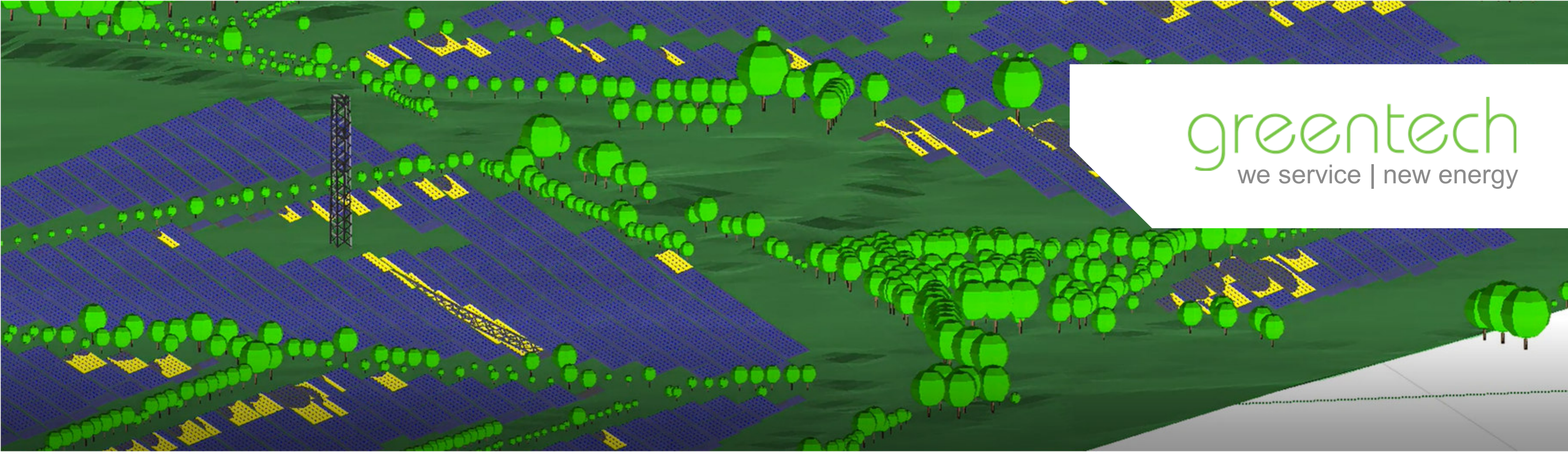

greentech whitepaper

From the green field to the final plant design

In order to determine whether a certain field or roof area is suitable for a new photovoltaic project, a first, initial system design is usually created. It takes the available site information into account and indicatively shows a standardized layout design, for example by using defined module tables and a common electrical wiring. Today, 3D layout planning software is usually used to create the plant layout. If the area basically shows potential for a photovoltaic system, the layout is optimized in the next step. For this purpose, the initial planning is refined in various parameters, for example, to better utilize the area or to further increase the possible yield.

Good plant design is crucial for the subsequent generation of the best possible yield. It also forms the basis for the later required yield report and is, among other things, part of the building permission.

Clarify basic conditions and consider them during planning

Various details play a role in considering whether a system is suitable for a particular area:

- What, for example, are the **characteristics and specific conditions** of the respective area? How does the solar irradiation behave at this location? Is an elevation profile available or are only the outer boundaries defined Is there information on relevant shading objects such as trees or high-voltage pylons? Are there restricted areas such as drainage ditches, that have to be taken into account in the planning?
- To clarify questions regarding the **grid connection capacity**, the responsible grid operator should also be contacted early in the process. This is because it is not always possible to feed in unlimited capacity at every connection point. If for a large area only a low feed-in capacity is offered, the plant design will probably provide for greater row spacing to achieve a high specific yield. Conversely, if the area is small and the feed-in capacity is high, the rows can be spaced closer together to maximize the absolute yield. For rooftop systems, the feed-in requires a connection to the site's electrical system or a separate grid connection.
- Which **official requirements** have already to be observed on the construction side during the planning of the plant design? What limits are set by the development plan in terms of building height and ground coverage? Is the site located in a water protection or flood zone? Do local nature conservation authorities require compensatory measures for plant building? These details can also have an impact on the design of the plant.
- For open areas, the **soil conditions** must be checked in advance: Samples, pile driving and drawing tests are used to determine the amount of weight the surface is able to support. This influences the selection and design of the rack system and appropriate preparation of the ground in relation to station foundations and internal roads.

