AgriPV: A huge opportunity for agriculture and the energy transition

Dr. Erich Merkle, GridParity AG, September, 15, 2022

The worst drought in decades is currently hitting farmers in Europe particularly hard. In many regions, the picture is the same: parched fields, dried-up riverbeds, empty wells. Der Spiegel writes in mid-August 22 „we are currently experiencing what it feels like when our planet becomes uninhabitable. In Europe, we thought for a long time that we still had time to prepare for it; but that is just turning out to be a fallacy.“ Heat waves and water shortages are becoming the new normal with drier winters and scorching summers. Add to this the energy crisis, and climate protection measures are being reduced instead of increased. Yet there is great potential in climate protection if synergies are exploited. A particularly impressive example is AgriPV, i.e. the installation of PV systems on agricultural land. By leveling the EEG, Germany has also created the conditions for AgriPV systems to be built on a broad front and for the yields to also be remunerated. This change in thinking is also urgently needed, as much land as possible can be used for the further expansion of photovoltaics. Otherwise, the solar expansion targets set for the energy transition in Europe cannot be achieved at all. Dual use of agricultural land is a key factor for Germany to achieve the targeted quadrupling of PV installation in just 7 years to 215 gigawatts by 2030. In the last 25 years, about 54 GW have been installed.A major advantage of decentralized AgriPV systems is that their electricity output is often used locally to a significant extent, and grid connection usually does not require as much grid expansion as other ground-mounted systems. Two different systems have developed.

1. elevated systems with semi-transparent PV modules

The use of such systems offers protection against the increasingly frequent extreme weather events such as hail, heavy rain, frost and against excessive UV radiation. The use of spraying agents can be reduced by up to 80 % and the plants receive the necessary moisture in dry periods thanks to an easily integrated economical direct irrigation.

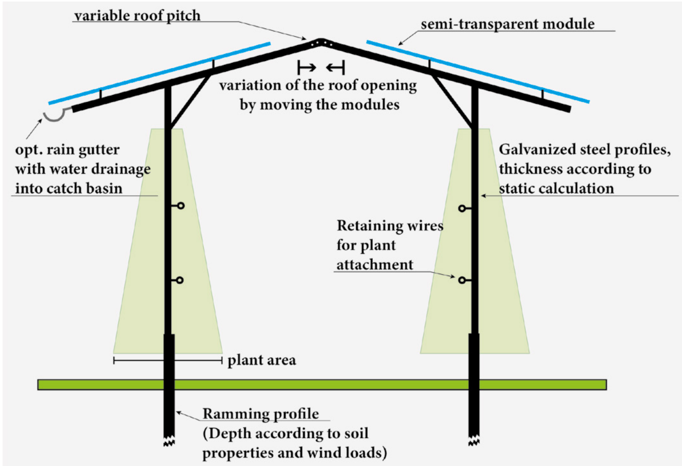

Figure 1: schematic structure

1.1 Criteria in plant construction

The installations should be able to flexibly compensate for different terrain conditions, i.e. inclines, bumps and slopes. The statics of the frames must also withstand considerable snow and wind loads.The essential 3 parameters are shown in the following sketch.

