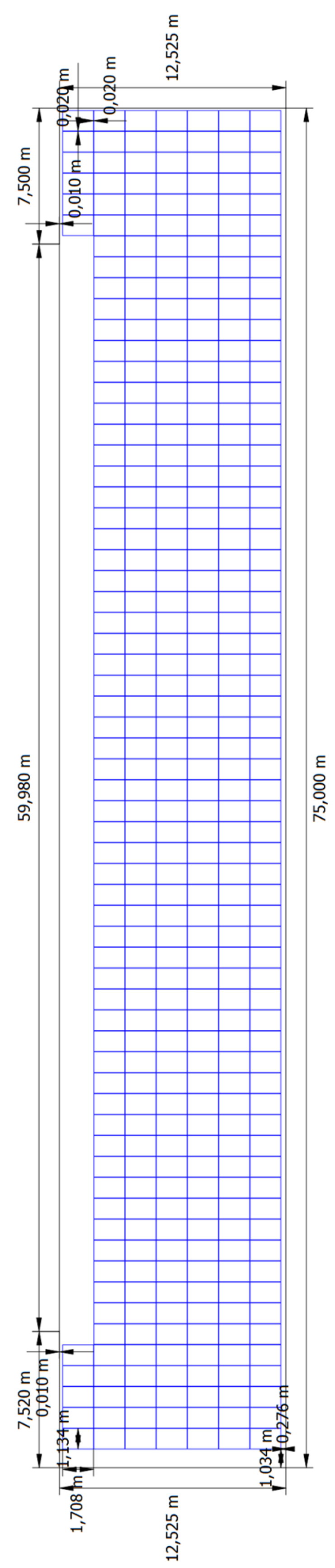



Figure: Halle 3 osthaus & beckert GmbH 01-Fläche West

# String Plan

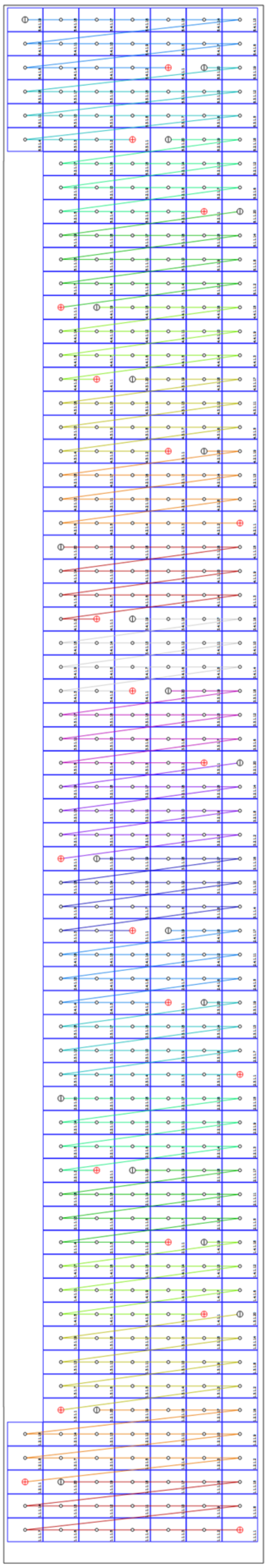


Figure: Halle 3 osthaus & beckert GmbH 01-Fläche West

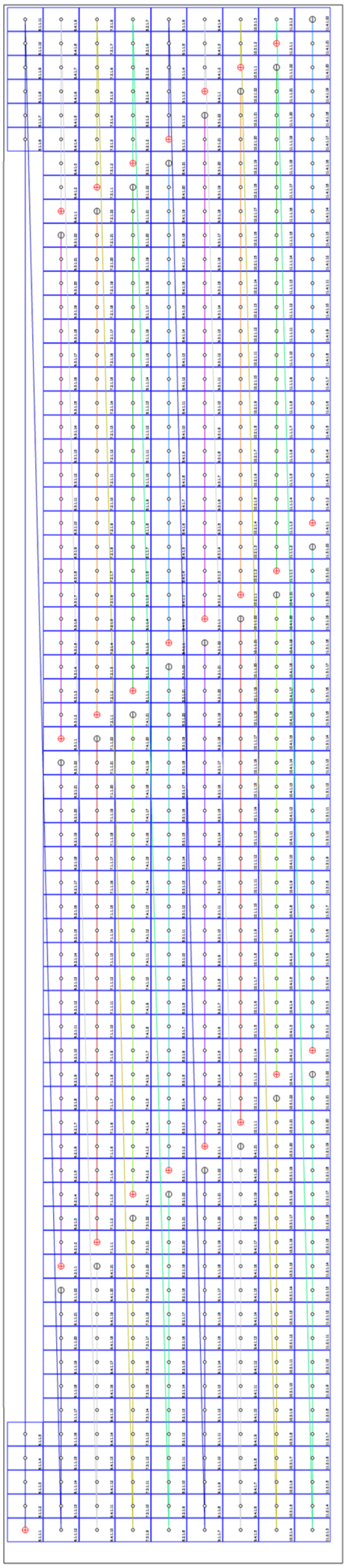


Figure: Halle 3 osthaus & beckert GmbH 01-Fläche Ost

# Parts list

## Parts list

| # | Type | Item number | Manufacturer | Name | Quantity | Unit |
|---|---|---|---|---|---|---|
| 1 | PV Module | | SOLARWATT | SOLARWATT Panel classic H 2.0 pure, 405Wp | 918 | Piece |
| 2 | Inverter | | Huawei Technologies | SUN2000-33KTL-A | 5 | Piece |
| 3 | Inverter | | Huawei Technologies | SUN2000-30KTL-M3（440Vac） | 6 | Piece |
| 4 | Components | | | Feed-in Meter | 1 | Piece |

# Annex I: Simulation report Scenario 3 (Surplus Feeder)

**osthaus & beckert GmbH**
Beckert, Andreas; Osthaus, Christian
Industriepark Brundorf 14, 28790
Schwanewede

**Customer No.:** 123456789
**Project Name:** PV-Anlage osthaus & beckert GmbH
**Offer no.:** 123456

02.08.2022

## Your PV system

### Address of Installation

Industriepark Brundorf 14, 28790 Schwanewede


Project Description:
Planning of a company-owned PV system for osthaus & beckert GmbH

# Project Overview

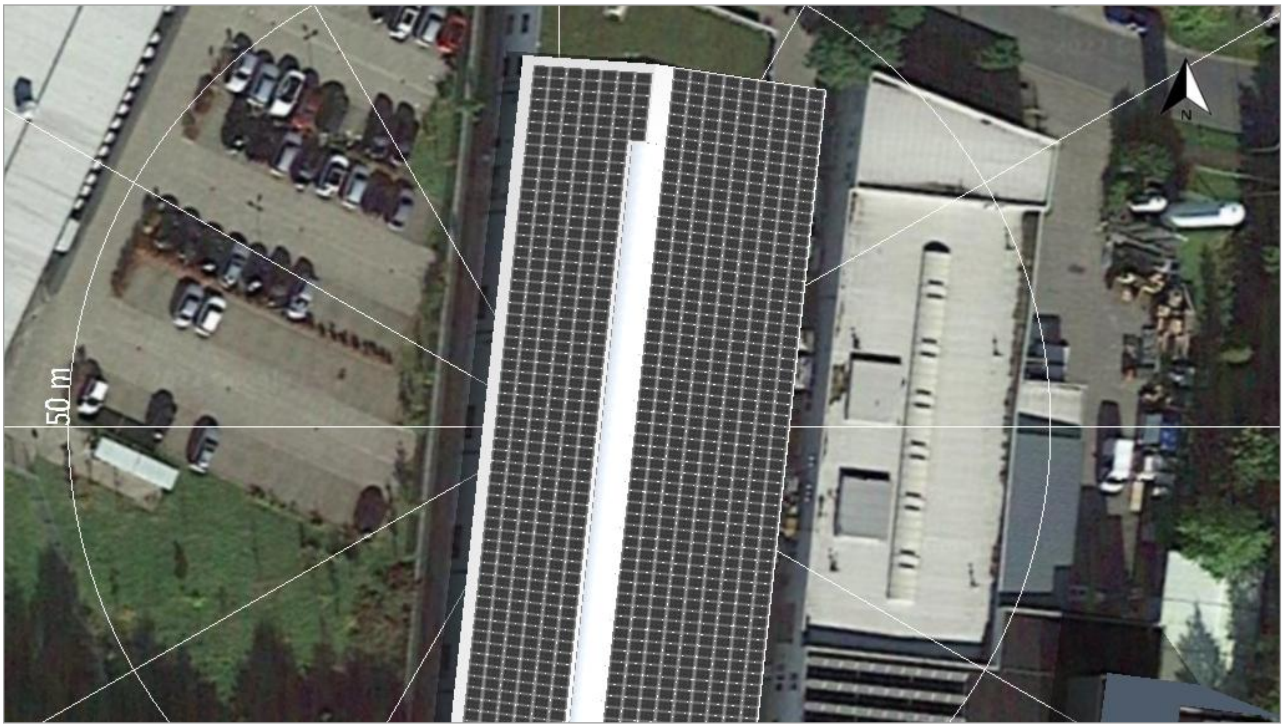



Figure: Overview Image, 3D Design

## PV System

### 3D, Grid-connected PV System with Electrical Appliances and Battery Systems

| | | |
|---|---|---|
| Climate Data | Osterholz-Scharmbeck, DEU (1995 - 2012) | |
| Values source | DWD | |
| PV Generator Output | 345,51 | kWp |
| PV Generator Surface | 1.753,0 | m² |
| Number of PV Modules | 1047 | |
| Number of Inverters | 12 | |
| No. of battery systems | 1 | |

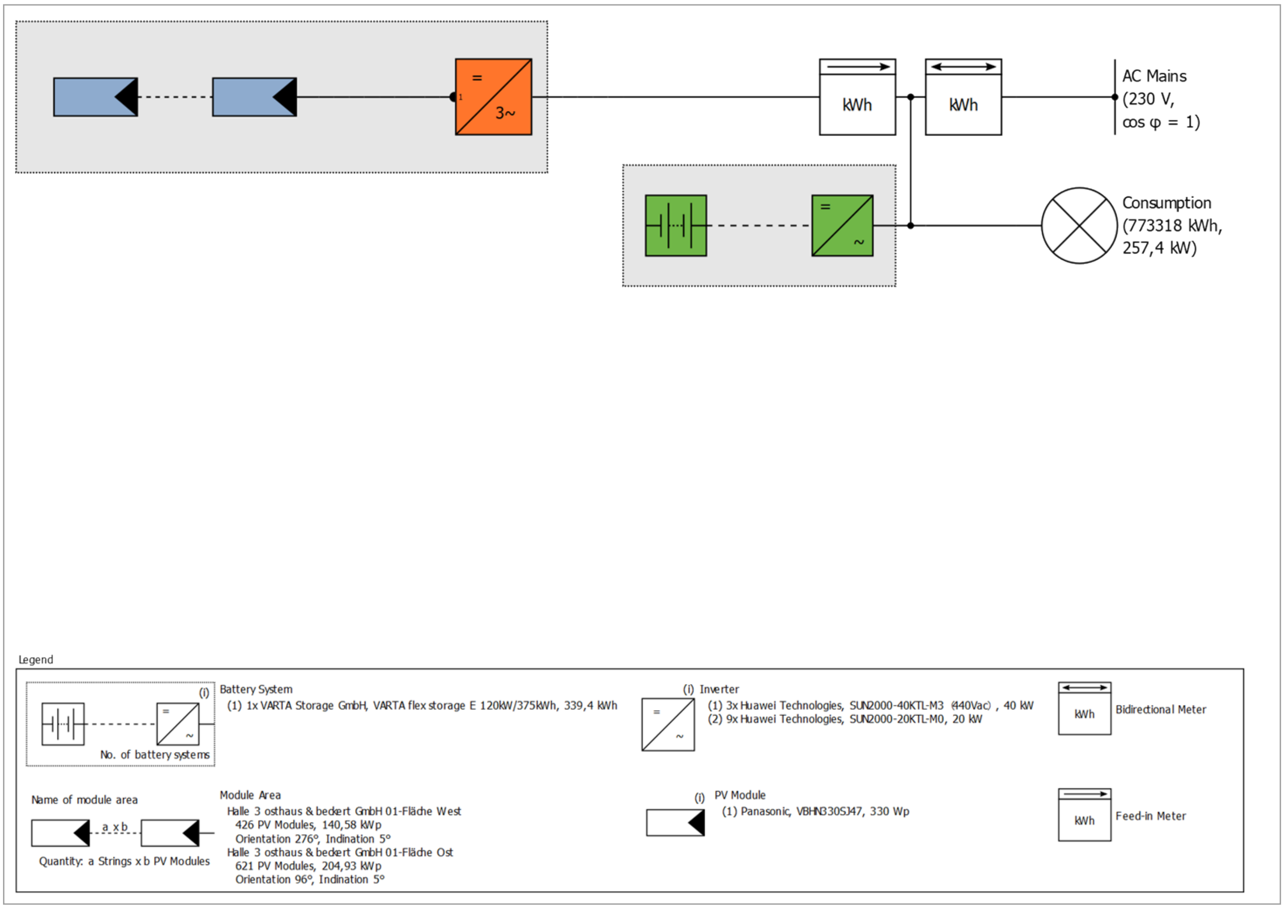



Figure: Schematic diagram

# Production Forecast

| Production Forecast | |
|---|---|
| PV Generator Output | 345,51 kWp |
| Spec. Annual Yield | 851,50 kWh/kWp |
| Performance Ratio (PR) | 86,40 % |
| Yield Reduction due to Shading | 0,6 %/Year |
| | |
| PV Generator Energy (AC grid) | 294.286 kWh/Year |
| Direct Own Use | 212.113 kWh/Year |
| Battery Charge | 45.097 kWh/Year |
| Down-regulation at Feed-in Point | 0 kWh/Year |
| Grid Feed-in | 37.075 kWh/Year |
| | |
| Own Power Consumption | 87,4 % |
| | |
| $CO_2$ Emissions avoided | 140.489 kg / year |
| | |
| Level of Self-sufficiency | 32,7 % |

# Financial Analysis

## Your Gain

| | |
|---|---|
| Total investment costs | 486.325,00 € |
| Internal Rate of Return of Capital Resources | 7,33 % |
| Amortization Period | 16,0 Years |
| Electricity Production Costs | 0,0732 €/kWh |
| Energy Balance/Feed-in Concept | Surplus Feed-in |

The results have been calculated with a mathematical model calculation from Valentin Software GmbH (PV*SOL algorithms). The actual yields from the solar power system may differ as a result of weather variations, the efficiency of the modules and inverter, and other factors.

# Set-up of the System

## Overview

### System Data

| | |
|---|---|
| Type of System | 3D, Grid-connected PV System with Electrical Appliances and Battery Systems |

### Climate Data

| | |
|---|---|
| Location | Osterholz-Scharmbeck, DEU (1995 - 2012) |
| Values source | DWD |
| Resolution of the data | 1 min |
| Simulation models used: | |
| - Diffuse Irradiation onto Horizontal Plane | Hofmann |
| - Irradiance onto tilted surface | Hay & Davies |

### Consumption

| | |
|---|---|
| Total Consumption | 773318 kWh |
| osthaus und beckert GmbH Halle 3 | 773318 kWh |
| Load Peak | 257,4 kW |

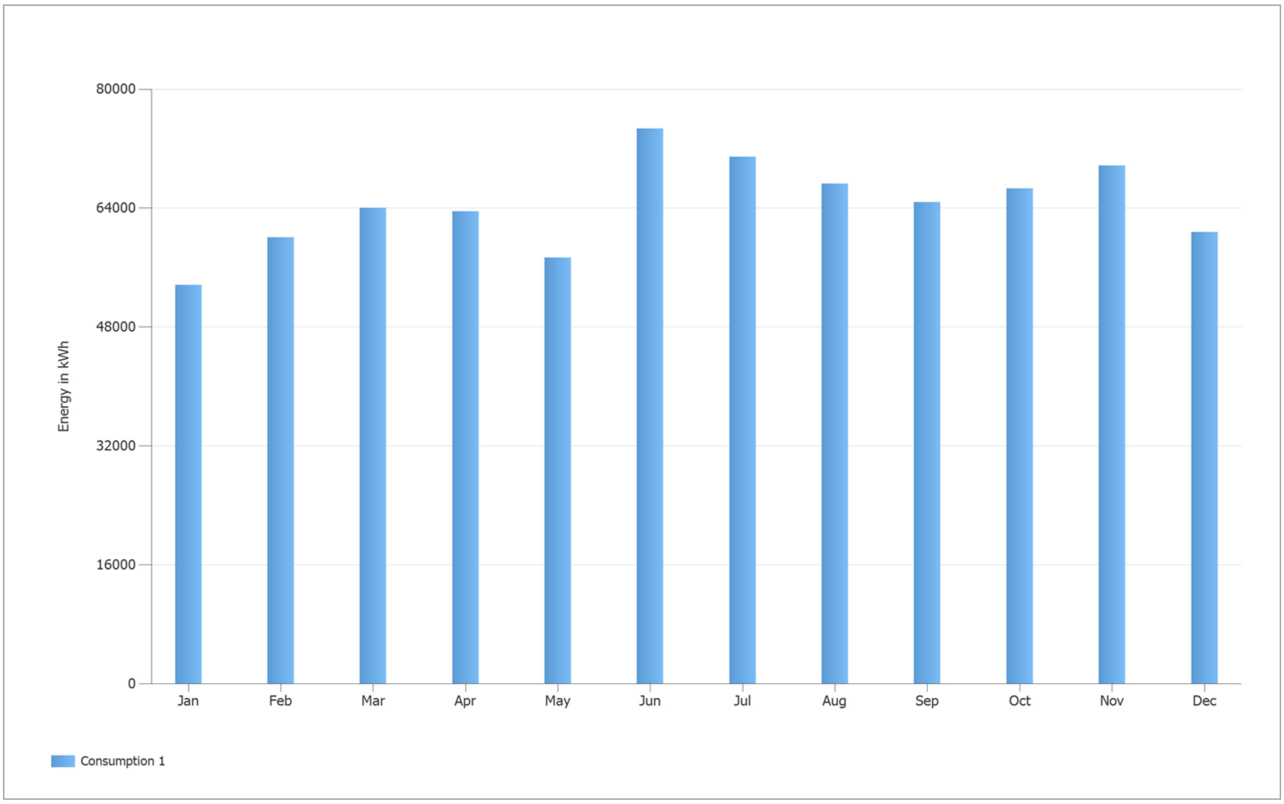



Figure: Consumption

# Module Areas

## 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West

### PV Generator, 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West

| | | |
|---|---|---|
| Name | Halle 3 osthaus & beckert GmbH 01-Fläche West | |
| PV Modules | 426 x VBHN330SJ47 (v1) | |
| Manufacturer | Panasonic | |
| Inclination | 5 | ° |
| Orientation | West 276 | ° |
| Installation Type | Roof parallel | |
| PV Generator Surface | 713,2 | m² |

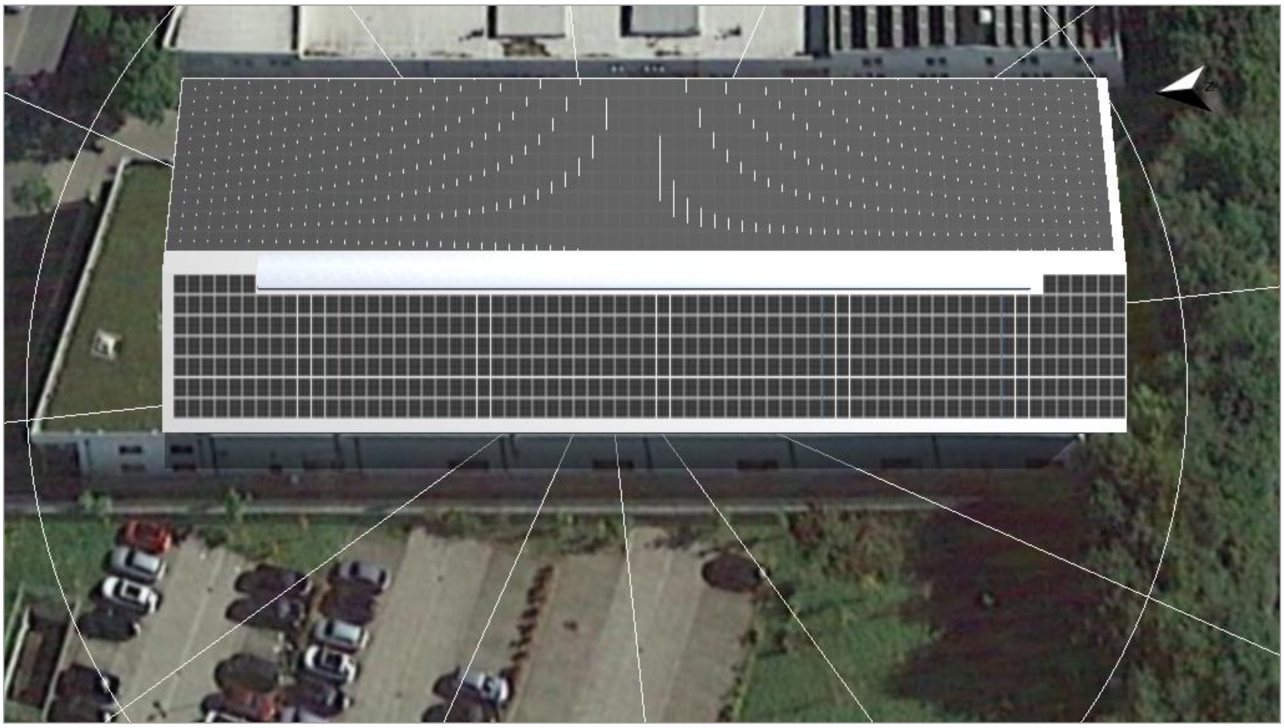


Figure: 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West

## *2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost*

### PV Generator, 2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost

| | |
|---|---|
| Name | Halle 3 osthaus & beckert GmbH 01-Fläche Ost |
| PV Modules | 621 x VBHN330SJ47 (v1) |
| Manufacturer | Panasonic |
| Inclination | 5 ° |
| Orientation | East 96 ° |
| Installation Type | Roof parallel |
| PV Generator Surface | 1.039,7 m² |

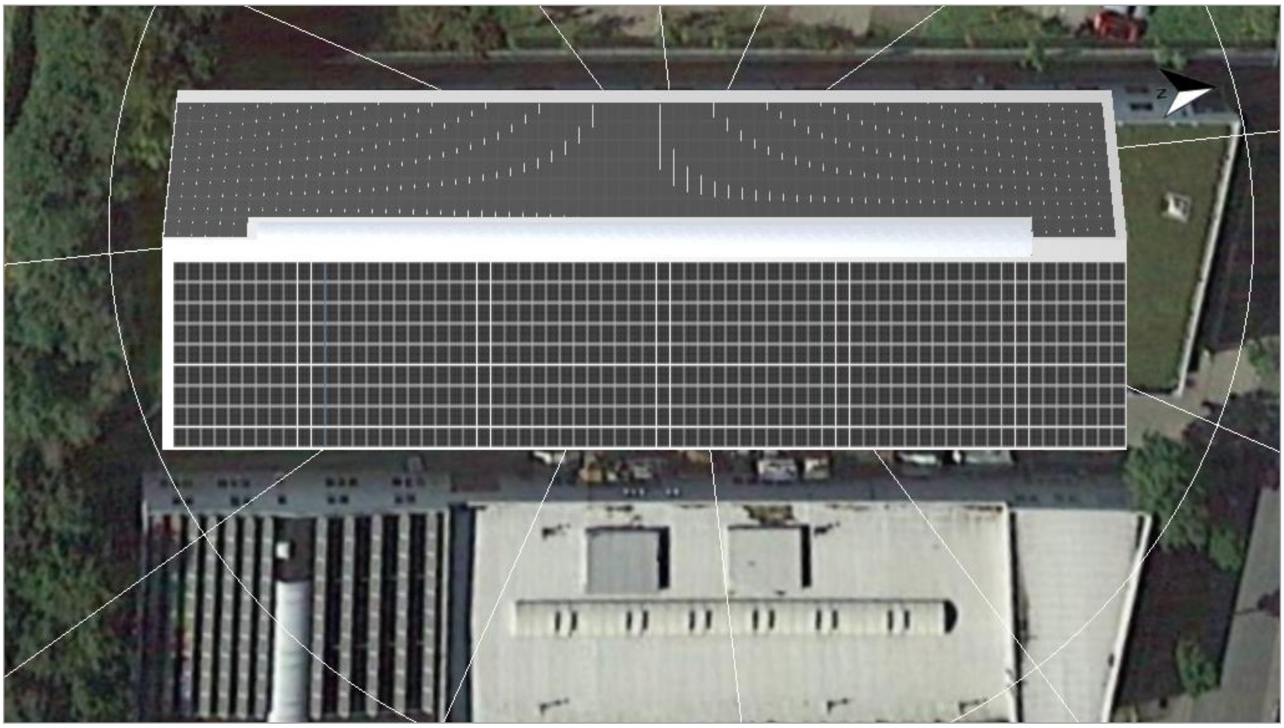


Figure: 2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost

# Horizon Line, 3D Design

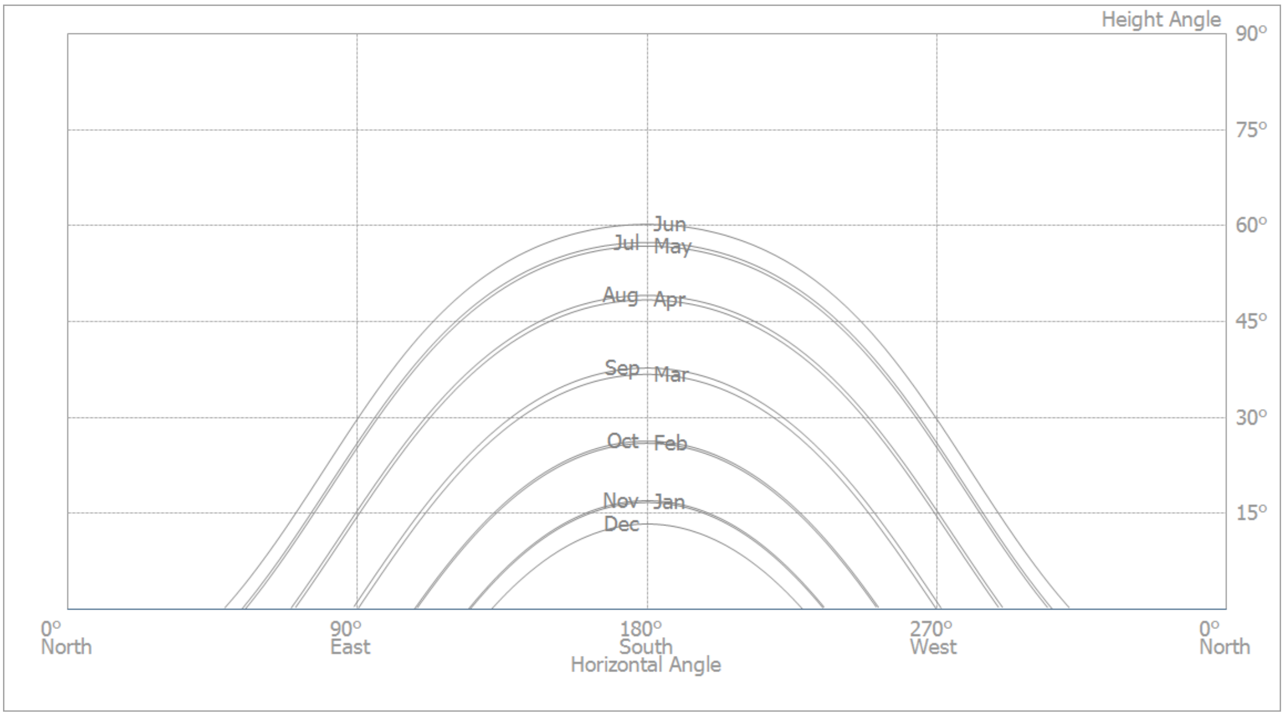



Figure: Horizon (3D Design)

# Inverter configuration

## Configuration 1

| | |
|---|---|
| Module Area | Halle 3 osthaus & beckert GmbH 01-Fläche West |
| Inverter 1 | |
| Model | SUN2000-40KTL-M3（440Vac） (v1) |
| Manufacturer | Huawei Technologies |
| Quantity | 3 |
| Sizing Factor | 117,2 % |
| Configuration | MPP 1: 4 x 10 |
| | MPP 2: 3 x 12 |
| | MPP 3: 3 x 11 |
| | MPP 4: 3 x 11 |

## Configuration 2

| | |
|---|---|
| Module Area | Halle 3 osthaus & beckert GmbH 01-Fläche Ost |
| Inverter 1 | |
| Model | SUN2000-20KTL-M0 (v2) |
| Manufacturer | Huawei Technologies |
| Quantity | 9 |
| Sizing Factor | 113,9 % |
| Configuration | MPP 1: 4 x 9 |
| | MPP 2: 3 x 11 |

# AC Mains

| AC Mains | | |
|---|---|---|
| Number of Phases | 3 | |
| Mains voltage between phase and neutral | 230 | V |
| Displacement Power Factor (cos phi) | +/- 1 | |

# Battery Systems

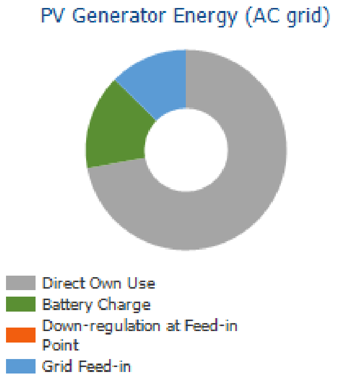
| Battery System | | |
|---|---|---|
| Model | VARTA flex storage E 120kW/375kWh (v3) | |
| Manufacturer | VARTA Storage GmbH | |
| Quantity | 1 | |
| Battery Inverter | | |
| Type of Coupling | AC coupling | |
| Nominal output | 120 | kW |
| Battery | | |
| Manufacturer | VARTA Storage GmbH | |
| Model | VARTA flex storage E BM (v1) | |
| Quantity | 65 | |
| Battery Energy | 339,4 | kWh |
| Battery Type | Lithium nickel manganese cobalt oxide/graphite | |

# Simulation Results

## Results Total System

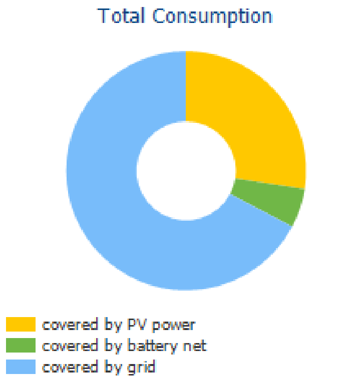
### PV System

| | | |
|---|---|---|
| PV Generator Output | 345,51 | kWp |
| Spec. Annual Yield | 851,50 | kWh/kWp |
| Performance Ratio (PR) | 86,40 | % |
| Yield Reduction due to Shading | 0,6 | %/Year |
| PV Generator Energy (AC grid) | 294.286 | kWh/Year |
| Direct Own Use | 212.113 | kWh/Year |
| Battery Charge | 45.097 | kWh/Year |
| Down-regulation at Feed-in Point | 0 | kWh/Year |
| Grid Feed-in | 37.075 | kWh/Year |
| Own Power Consumption | 87,4 | % |
| $CO_2$ Emissions avoided | 140.489 | kg / year |



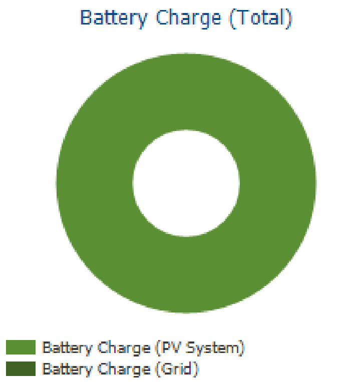

### Appliances

| | | |
|---|---|---|
| Appliances | 773.318 | kWh/Year |
| Standby Consumption (Inverter) | 85 | kWh/Year |
| Total Consumption | 773.403 | kWh/Year |
| covered by PV power | 212.113 | kWh/Year |
| covered by battery net | 40.903 | kWh/Year |
| covered by grid | 520.387 | kWh/Year |
| Solar Fraction | 32,7 | % |




### Battery System

| | | |
|---|---|---|
| Charge at beginning | 339 | kWh |
| Battery Charge (Total) | 45.097 | kWh/Year |
| Battery Charge (PV System) | 45.097 | kWh/Year |
| Battery Charge (Grid) | 0 | kWh/Year |
| Battery Energy for the Covering of Consumption | 40.903 | kWh/Year |
| Losses due to charging/discharging | 4.533 | kWh/Year |
| Losses in Battery | 0 | kWh/Year |
| Cycle Load | 2,2 | % |
| Service Life | >20 | Years |




### Level of Self-sufficiency

| | | |
|---|---|---|
| Total Consumption | 773.403 | kWh/Year |
| covered by grid | 520.387 | kWh/Year |
| Level of Self-sufficiency | 32,7 | % |