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Definition of terms:
Absolute vs. specific yield

PV plants can be planned under various aspects with regard to their subsequent yield. Basically, the system design determines how much sunlight is collected and converted into energy. If the modules are arranged in such a way that they are not shaded by trees during the day or there is less row shading, the specific yield (measured in kWh/kWp) or the performance ratio increases.

However, smaller row spacing allows more rows of modules to be installed on the same area. But they shade each other and thus reduce the yield they could generally generate. Nevertheless, in the end, the larger number of module rows on the same area is able to generate a higher yield overall. In this case, the focus is put on the absolute yield (measured in kWh).

When designing the system, it is important to find the constellation that represents the optimum between absolute and specific yield, taking the individual circumstances into account.

For roof systems, the statics and load-bearing capacity of the building play a decisive role.
Photo: AboveSurveying_Energiebunker/HamburgEnergie

- In the case of **roof systems**, there is also a big focus on the structural and load-bearing capacity of the roof. Here, the effects of the additional loads of the PV system in terms of local wind and snow loads must be calculated. In addition, the question of how the system can be attached to the roof must be clarified. Is a roof attachment possible? Or is only an aerodynamic solution with appropriate ballasting an option? And of course, roof areas may be affected by shading objects such as the chimney or obstacles such as roof windows or lightning protection, which must be taken into account during planning. In addition, it must be ensured in terms of fire protection that, in the event of an emergency, the system does not allow a fire to spread to adjacent areas. Walls may therefore only be built over under certain conditions. In addition, the system must be integrated into the building's lightning protection concept.

Design determining parameters

The table design, the type of arrangement of the modules and strings, and the associated cabling significantly determine the design of a system. Usually, an initial layout of the given area is carried out using a standard table design with standard available components. greentech, for example, relies here on its own design, which is optimized for the layout planning of areas in the European region and constantly adapted to available technology. This design is then used as a basis for fine-tuning through various iterations and simulations to achieve the best possible design result.

Today, relevant 3D software applications such as AutoCAD or PVcase support a sound and reliable layout planning. They enable the area to be mapped and designed exactly to the centimeter. Step-by-step changes to the design can be implemented quickly, flexibly and precisely.

In addition, the effects of the respective layout iterations in terms of shading and expected yield can be quickly determined and used for further optimization. This not only increases efficiency, but also significantly improves the quality and resilience of the planning.

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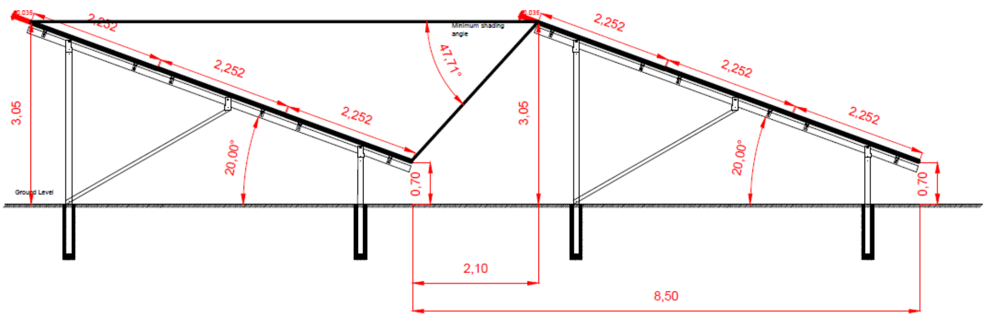

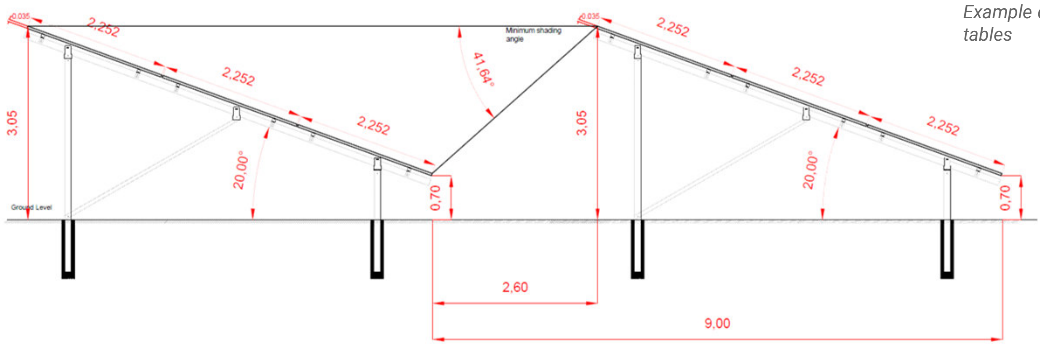

Example designs of different module tables

Mechanical design

The following parameters in particular are relevant when optimizing the mechanical design:

- **Arrangement of the module tables:** At what angle of inclination are the tables set up? How large is the row spacing or the shading angle of the module tables? And which alignment to the sun (azimuth) is selected?
- **Type of module tables:** Is a standard table design with optimal string length applicable? Is the area so narrow that tables and / or string rows should be divided to make the best use of the available space?
- **Appropriate azimuth:** Is a south alignment favored? Or is an east-west orientation preferred, where the modules are placed against each other so that they receive as much morning and evening sun as possible. Tracker systems, on the other hand, automatically follow the sun, but are more likely to be used in areas with a lot of direct solar radiation.
- **Framework conditions of the selectable components:** For example, how many connection options for module strings does a particular inverter provide?

Electrical design

When optimizing the electrical design, relevant aspects include the following:

- **The characteristics of the components:** These information is made available in form of data sheets by the manufacturers. They contain, among other things, information on the respective components and operating conditions as well as technical parameters.
- **The use and placement of the inverters:** Long cable lengths from the generators to the inverter or generator combiner box can lead to power losses on the DC side. Would it be more worthwhile to accept these losses and to place the inverters centrally due to a more efficient maintenance and repair handling or should they be distributed all over the field at the respective module rows?
- **A sensible interconnection of strings and modules:** If strings run beyond a row or be split due to local conditions, this circumstance may require more material and effort for the cabling. In addition to yield losses, this may also increase the number of faults during operations. Will the string inverters be connected directly to the transformer station or combined via AC collectors? For simple and large areas, a central inverter design could also be considered.
- **A sensible string length of the modules and the question of how many strings should be connected in parallel to the inverter:** The connected module power (also called DC-AC ratio) has an influence on the utilization of the inverter. If a high utilization is aimed for, the DC power may be limited in times of high irradiation. On the other hand, a high utilization of the inverter also leads to higher yields in times with lower irradiation. In this case, simulations with different load ratios help to determine the optimal inverter configuration for a specific site during system design.
- **The placement of the transformers and the connected inverter capacity:** Are the transformers placed according to an optimized cable requirement? Then the cable lengths and yield losses are lower. Are the transformers accessible for service during the operating phase, to be repaired or replaced if necessary? Are there separate transmission stations, if necessary?