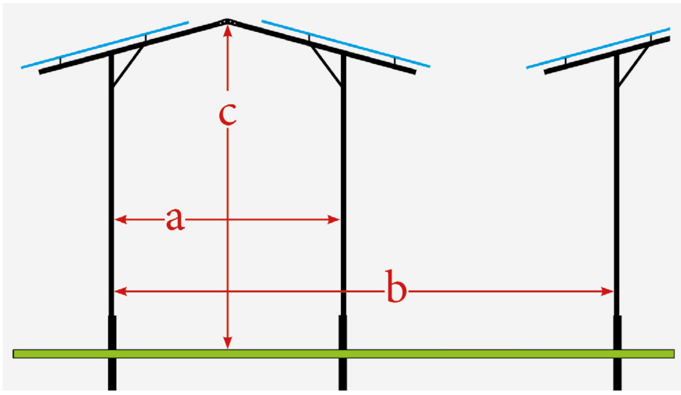

Figure 2: Parameters for planning an AgriPV plant

The construction of such plants is carried out in rows with different widths (a) of the racks and the distances (b) between the rows. Both are essentially determined by the type of fruit grown and the method of cultivation. In already existing orchards, compromises have to be made, while new plantations for both aspects: Fruit and energy yield can be optimized. To this end, test facilities are currently being operated by many agricultural experimental stations around the world. During a conference in Piacenza/Italy in May 2022 results were presented, which I have compiled in a paper (download at www.gridparityag.com/agripv). The height c is determined by the growth height of the plants. Above approx. 4 m, the static loads and thus the costs increase strongly.The row spacing b determines the possible installation of PV modules on the surfaces.If the row spacings are relatively close together at 5-6 m, the high connected loads per hectare (ha) shown in the table result.

row width (m) b	5	6
rows per ha	20	17
kWp/row*	55	55
kWp/ha	1.100	917
*Basis B48-300 Wp Module mit 40 % Transparenz		

Table 1: Calculation of the installation volume per hectare (ha)

1.2 AgriPV for fruit-growing, viticulture and horticulture

The AgriPV solar roofs provide protection from extreme climate events for fruit crops such as pome or stone fruits, but also for other trellis crops such as vines. Some plants are already in operation in Germany, Holland, France and Italy and have produced positive results in the first harvests.The photo below shows the plant of about 250 kW above the Bernhardt apple orchard in Kressbronn on Lake Constance, which went into operation in May 2022. The Almaden M50-260 Wp PV modules with a transparency of 40% developed by GridParity were used. During my visits, apple farmer Hubert Bernhard was impressed by the electricity yields, which exceeded expectations. The development of the apples was also pleasing and the quality factors were only slightly below those of comparable crops in his large orchard. He is therefore already planning to build a much larger plant in 2023, provided that the feed-in option is available.

Figure 3: AgriPV plant with semi-transparent Almaden M50w-260 Wp modules in Kressbronn

The optimization of electricity yields can be determined relatively accurately for new plantations and simultaneous construction of an AgriPV system in terms of electricity yield. For example, yields of about 985 kWh per kilowatt peak of installed capacity can be achieved for plants over pome fruit orchards (e.g. apple trees) in the Lake Constance area and over 1250 kWh/KWp in South Tyrol. The use of bifacial modules (with active surfaces above and below) even results in additional yields of up to 10% for the same investment costs. The results are shown in the table below:

Row width (m) b	5	6
Power yield kWh per ha*	1.083.500	902.917
Power yield/ha at € 0.10 kWh	108.350	90.292
Power yield/ha at € 0.18 kWh	195.030	162.525
Investment pay-back in years**	5,74	6,89
*Bereich Bodensee 985 kWh/kWp ** Anlage 3 ha, Invest 1.120 je kWp		

Table 2: Electricity yields and pay-back periods for the plant in Table 1.

With construction costs of € 1,150 per kW of installed plant capacity, pay-back periods of up to less than 6 years result if the pure electricity yield is taken as a basis. This calculation does not take into account the „additional“ benefit for the fruit yield due to avoided environmental damage such as hail, heavy rain, extreme heat, etc.

1.3 Lower elevations for berry crops or horticulture

Berry crops (e.g. raspberries, blackberries, blueberries, strawberries in high cultivation) are planted with closer spacing of both the rows and the plants. Here, too, climate change requires protective measures that can be achieved by AgriPV plants.Due to the closer spacing of the rows, such plants also give rise to the possibility of connecting the individual rows to form a partially enclosed greenhouse (Figure B).