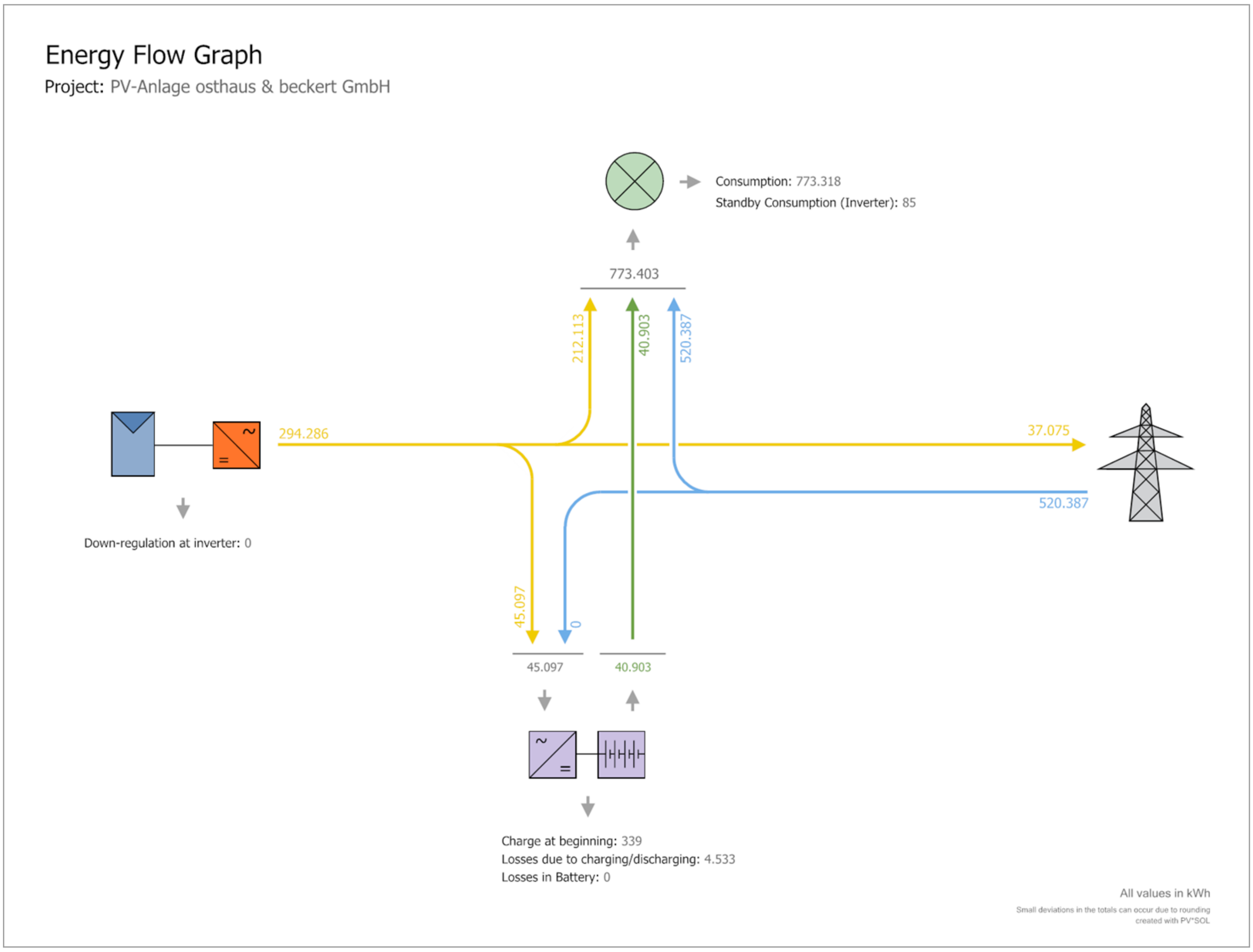



Figure: Energy flow

## PV-Anlage osthaus & beckert GmbH

**Offer Number:** 123456

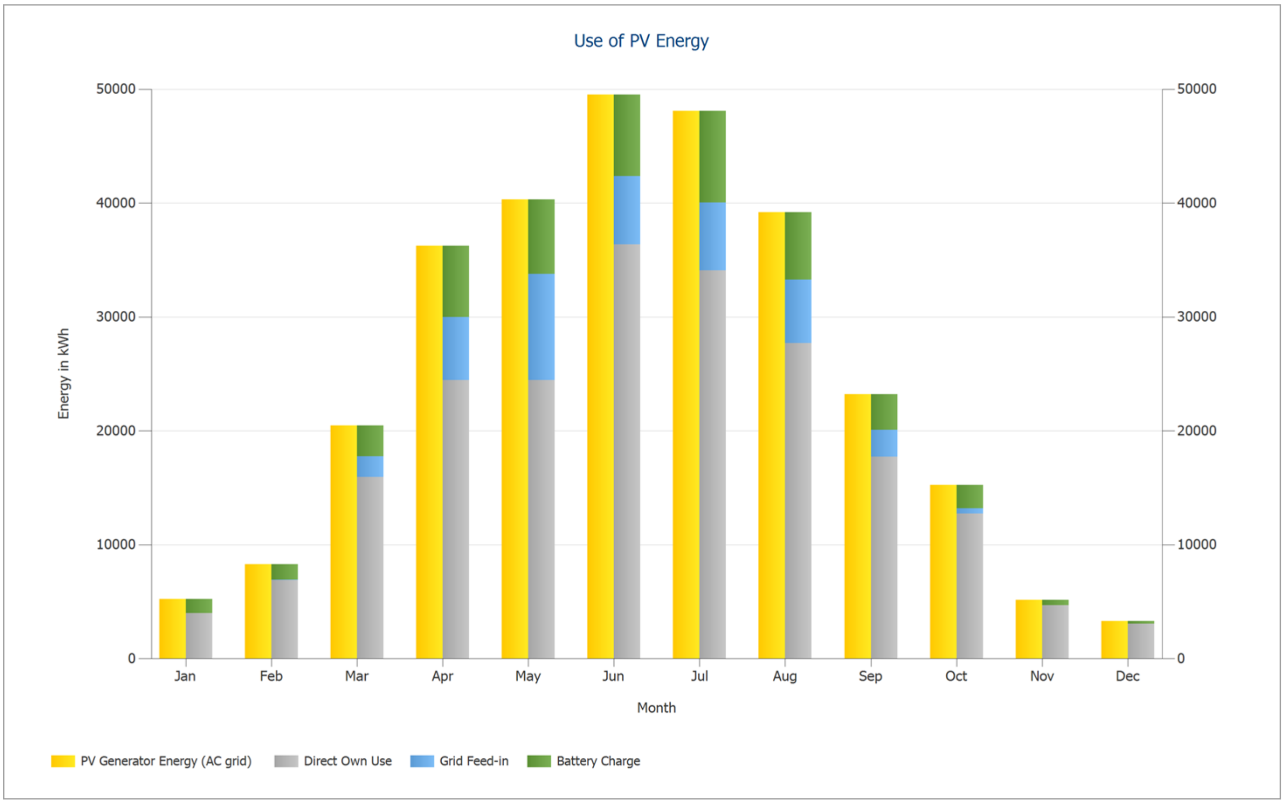



Figure: Use of PV Energy

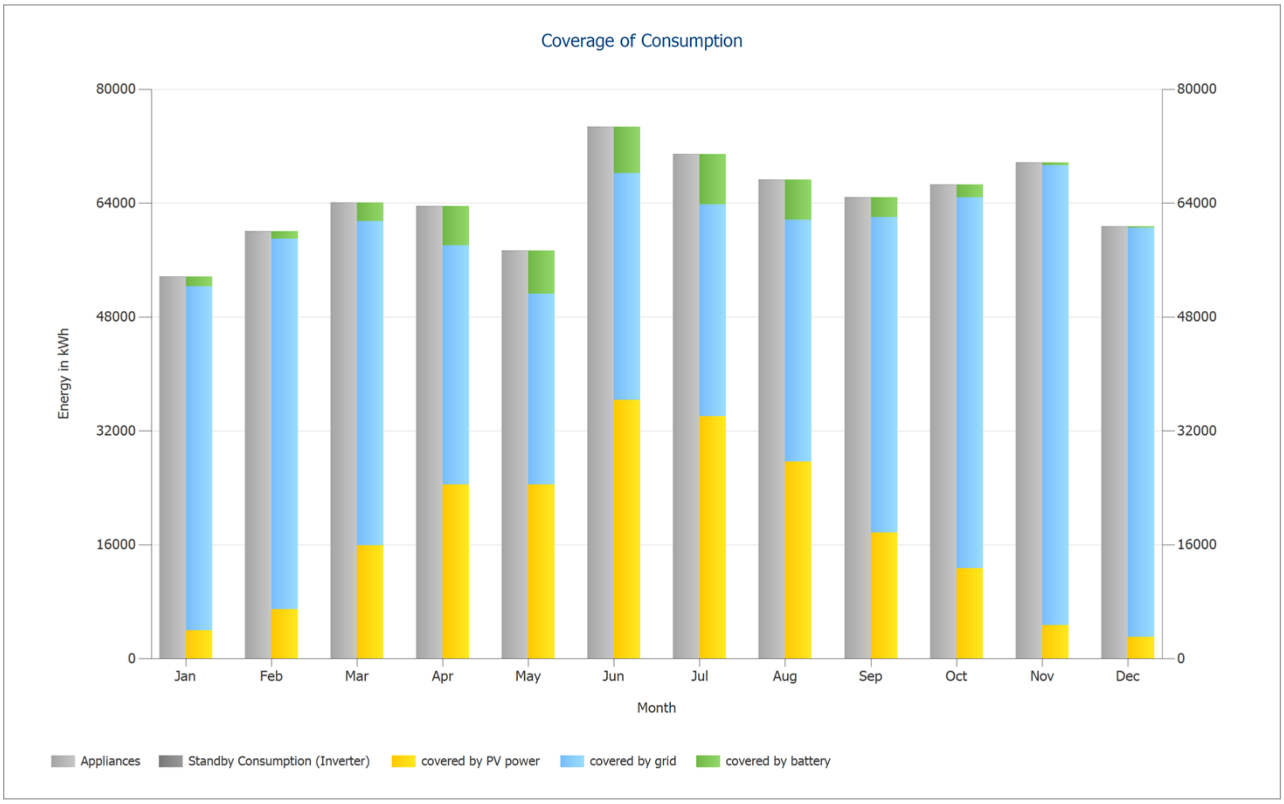



Figure: Coverage of Consumption

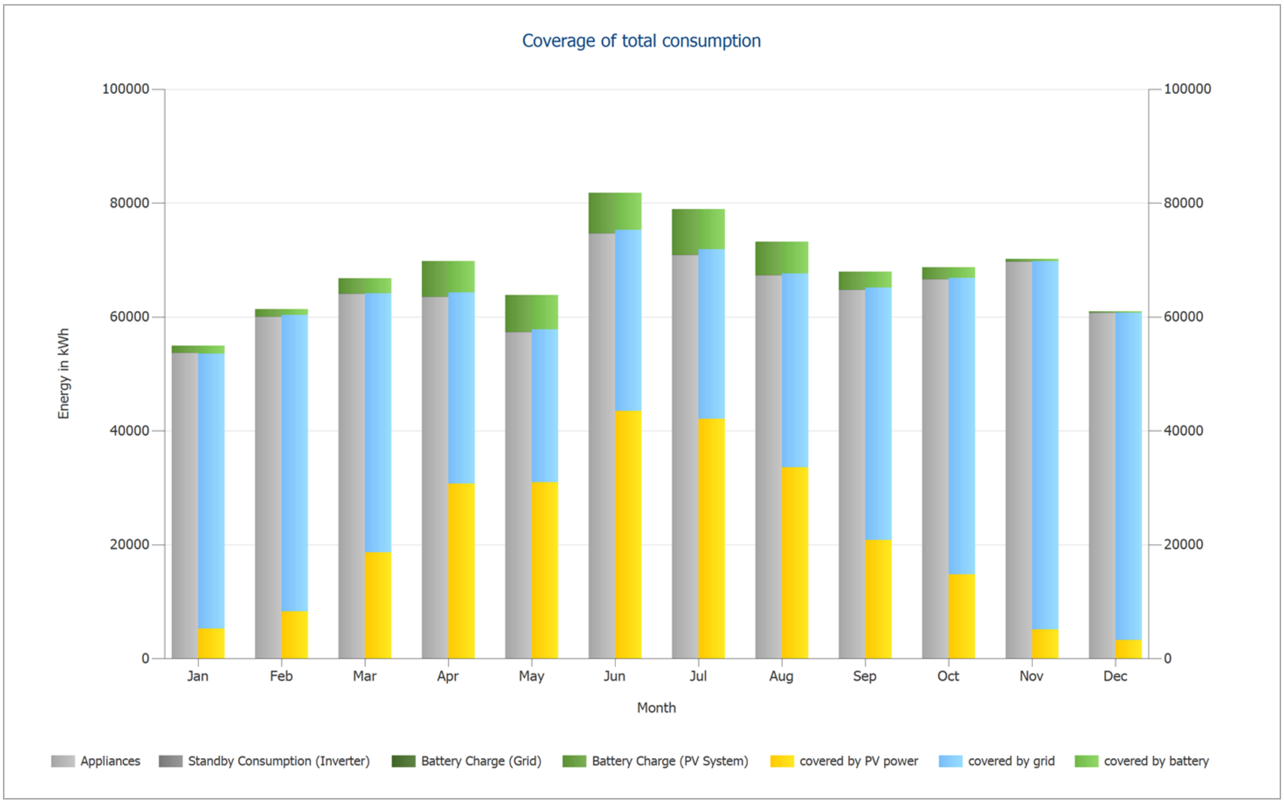



Figure: Coverage of total consumption

# Yield for EnEV

## Yield in accordance with DIN 15316-4-6

| | |
|---|---|
| January | 5300,4 kWh |
| February | 7263,7 kWh |
| March | 17728,8 kWh |
| April | 33429,4 kWh |
| May | 40392,4 kWh |
| June | 42626,9 kWh |
| July | 38381,9 kWh |
| August | 32898,8 kWh |
| September | 22463,1 kWh |
| October | 14073,4 kWh |
| November | 5483,1 kWh |
| December | 3107,1 kWh |
| **Annual Value** | **263.148,9 kWh** |

Boundary Conditions:
Climate Data according to DIN V 18599-10
HALLE 3 OSTHAUS & BECKERT GMBH 01-FLÄCHE WEST
System Power Factor: 0.77
Peak Power Coefficient: 0.182
Orientation: West
Inclination: 0°

HALLE 3 OSTHAUS & BECKERT GMBH 01-FLÄCHE OST
System Power Factor: 0.77
Peak Power Coefficient: 0.182
Orientation: East
Inclination: 0°

# Financial Analysis

## Overview

### System Data

| | | |
|---|---|---|
| Grid Feed-in in the first year (incl. module degradation) | 36.894 | kWh/Year |
| PV Generator Output | 345,5 | kWp |
| Start of Operation of the System | 01.07.2022 | |
| Assessment Period | 30 | Years |
| Interest on Capital | 1 | % |

### Economic Parameters

| | | |
|---|---|---|
| Internal Rate of Return of Capital Resources | 7,33 | % |
| Accrued Cash Flow (Cash Balance) | 318.368,84 | € |
| Amortization Period | 16,0 | Years |
| Electricity Production Costs | 0,0732 | €/kWh |

### Payment Overview

| | | |
|---|---|---|
| Specific Investment Costs | 1.407,56 | €/kWp |
| Investment Costs | 486.325,00 | € |
| One-off Payments | 0,00 | € |
| Incoming Subsidies | 0,00 | € |
| Annual Costs | 1.400,00 | €/Year |
| Other Revenue or Savings | 0,00 | €/Year |

### Loans

| **Reference** | **Loan 1** | |
|---|---|---|
| Loan Capital | 400.000,00 | € |
| Payment Installment | 100,00 | % |
| Credit type | Installment Loan | |
| Term | 10,00 | Years |
| Grace period | 0,00 | Years |
| Interest | 3,50 | |
| Repayment Period | quarterly | |

### Remuneration and Savings

| | | |
|---|---|---|
| Total Payment from Utility in First Year | 1.954,63 | €/Year |
| First year savings | 40.893,95 | €/Year |
| | | |
| EEG 2022 (Juli) Marktprämienmodell - Gebäudeanlage | | |
| Validity | 01.07.2022 - | 31.12.2042 |
| Specific feed-in / export Remuneration | 0,053 | €/kWh |
| Feed-in / Export Tariff | 1954,6333 | €/Year |
| | | |
| Tarif oshaus & beckert GmbH (Wattline) | | |
| Energy Price | 0,1624 | €/kWh |
| Inflation Rate for Energy Price | 1 | %/Year |

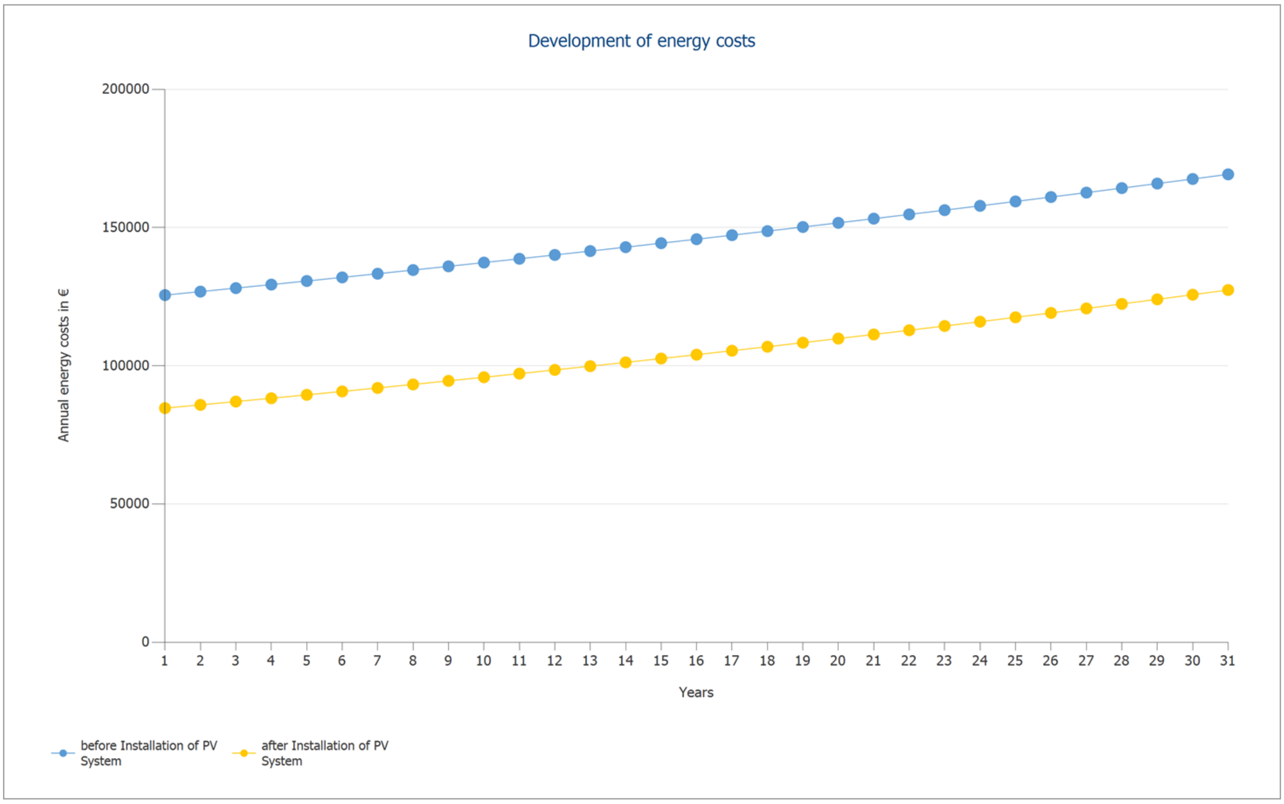



Figure: Development of energy costs

# Cash flow

## Cash flow

| | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| Operating costs | -1.386,14 € | -1.372,41 € | -1.358,83 € | -1.345,37 € | -1.332,05 € |
| Depreciation | -24.075,50 € | -23.837,12 € | -23.601,11 € | -23.367,44 € | -23.136,08 € |
| Self-Financing | -86.325,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 1.935,28 € | 1.900,71 € | 1.866,64 € | 1.833,06 € | 1.799,96 € |
| Electricity Savings | 40.489,06 € | 40.163,79 € | 39.838,52 € | 39.513,24 € | 39.187,97 € |
| Loan repayments | -39.603,96 € | -39.211,84 € | -38.823,61 € | -38.439,21 € | -38.058,63 € |
| Loan Interest | -13.341,58 € | -11.837,07 € | -10.361,05 € | -8.913,09 € | -7.492,79 € |
| Results before Tax | 3.621,12 € | 5.017,89 € | 6.384,17 € | 7.720,40 € | 9.027,01 € |
| Tax Refund | -1.557,08 € | -2.157,69 € | -2.745,19 € | -3.319,77 € | -3.881,61 € |
| Results after Tax | 2.064,04 € | 2.860,20 € | 3.638,98 € | 4.400,63 € | 5.145,40 € |
| **Annual Cash Flow** | **-99.789,43 €** | **-12.514,52 €** | **-11.583,52 €** | **-10.671,15 €** | **-9.777,15 €** |
| Accrued Cash Flow (Cash Balance) | -99.789,43 € | -112.303,95 € | -123.887,46 € | -134.558,61 € | -144.335,76 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -494.740,99 € | -456.206,60 € | -418.605,46 € | -381.924,30 € | -346.150,03 € |

## Cash flow

| | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 |
|---|---|---|---|---|---|
| Operating costs | -1.318,86 € | -1.305,81 € | -1.292,88 € | -1.280,08 € | -1.267,40 € |
| Depreciation | -22.907,01 € | -22.680,21 € | -22.455,65 € | -22.233,32 € | -22.013,18 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 1.767,34 € | 1.735,18 € | 1.703,49 € | 1.672,25 € | 1.641,47 € |
| Electricity Savings | 38.862,70 € | 38.537,42 € | 38.212,14 € | 37.886,90 € | 37.561,60 € |
| Loan repayments | -37.681,81 € | -37.308,72 € | -36.939,33 € | -36.573,59 € | -36.211,48 € |
| Loan Interest | -6.099,74 € | -4.733,54 € | -3.393,80 € | -2.080,12 € | -792,13 € |
| Results before Tax | 10.304,42 € | 11.553,05 € | 12.773,31 € | 13.965,64 € | 15.130,36 € |
| Tax Refund | -4.430,90 € | -4.967,81 € | -5.492,52 € | -6.005,22 € | -6.506,06 € |
| Results after Tax | 5.873,52 € | 6.585,24 € | 7.280,79 € | 7.960,41 € | 8.624,31 € |
| **Annual Cash Flow** | **-8.901,28 €** | **-8.043,28 €** | **-7.202,89 €** | **-6.379,86 €** | **-5.573,99 €** |
| Accrued Cash Flow (Cash Balance) | -153.237,04 € | -161.280,32 € | -168.483,22 € | -174.863,08 € | -180.437,07 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -311.269,76 € | -277.270,77 € | -244.140,54 € | -211.866,69 € | -180.437,07 € |

## Cash flow

| | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 |
|---|---|---|---|---|---|
| Operating costs | -1.254,85 € | -1.242,43 € | -1.230,13 € | -1.217,95 € | -1.205,89 € |
| Depreciation | -21.795,23 € | -21.579,44 € | -21.365,78 € | -21.154,24 € | -20.944,79 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 1.611,13 € | 1.581,24 € | 1.551,77 € | 1.522,74 € | 1.494,13 € |
| Electricity Savings | 37.236,34 € | 36.911,06 € | 36.585,80 € | 36.260,52 € | 35.935,25 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 15.797,39 € | 15.670,43 € | 15.541,66 € | 15.411,07 € | 15.278,70 € |
| Tax Refund | -6.792,88 € | -6.738,28 € | -6.682,92 € | -6.626,76 € | -6.569,84 € |
| Results after Tax | 9.004,51 € | 8.932,15 € | 8.858,75 € | 8.784,31 € | 8.708,86 € |
| **Annual Cash Flow** | **30.799,74 €** | **30.511,58 €** | **30.224,53 €** | **29.938,55 €** | **29.653,65 €** |
| Accrued Cash Flow (Cash Balance) | -149.637,33 € | -119.125,74 € | -88.901,22 € | -58.962,67 € | -29.309,02 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -149.637,33 € | -119.125,74 € | -88.901,22 € | -58.962,67 € | -29.309,02 € |

## Cash flow

| | Year 16 | Year 17 | Year 18 | Year 19 | Year 20 |
|---|---|---|---|---|---|
| Operating costs | -1.193,95 € | -1.182,13 € | -1.170,42 € | -1.158,84 € | -1.147,36 € |
| Depreciation | -20.737,42 € | -20.532,09 € | -20.328,81 € | -20.127,53 € | -19.928,25 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 1.465,93 € | 1.438,15 € | 1.410,77 € | 1.383,80 € | 1.357,22 € |
| Electricity Savings | 35.609,98 € | 35.284,72 € | 34.959,43 € | 34.634,15 € | 34.308,90 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 15.144,55 € | 15.008,65 € | 14.870,97 € | 14.731,59 € | 14.590,51 € |
| Tax Refund | -6.512,16 € | -6.453,72 € | -6.394,52 € | -6.334,58 € | -6.273,92 € |
| Results after Tax | 8.632,39 € | 8.554,93 € | 8.476,45 € | 8.397,00 € | 8.316,59 € |
| **Annual Cash Flow** | **29.369,81 €** | **29.087,02 €** | **28.805,26 €** | **28.524,53 €** | **28.244,84 €** |
| Accrued Cash Flow (Cash Balance) | 60,79 € | 29.147,81 € | 57.953,07 € | 86.477,61 € | 114.722,44 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 60,79 € | 29.147,81 € | 57.953,07 € | 86.477,61 € | 114.722,44 € |

## Cash flow

| | Year 21 | Year 22 | Year 23 | Year 24 | Year 25 |
|---|---|---|---|---|---|
| Operating costs | -1.136,00 € | -1.124,75 € | -1.113,62 € | -1.102,59 € | -1.091,68 € |
| Depreciation | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 1.328,26 € | 1.300,79 € | 1.275,45 € | 1.250,49 € | 1.225,89 € |
| Electricity Savings | 33.983,62 € | 33.658,35 € | 33.333,08 € | 33.007,81 € | 32.682,55 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 34.175,88 € | 33.834,39 € | 33.494,92 € | 33.155,70 € | 32.816,77 € |
| Tax Refund | -14.695,63 € | -14.548,79 € | -14.402,81 € | -14.256,95 € | -14.111,21 € |
| Results after Tax | 19.480,25 € | 19.285,60 € | 19.092,10 € | 18.898,75 € | 18.705,56 € |
| **Annual Cash Flow** | **19.480,25 €** | **19.285,60 €** | **19.092,10 €** | **18.898,75 €** | **18.705,56 €** |
| Accrued Cash Flow (Cash Balance) | 134.202,70 € | 153.488,30 € | 172.580,40 € | 191.479,15 € | 210.184,71 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 134.202,70 € | 153.488,30 € | 172.580,40 € | 191.479,15 € | 210.184,71 € |

## Cash flow

| | Year 26 | Year 27 | Year 28 | Year 29 | Year 30 |
|---|---|---|---|---|---|
| Operating costs | -1.080,87 € | -1.070,17 € | -1.059,57 € | -1.049,08 € | -1.038,69 € |
| Depreciation | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 1.201,67 € | 1.177,80 € | 1.154,28 € | 1.131,12 € | 1.108,30 € |
| Electricity Savings | 32.357,27 € | 32.031,99 € | 31.706,73 € | 31.381,45 € | 31.056,18 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 32.478,07 € | 32.139,62 € | 31.801,44 € | 31.463,49 € | 31.125,79 € |
| Tax Refund | -13.965,57 € | -13.820,04 € | -13.674,62 € | -13.529,30 € | -13.384,09 € |
| Results after Tax | 18.512,50 € | 18.319,58 € | 18.126,82 € | 17.934,19 € | 17.741,70 € |
| **Annual Cash Flow** | **18.512,50 €** | **18.319,58 €** | **18.126,82 €** | **17.934,19 €** | **17.741,70 €** |
| Accrued Cash Flow (Cash Balance) | 228.697,20 € | 247.016,79 € | 265.143,61 € | 283.077,80 € | 300.819,50 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 228.697,20 € | 247.016,79 € | 265.143,61 € | 283.077,80 € | 300.819,50 € |

## Cash flow

| | Year 31 |
|---|---|
| Operating costs | -1.028,41 € |
| Depreciation | 0,00 € |
| Self-Financing | 0,00 € |
| Feed-in / Export Tariff | 1.085,82 € |
| Electricity Savings | 30.730,91 € |
| Loan repayments | 0,00 € |
| Loan Interest | 0,00 € |
| Results before Tax | 30.788,33 € |
| Tax Refund | -13.238,98 € |
| Results after Tax | 17.549,35 € |
| **Annual Cash Flow** | **17.549,35 €** |
| Accrued Cash Flow (Cash Balance) | 318.368,84 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 318.368,84 € |

Degradation and inflation rates are applied on a monthly basis over the entire observation period. This is done in the first year.

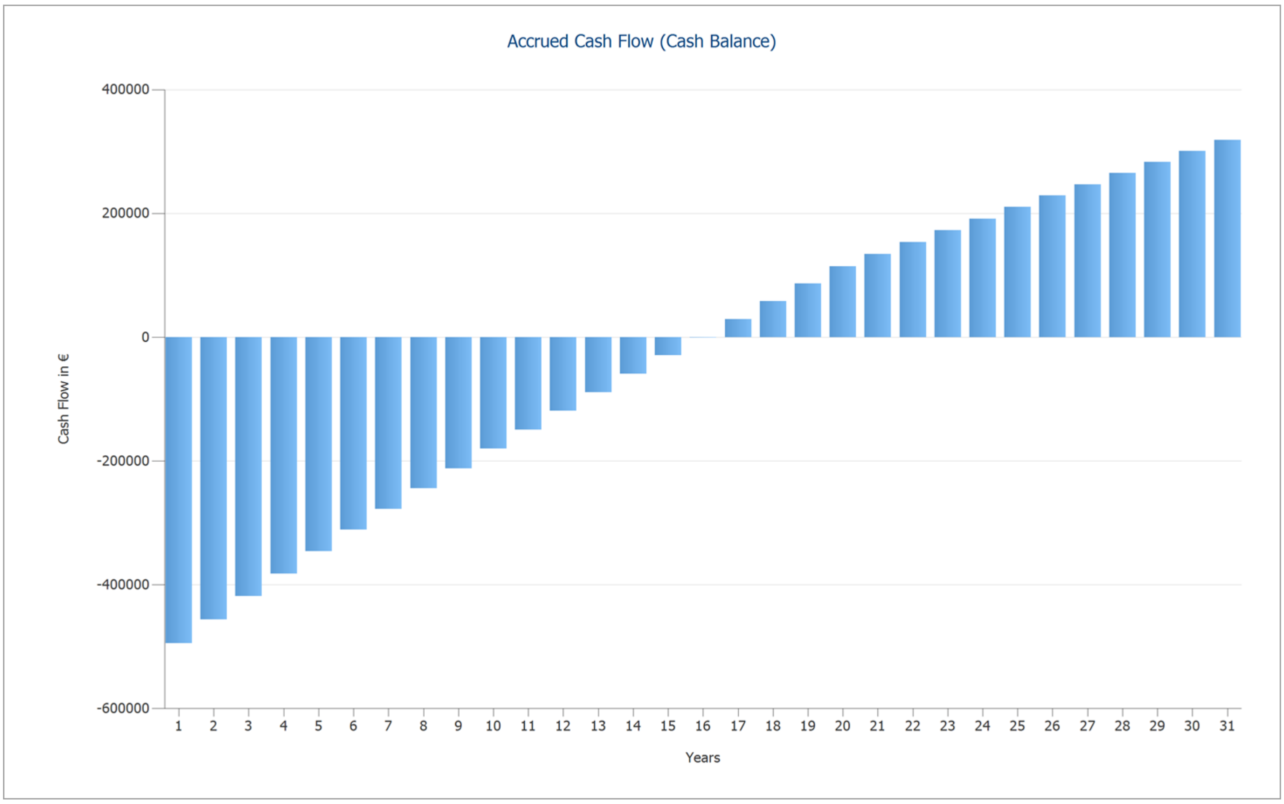



Figure: Accrued Cash Flow (Cash Balance)