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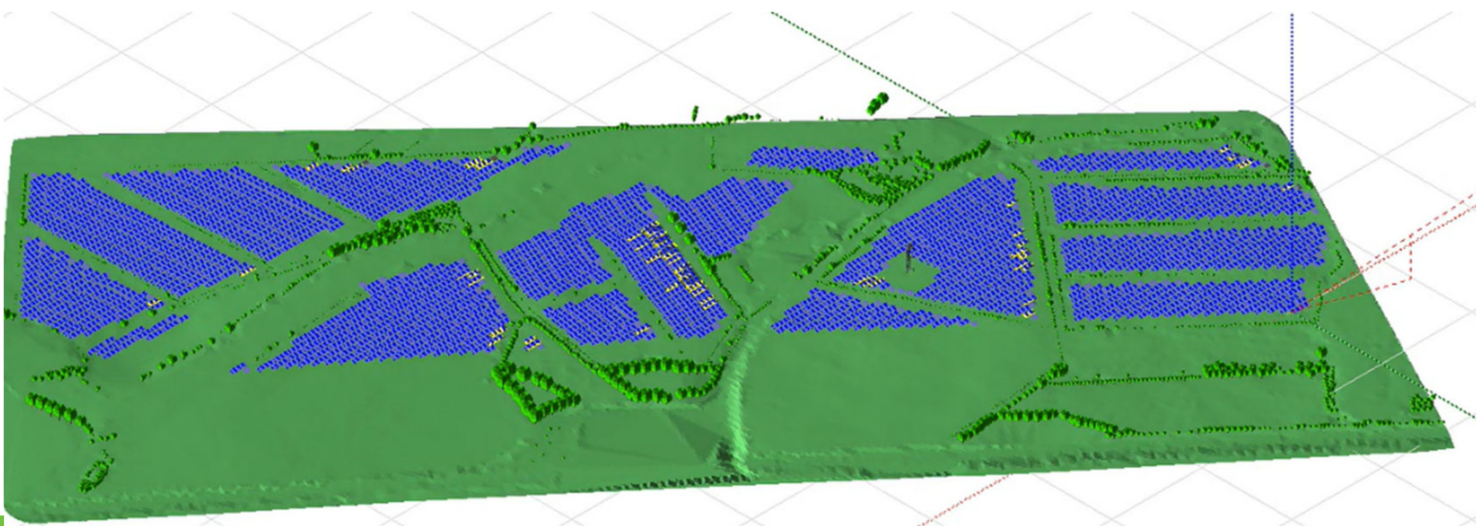
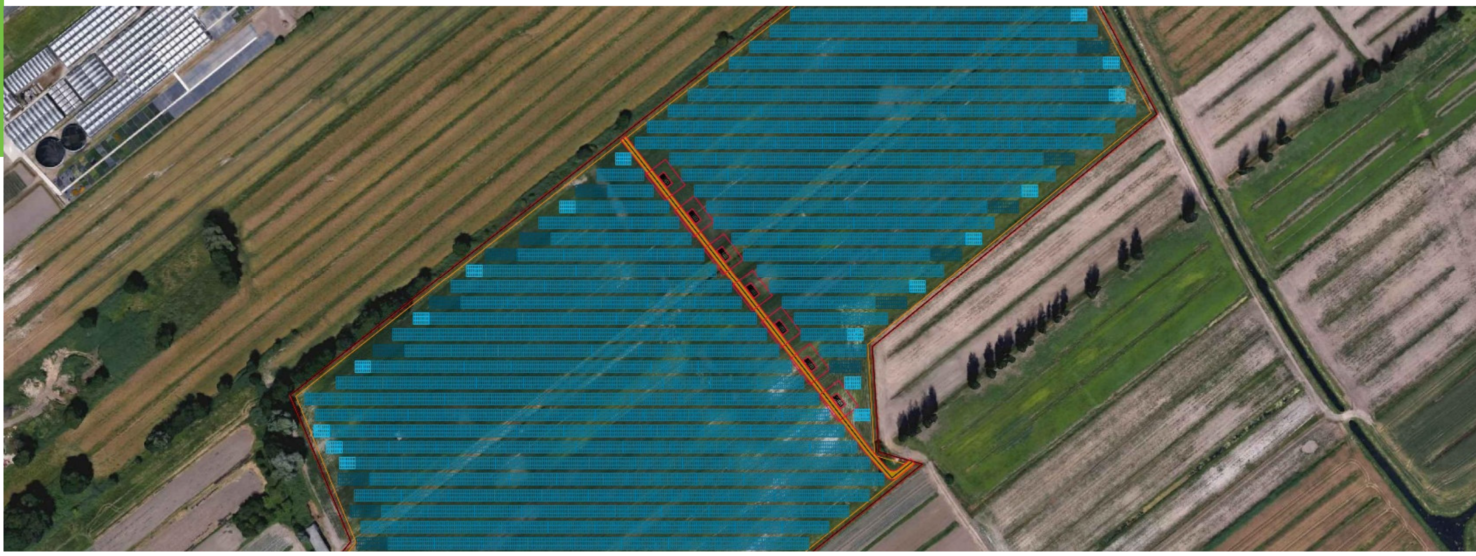


3D plant design with simulation of the shading scene

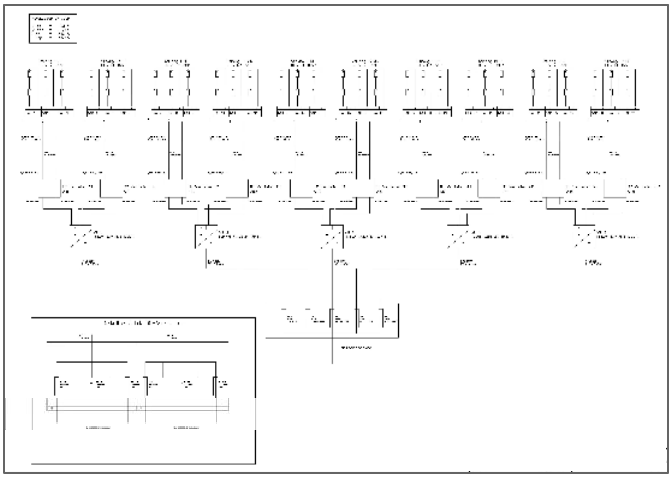


Plant design with Google Maps background

Detail and execution planning

Once the design has been finalized, the next step is usually the detailed and execution planning. It provides the executing parties with all the parameters and details relevant for the implementation of the construction. These include:

- **Pile driving plans:** which posts need to be placed at exactly what distances and depth so that the installation can withstand specific wind, soil or snow loads and the racks are able to support the weight of the modules?
- **Electrical grounding plans:** How is the grounding concept designed: Is stainless or galvanized steel used as material? How are the equipotential bonding conductors between the tables planned? The plans should give a detailed overview of the positions and the material composition of the system.
- **String layout plan:** The plan shows which string with which tables is connected to which inverter or generator combiner box. The plans should additionally show information about material selection or module areas as well as code numbers of the strings, tables and rows.
- **Specifications for the execution of the cable trenches:** The cable trench plan can be accompanied by the cable plan. The cable trenches should be shown in their design in the cable plan (depth, width, structure). Is a sand bed provided for the cables? Is warning tape or are additional cover plates or cable protection tubes provided?
- **Interfaces:** For example, do the string connectors fit the module connectors and the terminals fit the cables? Here, the manufacturer's specifications and available certificates have to be observed in detail.



Single line diagram with a schematic illustration of the electrical installations of the PV system.

- **Single line diagrams (SLD):** SLDs provide a detailed overview of the electrical installations of the plant. They show the electrical functions and current characteristics of the system in an abstracted form. The diagrams should provide information about module wiring, MPP assignment, inverter type and number, and all components up to the grid connection point.

As-built documentation

After successful construction of the PV plant, the final revision of all plans takes place. In the so-called as-built documentation, the actual status of construction is depicted. Particular attention should be paid to thoroughness and completeness, as this documentation forms the basis for the operational phase of the plant. Usually, corrections in the documentation or missing documents can subsequently only be created with increased effort.

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The perfect design - profitable and practical

It goes without saying that a PV system should be economically profitable. However, at the same time, the focus should also be on a practical approach that constantly questions the design. The most profitable plant design is of no use in the end if the rows are built so tightly that efficient green care is no longer possible and high sums have to be spent on manual maintenance. Maintenance and repair costs also add up over a 20 to 30 year period: Depending on the size of the plant, the best possible infrastructure, such as the joint placement of components in central stations, ensures short distances. This saves the responsible technical personnel valuable time and great effort.

For roof systems, depending on their size, it is advisable to plan appropriate maintenance aisles to ensure good accessibility to the system. The dimensioning of the system and the generation profile are usually designed according to the electricity consumption of the building. In the private sector, the consumption can be seen in the annual electricity bill. Industrial companies usually have their load profile recorded by the electricity supplier on a quarter-hourly basis. It is then possible to design the plant optimized for the time-of-day consumption. The data is used to simulate corresponding load profiles of the planned plant and match them with the respective demand.

An intensive exchange with the client before the start of the design helps to understand his goals and intentions and to incorporate them later into the planning. Problems, challenges, or specific wishes can also be discussed in advance so that they can be satisfactorily included in the design.

Design activities should start with an intensive exchange with the client.

Outlook:
what future plant design might be about

Today, plant design is mostly designed to generate as much yield as possible overall. According to most feed-in-tariffs, remuneration is based on the amount of electricity fed into the grid. However, it is currently not relevant at what time of day the electricity was fed in, for example.

This could change if, a plant is planned separately from a subsidy and for marketing on the power markets: It remunerates the electricity provided according to demand. Therefore, future plant design could increasingly focus on designing a plant to produce a lot of electricity at certain, "in demand" times of the day. This could be sold at a higher price than electricity produced at times when a lot of electricity is already available on the market.

You have questions?
Please contact us!

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greentech is a service company specializing in the operation and maintenance of photovoltaic plants. We offer a full-service maintenance concept for PV plants of all sizes as well as services for quality assurance and yield maximization. In addition, we advise our customers holistically with a comprehensive service portfolio in the field of engineering and technical advisory.