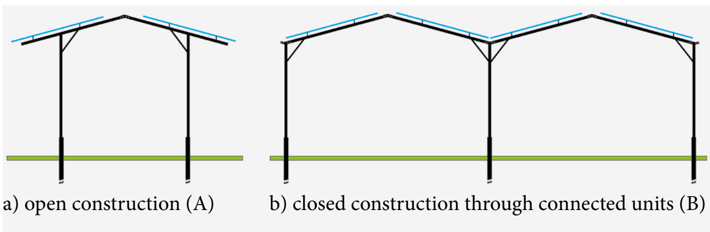

Figure 4: Open and closed systems of an AgriPV plant for soft fruit.

The connection values and thus the power yields are higher in closed constructions (B) than in open constructions (A).In both cases, the combination with systems for rainwater harvesting is useful through gutters that direct the water into collection basins. From there, enriched with nutrients if necessary, it can be used for drip irrigation via hoses attached to the supports.If irrigation is controlled via moisture sensors in the soft, up to 95% of the increasingly precious water can be saved.

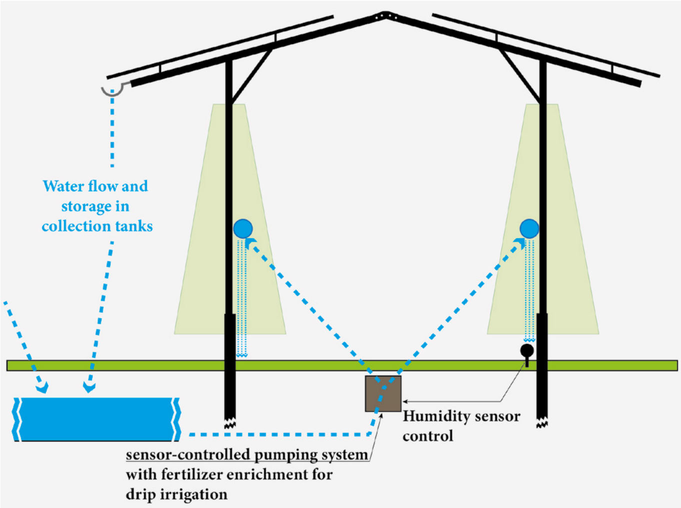

Figure 5: Schematic representation of the irrigation system of an AgriPV plant.

2. vertical elevation: AgriPV Fence

These systems are characterized by rows of vertically elevated bifacial double glass PV modules. In order to achieve a high yield from both sides, shading at all times of the day (with different angles of solar radiation) must be avoided. Therefore, only frameless bifacial (double-sided) modules with a high output can be considered.

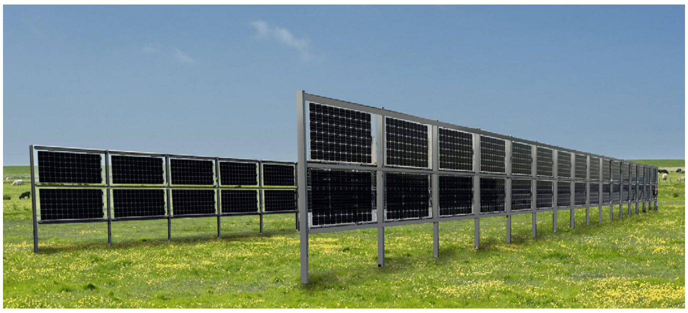

Figure 6: AgriPV Fence system with 8 m row spacing and bifacial modules B72/6 - 450 Wp

The installed power per hectare (ha) also depends on the spacing of the rows for this type of installation, as shown in the following table:

	Distance between rows			
Row distance in m	6	8	10	12
Number of rows ha	18	14	11	9
kWp/row*	41	41	41	41
kWp/ha	724	554	451	383
* with 2 modules B72/6 - 450 Wp per field				

Table 3: Calculation of the installation volume per hectare (ha) for AgriPV Fence Systems

The row spacing is determined by the agricultural use. If harvesting machines are to be used, then a large spacing of approx. 12 m should be selected. In this case, only approx. 400 kWp per hectare can be installed at present.If, however, another use or also a pasture management, e.g. with sheep, is intended, then plants with up to one megawatt per hectare can be installed, i.e. almost the same output as with a free-standing plant. The yields are similar to those of elevated systems so that, depending on the remuneration for the electricity produced, pay-back periods of only up to 10 years result. The yield curve, however, deviates significantly from that of elevated systems with clear peaks in the morning and afternoon hours. Schematically, this results in the following curve.