# Plans and parts list

## Circuit Diagram

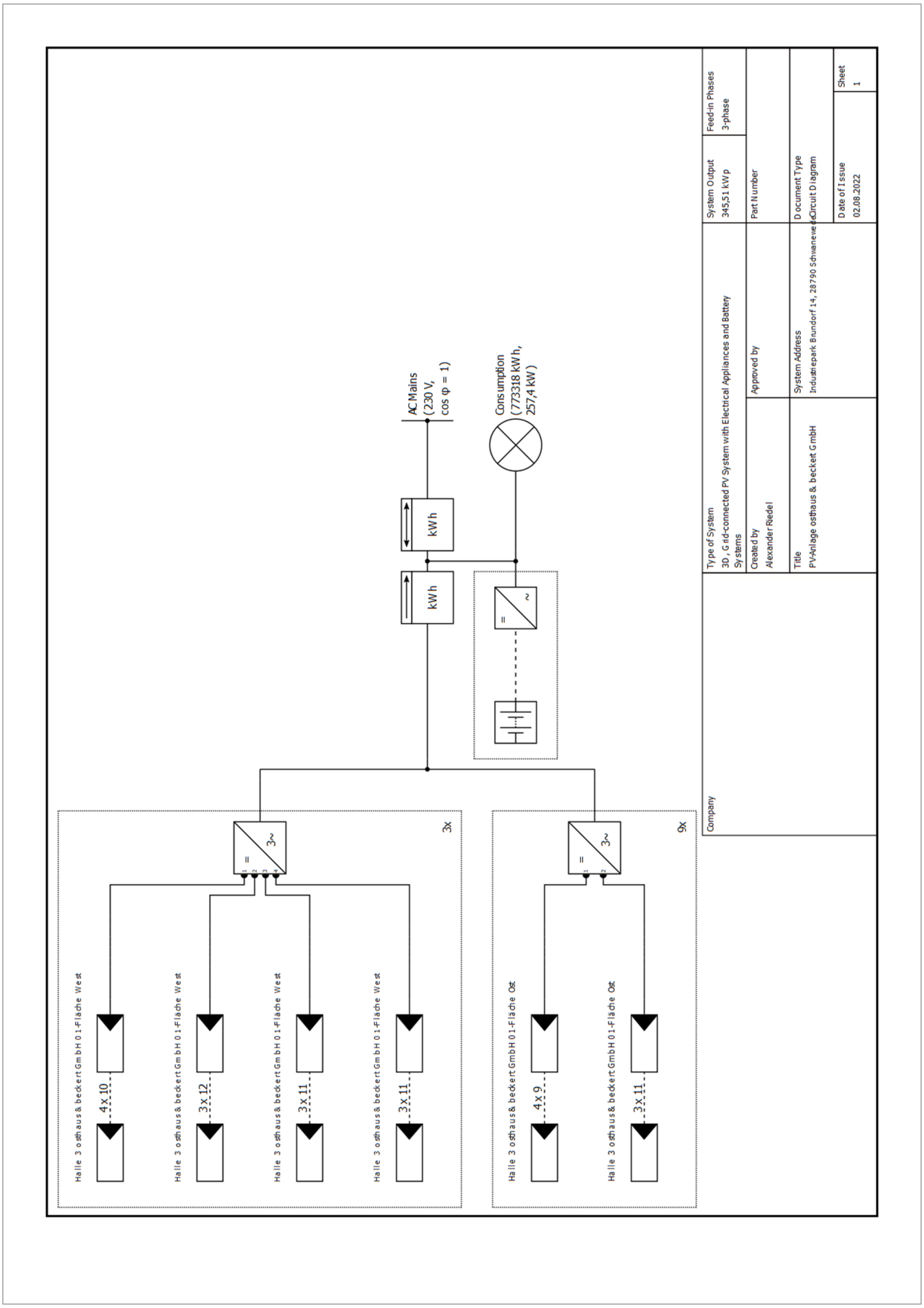



Figure: Circuit Diagram

# Overview plan

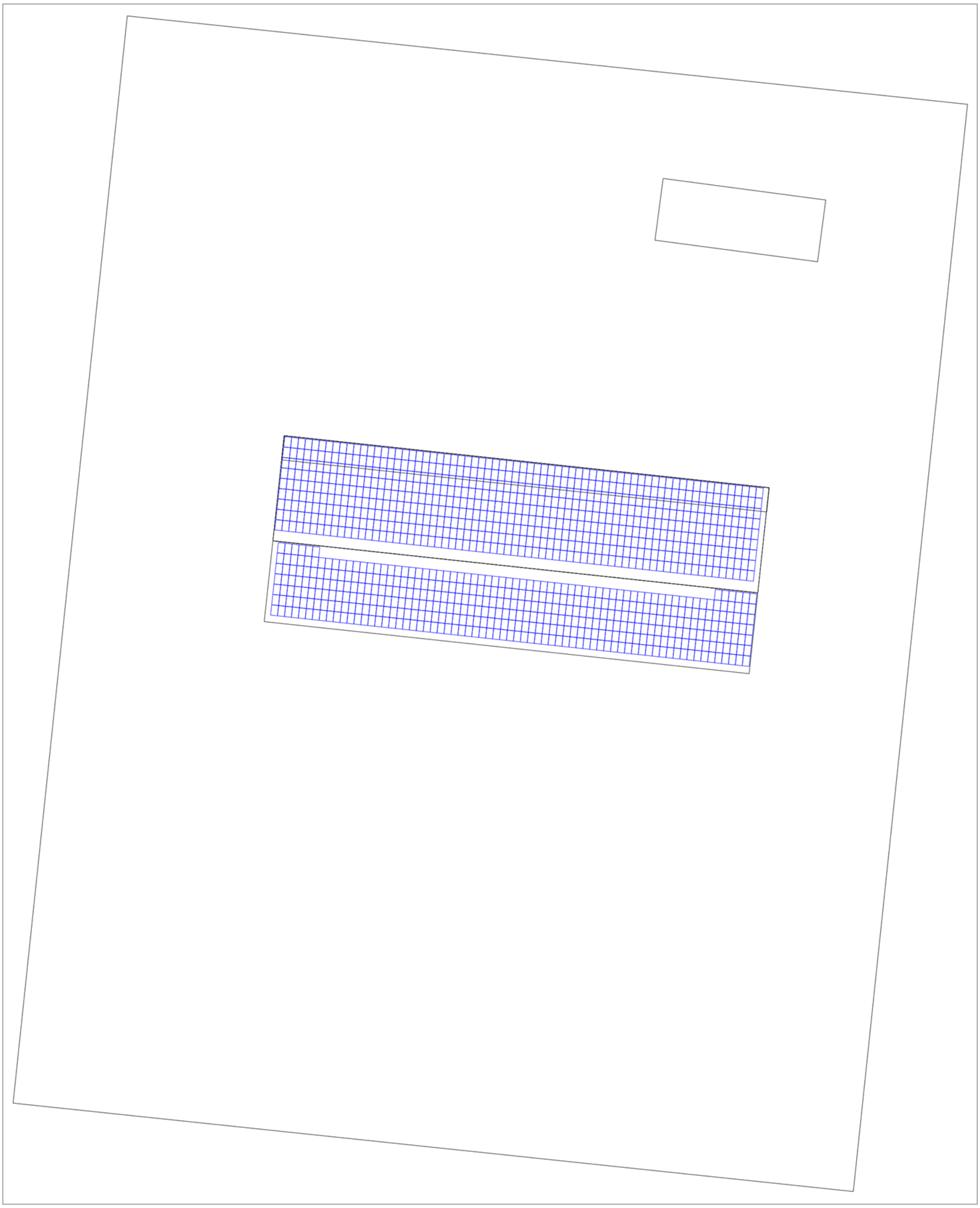


Figure: Overview plan

# Dimensioning Plan

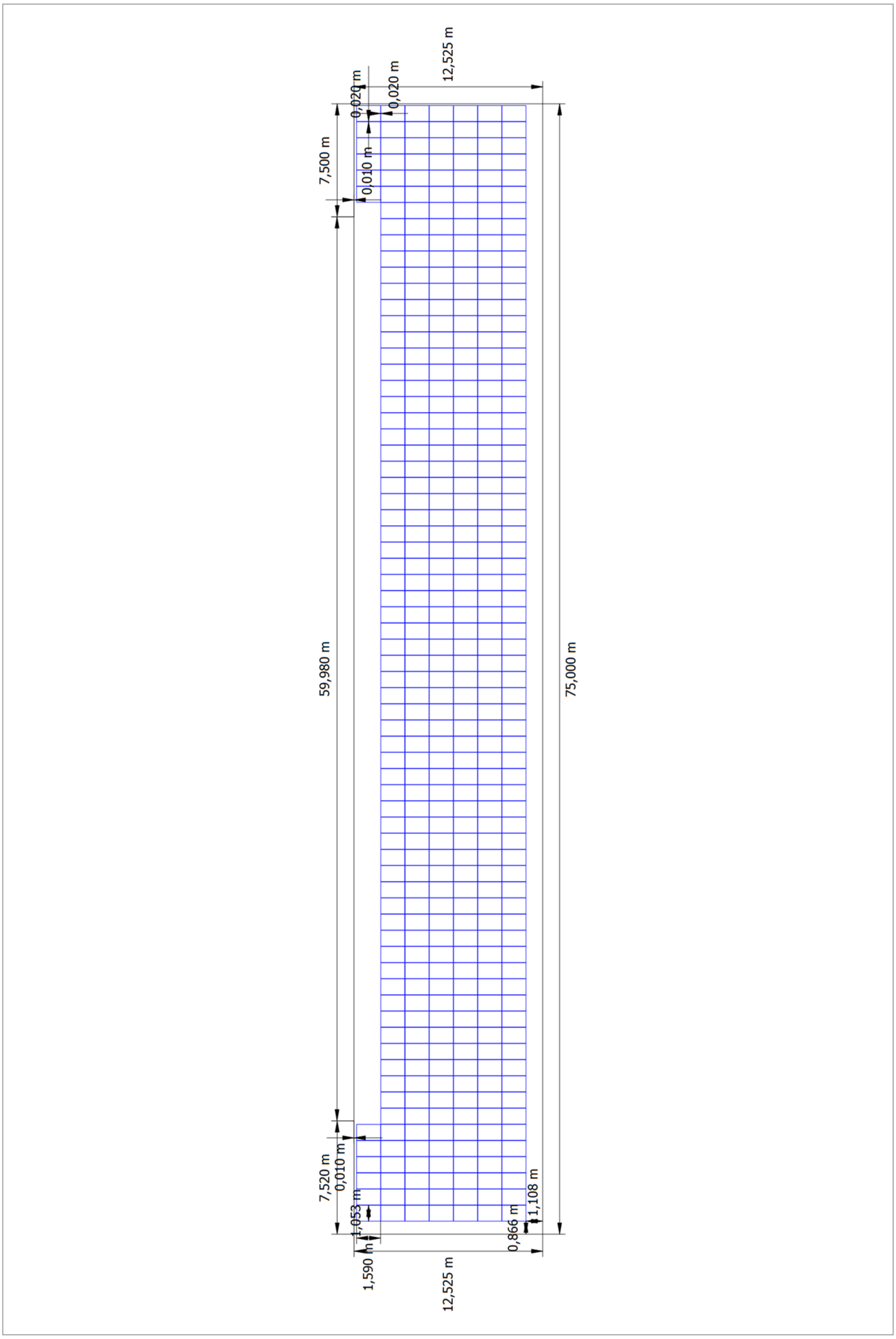



Figure: Halle 3 osthaus & beckert GmbH 01-Fläche West

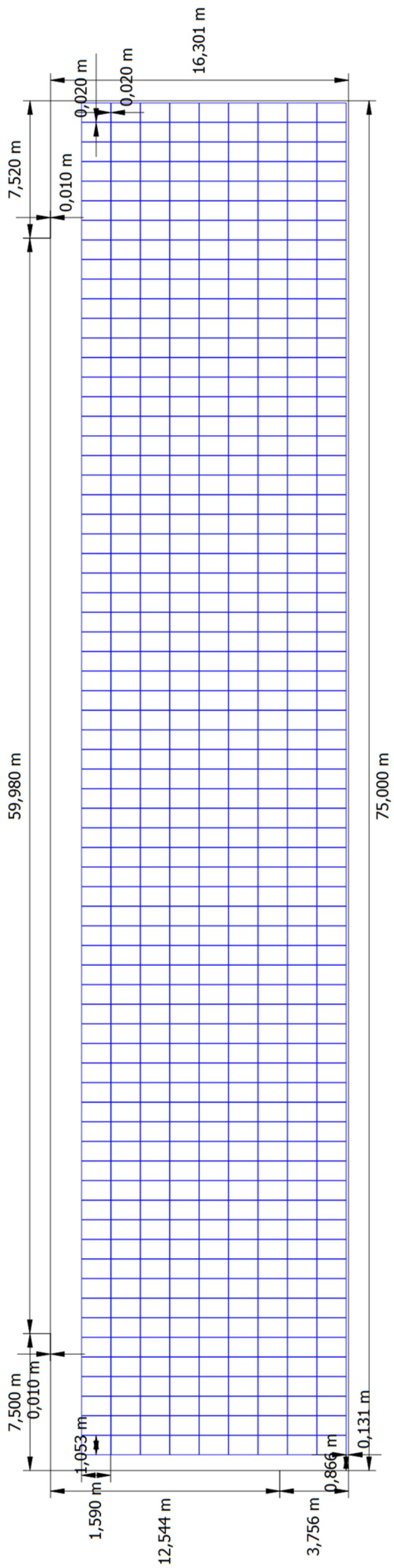



Figure: Halle 3 osthaus & beckert GmbH 01-Fläche Ost

# String Plan

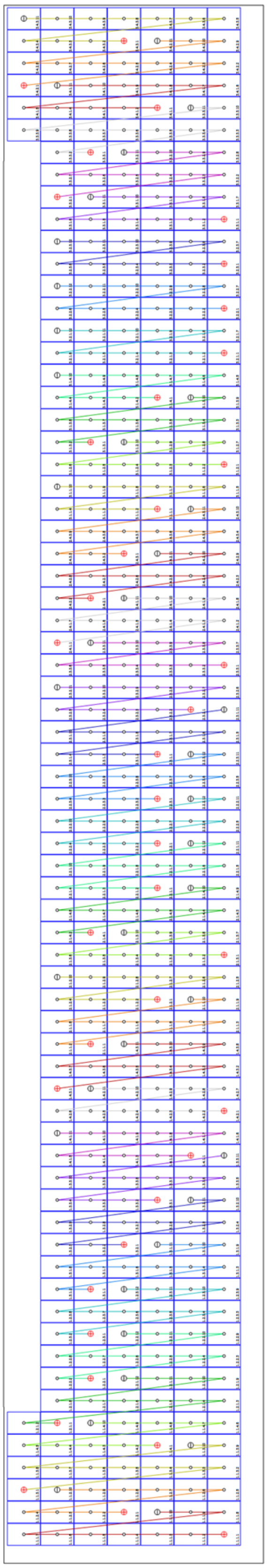


Figure: Halle 3 osthaus & beckert GmbH 01-Fläche West

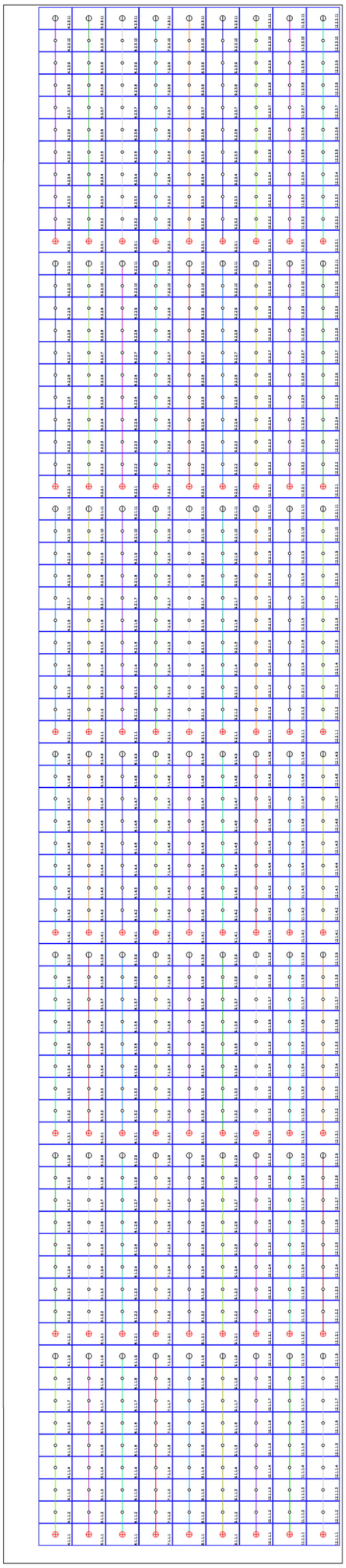


Figure: Halle 3 osthaus & beckert GmbH 01-Fläche Ost

# Parts list

## Parts list

| # | Type | Item number | Manufacturer | Name | Quantity | Unit |
|---|---|---|---|---|---|---|
| 1 | PV Module | | Panasonic | VBHN330SJ47 | 1047 | Piece |
| 2 | Inverter | | Huawei Technologies | SUN2000-40KTL-M3（440Vac） | 3 | Piece |
| 3 | Inverter | | Huawei Technologies | SUN2000-20KTL-M0 | 9 | Piece |
| 4 | Battery System | | VARTA Storage GmbH | VARTA flex storage E 120kW/375kWh | 1 | Piece |
| 5 | Components | | | Feed-in Meter | 1 | Piece |
| 6 | Components | | | Bidirectional Meter | 1 | Piece |

# Annex J: Simulation report Scenario 3 (Full Feeder)

**osthaus & beckert GmbH**
Beckert, Andreas; Osthaus, Christian
Industriepark Brundorf 14, 28790
Schwanewede

**Customer No.:** 123456789
**Project Name:** PV-Anlage osthaus & beckert GmbH
**Offer no.:** 123456

02.08.2022

## Your PV system

### Address of Installation

Industriepark Brundorf 14, 28790 Schwanewede


Project Description:
Planning of a company-owned PV system for osthaus & beckert GmbH

# Project Overview

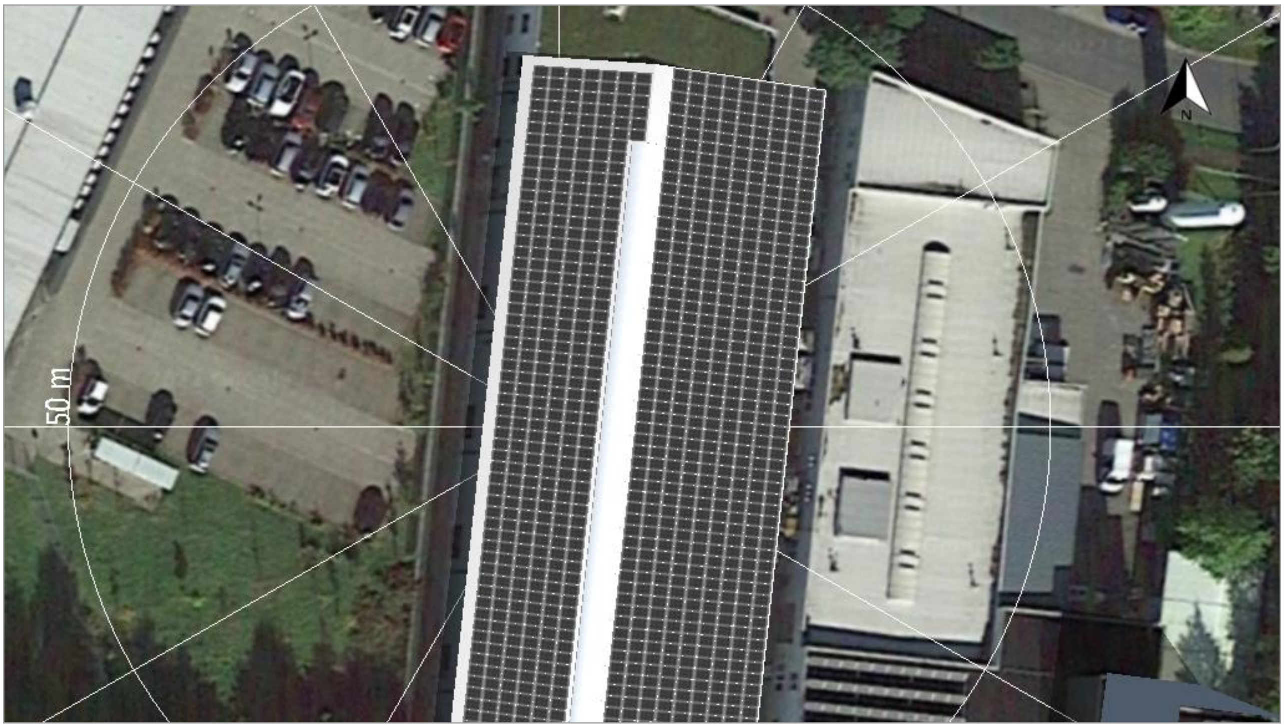



Figure: Overview Image, 3D Design

## PV System

3D, Grid-connected PV System

| | | |
|---|---|---|
| Climate Data | Osterholz-Scharmbeck, DEU (1995 - 2012) | |
| Values source | DWD | |
| PV Generator Output | 345,51 | kWp |
| PV Generator Surface | 1.753,0 | m² |
| Number of PV Modules | 1047 | |
| Number of Inverters | 12 | |

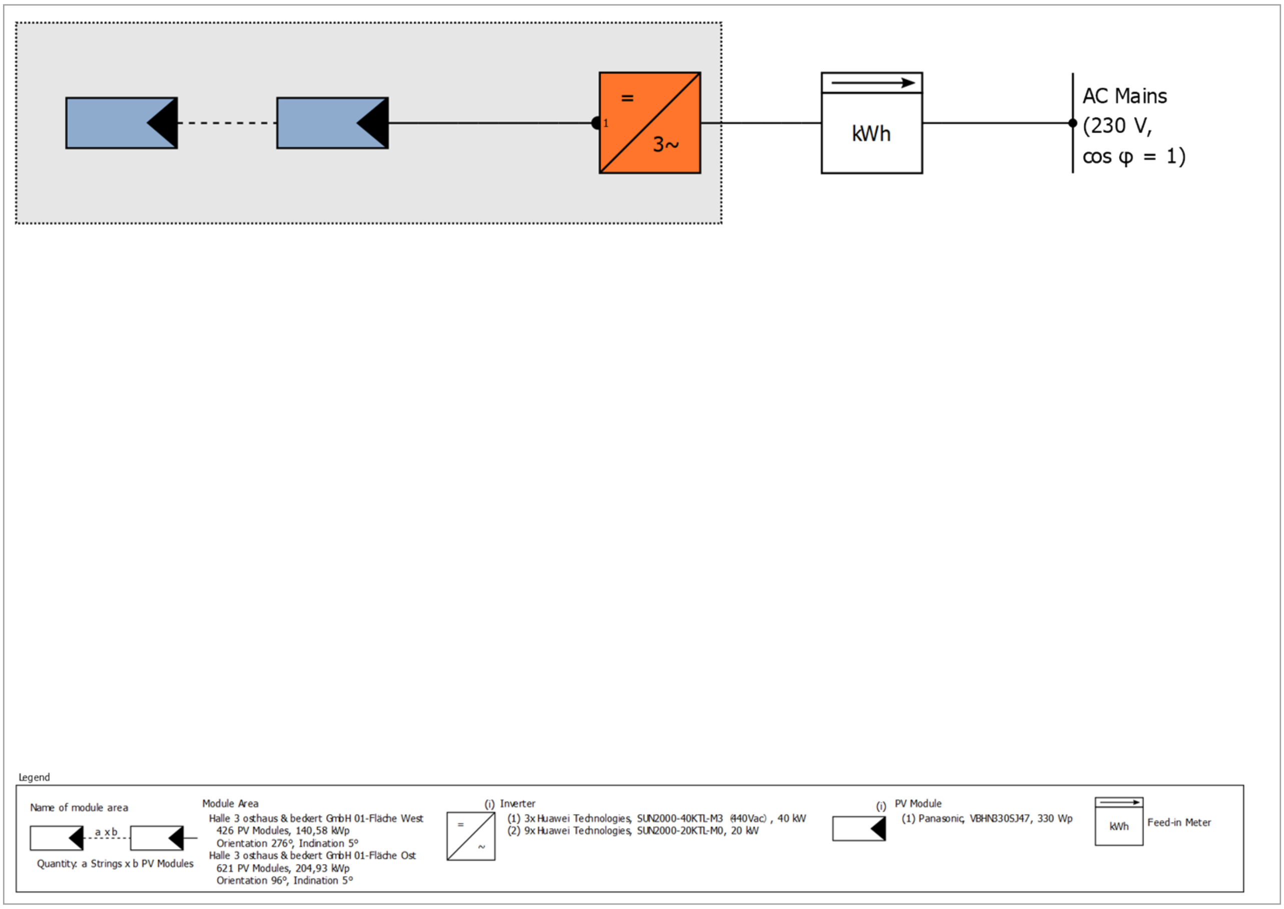


Figure: Schematic diagram

# Production Forecast

## Production Forecast

| | |
|---|---|
| PV Generator Output | 345,51 kWp |
| Spec. Annual Yield | 851,50 kWh/kWp |
| Performance Ratio (PR) | 86,40 % |
| Yield Reduction due to Shading | 0,6 %/Year |
| | |
| Grid Feed-in | 294.286 kWh/Year |
| Grid Feed-in in the first year (incl. module degradation) | 292.959 kWh/Year |
| Standby Consumption (Inverter) | 85 kWh/Year |
| | |
| $CO_2$ Emissions avoided | 142.687 kg / year |

# Financial Analysis

## Your Gain

| | |
|---|---|
| Total investment costs | 236.118,00 € |
| Internal Rate of Return of Capital Resources | 2,40 % |
| Amortization Period | 23,4 Years |
| Electricity Production Costs | 0,0373 €/kWh |
| Energy Balance/Feed-in Concept | Full Feed-in |

The results have been calculated with a mathematical model calculation from Valentin Software GmbH (PV*SOL algorithms). The actual yields from the solar power system may differ as a result of weather variations, the efficiency of the modules and inverter, and other factors.

# Set-up of the System

## Overview

| System Data | |
|---|---|
| Type of System | 3D, Grid-connected PV System |

| Climate Data | |
|---|---|
| Location | Osterholz-Scharmbeck, DEU (1995 - 2012) |
| Values source | DWD |
| Resolution of the data | 1 min |
| Simulation models used: | |
| - Diffuse Irradiation onto Horizontal Plane | Hofmann |
| - Irradiance onto tilted surface | Hay & Davies |

## Module Areas

### 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West

| PV Generator, 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West | | |
|---|---|---|
| Name | Halle 3 osthaus & beckert GmbH 01-Fläche West | |
| PV Modules | 426 x VBHN330SJ47 (v1) | |
| Manufacturer | Panasonic | |
| Inclination | 5 | ° |
| Orientation | West 276 | ° |
| Installation Type | Roof parallel | |
| PV Generator Surface | 713,2 | m² |

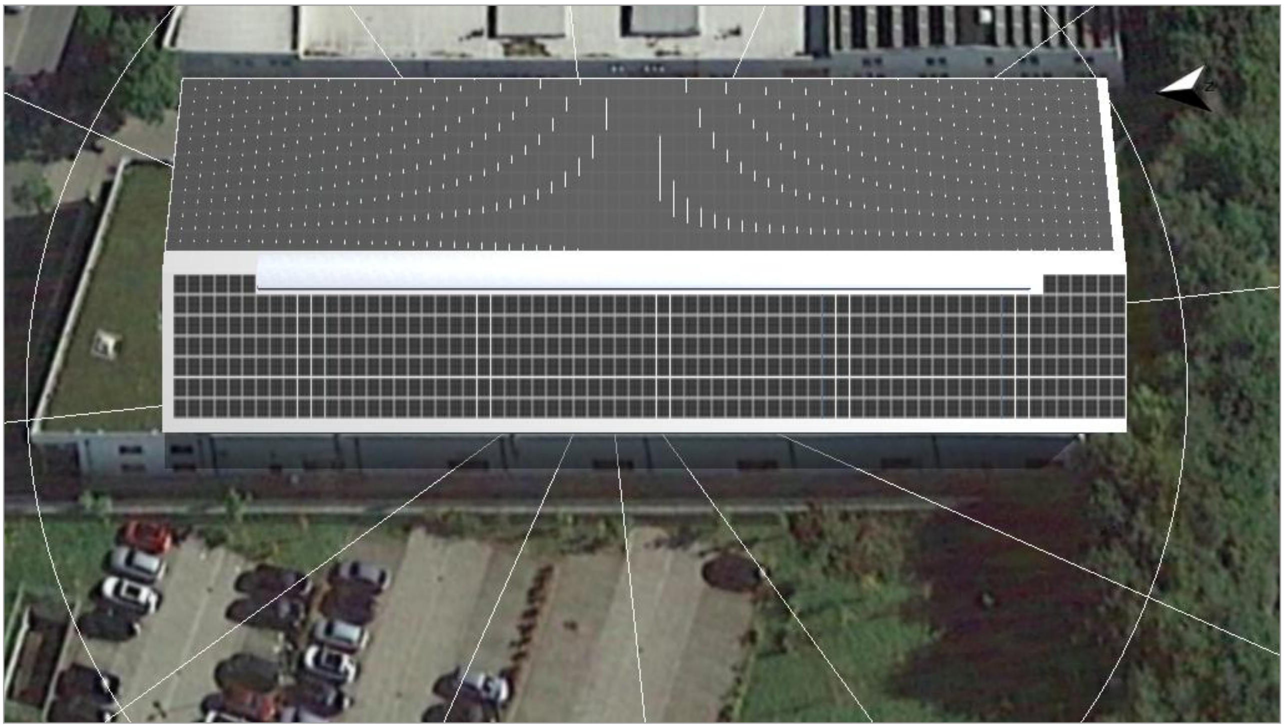


Figure: 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West

## *2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost*

### PV Generator, 2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost

| | |
|---|---|
| Name | Halle 3 osthaus & beckert GmbH 01-Fläche Ost |
| PV Modules | 621 x VBHN330SJ47 (v1) |
| Manufacturer | Panasonic |
| Inclination | 5 ° |
| Orientation | East 96 ° |
| Installation Type | Roof parallel |
| PV Generator Surface | 1.039,7 m² |

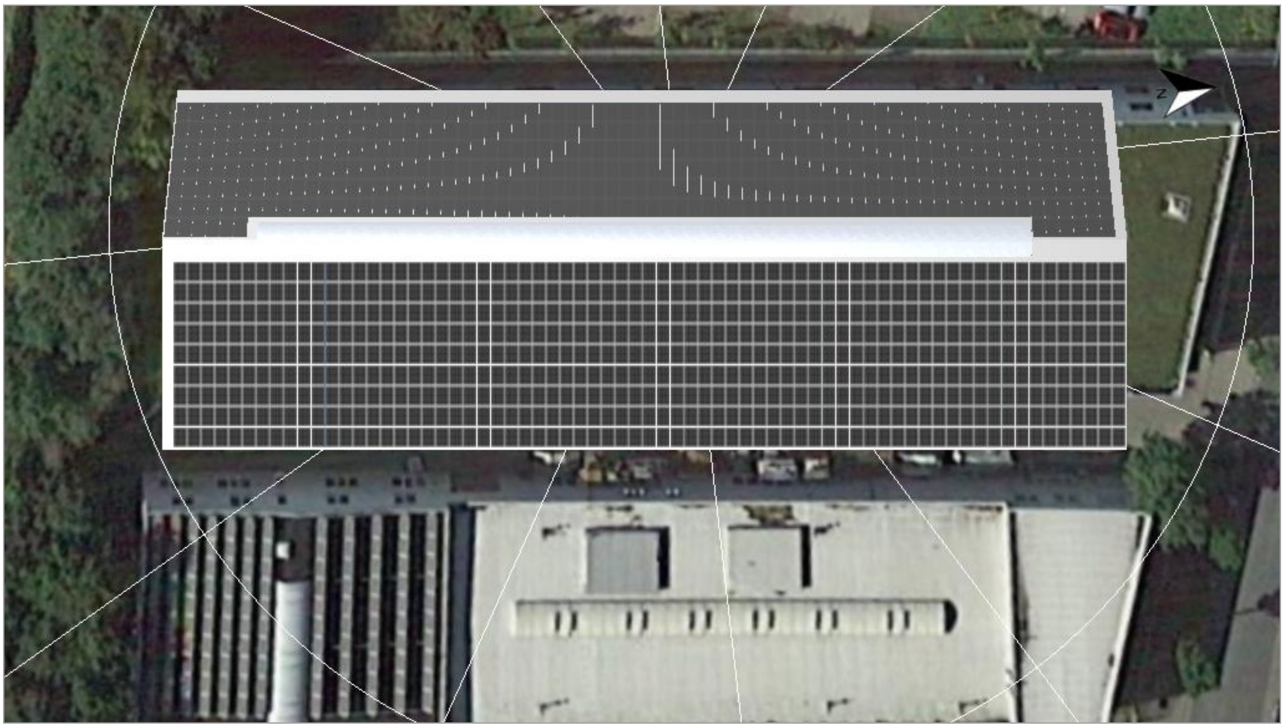


Figure: 2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost

# Horizon Line, 3D Design

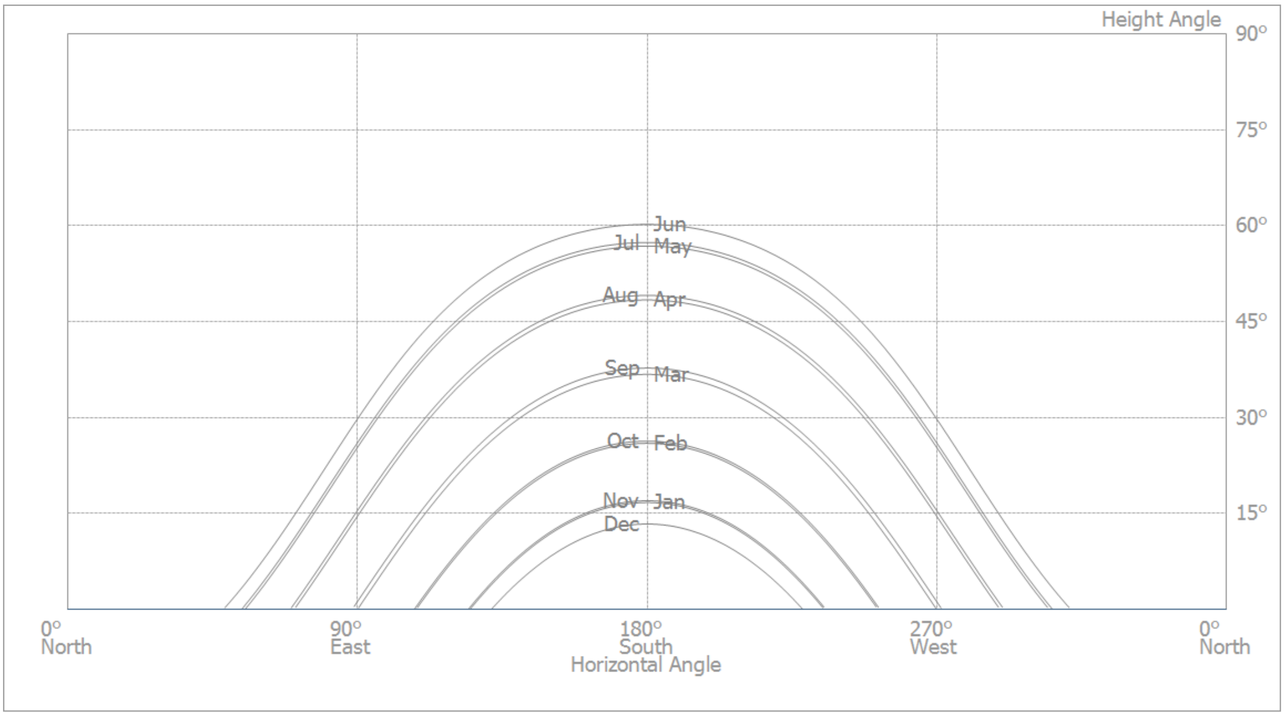



Figure: Horizon (3D Design)

# Inverter configuration

## Configuration 1

| | |
|---|---|
| Module Area | Halle 3 osthaus & beckert GmbH 01-Fläche West |
| Inverter 1 | |
| Model | SUN2000-40KTL-M3（440Vac） (v1) |
| Manufacturer | Huawei Technologies |
| Quantity | 3 |
| Sizing Factor | 117,2 % |
| Configuration | MPP 1: 4 x 10 |
| | MPP 2: 3 x 12 |
| | MPP 3: 3 x 11 |
| | MPP 4: 3 x 11 |

## Configuration 2

| | |
|---|---|
| Module Area | Halle 3 osthaus & beckert GmbH 01-Fläche Ost |
| Inverter 1 | |
| Model | SUN2000-20KTL-M0 (v2) |
| Manufacturer | Huawei Technologies |
| Quantity | 9 |
| Sizing Factor | 113,9 % |
| Configuration | MPP 1: 4 x 9 |
| | MPP 2: 3 x 11 |

# AC Mains

## AC Mains

| | |
|---|---|
| Number of Phases | 3 |
| Mains voltage between phase and neutral | 230 V |
| Displacement Power Factor (cos phi) | +/- 1 |

# Simulation Results

## Results Total System

### PV System

| | | |
|---|---|---|
| PV Generator Output | 345,51 | kWp |
| Spec. Annual Yield | 851,50 | kWh/kWp |
| Performance Ratio (PR) | 86,40 | % |
| Yield Reduction due to Shading | 0,6 | %/Year |
| Grid Feed-in | 294.286 | kWh/Year |
| Grid Feed-in in the first year (incl. module degradation) | 292.959 | kWh/Year |
| Standby Consumption (Inverter) | 85 | kWh/Year |
| $CO_2$ Emissions avoided | 142.687 | kg / year |

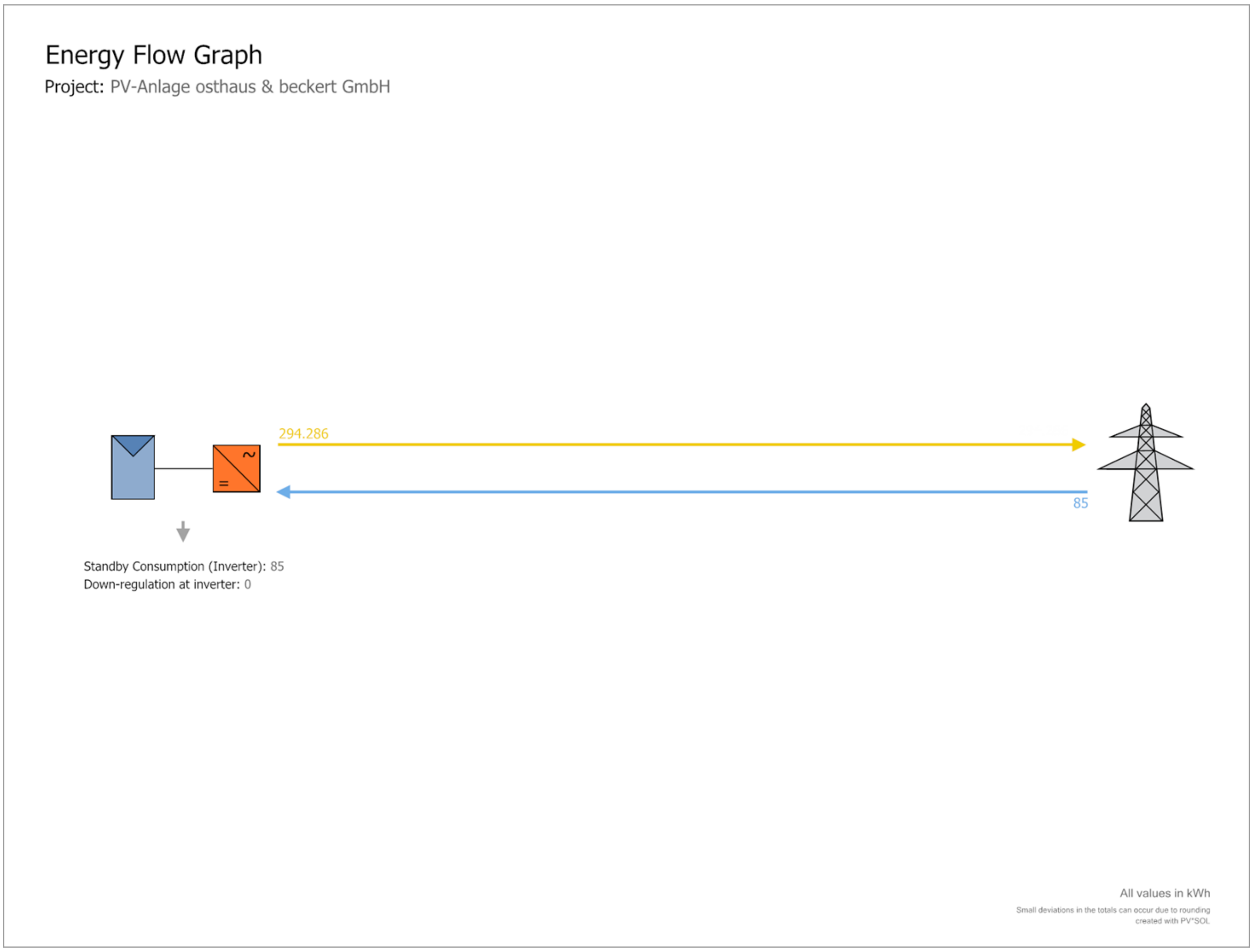



Figure: Energy flow

# Yield for EnEV

## Yield in accordance with DIN 15316-4-6

| | |
|---|---|
| January | 5300,4 kWh |
| February | 7263,7 kWh |
| March | 17728,8 kWh |
| April | 33429,4 kWh |
| May | 40392,4 kWh |
| June | 42626,9 kWh |
| July | 38381,9 kWh |
| August | 32898,8 kWh |
| September | 22463,1 kWh |
| October | 14073,4 kWh |
| November | 5483,1 kWh |
| December | 3107,1 kWh |
| **Annual Value** | **263.148,9 kWh** |

Boundary Conditions:
Climate Data according to DIN V 18599-10
HALLE 3 OSTHAUS & BECKERT GMBH 01-FLÄCHE WEST
System Power Factor: 0.77
Peak Power Coefficient: 0.182
Orientation: West
Inclination: 0°

HALLE 3 OSTHAUS & BECKERT GMBH 01-FLÄCHE OST
System Power Factor: 0.77
Peak Power Coefficient: 0.182
Orientation: East
Inclination: 0°

# Financial Analysis

## Overview

### System Data

| | | |
|---|---|---|
| Grid Feed-in in the first year (incl. module degradation) | 292.959 | kWh/Year |
| PV Generator Output | 345,5 | kWp |
| Start of Operation of the System | 01.07.2022 | |
| Assessment Period | 30 | Years |
| Interest on Capital | 1 | % |

### Economic Parameters

| | | |
|---|---|---|
| Internal Rate of Return of Capital Resources | 2,40 | % |
| Accrued Cash Flow (Cash Balance) | 35.300,31 | € |
| Amortization Period | 23,4 | Years |
| Electricity Production Costs | 0,0373 | €/kWh |

### Payment Overview

| | | |
|---|---|---|
| Specific Investment Costs | 683,39 | €/kWp |
| Investment Costs | 236.118,00 | € |
| One-off Payments | 0,00 | € |
| Incoming Subsidies | 0,00 | € |
| Annual Costs | 1.400,00 | €/Year |
| Other Revenue or Savings | 0,00 | €/Year |

### Loans

| **Reference** | **Loan 1** | |
|---|---|---|
| Loan Capital | 150.000,00 | € |
| Payment Installment | 100,00 | % |
| Credit type | Installment Loan | |
| Term | 10,00 | Years |
| Grace period | 0,00 | Years |
| Interest | 3,50 | |
| Repayment Period | quarterly | |

### Remuneration and Savings

| | | |
|---|---|---|
| Total Payment from Utility in First Year | 15.521,04 | €/Year |
| | | |
| EEG 2022 (Juli) Marktprämienmodell - Gebäudeanlage | | |
| Validity | 01.07.2022 - 31.12.2042 | |
| Specific feed-in / export Remuneration | 0,053 | €/kWh |
| Feed-in / Export Tariff | 15521,0424 | €/Year |

# Cash flow

## Cash flow

| | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| Operating costs | -1.386,14 € | -1.372,41 € | -1.358,83 € | -1.345,37 € | -1.332,05 € |
| Depreciation | -11.689,01 € | -11.573,28 € | -11.458,69 € | -11.345,24 € | -11.232,91 € |
| Self-Financing | -86.118,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 15.367,37 € | 15.092,94 € | 14.822,45 € | 14.555,83 € | 14.293,03 € |
| Loan repayments | -14.851,49 € | -14.704,44 € | -14.558,85 € | -14.414,71 € | -14.271,99 € |
| Loan Interest | -5.003,09 € | -4.438,90 € | -3.885,39 € | -3.342,41 € | -2.809,80 € |
| Results before Tax | -2.710,87 € | -2.291,65 € | -1.880,46 € | -1.477,19 € | -1.081,73 € |
| Tax Refund | 1.165,68 € | 985,41 € | 808,60 € | 635,19 € | 465,14 € |
| Results after Tax | -1.545,20 € | -1.306,24 € | -1.071,86 € | -842,00 € | -616,58 € |
| **Annual Cash Flow** | **-90.825,67 €** | **-4.437,40 €** | **-4.172,03 €** | **-3.911,47 €** | **-3.655,66 €** |
| Accrued Cash Flow (Cash Balance) | -90.825,67 € | -95.263,08 € | -99.435,10 € | -103.346,57 € | -107.002,23 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -238.932,51 € | -224.226,57 € | -209.954,35 € | -196.108,71 € | -182.682,58 € |

## Cash flow

| | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 |
|---|---|---|---|---|---|
| Operating costs | -1.318,86 € | -1.305,81 € | -1.292,88 € | -1.280,08 € | -1.267,40 € |
| Depreciation | -11.121,69 € | -11.011,58 € | -10.902,55 € | -10.794,60 € | -10.687,73 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 14.034,01 € | 13.778,73 € | 13.527,12 € | 13.279,14 € | 13.034,74 € |
| Loan repayments | -14.130,68 € | -13.990,77 € | -13.852,25 € | -13.715,10 € | -13.579,30 € |
| Loan Interest | -2.287,40 € | -1.775,08 € | -1.272,68 € | -780,05 € | -297,05 € |
| Results before Tax | -693,94 € | -313,74 € | 59,01 € | 424,41 € | 782,57 € |
| Tax Refund | 298,40 € | 134,91 € | -25,38 € | -182,50 € | -336,50 € |
| Results after Tax | -395,55 € | -178,83 € | 33,64 € | 241,91 € | 446,06 € |
| **Annual Cash Flow** | **-3.404,53 €** | **-3.158,02 €** | **-2.916,06 €** | **-2.678,58 €** | **-2.445,51 €** |
| Accrued Cash Flow (Cash Balance) | -110.406,77 € | -113.564,79 € | -116.480,85 € | -119.159,43 € | -121.604,94 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -169.669,04 € | -157.061,21 € | -144.852,35 € | -133.035,78 € | -121.604,94 € |

## Cash flow

| | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 |
|---|---|---|---|---|---|
| Operating costs | -1.254,85 € | -1.242,43 € | -1.230,13 € | -1.217,95 € | -1.205,89 € |
| Depreciation | -10.581,91 € | -10.477,14 € | -10.373,40 € | -10.270,70 € | -10.169,01 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 12.793,89 € | 12.556,52 € | 12.322,61 € | 12.092,09 € | 11.864,93 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 957,13 € | 836,96 € | 719,07 € | 603,44 € | 490,03 € |
| Tax Refund | -411,56 € | -359,89 € | -309,20 € | -259,48 € | -210,71 € |
| Results after Tax | 545,56 € | 477,07 € | 409,87 € | 343,96 € | 279,32 € |
| **Annual Cash Flow** | **11.127,47 €** | **10.954,20 €** | **10.783,28 €** | **10.614,66 €** | **10.448,32 €** |
| Accrued Cash Flow (Cash Balance) | -110.477,47 € | -99.523,27 € | -88.740,00 € | -78.125,34 € | -67.677,01 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -110.477,47 € | -99.523,27 € | -88.740,00 € | -78.125,34 € | -67.677,01 € |

## Cash flow

| | Year 16 | Year 17 | Year 18 | Year 19 | Year 20 |
|---|---|---|---|---|---|
| Operating costs | -1.193,95 € | -1.182,13 € | -1.170,42 € | -1.158,84 € | -1.147,36 € |
| Depreciation | -10.068,32 € | -9.968,64 € | -9.869,94 € | -9.772,21 € | -9.675,46 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 11.641,08 € | 11.420,50 € | 11.203,15 € | 10.988,98 € | 10.777,96 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 378,81 € | 269,74 € | 162,79 € | 57,93 € | -44,86 € |
| Tax Refund | -162,89 € | -115,99 € | -70,00 € | -24,91 € | 19,29 € |
| Results after Tax | 215,92 € | 153,75 € | 92,79 € | 33,02 € | -25,57 € |
| **Annual Cash Flow** | **10.284,24 €** | **10.122,39 €** | **9.962,73 €** | **9.805,24 €** | **9.649,89 €** |
| Accrued Cash Flow (Cash Balance) | -57.392,77 € | -47.270,38 € | -37.307,66 € | -27.502,42 € | -17.852,53 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -57.392,77 € | -47.270,38 € | -37.307,66 € | -27.502,42 € | -17.852,53 € |

## Cash flow

| | Year 21 | Year 22 | Year 23 | Year 24 | Year 25 |
|---|---|---|---|---|---|
| Operating costs | -1.136,00 € | -1.124,75 € | -1.113,62 € | -1.102,59 € | -1.091,68 € |
| Depreciation | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 10.550,53 € | 10.329,91 € | 10.128,75 € | 9.930,57 € | 9.735,32 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 9.414,53 € | 9.205,15 € | 9.015,13 € | 8.827,98 € | 8.643,64 € |
| Tax Refund | -4.048,25 € | -3.958,22 € | -3.876,51 € | -3.796,03 € | -3.716,76 € |
| Results after Tax | 5.366,28 € | 5.246,94 € | 5.138,63 € | 5.031,95 € | 4.926,87 € |
| **Annual Cash Flow** | **5.366,28 €** | **5.246,94 €** | **5.138,63 €** | **5.031,95 €** | **4.926,87 €** |
| Accrued Cash Flow (Cash Balance) | -12.486,25 € | -7.239,31 € | -2.100,69 € | 2.931,26 € | 7.858,13 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -12.486,25 € | -7.239,31 € | -2.100,69 € | 2.931,26 € | 7.858,13 € |

## Cash flow

| | Year 26 | Year 27 | Year 28 | Year 29 | Year 30 |
|---|---|---|---|---|---|
| Operating costs | -1.080,87 € | -1.070,17 € | -1.059,57 € | -1.049,08 € | -1.038,69 € |
| Depreciation | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 9.542,96 € | 9.353,45 € | 9.166,76 € | 8.982,85 € | 8.801,69 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 8.462,09 € | 8.283,29 € | 8.107,19 € | 7.933,78 € | 7.763,00 € |
| Tax Refund | -3.638,70 € | -3.561,81 € | -3.486,09 € | -3.411,52 € | -3.338,09 € |
| Results after Tax | 4.823,39 € | 4.721,47 € | 4.621,10 € | 4.522,25 € | 4.424,91 € |
| **Annual Cash Flow** | **4.823,39 €** | **4.721,47 €** | **4.621,10 €** | **4.522,25 €** | **4.424,91 €** |
| Accrued Cash Flow (Cash Balance) | 12.681,52 € | 17.403,00 € | 22.024,10 € | 26.546,35 € | 30.971,26 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 12.681,52 € | 17.403,00 € | 22.024,10 € | 26.546,35 € | 30.971,26 € |

## Cash flow

| | Year 31 |
|---|---|
| Operating costs | -1.028,41 € |
| Depreciation | 0,00 € |
| Self-Financing | 0,00 € |
| Feed-in / Export Tariff | 8.623,23 € |
| Loan repayments | 0,00 € |
| Loan Interest | 0,00 € |
| Results before Tax | 7.594,82 € |
| Tax Refund | -3.265,77 € |
| Results after Tax | 4.329,05 € |
| **Annual Cash Flow** | **4.329,05 €** |
| Accrued Cash Flow (Cash Balance) | 35.300,31 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 35.300,31 € |

Degradation and inflation rates are applied on a monthly basis over the entire observation period. This is done in the first year.

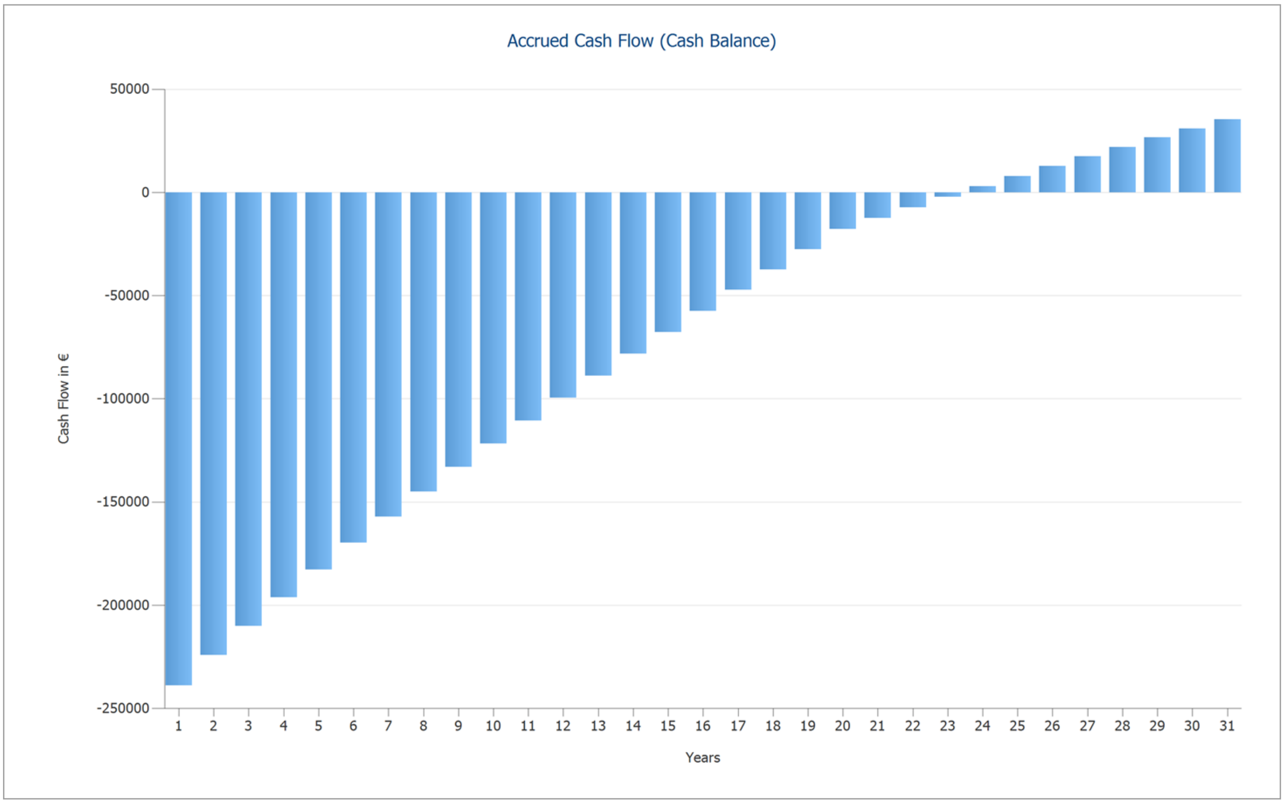



Figure: Accrued Cash Flow (Cash Balance)

# Plans and parts list

## Circuit Diagram

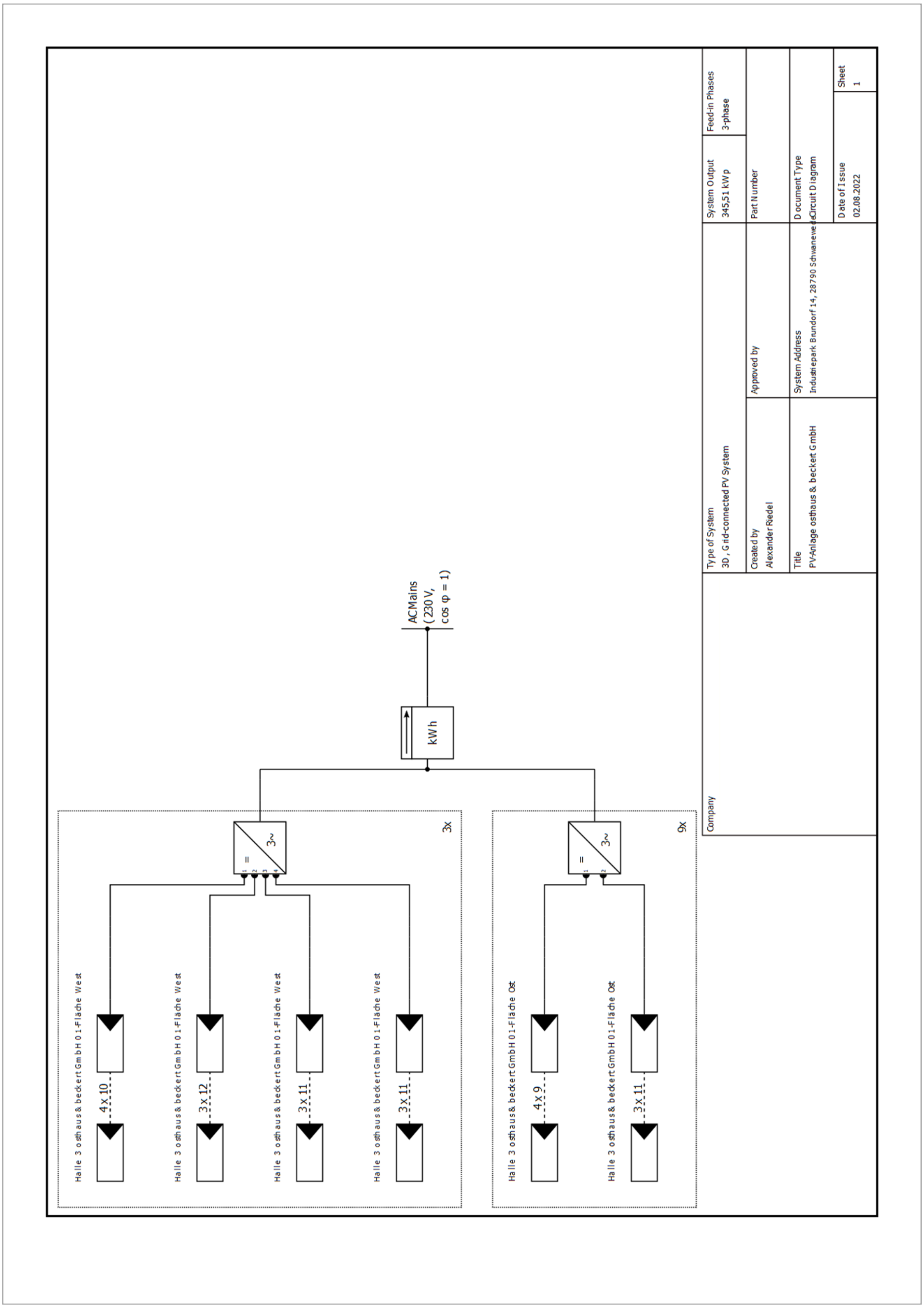



Figure: Circuit Diagram

# Overview plan

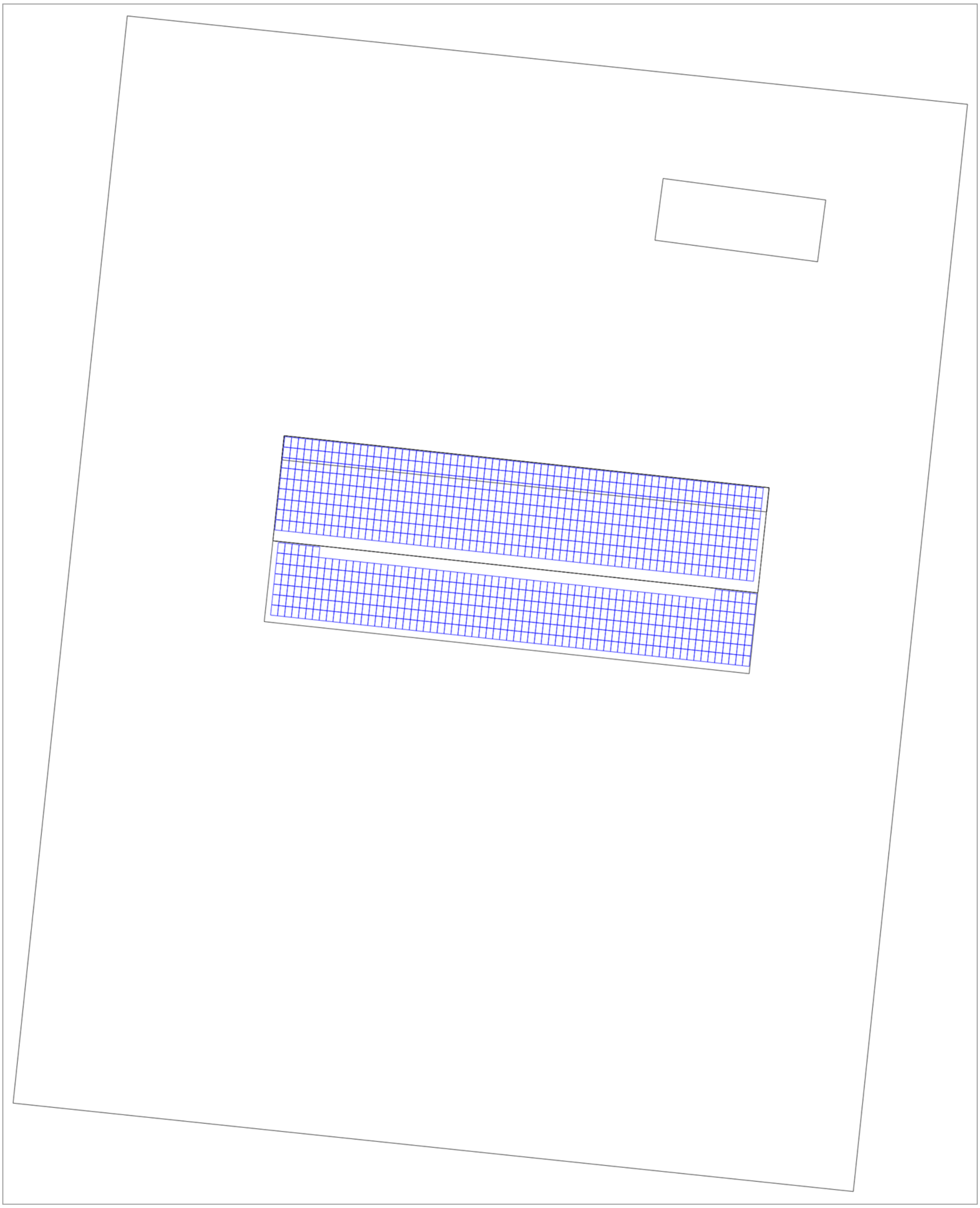


Figure: Overview plan

# Dimensioning Plan

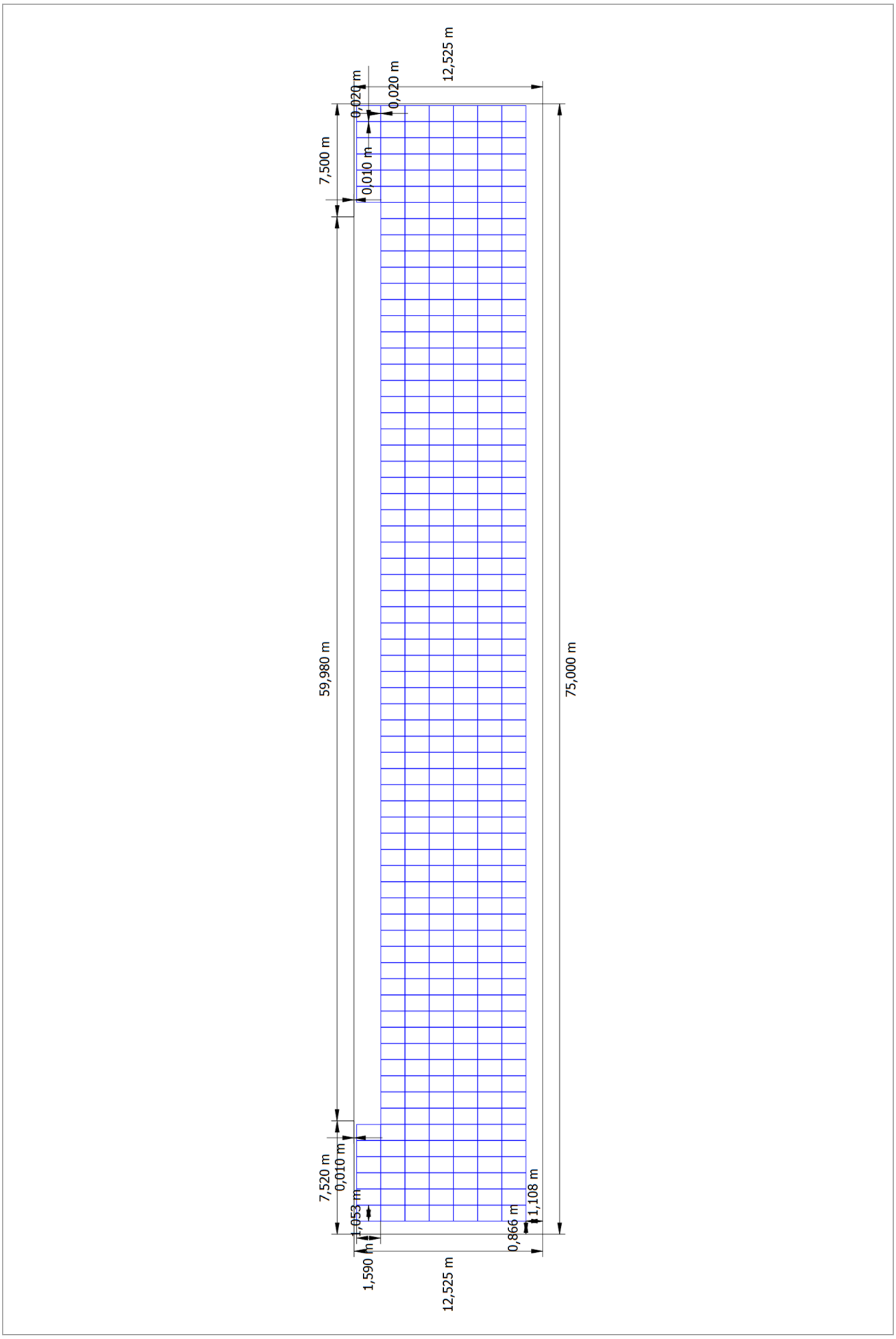



Figure: Halle 3 osthaus & beckert GmbH 01-Fläche West

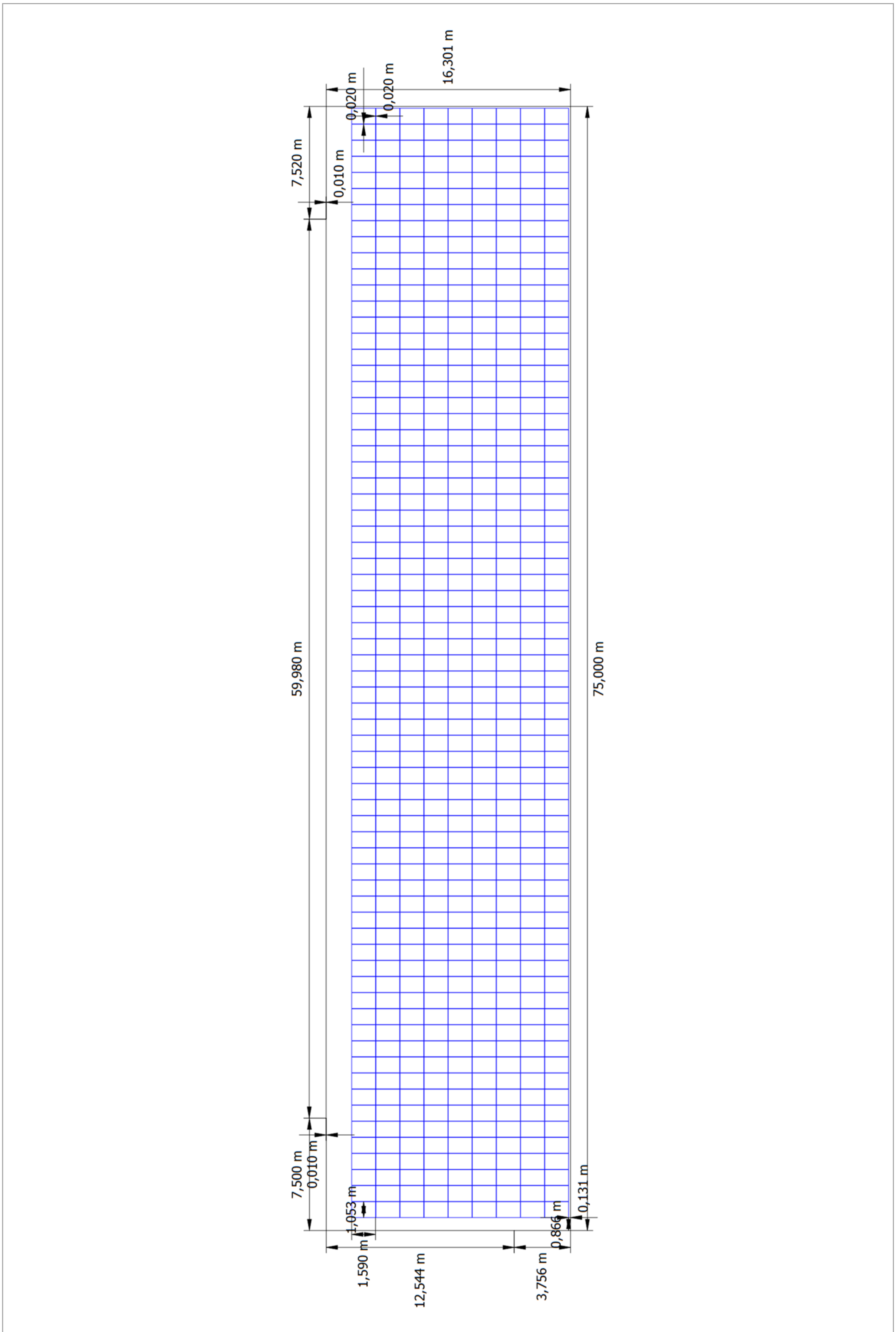



Figure: Halle 3 osthaus & beckert GmbH 01-Fläche Ost

# String Plan

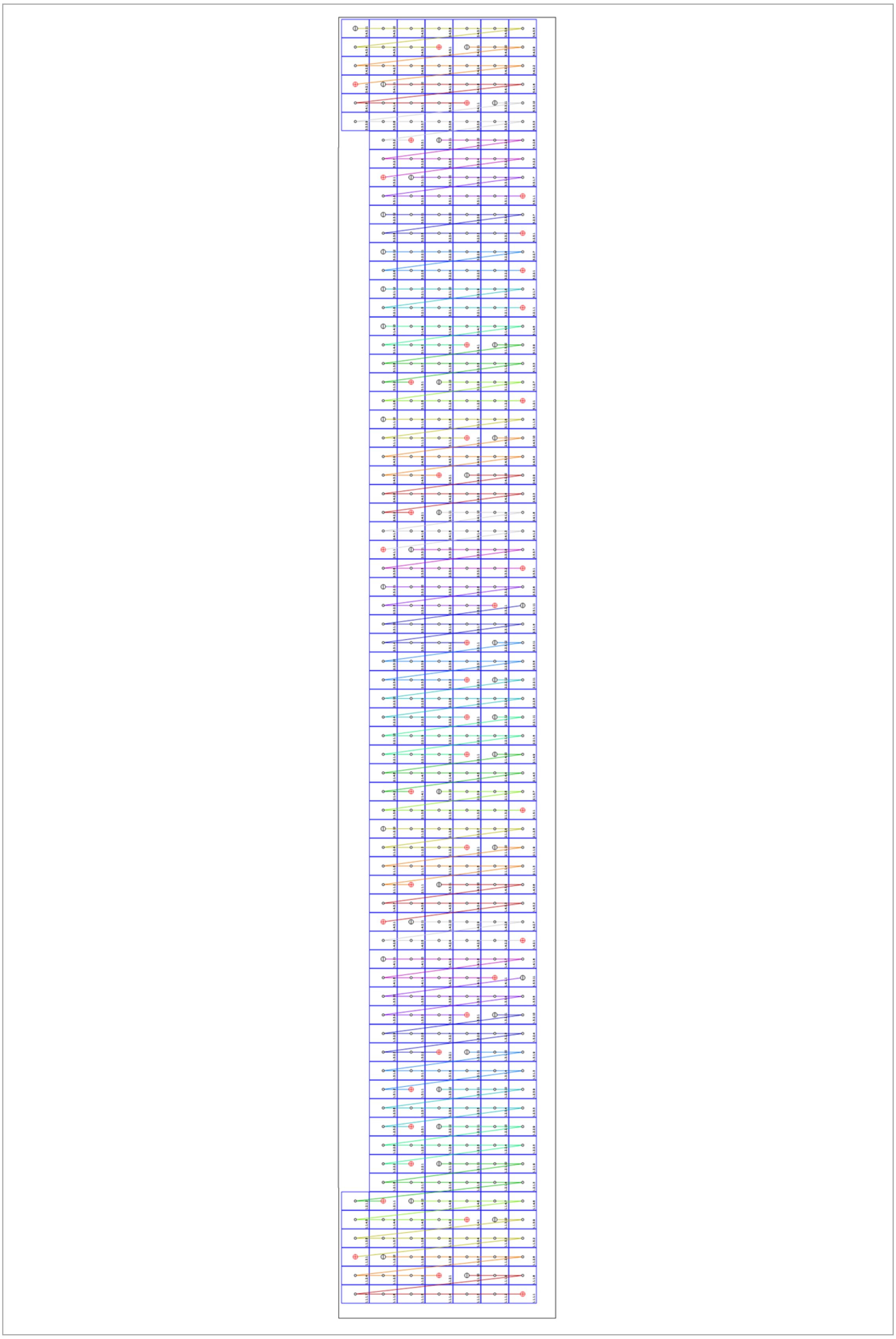


Figure: Halle 3 osthaus & beckert GmbH 01-Fläche West

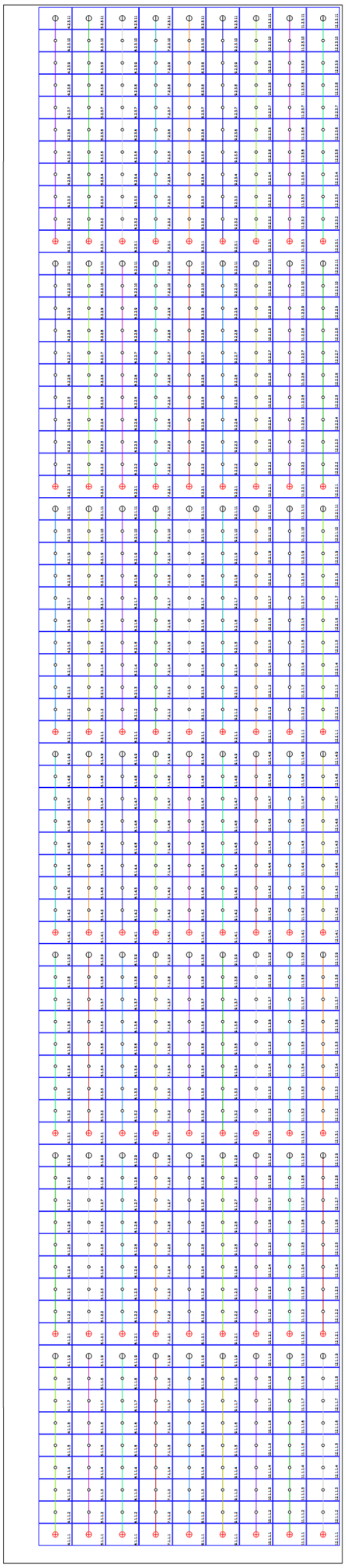


Figure: Halle 3 osthaus & beckert GmbH 01-Fläche Ost

# Parts list

## Parts list

| # | Type | Item number | Manufacturer | Name | Quantity | Unit |
|---|---|---|---|---|---|---|
| 1 | PV Module | | Panasonic | VBHN330SJ47 | 1047 | Piece |
| 2 | Inverter | | Huawei Technologies | SUN2000-40KTL-M3（440Vac） | 3 | Piece |
| 3 | Inverter | | Huawei Technologies | SUN2000-20KTL-M0 | 9 | Piece |
| 4 | Components | | | Feed-in Meter | 1 | Piece |

# Annex K: Simulation report Scenario 4 (Surplus Feeder)

**osthaus & beckert GmbH**
Beckert, Andreas; Osthaus, Christian
Industriepark Brundorf 14, 28790
Schwanewede

**Customer No.:** 123456789
**Project Name:** PV-Anlage osthaus & beckert GmbH
**Offer no.:** 123456

02.08.2022

## Your PV system

### Address of Installation

Industriepark Brundorf 14, 28790 Schwanewede


Project Description:
Planning of a company-owned PV system for osthaus & beckert GmbH

# Project Overview

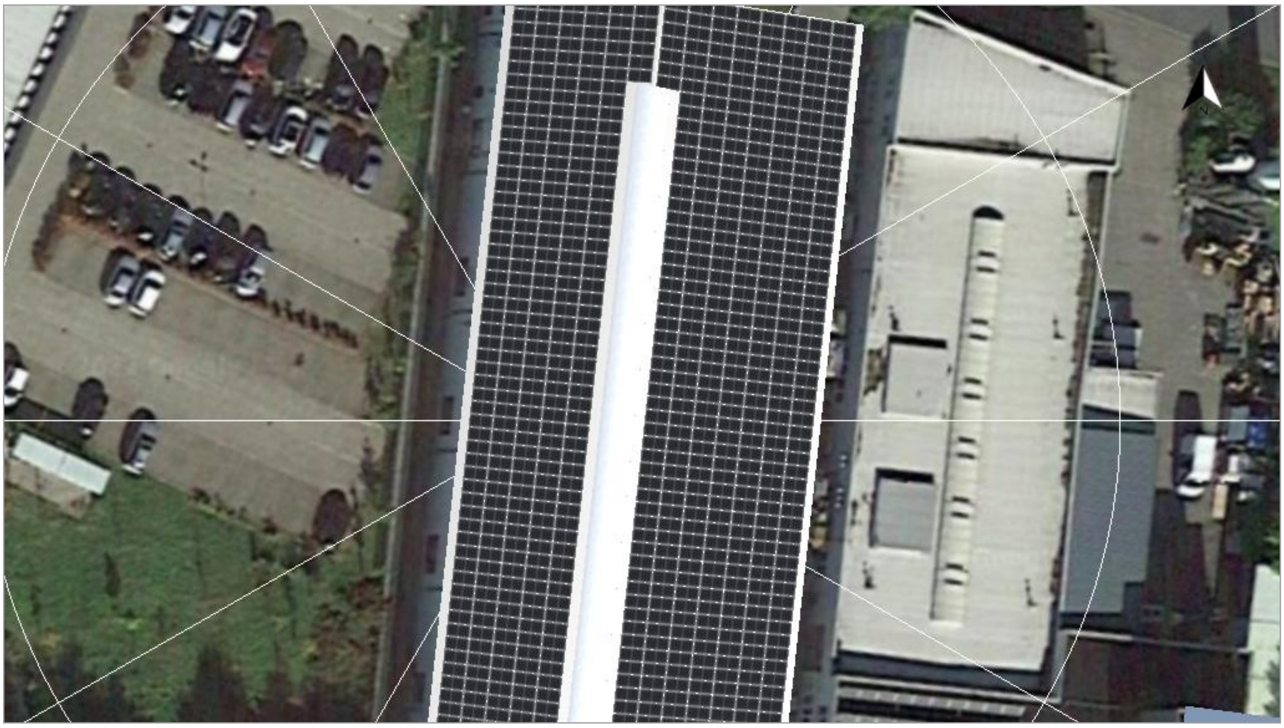


Figure: Overview Image, 3D Design

## PV System

3D, Grid-connected PV System with Electrical Appliances and Battery Systems

| | | |
|---|---|---|
| Climate Data | Osterholz-Scharmbeck, DEU (1995 - 2012) | |
| Values source | DWD | |
| PV Generator Output | 363,72 | kWp |
| PV Generator Surface | 1.729,5 | m² |
| Number of PV Modules | 866 | |
| Number of Inverters | 3 | |
| No. of battery systems | 1 | |

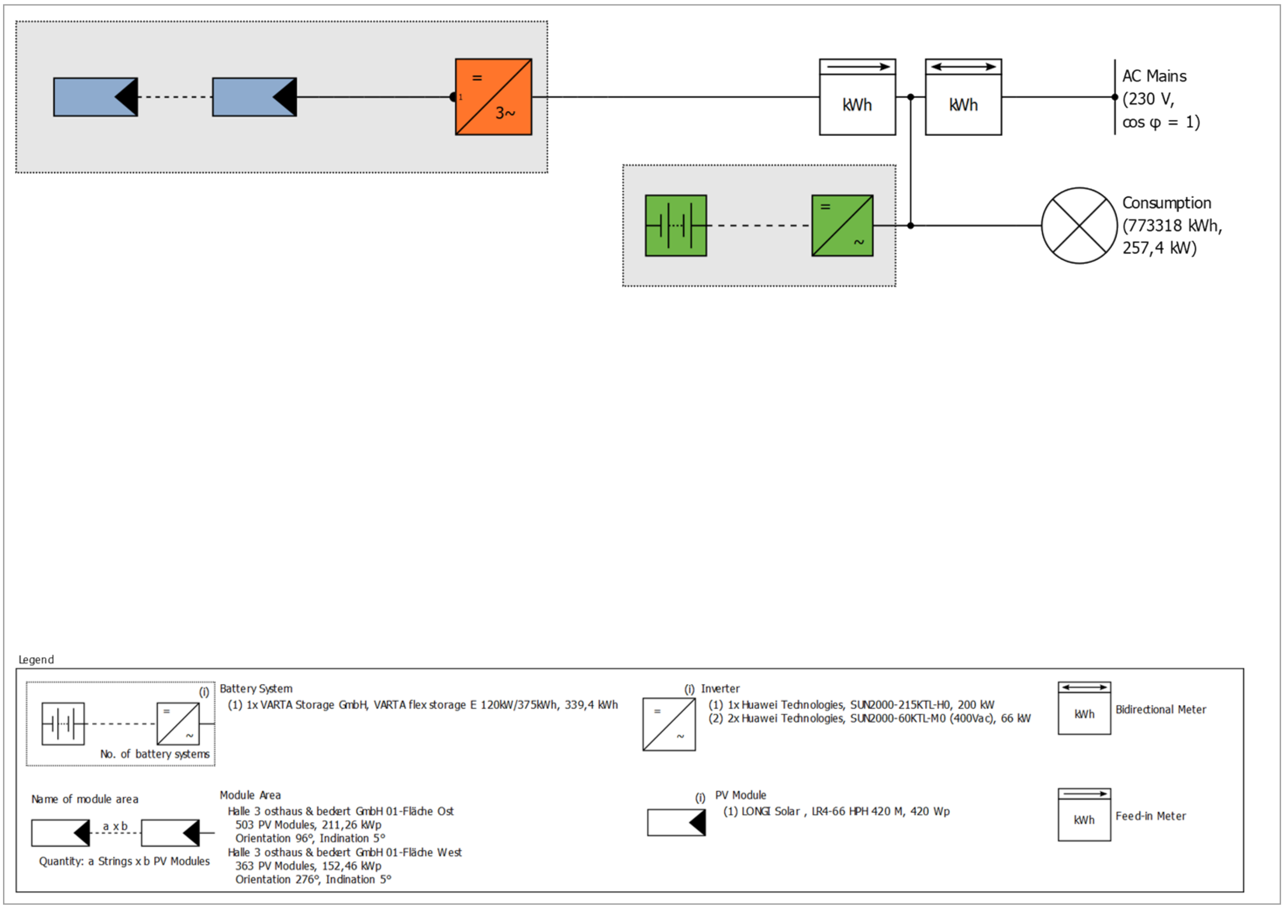



Figure: Schematic diagram

# Production Forecast

| Production Forecast | | |
|---|---:|---|
| PV Generator Output | 363,72 | kWp |
| Spec. Annual Yield | 876,32 | kWh/kWp |
| Performance Ratio (PR) | 89,08 | % |
| Yield Reduction due to Shading | 0,4 | %/Year |
| | | |
| PV Generator Energy (AC grid) | 318.774 | kWh/Year |
| Direct Own Use | 225.666 | kWh/Year |
| Battery Charge | 49.737 | kWh/Year |
| Down-regulation at Feed-in Point | 0 | kWh/Year |
| Grid Feed-in | 43.371 | kWh/Year |
| | | |
| Own Power Consumption | 86,4 | % |
| | | |
| $CO_2$ Emissions avoided | 152.207 | kg / year |
| | | |
| Level of Self-sufficiency | 35,0 | % |

# Financial Analysis

## Your Gain

| | | |
|---|---|---|
| Total investment costs | 429.474,00 | € |
| Internal Rate of Return of Capital Resources | 9,45 | % |
| Amortization Period | 13,5 | Years |
| Electricity Production Costs | 0,0594 | €/kWh |
| Energy Balance/Feed-in Concept | Surplus Feed-in | |

The results have been calculated with a mathematical model calculation from Valentin Software GmbH (PV*SOL algorithms). The actual yields from the solar power system may differ as a result of weather variations, the efficiency of the modules and inverter, and other factors.

# Set-up of the System

## Overview

### System Data

| | |
|---|---|
| Type of System | 3D, Grid-connected PV System with Electrical Appliances and Battery Systems |

### Climate Data

| | |
|---|---|
| Location | Osterholz-Scharmbeck, DEU (1995 - 2012) |
| Values source | DWD |
| Resolution of the data | 1 min |
| Simulation models used: | |
| - Diffuse Irradiation onto Horizontal Plane | Hofmann |
| - Irradiance onto tilted surface | Hay & Davies |

### Consumption

| | |
|---|---|
| Total Consumption | 773318 kWh |
| osthaus und beckert GmbH Halle 3 | 773318 kWh |
| Load Peak | 257,4 kW |

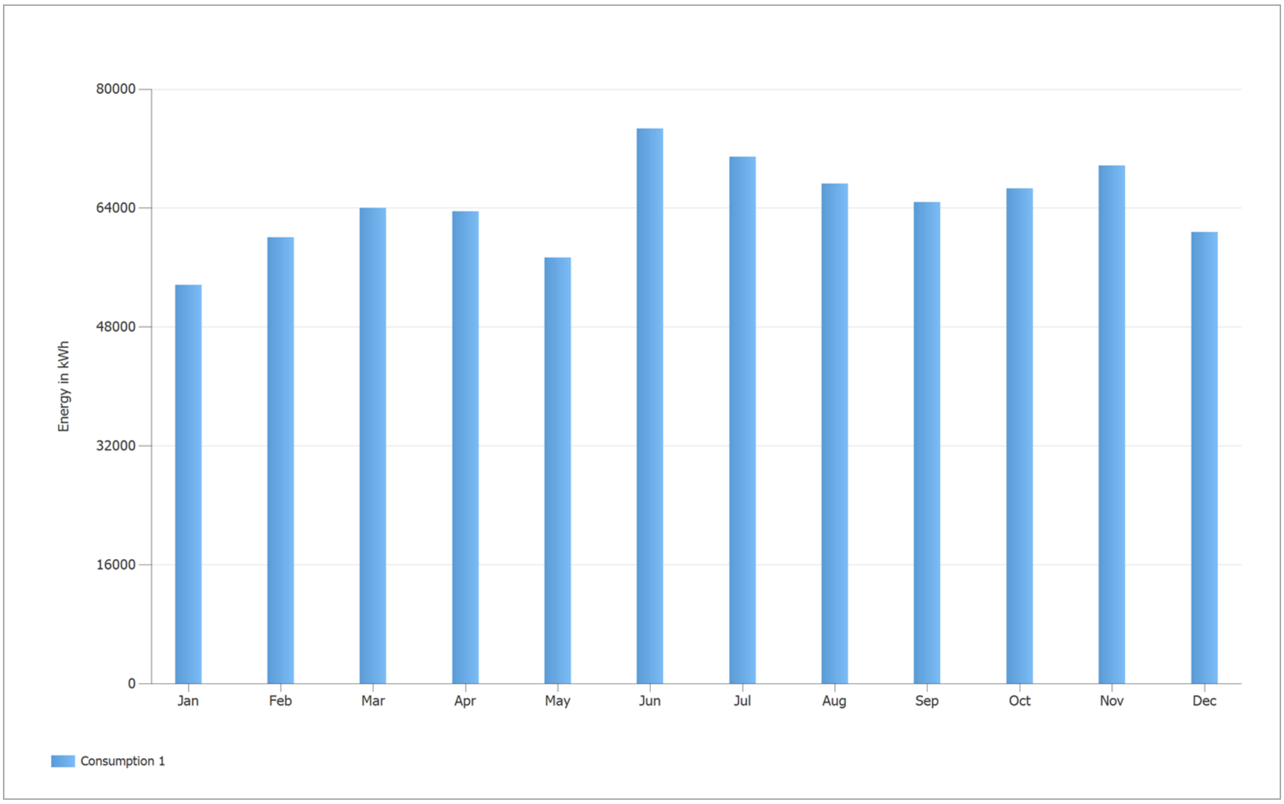



Figure: Consumption

# Module Areas

## 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost

### PV Generator, 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost

| | |
|---|---|
| Name | Halle 3 osthaus & beckert GmbH 01-Fläche Ost |
| PV Modules | 503 x LR4-66 HPH 420 M (v1) |
| Manufacturer | LONGI Solar |
| Inclination | 5 ° |
| Orientation | East 96 ° |
| Installation Type | Roof parallel |
| PV Generator Surface | 1.004,5 m² |

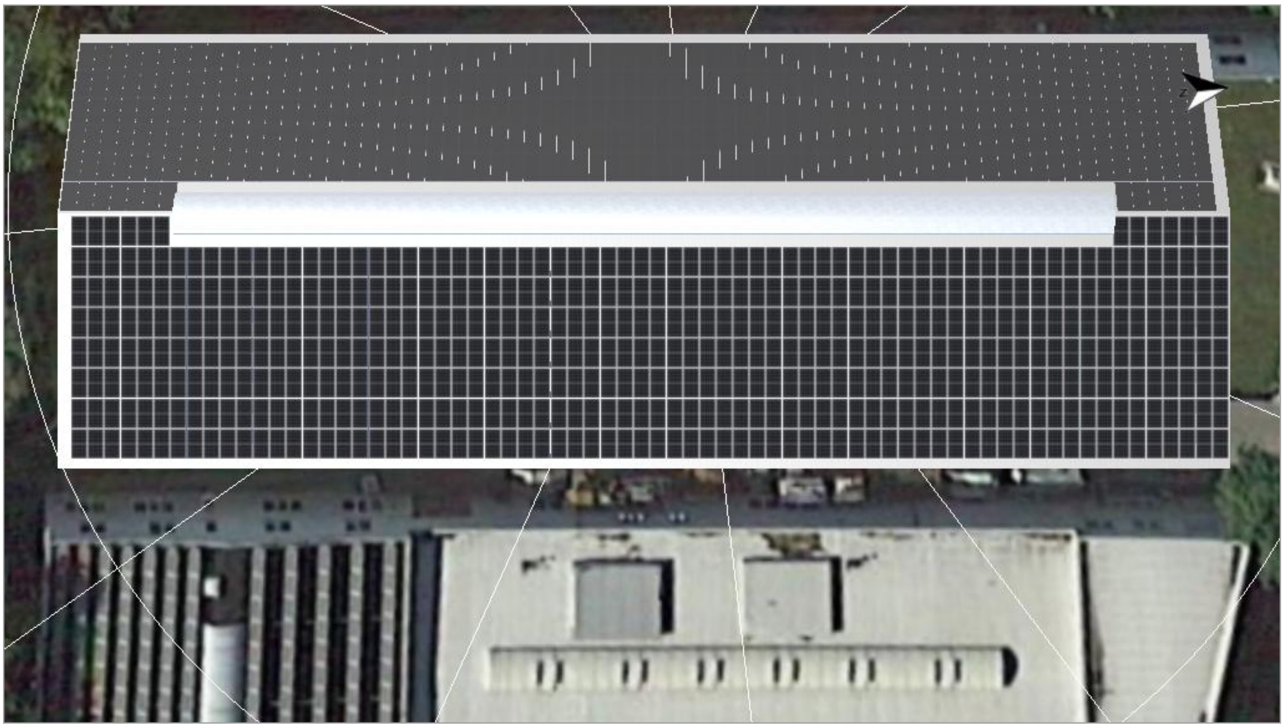


Figure: 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost

## *2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West*

### PV Generator, 2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West

| | | |
|---|---|---|
| Name | Halle 3 osthaus & beckert GmbH 01-Fläche West | |
| PV Modules | 363 x LR4-66 HPH 420 M (v1) | |
| Manufacturer | LONGI Solar | |
| Inclination | 5 | ° |
| Orientation | West 276 | ° |
| Installation Type | Roof parallel | |
| PV Generator Surface | 725,0 | m² |

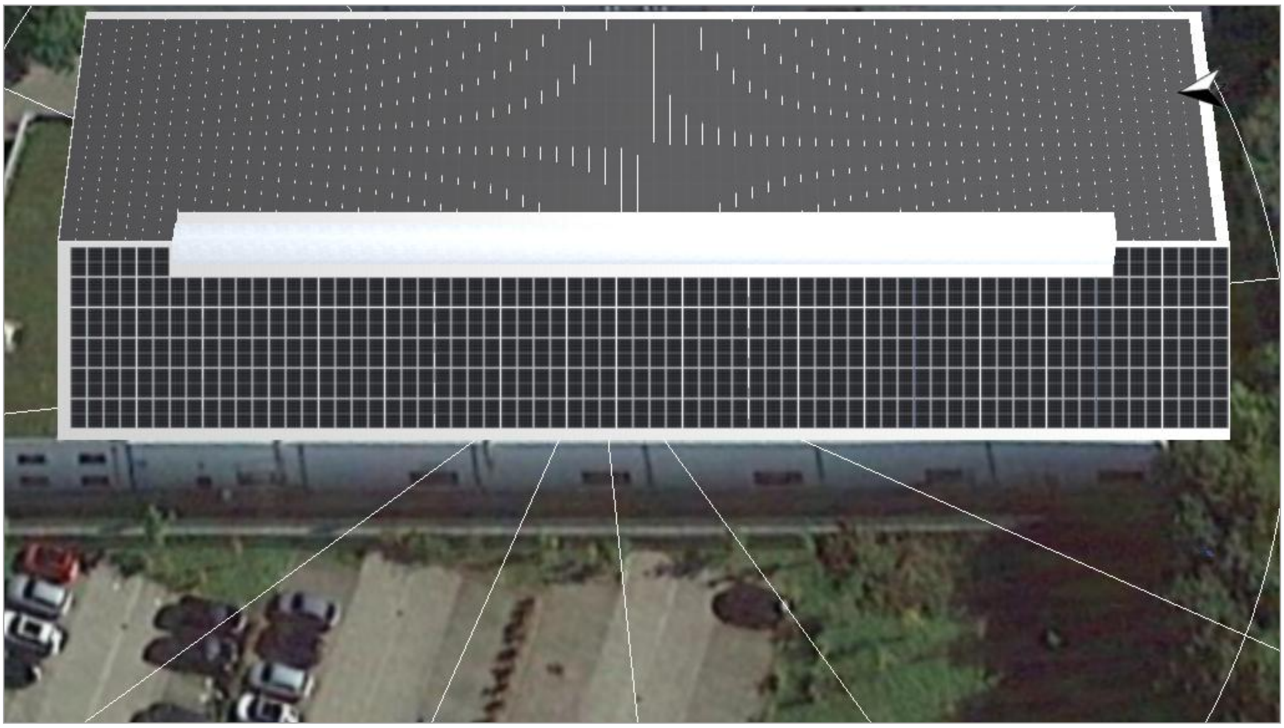


Figure: 2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West

# Horizon Line, 3D Design

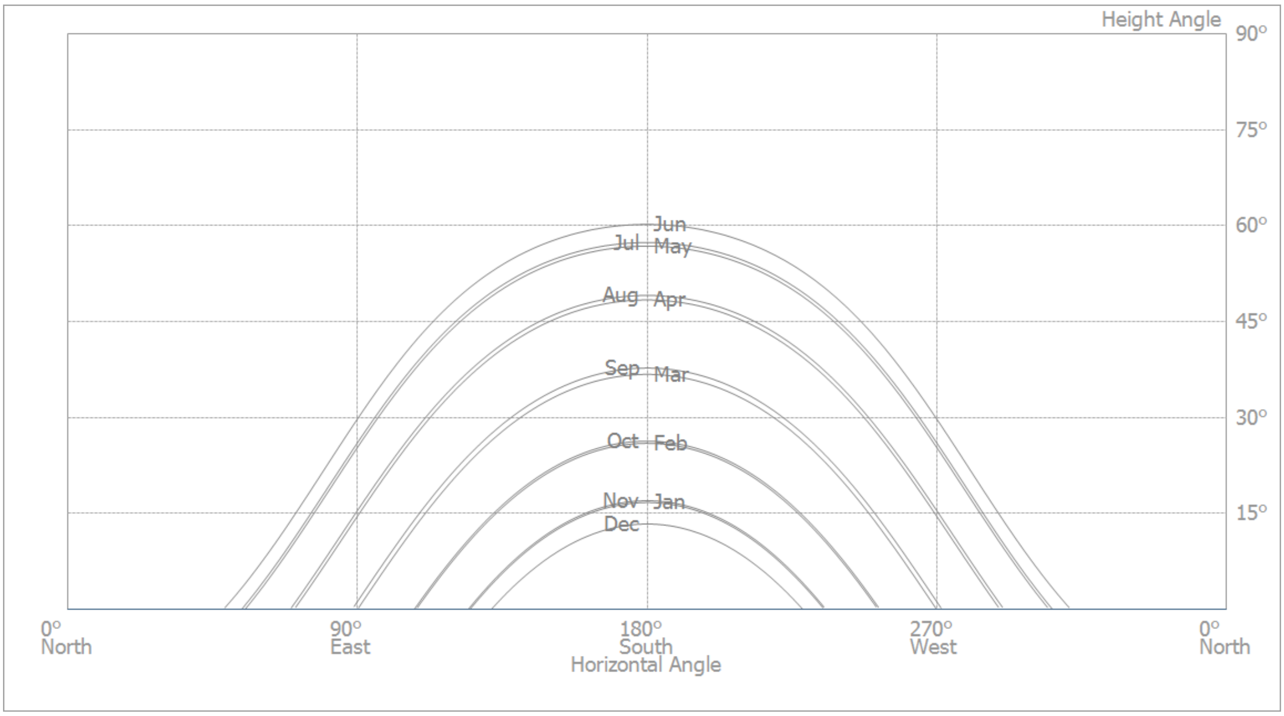



Figure: Horizon (3D Design)

# Inverter configuration

Configuration 1

| | |
|---|---|
| Module Area | Halle 3 osthaus & beckert GmbH 01-Fläche Ost |
| Inverter 1 | |
| Model | SUN2000-215KTL-H0 (v1) |
| Manufacturer | Huawei Technologies |
| Quantity | 1 |
| Sizing Factor | 105,6 % |
| Configuration | MPP 1: 2 x 30 |
| | MPP 2: 2 x 30 |
| | MPP 3: 2 x 30 |
| | MPP 4: 2 x 30 |
| | MPP 5: 2 x 30 |
| | MPP 6: 2 x 30 |
| | MPP 7: 2 x 30 |
| | MPP 8: 2 x 27 |
| | MPP 9: 1 x 29 |

Configuration 2

| | |
|---|---|
| Module Area | Halle 3 osthaus & beckert GmbH 01-Fläche West |
| Inverter 1 | |
| Model | SUN2000-60KTL-M0 (400Vac) (v2) |
| Manufacturer | Huawei Technologies |
| Quantity | 1 |
| Sizing Factor | 115,8 % |
| Configuration | MPP 1: 2 x 16 |
| | MPP 2: 2 x 16 |
| | MPP 3: 2 x 16 |
| | MPP 4: 2 x 16 |
| | MPP 5: 2 x 15 |
| | MPP 6: 2 x 12 |
| Inverter 2 | |
| Model | SUN2000-60KTL-M0 (400Vac) (v2) |
| Manufacturer | Huawei Technologies |
| Quantity | 1 |
| Sizing Factor | 115,2 % |
| Configuration | MPP 1: 2 x 16 |
| | MPP 2: 2 x 16 |
| | MPP 3: 2 x 16 |
| | MPP 4: 2 x 16 |
| | MPP 5: 2 x 16 |
| | MPP 6: 1 x 21 |

# AC Mains

AC Mains

| | | |
|---|---|---|
| Number of Phases | 3 | |
| Mains voltage between phase and neutral | 230 | V |
| Displacement Power Factor (cos phi) | +/- 1 | |

# Battery Systems

Battery System

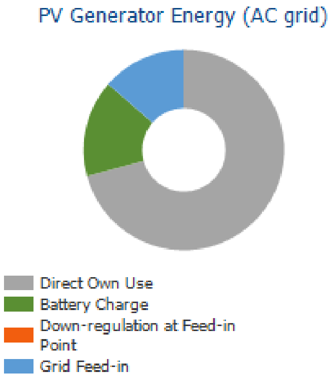
| | | |
|---|---|---|
| Model | VARTA flex storage E 120kW/375kWh (v3) | |
| Manufacturer | VARTA Storage GmbH | |
| Quantity | 1 | |
| Battery Inverter | | |
| Type of Coupling | AC coupling | |
| Nominal output | 120 | kW |
| Battery | | |
| Manufacturer | VARTA Storage GmbH | |
| Model | VARTA flex storage E BM (v1) | |
| Quantity | 65 | |
| Battery Energy | 339,4 | kWh |
| Battery Type | Lithium nickel manganese cobalt oxide/graphite | |

# Simulation Results

## Results Total System

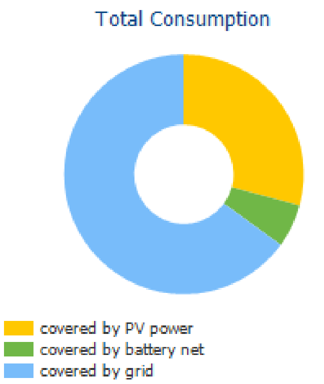
### PV System

| | | |
|---|---|---|
| PV Generator Output | 363,72 | kWp |
| Spec. Annual Yield | 876,32 | kWh/kWp |
| Performance Ratio (PR) | 89,08 | % |
| Yield Reduction due to Shading | 0,4 | %/Year |
| PV Generator Energy (AC grid) | 318.774 | kWh/Year |
| Direct Own Use | 225.666 | kWh/Year |
| Battery Charge | 49.737 | kWh/Year |
| Down-regulation at Feed-in Point | 0 | kWh/Year |
| Grid Feed-in | 43.371 | kWh/Year |
| Own Power Consumption | 86,4 | % |
| $CO_2$ Emissions avoided | 152.207 | kg / year |



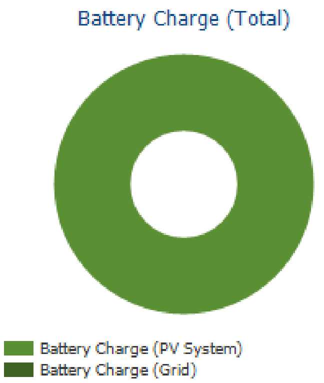

### Appliances

| | | |
|---|---|---|
| Appliances | 773.318 | kWh/Year |
| Standby Consumption (Inverter) | 38 | kWh/Year |
| Total Consumption | 773.356 | kWh/Year |
| covered by PV power | 225.666 | kWh/Year |
| covered by battery net | 45.169 | kWh/Year |
| covered by grid | 502.520 | kWh/Year |
| Solar Fraction | 35,0 | % |




### Battery System

| | | |
|---|---|---|
| Charge at beginning | 339 | kWh |
| Battery Charge (Total) | 49.737 | kWh/Year |
| Battery Charge (PV System) | 49.737 | kWh/Year |
| Battery Charge (Grid) | 0 | kWh/Year |
| Battery Energy for the Covering of Consumption | 45.169 | kWh/Year |
| Losses due to charging/discharging | 4.904 | kWh/Year |
| Losses in Battery | 3 | kWh/Year |
| Cycle Load | 2,5 | % |
| Service Life | >20 | Years |




### Level of Self-sufficiency

| | | |
|---|---|---|
| Total Consumption | 773.356 | kWh/Year |
| covered by grid | 502.520 | kWh/Year |
| Level of Self-sufficiency | 35,0 | % |

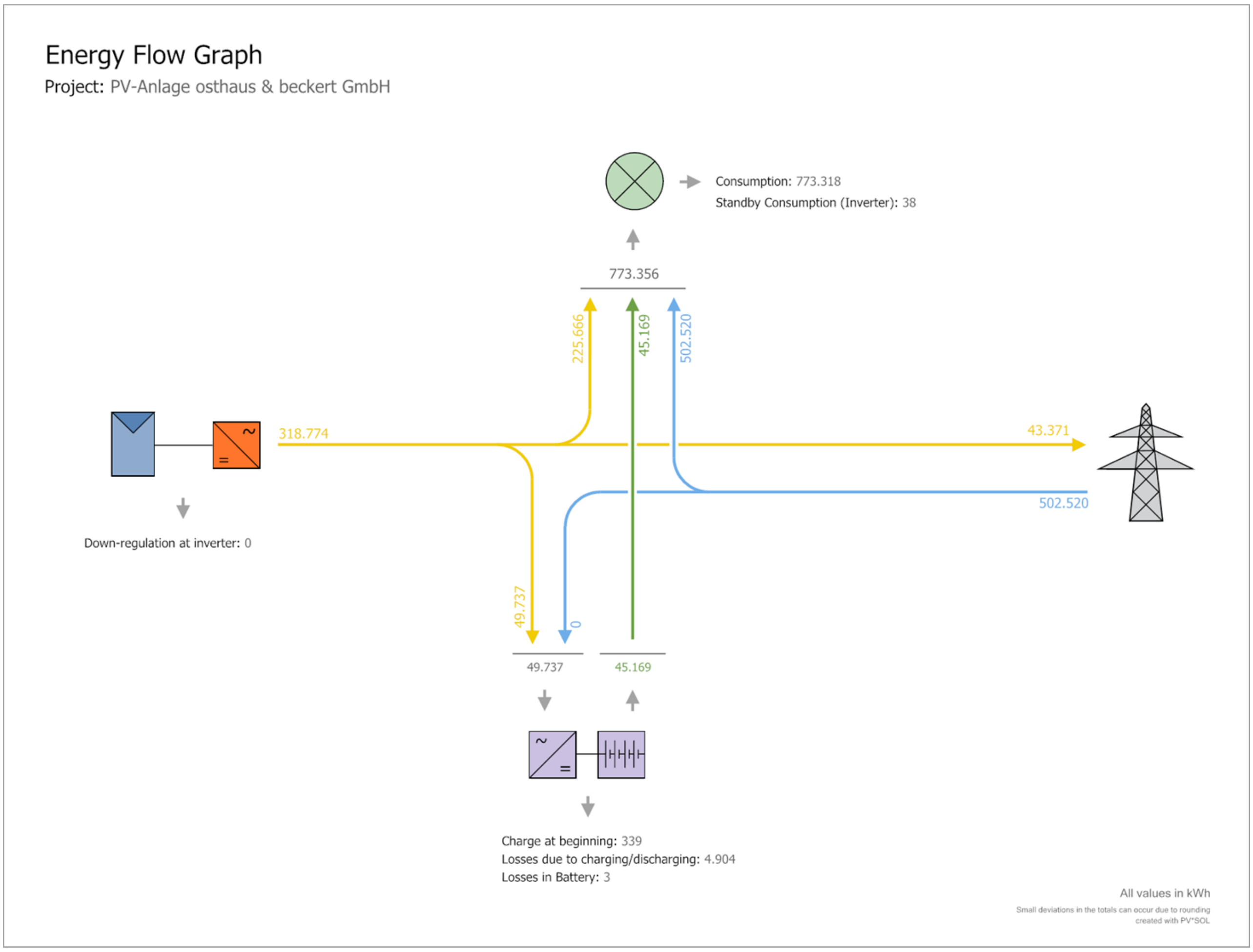



Figure: Energy flow

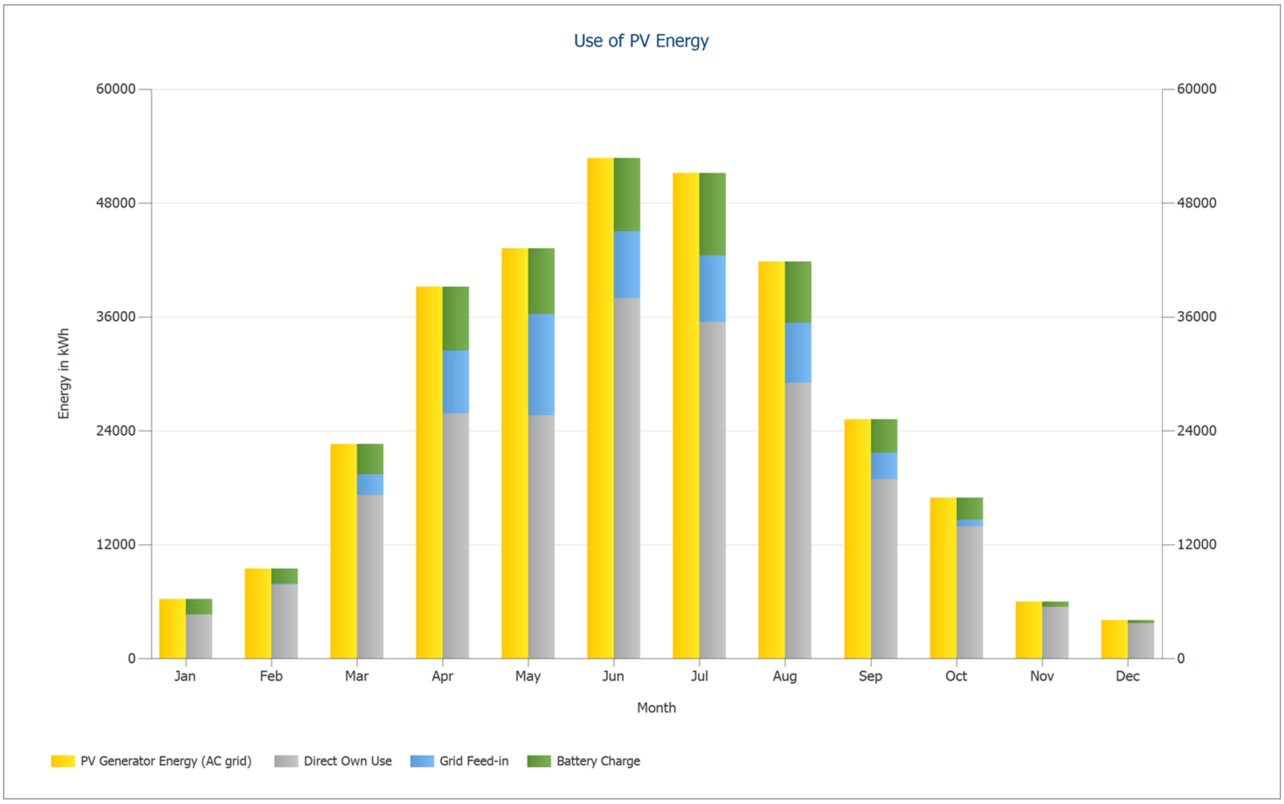



Figure: Use of PV Energy

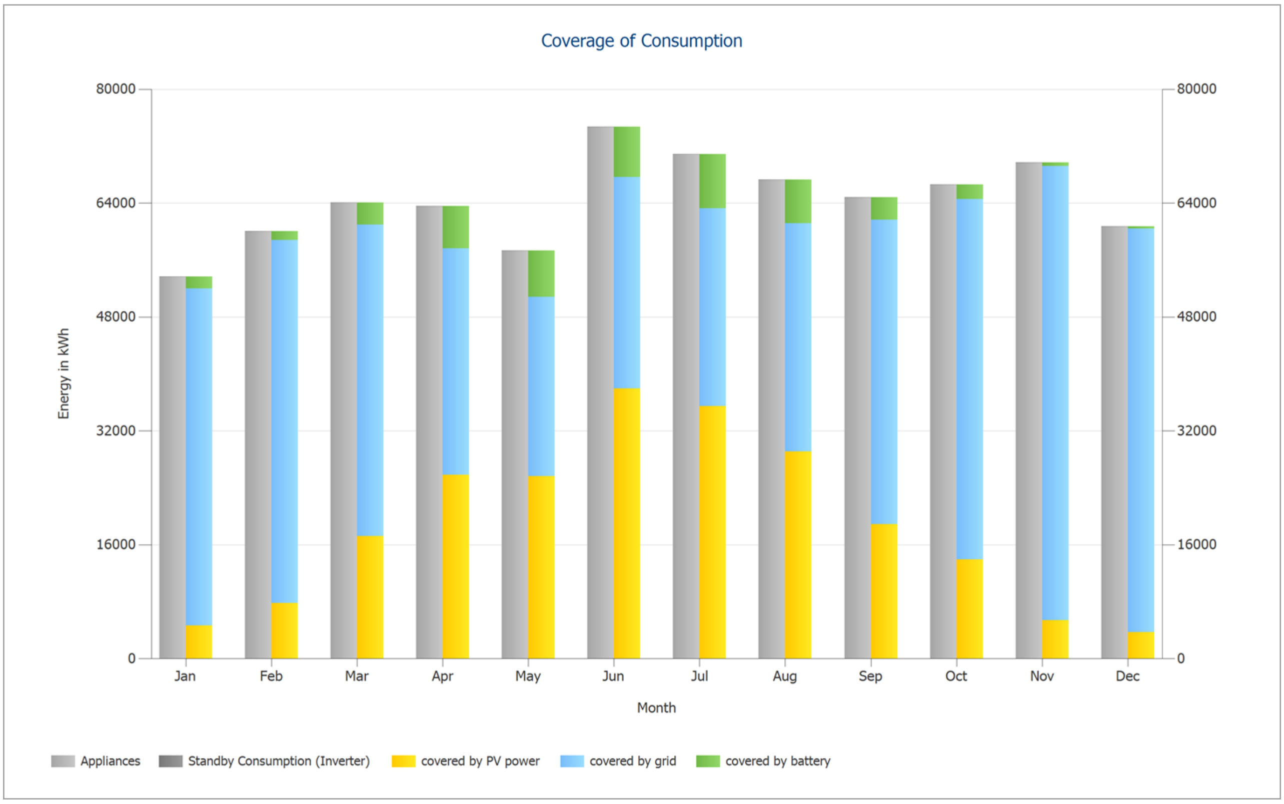



Figure: Coverage of Consumption

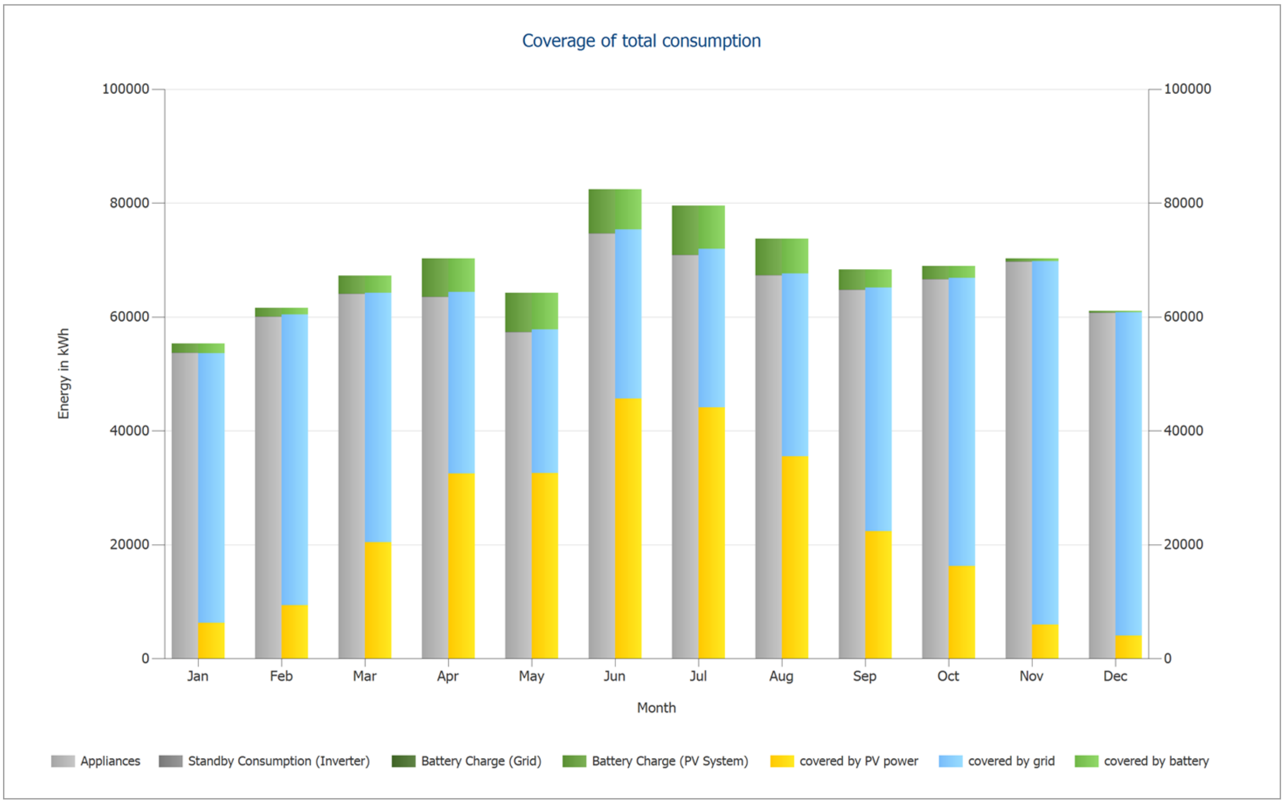



Figure: Coverage of total consumption

# Yield for EnEV

Yield in accordance with DIN 15316-4-6

| | |
|---|---|
| January | 5093,6 kWh |
| February | 6980,3 kWh |
| March | 17037,2 kWh |
| April | 32125,3 kWh |
| May | 38816,7 kWh |
| June | 40964 kWh |
| July | 36884,6 kWh |
| August | 31615,4 kWh |
| September | 21586,8 kWh |
| October | 13524,4 kWh |
| November | 5269,2 kWh |
| December | 2985,9 kWh |
| **Annual Value** | **252.883,4 kWh** |

Boundary Conditions:
Climate Data according to DIN V 18599-10
HALLE 3 OSTHAUS & BECKERT GMBH 01-FLÄCHE OST
System Power Factor: 0.75
Peak Power Coefficient: 0.182
Orientation: East
Inclination: 0°

HALLE 3 OSTHAUS & BECKERT GMBH 01-FLÄCHE WEST
System Power Factor: 0.75
Peak Power Coefficient: 0.182
Orientation: West
Inclination: 0°

# Financial Analysis

## Overview

### System Data

| | | |
|---|---|---|
| Grid Feed-in in the first year (incl. module degradation) | 43.211 | kWh/Year |
| PV Generator Output | 363,7 | kWp |
| Start of Operation of the System | 01.07.2022 | |
| Assessment Period | 30 | Years |
| Interest on Capital | 1 | % |

### Economic Parameters

| | | |
|---|---|---|
| Internal Rate of Return of Capital Resources | 9,45 | % |
| Accrued Cash Flow (Cash Balance) | 431.479,07 | € |
| Amortization Period | 13,5 | Years |
| Electricity Production Costs | 0,0594 | €/kWh |

### Payment Overview

| | | |
|---|---|---|
| Specific Investment Costs | 1.180,78 | €/kWp |
| Investment Costs | 429.474,00 | € |
| One-off Payments | 0,00 | € |
| Incoming Subsidies | 0,00 | € |
| Annual Costs | 1.400,00 | €/Year |
| Other Revenue or Savings | 0,00 | €/Year |

### Loans

| **Reference** | **Loan 1** | |
|---|---|---|
| Loan Capital | 300.000,00 | € |
| Payment Installment | 100,00 | % |
| Credit type | Installment Loan | |
| Term | 10,00 | Years |
| Grace period | 0,00 | Years |
| Interest | 3,50 | |
| Repayment Period | quarterly | |

### Remuneration and Savings

| | | |
|---|---|---|
| Total Payment from Utility in First Year | 2.285,92 | €/Year |
| First year savings | 43.828,51 | €/Year |
| | | |
| EEG 2022 (Juli) Marktprämienmodell - Gebäudeanlage | | |
| Validity | 01.07.2022 | - 31.12.2042 |
| Specific feed-in / export Remuneration | 0,0529 | €/kWh |
| Feed-in / Export Tariff | 2285,9225 | €/Year |
| | | |
| Tarif oshaus & beckert GmbH (Wattline) | | |
| Energy Price | 0,1624 | €/kWh |
| Inflation Rate for Energy Price | 1 | %/Year |

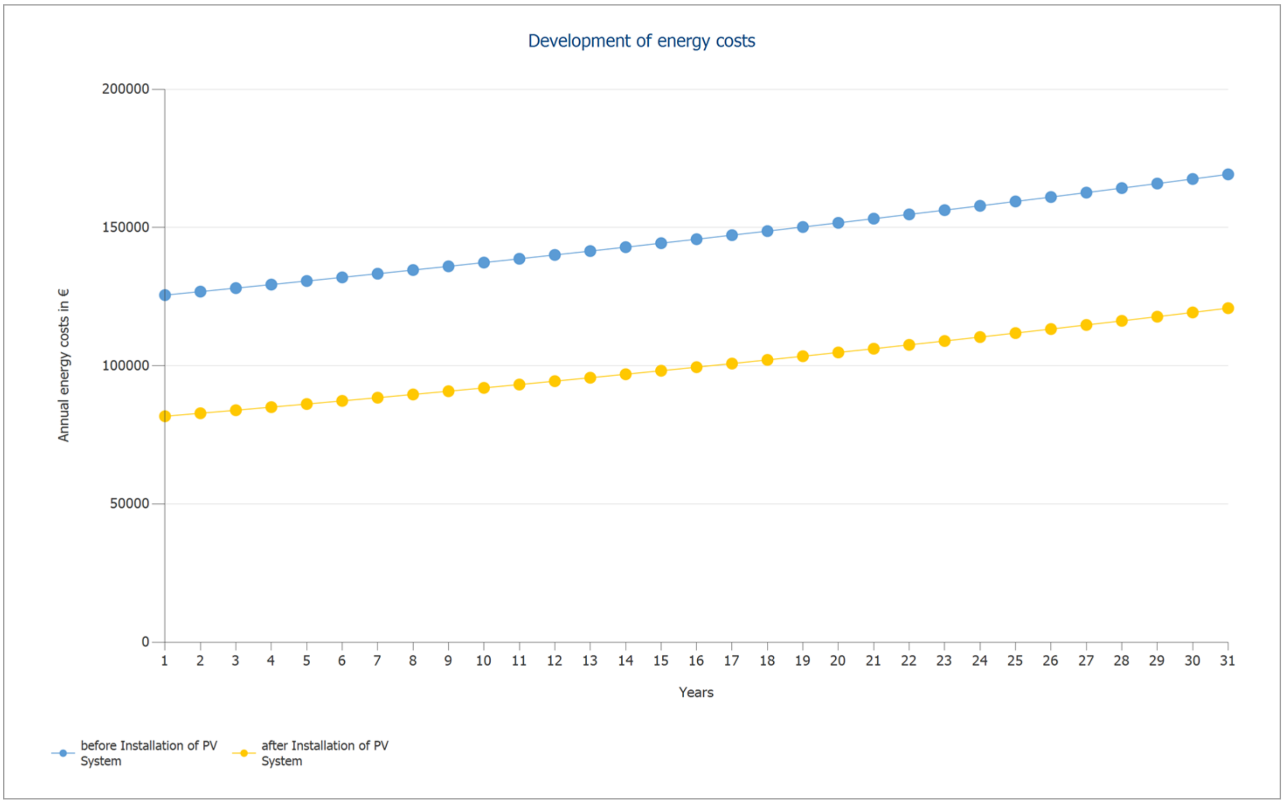



Figure: Development of energy costs

# Cash flow

## Cash flow

| | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| Operating costs | -1.386,14 € | -1.372,41 € | -1.358,83 € | -1.345,37 € | -1.332,05 € |
| Depreciation | -21.261,09 € | -21.050,58 € | -20.842,16 € | -20.635,80 € | -20.431,49 € |
| Self-Financing | -129.474,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 2.263,29 € | 2.227,39 € | 2.191,97 € | 2.157,04 € | 2.122,58 € |
| Electricity Savings | 43.394,56 € | 43.133,37 € | 42.872,19 € | 42.611,00 € | 42.349,82 € |
| Loan repayments | -29.702,97 € | -29.408,88 € | -29.117,70 € | -28.829,41 € | -28.543,97 € |
| Loan Interest | -10.006,19 € | -8.877,81 € | -7.770,79 € | -6.684,82 € | -5.619,59 € |
| Results before Tax | 13.004,43 € | 14.059,96 € | 15.092,38 € | 16.102,05 € | 17.089,27 € |
| Tax Refund | -5.591,91 € | -6.045,78 € | -6.489,73 € | -6.923,88 € | -7.348,38 € |
| Results after Tax | 7.412,53 € | 8.014,18 € | 8.602,66 € | 9.178,17 € | 9.740,88 € |
| **Annual Cash Flow** | **-130.503,35 €** | **-344,12 €** | **327,12 €** | **984,56 €** | **1.628,40 €** |
| Accrued Cash Flow (Cash Balance) | -130.503,35 € | -130.847,48 € | -130.520,36 € | -129.535,80 € | -127.907,40 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -426.717,03 € | -388.774,46 € | -351.558,86 € | -315.060,07 € | -279.268,10 € |

## Cash flow

| | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 |
|---|---|---|---|---|---|
| Operating costs | -1.318,86 € | -1.305,81 € | -1.292,88 € | -1.280,08 € | -1.267,40 € |
| Depreciation | -20.229,20 € | -20.028,91 € | -19.830,60 € | -19.634,26 € | -19.439,86 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 2.088,60 € | 2.055,08 € | 2.022,02 € | 1.989,41 € | 1.957,25 € |
| Electricity Savings | 42.088,63 € | 41.827,44 € | 41.566,24 € | 41.305,08 € | 41.043,88 € |
| Loan repayments | -28.261,36 € | -27.981,54 € | -27.704,50 € | -27.430,19 € | -27.158,61 € |
| Loan Interest | -4.574,81 € | -3.550,16 € | -2.545,35 € | -1.560,09 € | -594,09 € |
| Results before Tax | 18.054,36 € | 18.997,65 € | 19.919,44 € | 20.820,07 € | 21.699,77 € |
| Tax Refund | -7.763,38 € | -8.168,99 € | -8.565,36 € | -8.952,63 € | -9.330,90 € |
| Results after Tax | 10.290,99 € | 10.828,66 € | 11.354,08 € | 11.867,44 € | 12.368,87 € |
| **Annual Cash Flow** | **2.258,83 €** | **2.876,03 €** | **3.480,18 €** | **4.071,50 €** | **4.650,12 €** |
| Accrued Cash Flow (Cash Balance) | -125.648,57 € | -122.772,55 € | -119.292,37 € | -115.220,86 € | -110.570,74 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -244.173,11 € | -209.765,39 € | -176.035,36 € | -142.973,56 € | -110.570,74 € |

## Cash flow

| | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 |
|---|---|---|---|---|---|
| Operating costs | -1.254,85 € | -1.242,43 € | -1.230,13 € | -1.217,95 € | -1.205,89 € |
| Depreciation | -19.247,39 € | -19.056,82 € | -18.868,14 € | -18.681,32 € | -18.496,36 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 1.925,54 € | 1.894,26 € | 1.863,40 € | 1.832,98 € | 1.802,97 € |
| Electricity Savings | 40.782,69 € | 40.521,50 € | 40.260,33 € | 39.999,13 € | 39.737,95 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 22.205,99 € | 22.116,51 € | 22.025,47 € | 21.932,84 € | 21.838,67 € |
| Tax Refund | -9.548,58 € | -9.510,10 € | -9.470,95 € | -9.431,12 € | -9.390,63 € |
| Results after Tax | 12.657,42 € | 12.606,41 € | 12.554,52 € | 12.501,72 € | 12.448,04 € |
| **Annual Cash Flow** | **31.904,80 €** | **31.663,23 €** | **31.422,65 €** | **31.183,04 €** | **30.944,40 €** |
| Accrued Cash Flow (Cash Balance) | -78.665,94 € | -47.002,71 € | -15.580,05 € | 15.602,99 € | 46.547,39 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -78.665,94 € | -47.002,71 € | -15.580,05 € | 15.602,99 € | 46.547,39 € |

## Cash flow

| | Year 16 | Year 17 | Year 18 | Year 19 | Year 20 |
|---|---|---|---|---|---|
| Operating costs | -1.193,95 € | -1.182,13 € | -1.170,42 € | -1.158,84 € | -1.147,36 € |
| Depreciation | -18.313,23 € | -18.131,91 € | -17.952,38 € | -17.774,64 € | -17.598,65 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 1.773,38 € | 1.744,20 € | 1.715,42 € | 1.687,04 € | 1.659,06 € |
| Electricity Savings | 39.476,77 € | 39.215,59 € | 38.954,38 € | 38.693,20 € | 38.432,03 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 21.742,97 € | 21.645,76 € | 21.546,99 € | 21.446,76 € | 21.345,07 € |
| Tax Refund | -9.349,48 € | -9.307,68 € | -9.265,21 € | -9.222,11 € | -9.178,38 € |
| Results after Tax | 12.393,50 € | 12.338,08 € | 12.281,79 € | 12.224,65 € | 12.166,69 € |
| **Annual Cash Flow** | **30.706,72 €** | **30.469,99 €** | **30.234,17 €** | **29.999,29 €** | **29.765,34 €** |
| Accrued Cash Flow (Cash Balance) | 77.254,11 € | 107.724,10 € | 137.958,28 € | 167.957,57 € | 197.722,91 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 77.254,11 € | 107.724,10 € | 137.958,28 € | 167.957,57 € | 197.722,91 € |

Cash flow

| | Year 21 | Year 22 | Year 23 | Year 24 | Year 25 |
|---|---|---|---|---|---|
| Operating costs | -1.136,00 € | -1.124,75 € | -1.113,62 € | -1.102,59 € | -1.091,68 € |
| Depreciation | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 1.629,55 € | 1.601,18 € | 1.574,40 € | 1.547,99 € | 1.521,95 € |
| Electricity Savings | 38.170,84 € | 37.909,65 € | 37.648,47 € | 37.387,28 € | 37.126,10 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 38.664,39 € | 38.386,08 € | 38.109,25 € | 37.832,68 € | 37.556,38 € |
| Tax Refund | -16.625,69 € | -16.506,01 € | -16.386,98 € | -16.268,05 € | -16.149,24 € |
| Results after Tax | 22.038,70 € | 21.880,07 € | 21.722,27 € | 21.564,62 € | 21.407,13 € |
| **Annual Cash Flow** | **22.038,70 €** | **21.880,07 €** | **21.722,27 €** | **21.564,62 €** | **21.407,13 €** |
| Accrued Cash Flow (Cash Balance) | 219.761,61 € | 241.641,68 € | 263.363,95 € | 284.928,57 € | 306.335,71 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 219.761,61 € | 241.641,68 € | 263.363,95 € | 284.928,57 € | 306.335,71 € |

Cash flow

| | Year 26 | Year 27 | Year 28 | Year 29 | Year 30 |
|---|---|---|---|---|---|
| Operating costs | -1.080,87 € | -1.070,17 € | -1.059,57 € | -1.049,08 € | -1.038,69 € |
| Depreciation | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 1.496,27 € | 1.470,95 € | 1.445,99 € | 1.421,38 € | 1.397,11 € |
| Electricity Savings | 36.864,91 € | 36.603,71 € | 36.342,54 € | 36.081,35 € | 35.820,17 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 37.280,31 € | 37.004,50 € | 36.728,96 € | 36.453,65 € | 36.178,59 € |
| Tax Refund | -16.030,53 € | -15.911,94 € | -15.793,45 € | -15.675,07 € | -15.556,79 € |
| Results after Tax | 21.249,78 € | 21.092,57 € | 20.935,51 € | 20.778,58 € | 20.621,79 € |
| **Annual Cash Flow** | **21.249,78 €** | **21.092,57 €** | **20.935,51 €** | **20.778,58 €** | **20.621,79 €** |
| Accrued Cash Flow (Cash Balance) | 327.585,48 € | 348.678,05 € | 369.613,56 € | 390.392,14 € | 411.013,93 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 327.585,48 € | 348.678,05 € | 369.613,56 € | 390.392,14 € | 411.013,93 € |

## Cash flow

| | Year 31 |
|---|---|
| Operating costs | -1.028,41 € |
| Depreciation | 0,00 € |
| Self-Financing | 0,00 € |
| Feed-in / Export Tariff | 1.373,19 € |
| Electricity Savings | 35.558,98 € |
| Loan repayments | 0,00 € |
| Loan Interest | 0,00 € |
| Results before Tax | 35.903,76 € |
| Tax Refund | -15.438,62 € |
| Results after Tax | 20.465,14 € |
| **Annual Cash Flow** | **20.465,14 €** |
| Accrued Cash Flow (Cash Balance) | 431.479,07 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 431.479,07 € |

Degradation and inflation rates are applied on a monthly basis over the entire observation period. This is done in the first year.

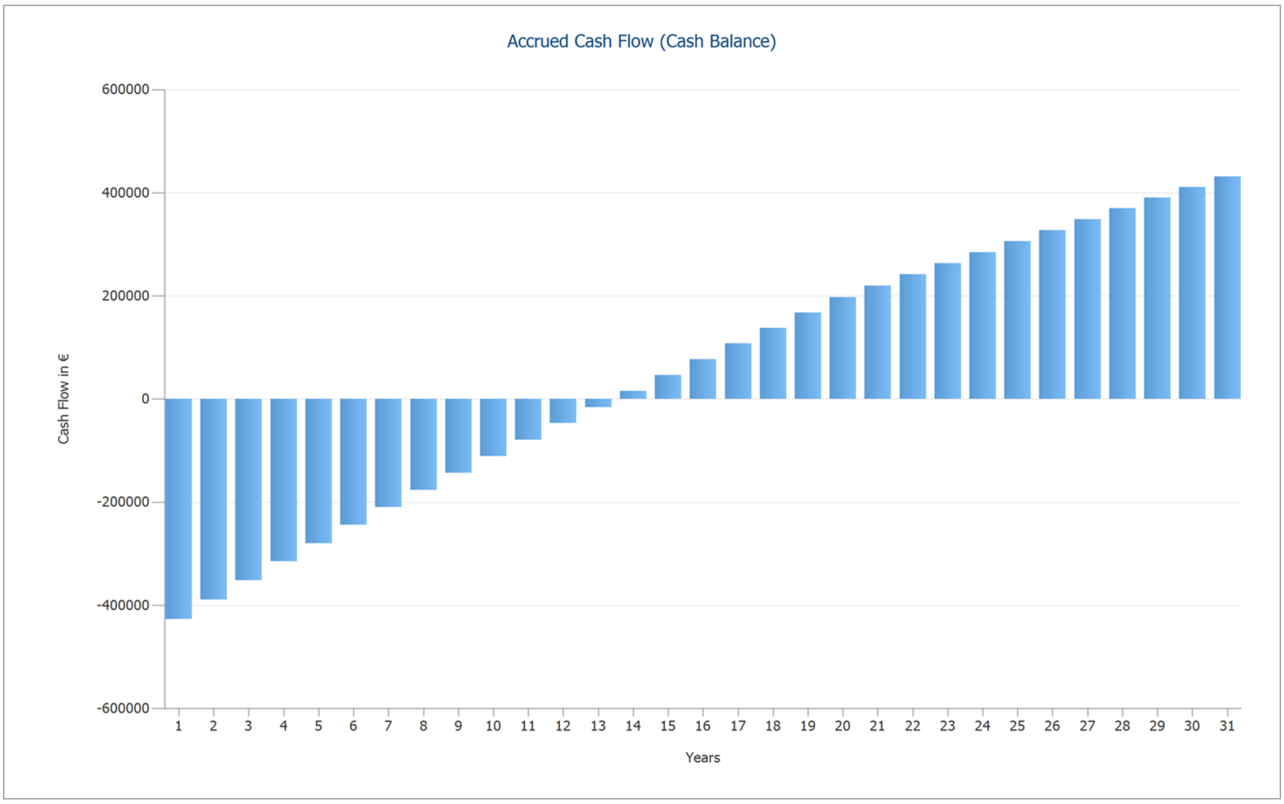



Figure: Accrued Cash Flow (Cash Balance)

# Plans and parts list

## Circuit Diagram

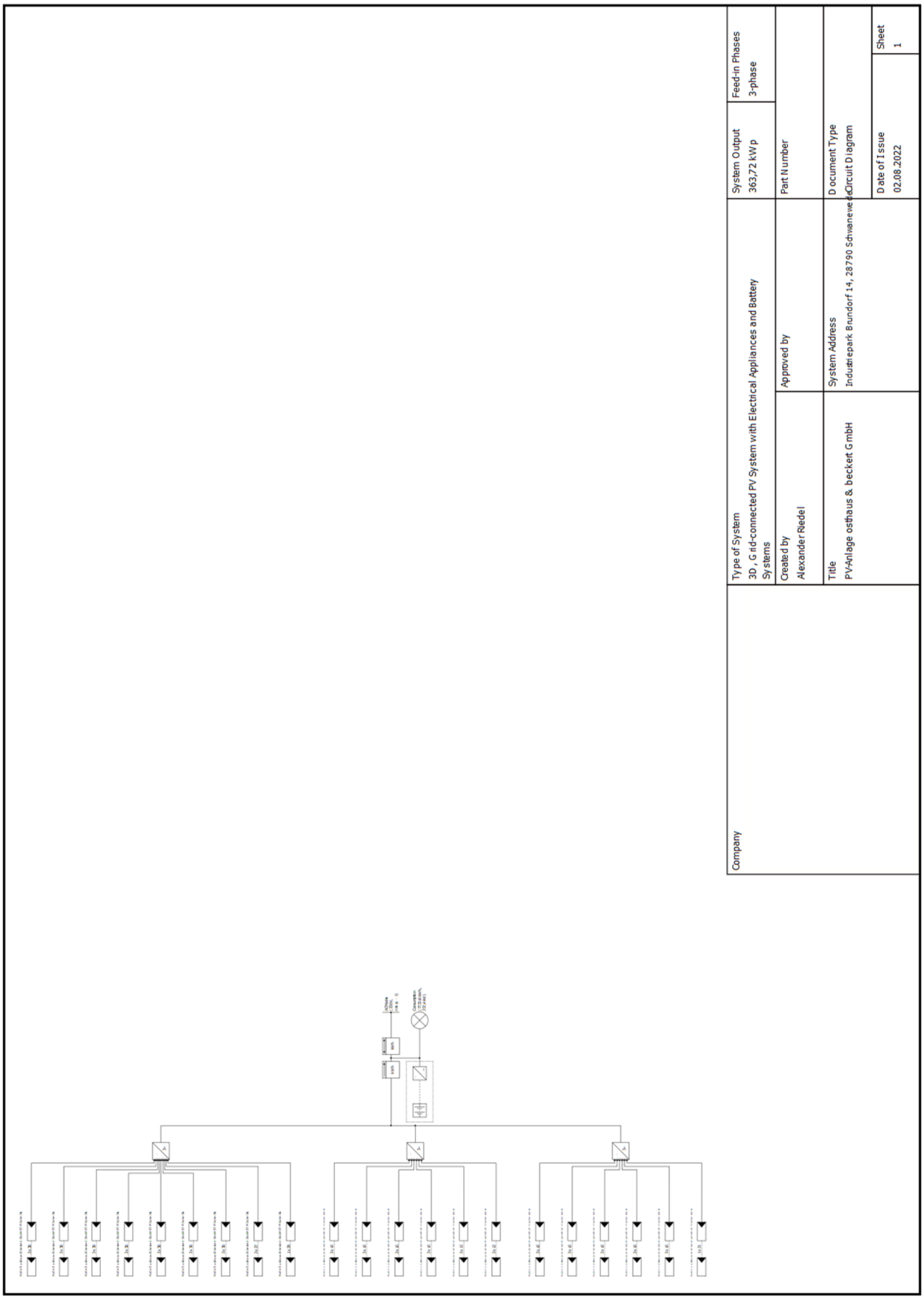



Figure: Circuit Diagram

# Overview plan

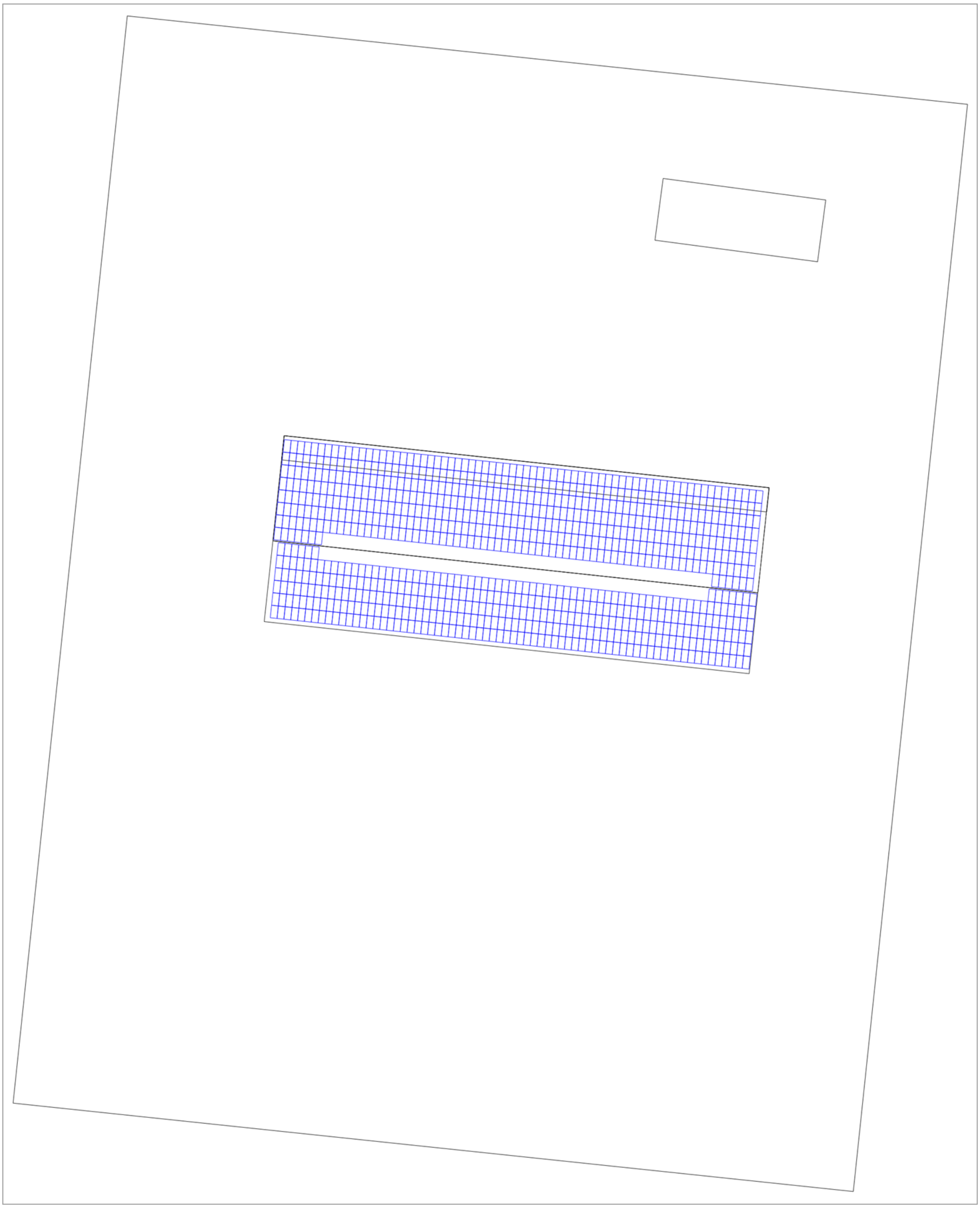


Figure: Overview plan

# Dimensioning Plan

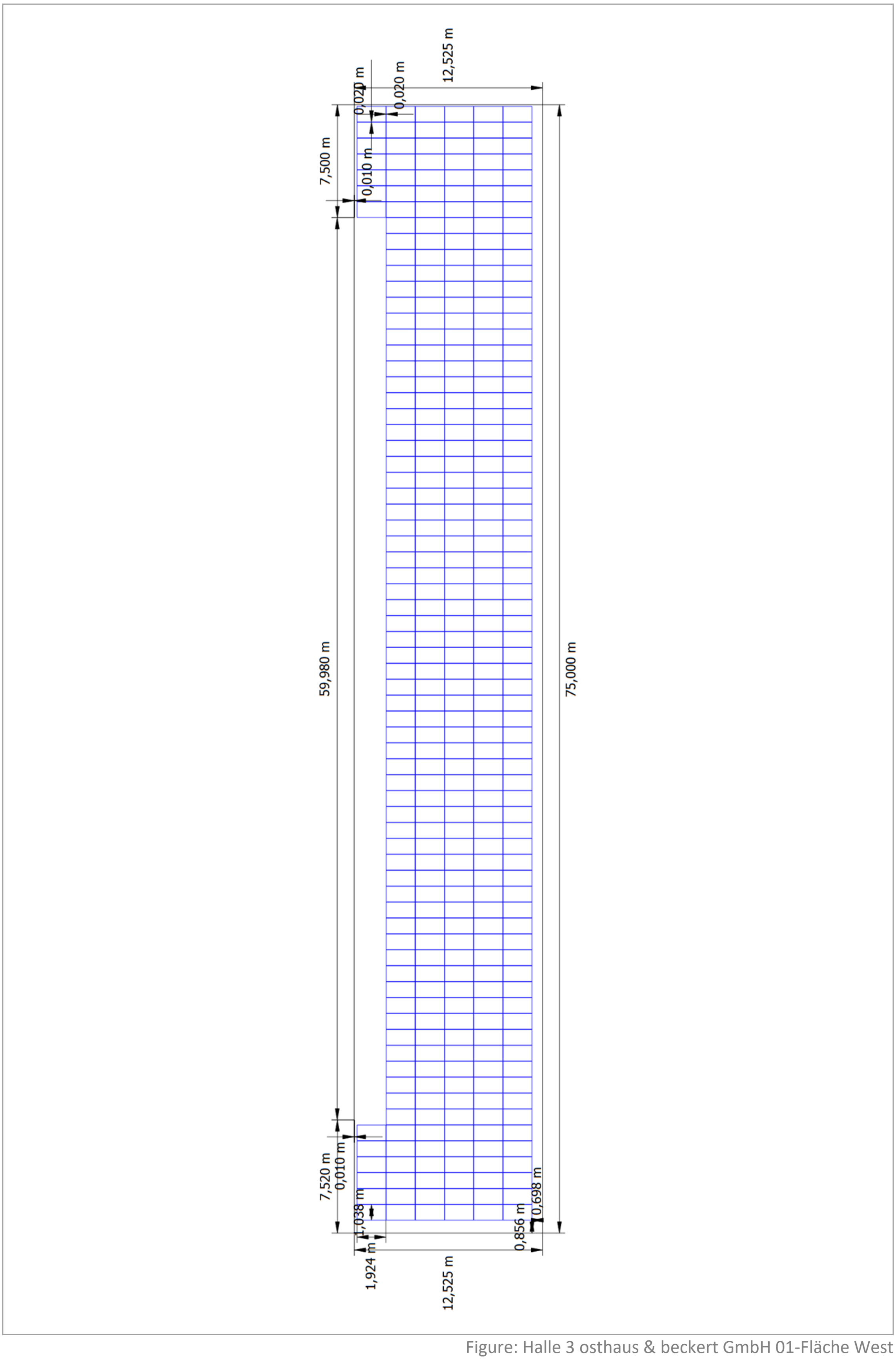



Figure: Halle 3 osthaus & beckert GmbH 01-Fläche West

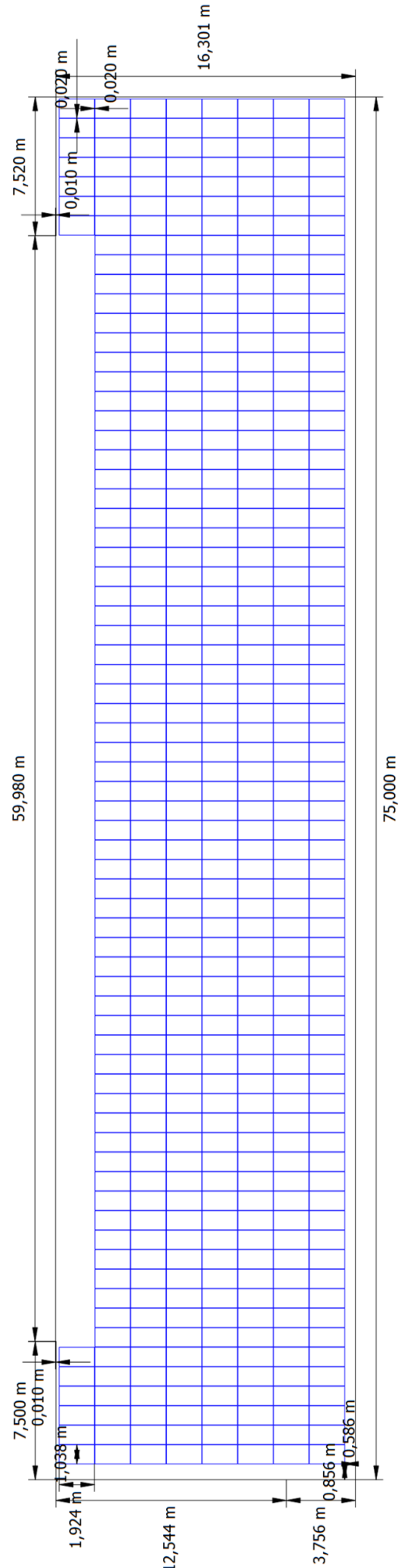



Figure: Halle 3 osthaus & beckert GmbH 01-Fläche Ost

# String Plan

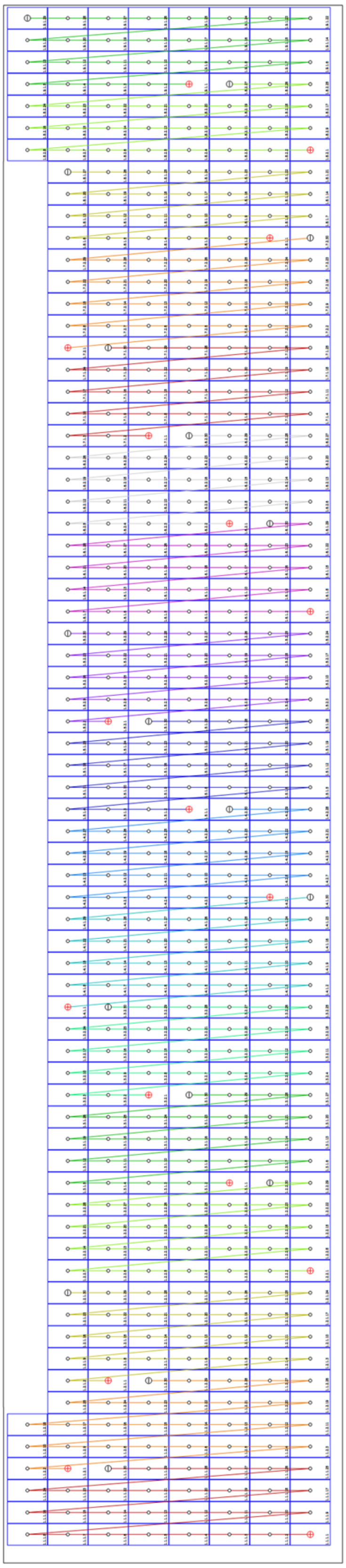


Figure: Halle 3 osthaus & beckert GmbH 01-Fläche Ost

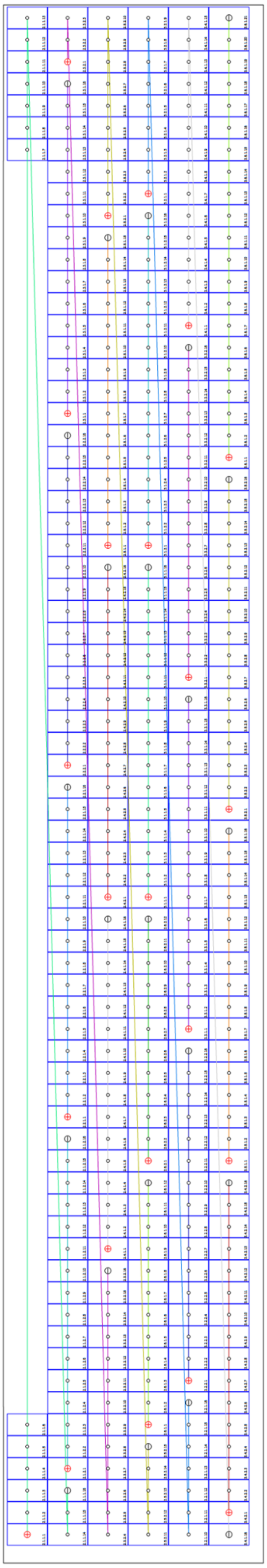


Figure: Halle 3 osthaus & beckert GmbH 01-Fläche West

# Parts list

Parts list

| # | Type | Item number | Manufacturer | Name | Quantity | Unit |
|---|---|---|---|---|---|---|
| 1 | PV Module | | LONGI Solar | LR4-66 HPH 420 M | 866 | Piece |
| 2 | Inverter | | Huawei Technologies | SUN2000-215KTL-H0 | 1 | Piece |
| 3 | Inverter | | Huawei Technologies | SUN2000-60KTL-M0 (400Vac) | 2 | Piece |
| 4 | Battery System | | VARTA Storage GmbH | VARTA flex storage E 120kW/375kWh | 1 | Piece |
| 5 | Components | | | Feed-in Meter | 1 | Piece |
| 6 | Components | | | Bidirectional Meter | 1 | Piece |

## Annex L: Simulation report Scenario 4 (Full Feeder)

**osthaus & beckert GmbH**
Beckert, Andreas; Osthaus, Christian
Industriepark Brundorf 14, 28790
Schwanewede

**Customer No.:** 123456789
**Project Name:** PV-Anlage osthaus & beckert GmbH
**Offer no.:** 123456

02.08.2022

# Your PV system

## Address of Installation

Industriepark Brundorf 14, 28790 Schwanewede


Project Description:
Planning of a company-owned PV system for osthaus & beckert GmbH

# Project Overview

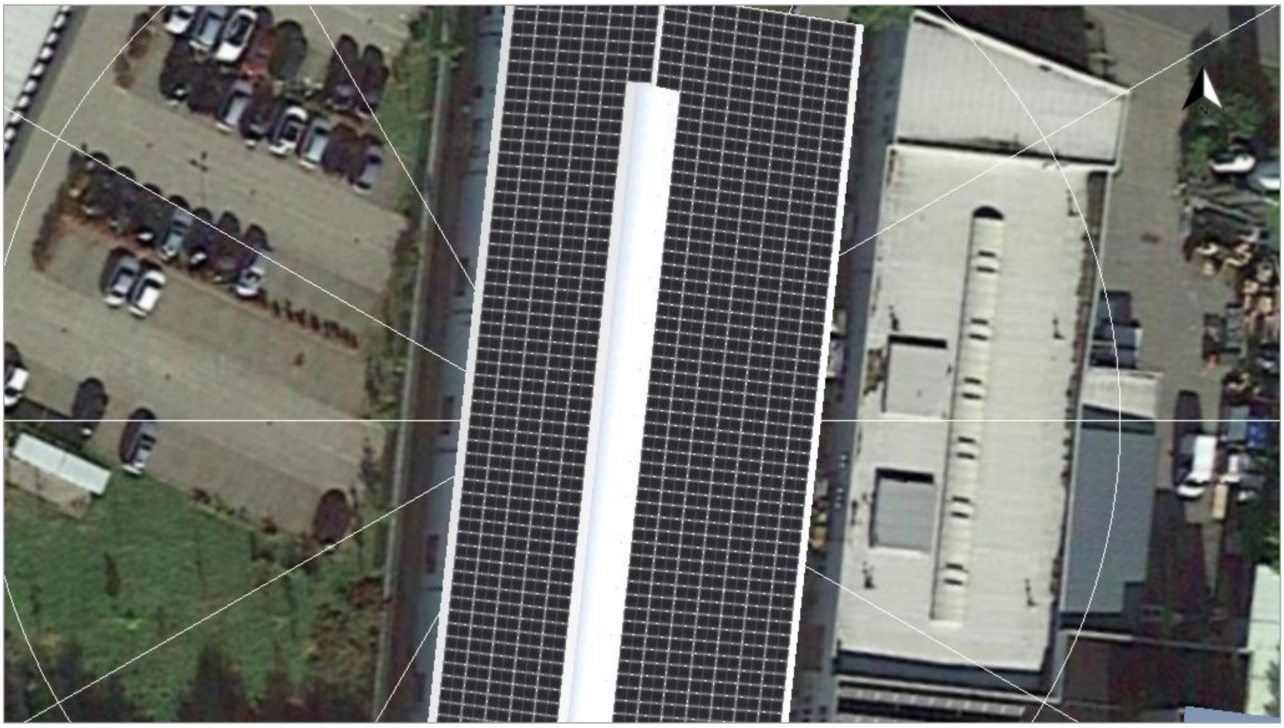


Figure: Overview Image, 3D Design

## PV System

3D, Grid-connected PV System

| | | |
|---|---|---|
| Climate Data | Osterholz-Scharmbeck, DEU (1995 - 2012) | |
| Values source | DWD | |
| PV Generator Output | 363,72 | kWp |
| PV Generator Surface | 1.729,5 | m² |
| Number of PV Modules | 866 | |
| Number of Inverters | 3 | |

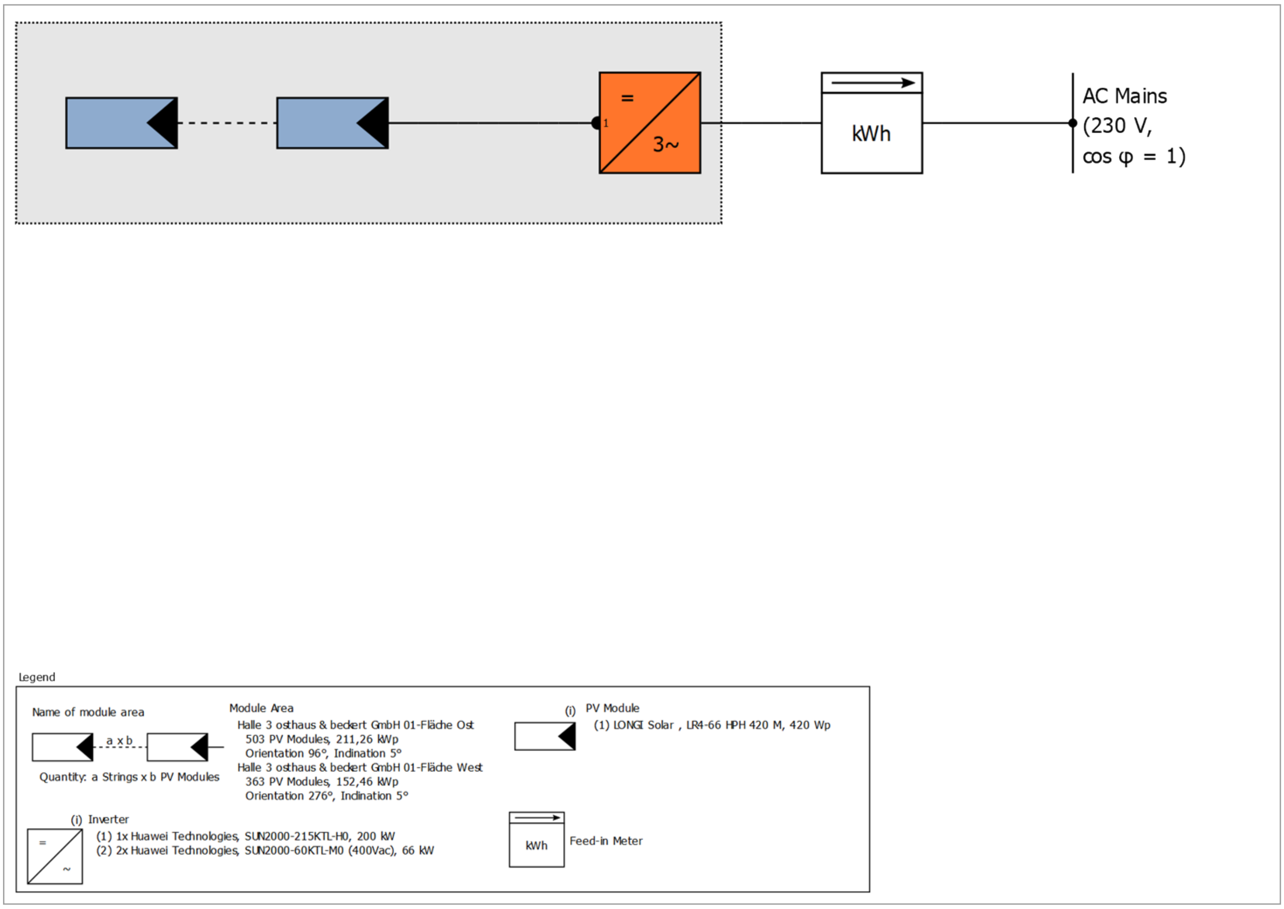



Figure: Schematic diagram

# Production Forecast

| Production Forecast | | |
|---|---|---|
| PV Generator Output | 363,72 | kWp |
| Spec. Annual Yield | 876,32 | kWh/kWp |
| Performance Ratio (PR) | 89,08 | % |
| Yield Reduction due to Shading | 0,4 | %/Year |
| | | |
| Grid Feed-in | 318.774 | kWh/Year |
| Grid Feed-in in the first year (incl. module degradation) | 317.696 | kWh/Year |
| Standby Consumption (Inverter) | 38 | kWh/Year |
| | | |
| $CO_2$ Emissions avoided | 154.587 | kg / year |

# Financial Analysis

| Your Gain | | |
|---|---|---|
| Total investment costs | 179.267,00 | € |
| Internal Rate of Return of Capital Resources | 5,64 | % |
| Amortization Period | 16,4 | Years |
| Electricity Production Costs | 0,027 | €/kWh |
| Energy Balance/Feed-in Concept | Full Feed-in | |

The results have been calculated with a mathematical model calculation from Valentin Software GmbH (PV*SOL algorithms). The actual yields from the solar power system may differ as a result of weather variations, the efficiency of the modules and inverter, and other factors.

# Set-up of the System

## Overview

| System Data | |
|---|---|
| Type of System | 3D, Grid-connected PV System |

| Climate Data | |
|---|---|
| Location | Osterholz-Scharmbeck, DEU (1995 - 2012) |
| Values source | DWD |
| Resolution of the data | 1 min |
| Simulation models used: | |
| - Diffuse Irradiation onto Horizontal Plane | Hofmann |
| - Irradiance onto tilted surface | Hay & Davies |

## Module Areas

### 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost

| PV Generator, 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost | | |
|---|---|---|
| Name | Halle 3 osthaus & beckert GmbH 01-Fläche Ost | |
| PV Modules | 503 x LR4-66 HPH 420 M (v1) | |
| Manufacturer | LONGI Solar | |
| Inclination | 5 | ° |
| Orientation | East 96 | ° |
| Installation Type | Roof parallel | |
| PV Generator Surface | 1.004,5 | m² |

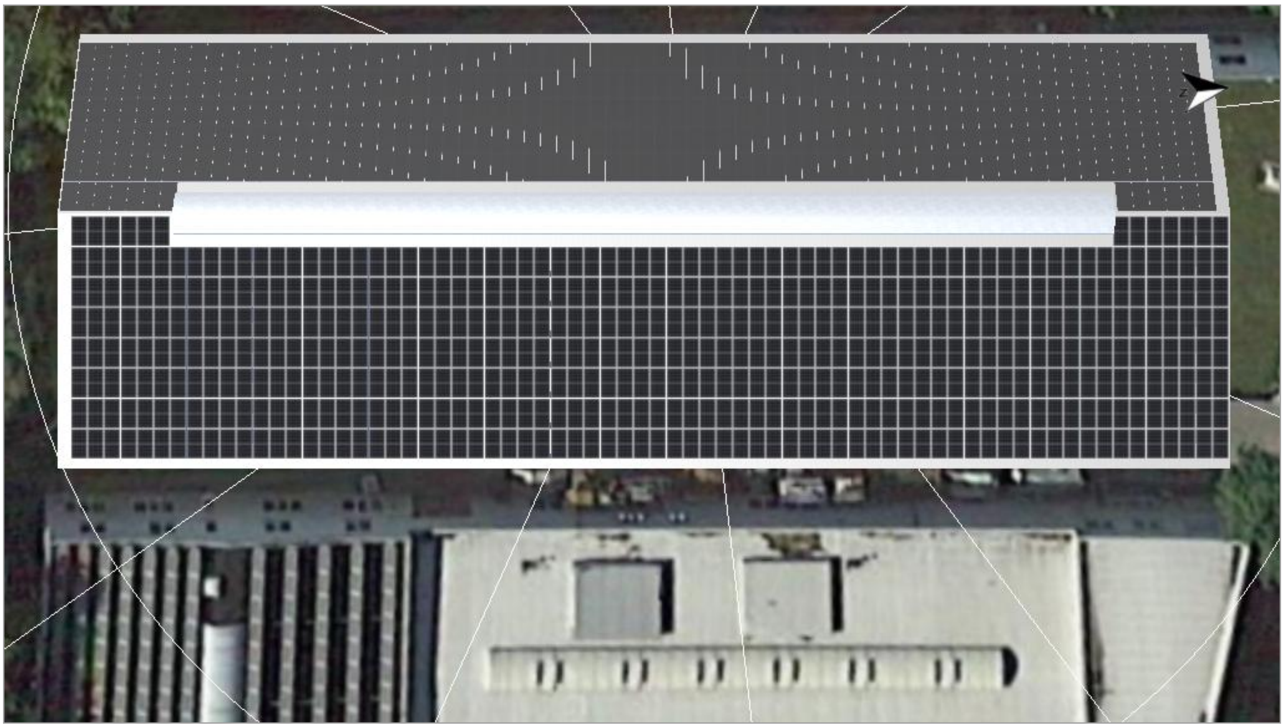


Figure: 1. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche Ost

## *2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West*

### PV Generator, 2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West

| | |
|---|---|
| Name | Halle 3 osthaus & beckert GmbH 01-Fläche West |
| PV Modules | 363 x LR4-66 HPH 420 M (v1) |
| Manufacturer | LONGI Solar |
| Inclination | 5 ° |
| Orientation | West 276 ° |
| Installation Type | Roof parallel |
| PV Generator Surface | 725,0 m² |

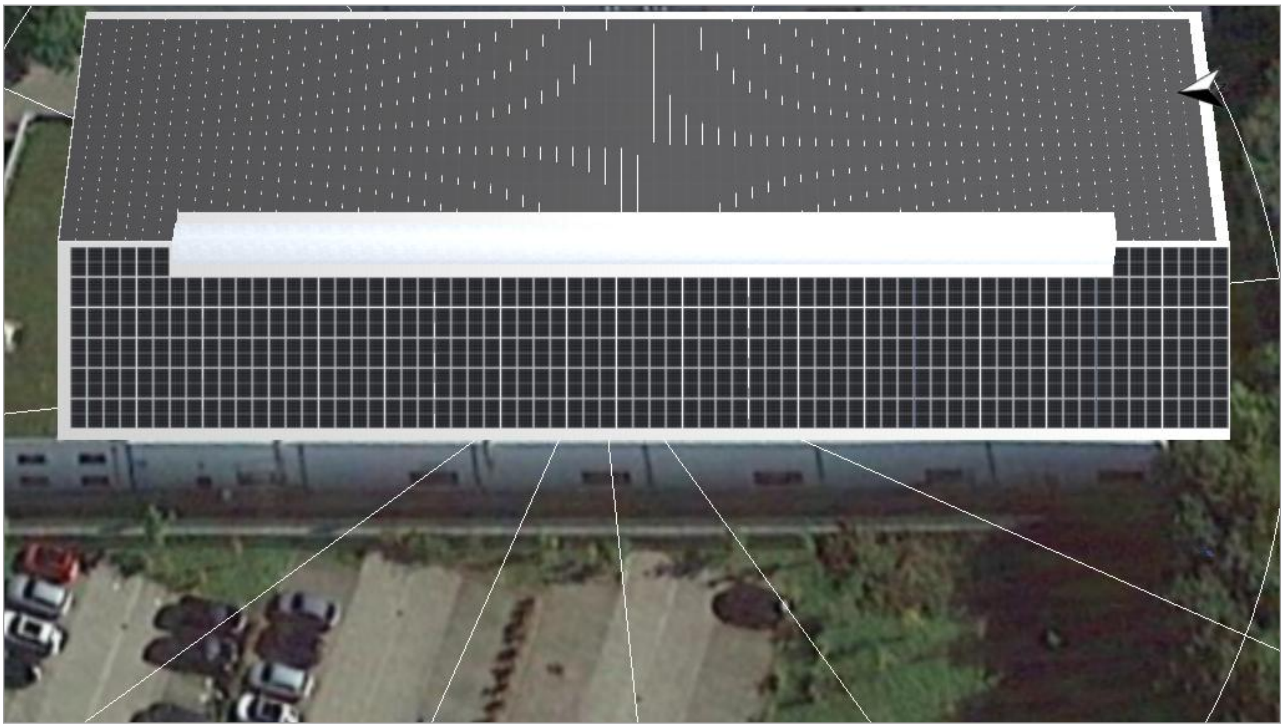


Figure: 2. Module Area - Halle 3 osthaus & beckert GmbH 01-Fläche West

# Horizon Line, 3D Design

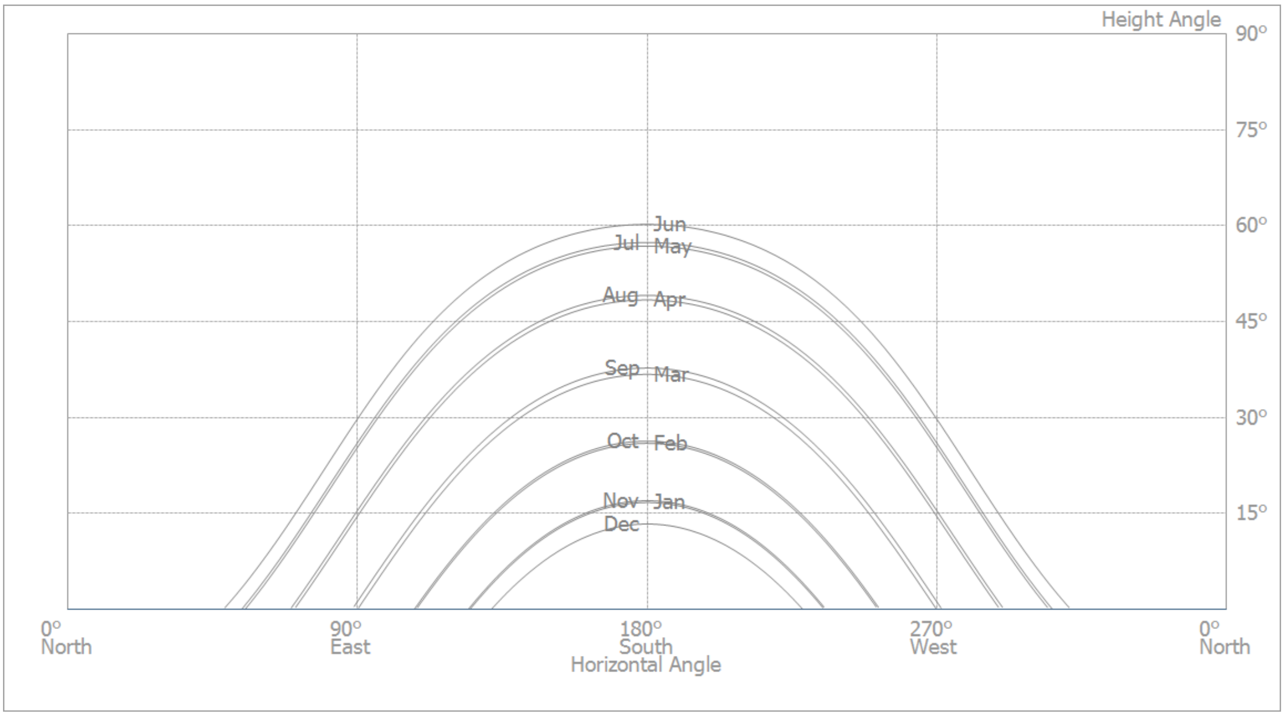



Figure: Horizon (3D Design)

# Inverter configuration

Configuration 1

| | |
|---|---|
| Module Area | Halle 3 osthaus & beckert GmbH 01-Fläche Ost |
| Inverter 1 | |
| Model | SUN2000-215KTL-H0 (v1) |
| Manufacturer | Huawei Technologies |
| Quantity | 1 |
| Sizing Factor | 105,6 % |
| Configuration | MPP 1: 2 x 30 |
| | MPP 2: 2 x 30 |
| | MPP 3: 2 x 30 |
| | MPP 4: 2 x 30 |
| | MPP 5: 2 x 30 |
| | MPP 6: 2 x 30 |
| | MPP 7: 2 x 30 |
| | MPP 8: 2 x 27 |
| | MPP 9: 1 x 29 |

| Configuration 2 | |
|---|---|
| Module Area | Halle 3 osthaus & beckert GmbH 01-Fläche West |
| Inverter 1 | |
| Model | SUN2000-60KTL-M0 (400Vac) (v2) |
| Manufacturer | Huawei Technologies |
| Quantity | 1 |
| Sizing Factor | 115,8 % |
| Configuration | MPP 1: 2 x 16 |
| | MPP 2: 2 x 16 |
| | MPP 3: 2 x 16 |
| | MPP 4: 2 x 16 |
| | MPP 5: 2 x 15 |
| | MPP 6: 2 x 12 |
| Inverter 2 | |
| Model | SUN2000-60KTL-M0 (400Vac) (v2) |
| Manufacturer | Huawei Technologies |
| Quantity | 1 |
| Sizing Factor | 115,2 % |
| Configuration | MPP 1: 2 x 16 |
| | MPP 2: 2 x 16 |
| | MPP 3: 2 x 16 |
| | MPP 4: 2 x 16 |
| | MPP 5: 2 x 16 |
| | MPP 6: 1 x 21 |

# AC Mains

| AC Mains | |
|---|---|
| Number of Phases | 3 |
| Mains voltage between phase and neutral | 230 V |
| Displacement Power Factor (cos phi) | +/- 1 |

# Simulation Results

## Results Total System

### PV System

| | | |
|---|---|---|
| PV Generator Output | 363,72 | kWp |
| Spec. Annual Yield | 876,32 | kWh/kWp |
| Performance Ratio (PR) | 89,08 | % |
| Yield Reduction due to Shading | 0,4 | %/Year |
| | | |
| Grid Feed-in | 318.774 | kWh/Year |
| Grid Feed-in in the first year (incl. module degradation) | 317.696 | kWh/Year |
| Standby Consumption (Inverter) | 38 | kWh/Year |
| | | |
| $CO_2$ Emissions avoided | 154.587 | kg / year |

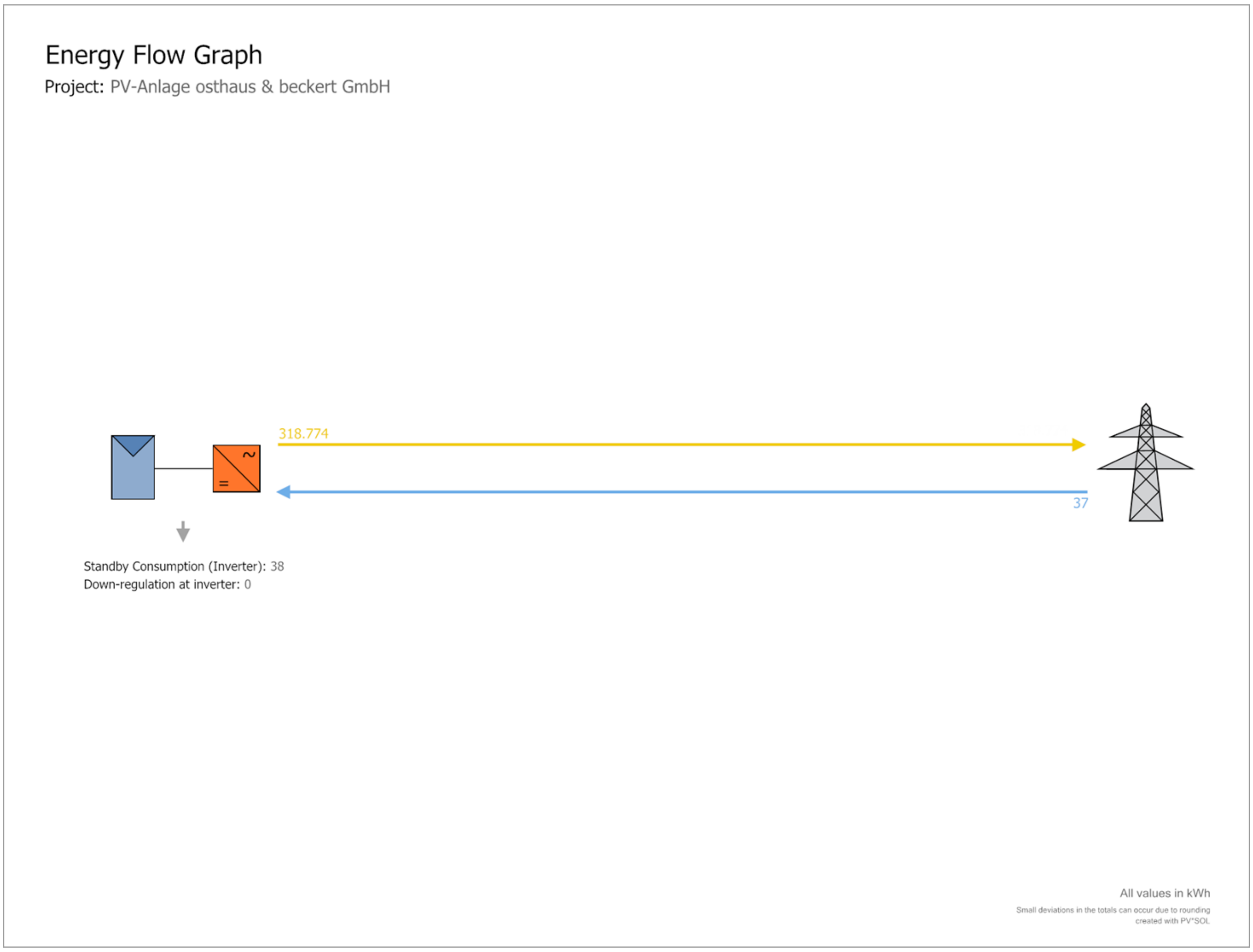



Figure: Energy flow

# Yield for EnEV

## Yield in accordance with DIN 15316-4-6

| | |
|---|---|
| January | 5093,6 kWh |
| February | 6980,3 kWh |
| March | 17037,2 kWh |
| April | 32125,3 kWh |
| May | 38816,7 kWh |
| June | 40964 kWh |
| July | 36884,6 kWh |
| August | 31615,4 kWh |
| September | 21586,8 kWh |
| October | 13524,4 kWh |
| November | 5269,2 kWh |
| December | 2985,9 kWh |
| **Annual Value** | **252.883,4 kWh** |

Boundary Conditions:
Climate Data according to DIN V 18599-10
HALLE 3 OSTHAUS & BECKERT GMBH 01-FLÄCHE OST
System Power Factor: 0.75
Peak Power Coefficient: 0.182
Orientation: East
Inclination: 0°

HALLE 3 OSTHAUS & BECKERT GMBH 01-FLÄCHE WEST
System Power Factor: 0.75
Peak Power Coefficient: 0.182
Orientation: West
Inclination: 0°

# Financial Analysis

## Overview

### System Data

| | | |
|---|---|---|
| Grid Feed-in in the first year (incl. module degradation) | 317.696 | kWh/Year |
| PV Generator Output | 363,7 | kWp |
| Start of Operation of the System | 01.07.2022 | |
| Assessment Period | 30 | Years |
| Interest on Capital | 1 | % |

### Economic Parameters

| | | |
|---|---|---|
| Internal Rate of Return of Capital Resources | 5,64 | % |
| Accrued Cash Flow (Cash Balance) | 96.947,47 | € |
| Amortization Period | 16,4 | Years |
| Electricity Production Costs | 0,027 | €/kWh |

### Payment Overview

| | | |
|---|---|---|
| Specific Investment Costs | 492,87 | €/kWp |
| Investment Costs | 179.267,00 | € |
| One-off Payments | 0,00 | € |
| Incoming Subsidies | 0,00 | € |
| Annual Costs | 1.400,00 | €/Year |
| Other Revenue or Savings | 0,00 | €/Year |

### Loans

| **Reference** | **Loan 1** | |
|---|---|---|
| Loan Capital | 100.000,00 | € |
| Payment Installment | 100,00 | % |
| Credit type | Installment Loan | |
| Term | 10,00 | Years |
| Grace period | 0,00 | Years |
| Interest | 3,50 | |
| Repayment Period | quarterly | |

### Remuneration and Savings

| | | |
|---|---|---|
| Total Payment from Utility in First Year | 16.806,46 | €/Year |
| | | |
| EEG 2022 (Juli) Marktprämienmodell - Gebäudeanlage | | |
| Validity | 01.07.2022 | - 31.12.2042 |
| Specific feed-in / export Remuneration | 0,0529 | €/kWh |
| Feed-in / Export Tariff | 16806,4598 | €/Year |

# Cash flow

## Cash flow

| | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|---|---|---|---|---|---|
| Operating costs | -1.386,14 € | -1.372,41 € | -1.358,83 € | -1.345,37 € | -1.332,05 € |
| Depreciation | -8.874,60 € | -8.786,74 € | -8.699,74 € | -8.613,60 € | -8.528,32 € |
| Self-Financing | -79.267,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 16.640,06 € | 16.376,12 € | 16.115,77 € | 15.858,98 € | 15.605,69 € |
| Loan repayments | -9.900,99 € | -9.802,96 € | -9.705,90 € | -9.609,80 € | -9.514,66 € |
| Loan Interest | -3.335,40 € | -2.959,27 € | -2.590,26 € | -2.228,27 € | -1.873,20 € |
| Results before Tax | 3.043,92 € | 3.257,70 € | 3.466,95 € | 3.671,73 € | 3.872,12 € |
| Tax Refund | -1.308,89 € | -1.400,81 € | -1.490,79 € | -1.578,84 € | -1.665,01 € |
| Results after Tax | 1.735,03 € | 1.856,89 € | 1.976,16 € | 2.092,89 € | 2.207,11 € |
| **Annual Cash Flow** | **-78.558,35 €** | **840,66 €** | **970,00 €** | **1.096,69 €** | **1.220,77 €** |
| Accrued Cash Flow (Cash Balance) | -78.558,35 € | -77.717,69 € | -76.747,69 € | -75.651,00 € | -74.430,23 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -177.296,24 € | -163.693,35 € | -150.427,19 € | -137.492,43 € | -124.883,80 € |

## Cash flow

| | Year 6 | Year 7 | Year 8 | Year 9 | Year 10 |
|---|---|---|---|---|---|
| Operating costs | -1.318,86 € | -1.305,81 € | -1.292,88 € | -1.280,08 € | -1.267,40 € |
| Depreciation | -8.443,88 € | -8.360,28 € | -8.277,50 € | -8.195,55 € | -8.114,40 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 15.355,86 € | 15.109,45 € | 14.866,41 € | 14.626,70 € | 14.390,29 € |
| Loan repayments | -9.420,45 € | -9.327,18 € | -9.234,83 € | -9.143,40 € | -9.052,87 € |
| Loan Interest | -1.524,94 € | -1.183,39 € | -848,45 € | -520,03 € | -198,03 € |
| Results before Tax | 4.068,18 € | 4.259,98 € | 4.447,58 € | 4.631,05 € | 4.810,45 € |
| Tax Refund | -1.749,32 € | -1.831,79 € | -1.912,46 € | -1.991,35 € | -2.068,49 € |
| Results after Tax | 2.318,86 € | 2.428,19 € | 2.535,12 € | 2.639,70 € | 2.741,96 € |
| **Annual Cash Flow** | **1.342,29 €** | **1.461,29 €** | **1.577,79 €** | **1.691,85 €** | **1.803,49 €** |
| Accrued Cash Flow (Cash Balance) | -73.087,94 € | -71.626,66 € | -70.048,86 € | -68.357,02 € | -66.553,52 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -112.596,12 € | -100.624,27 € | -88.963,19 € | -77.607,92 € | -66.553,52 € |

## Cash flow

| | Year 11 | Year 12 | Year 13 | Year 14 | Year 15 |
|---|---|---|---|---|---|
| Operating costs | -1.254,85 € | -1.242,43 € | -1.230,13 € | -1.217,95 € | -1.205,89 € |
| Depreciation | -8.034,06 € | -7.954,52 € | -7.875,76 € | -7.797,78 € | -7.720,58 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 14.157,12 € | 13.927,16 € | 13.700,36 € | 13.476,69 € | 13.256,10 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 4.868,20 € | 4.730,21 € | 4.594,47 € | 4.460,96 € | 4.329,64 € |
| Tax Refund | -2.093,33 € | -2.033,99 € | -1.975,62 € | -1.918,21 € | -1.861,74 € |
| Results after Tax | 2.774,88 € | 2.696,22 € | 2.618,85 € | 2.542,75 € | 2.467,89 € |
| **Annual Cash Flow** | **10.808,94 €** | **10.650,74 €** | **10.494,61 €** | **10.340,53 €** | **10.188,47 €** |
| Accrued Cash Flow (Cash Balance) | -55.744,59 € | -45.093,85 € | -34.599,24 € | -24.258,71 € | -14.070,24 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -55.744,59 € | -45.093,85 € | -34.599,24 € | -24.258,71 € | -14.070,24 € |

## Cash flow

| | Year 16 | Year 17 | Year 18 | Year 19 | Year 20 |
|---|---|---|---|---|---|
| Operating costs | -1.193,95 € | -1.182,13 € | -1.170,42 € | -1.158,84 € | -1.147,36 € |
| Depreciation | -7.644,14 € | -7.568,45 € | -7.493,52 € | -7.419,32 € | -7.345,86 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 13.038,57 € | 12.824,04 € | 12.612,48 € | 12.403,85 € | 12.198,12 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 4.200,48 € | 4.073,46 € | 3.948,54 € | 3.825,69 € | 3.704,89 € |
| Tax Refund | -1.806,21 € | -1.751,59 € | -1.697,87 € | -1.645,05 € | -1.593,10 € |
| Results after Tax | 2.394,27 € | 2.321,87 € | 2.250,67 € | 2.180,64 € | 2.111,79 € |
| **Annual Cash Flow** | **10.038,41 €** | **9.890,32 €** | **9.744,18 €** | **9.599,97 €** | **9.457,65 €** |
| Accrued Cash Flow (Cash Balance) | -4.031,83 € | 5.858,49 € | 15.602,67 € | 25.202,64 € | 34.660,29 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | -4.031,83 € | 5.858,49 € | 15.602,67 € | 25.202,64 € | 34.660,29 € |

## Cash flow

| | Year 21 | Year 22 | Year 23 | Year 24 | Year 25 |
|---|---|---|---|---|---|
| Operating costs | -1.136,00 € | -1.124,75 € | -1.113,62 € | -1.102,59 € | -1.091,68 € |
| Depreciation | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 11.982,78 € | 11.772,63 € | 11.575,74 € | 11.381,60 € | 11.190,16 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 10.846,78 € | 10.647,88 € | 10.462,13 € | 10.279,01 € | 10.098,49 € |
| Tax Refund | -4.664,11 € | -4.578,59 € | -4.498,71 € | -4.419,97 € | -4.342,35 € |
| Results after Tax | 6.182,66 € | 6.069,29 € | 5.963,41 € | 5.859,03 € | 5.756,14 € |
| **Annual Cash Flow** | **6.182,66 €** | **6.069,29 €** | **5.963,41 €** | **5.859,03 €** | **5.756,14 €** |
| Accrued Cash Flow (Cash Balance) | 40.842,95 € | 46.912,25 € | 52.875,66 € | 58.734,69 € | 64.490,83 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 40.842,95 € | 46.912,25 € | 52.875,66 € | 58.734,69 € | 64.490,83 € |

## Cash flow

| | Year 26 | Year 27 | Year 28 | Year 29 | Year 30 |
|---|---|---|---|---|---|
| Operating costs | -1.080,87 € | -1.070,17 € | -1.059,57 € | -1.049,08 € | -1.038,69 € |
| Depreciation | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Self-Financing | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Feed-in / Export Tariff | 11.001,40 € | 10.815,28 € | 10.631,77 € | 10.450,83 € | 10.272,43 € |
| Loan repayments | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Loan Interest | 0,00 € | 0,00 € | 0,00 € | 0,00 € | 0,00 € |
| Results before Tax | 9.920,53 € | 9.745,12 € | 9.572,20 € | 9.401,75 € | 9.233,74 € |
| Tax Refund | -4.265,83 € | -4.190,40 € | -4.116,05 € | -4.042,75 € | -3.970,51 € |
| Results after Tax | 5.654,70 € | 5.554,72 € | 5.456,15 € | 5.359,00 € | 5.263,23 € |
| **Annual Cash Flow** | **5.654,70 €** | **5.554,72 €** | **5.456,15 €** | **5.359,00 €** | **5.263,23 €** |
| Accrued Cash Flow (Cash Balance) | 70.145,53 € | 75.700,25 € | 81.156,40 € | 86.515,40 € | 91.778,63 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 70.145,53 € | 75.700,25 € | 81.156,40 € | 86.515,40 € | 91.778,63 € |

## Cash flow

| | Year 31 |
|---|---|
| Operating costs | -1.028,41 € |
| Depreciation | 0,00 € |
| Self-Financing | 0,00 € |
| Feed-in / Export Tariff | 10.096,54 € |
| Loan repayments | 0,00 € |
| Loan Interest | 0,00 € |
| Results before Tax | 9.068,13 € |
| Tax Refund | -3.899,30 € |
| Results after Tax | 5.168,84 € |
| **Annual Cash Flow** | **5.168,84 €** |
| Accrued Cash Flow (Cash Balance) | 96.947,47 € |
| Accrued Cash Flow (Cash Balance) minus pending loans | 96.947,47 € |

Degradation and inflation rates are applied on a monthly basis over the entire observation period. This is done in the first year.

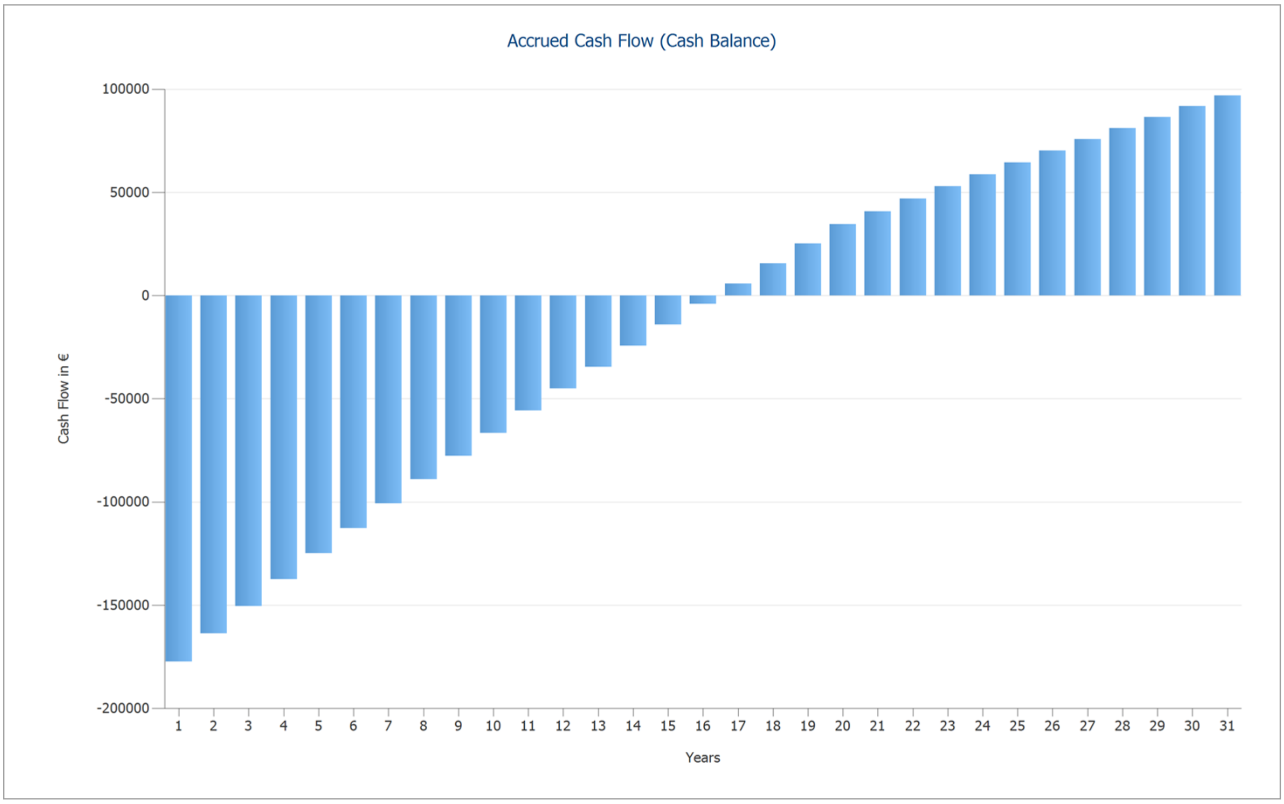



Figure: Accrued Cash Flow (Cash Balance)

# Plans and parts list

## Circuit Diagram

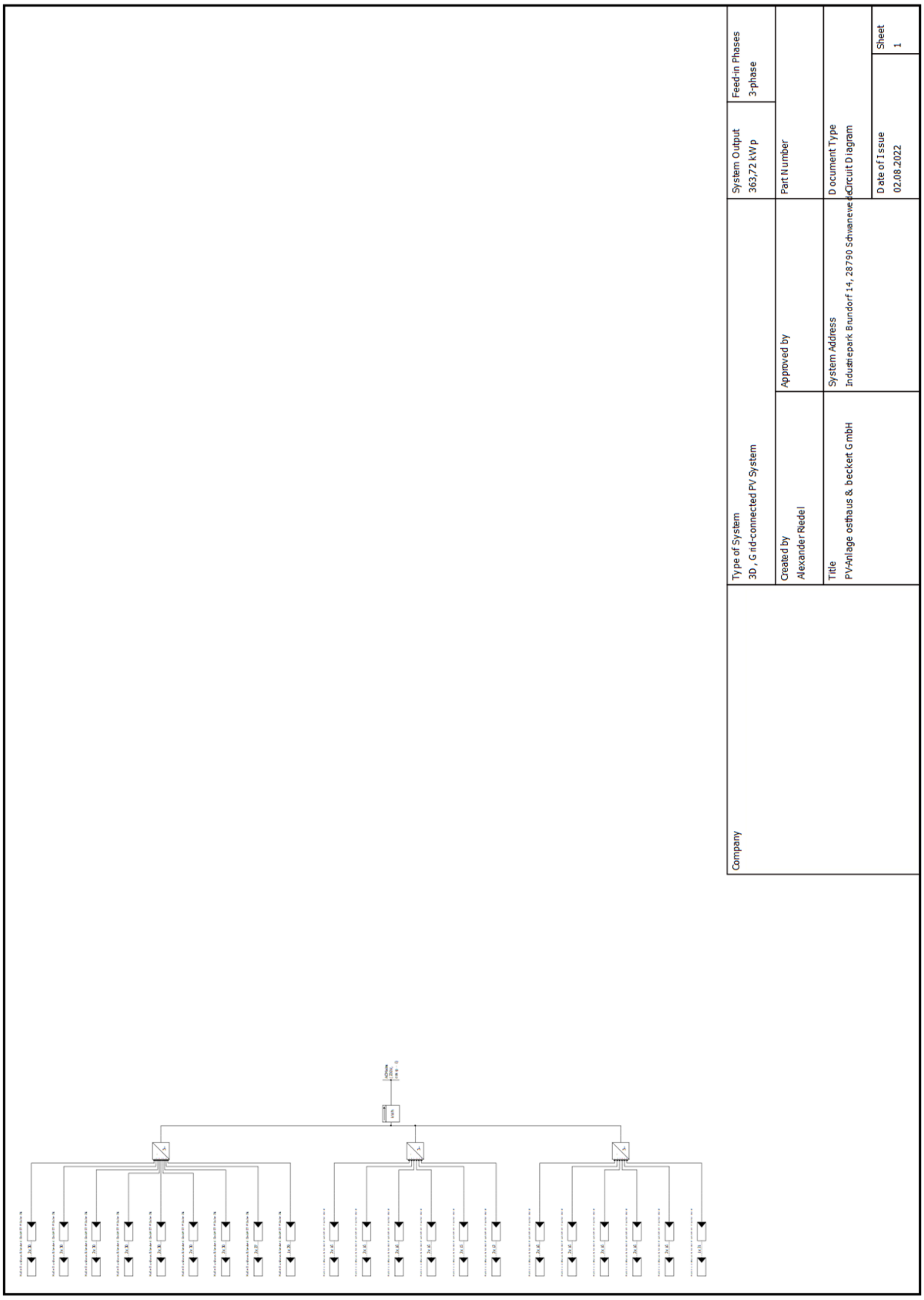



Figure: Circuit Diagram

# Overview plan

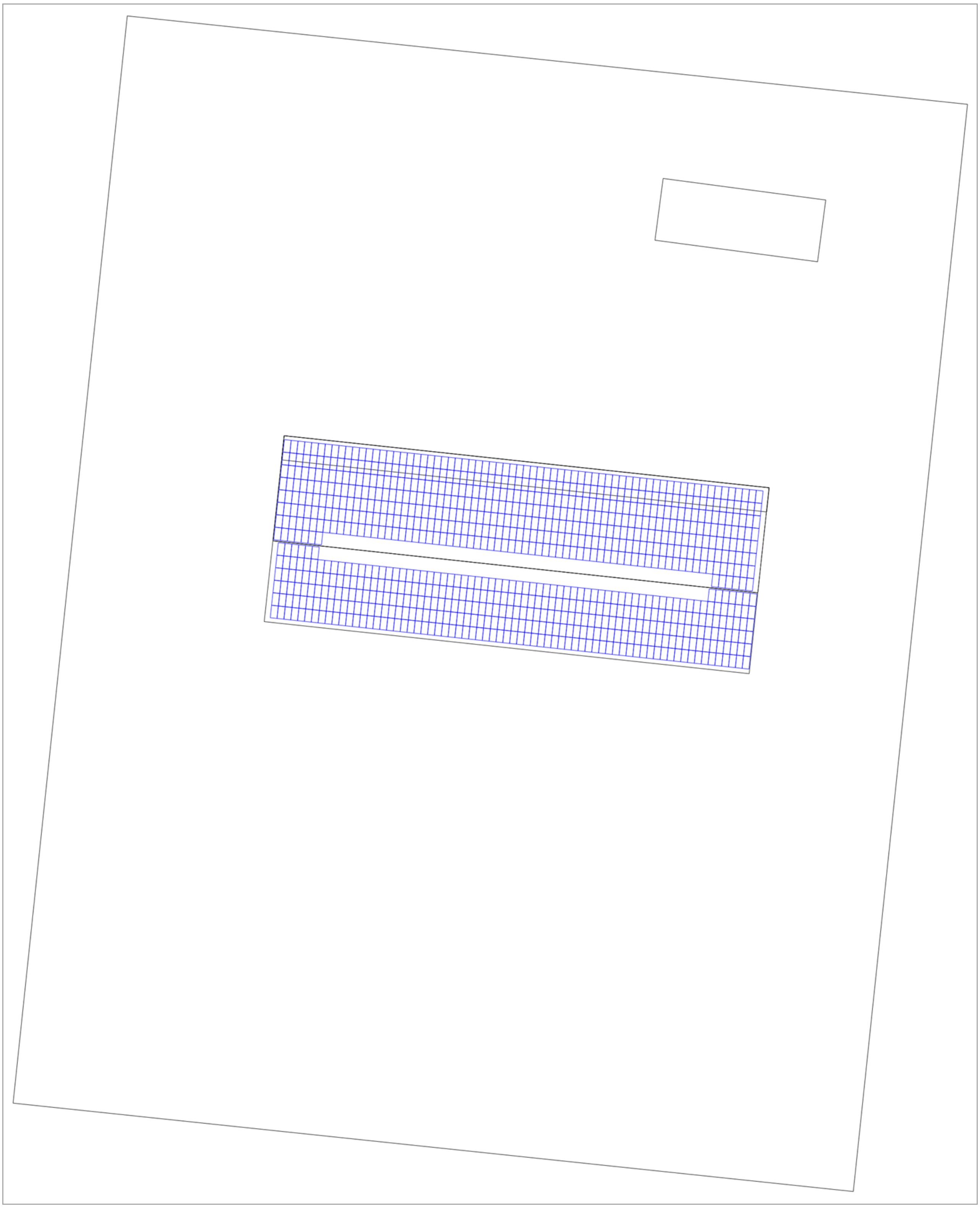


Figure: Overview plan

# Dimensioning Plan

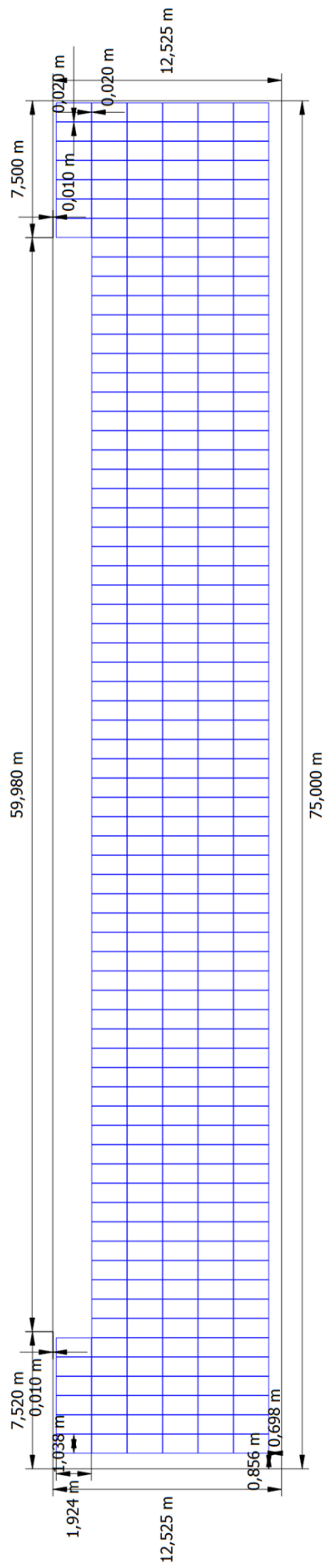



Figure: Halle 3 osthaus & beckert GmbH 01-Fläche West

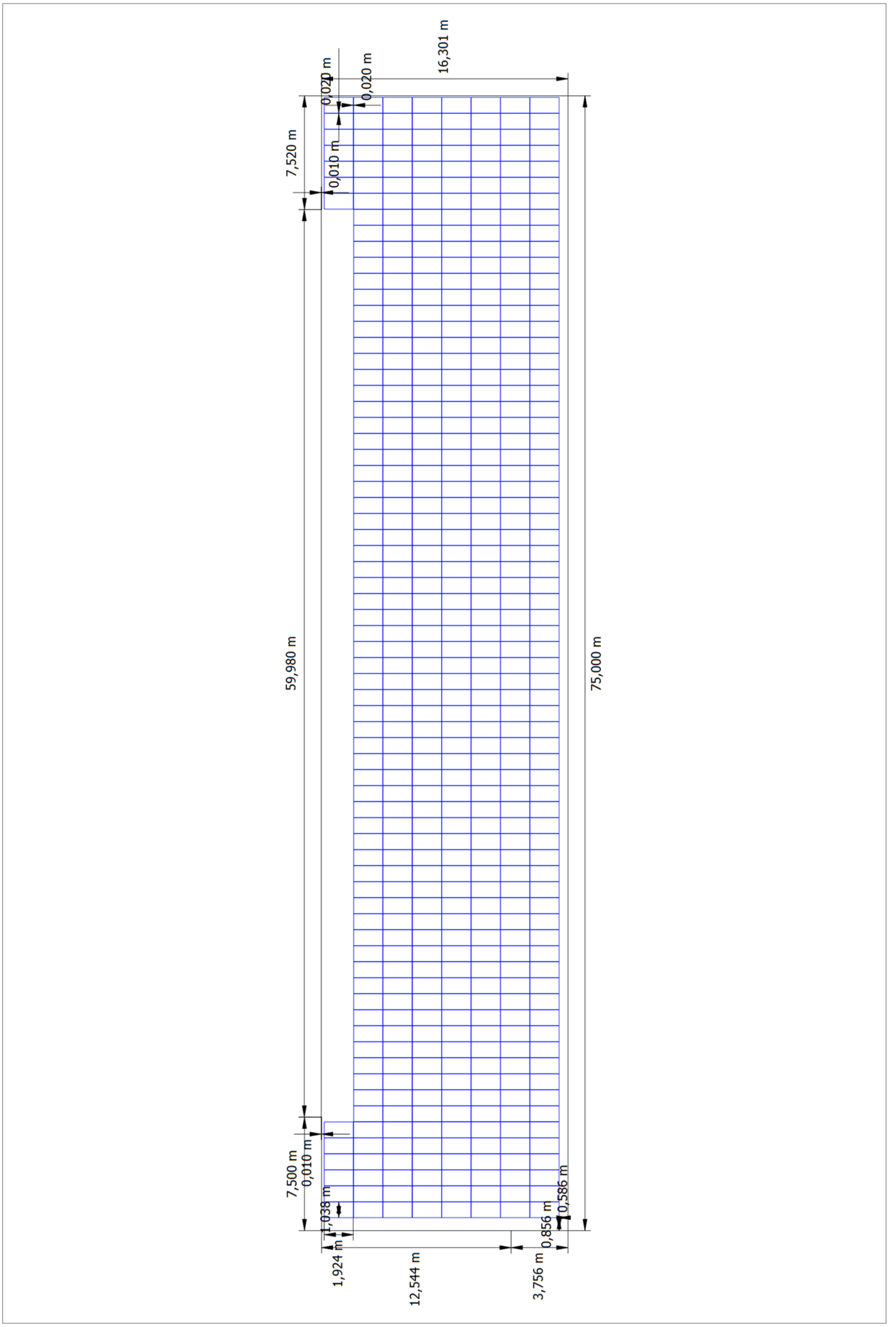



Figure: Halle 3 osthaus & beckert GmbH 01-Fläche Ost

# String Plan

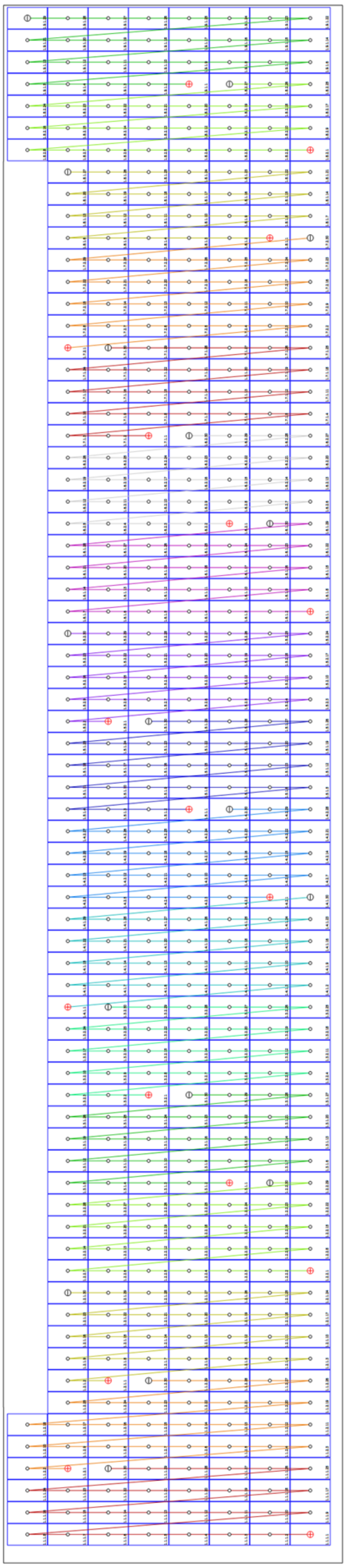


Figure: Halle 3 osthaus & beckert GmbH 01-Fläche Ost

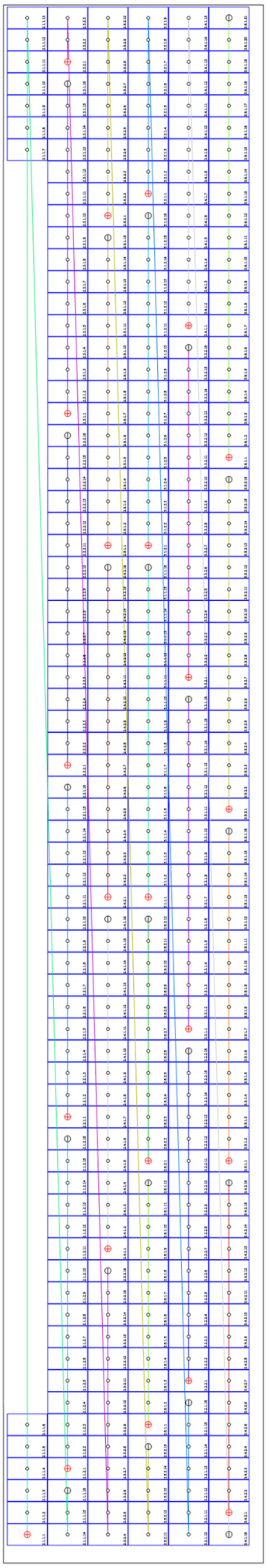


Figure: Halle 3 osthaus & beckert GmbH 01-Fläche West

# Parts list

Parts list

| # | Type | Item number | Manufacturer | Name | Quantity | Unit |
|---|---|---|---|---|---|---|
| 1 | PV Module | | LONGI Solar | LR4-66 HPH 420 M | 866 | Piece |
| 2 | Inverter | | Huawei Technologies | SUN2000-215KTL-H0 | 1 | Piece |
| 3 | Inverter | | Huawei Technologies | SUN2000-60KTL-M0 (400Vac) | 2 | Piece |
| 4 | Components | | | Feed-in Meter | 1 | Piece |