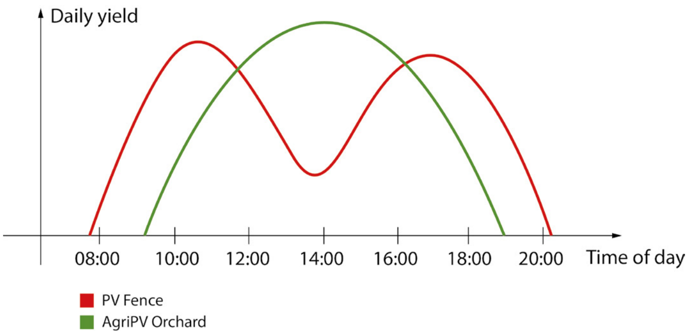

Figure 7: Yield curves for AgriPV roof and fence systems.

3. agriPV and climate change

AgriPV systems make agricultural use possible again in many arid regions. The Italian government has recognized this and is supporting AgriPV installations with € 1.2 billion. The funds are already flowing directly into the construction of installations, as the already existing crisis with several 100,000 hectares of unusable farmland requires an accelerated implementation process. Climate change is causing extremely high temperatures and extreme water shortages there and in many other countries. If counteracted with AgriPV systems, a slow reversal of the processes can result: protection from extreme solar radiation protects the plants and the electricity generated can be used to operate pumps for irrigation and other electrical consumers. The so-called „drip irrigation", is the most economical of all irrigation methods, with water savings of up to 95%. The normally high installation costs can be reduced, as the hoses required for this can be attached directly to the AgriPV racks. Only small amounts of water are released via the small outlets specially attached for the plant species, which can also be enriched with nutrients if necessary.The systems offer protection against extreme weather events such as heavy rain and hail. Especially in fruit growing, a considerable part of the harvest is often destroyed by hail or the marketing is impaired. The expensive hail nets are saved. The use of sprays can also be reduced by up to 80%, since they no longer have to be washed off by the rain and constantly renewed.The advantages of AgriPV use are offset by only a few disadvantages. These relate to the fact that not all plants or crops can cope with the reduced light intensity, resulting in reduced yields in some cases. Agricultural universities worldwide have already developed catalogs of which plants may be affected in which regions of the world. In breeding stations, plants have already been specifically selected with regard to their growth characteristics under lower light levels.AgriPV Fence systems, in turn, require adjustments to the processes involved in sowing and harvesting.

Given the constraints of ongoing climate change on food production and the immensely increasing demand for electricity while reducing the use of fossil fuels such as gas, the increased use of AgriPV represents a great opportunity.Forecasts calculate the German electricity demand for the energy turnaround in 2040 at up to 450 gigawatts. According to studies by the Fraunhofer Institute for Solar Energy Systems (ISE), four to eight times that amount can be generated in Germany on agricultural land. Crucial to the widespread application of AgriPV systems are innovative solutions with few components that can withstand high static loads. Industrial series production is an important prerequisite. The most important components, however, are extremely stable PV double-glass modules that perform well over the long term despite high transparency.

Conclusion

Due to the optimally coordinated components and efficient installation work, GridParity AG can completely supply and erect an AgriPV system for its customers with costs of currently only 1100 - 1200 €/KWp, about as much as for current ground-mounted systems. Due to the integration of extremely powerful PV modules, high electricity yields per hectare are possible with AgriPV plants, for example also with vertically built plants (PV fence). The yields per hectare are comparable with normal ground-mounted systems.

For more information, please visit:
www.gridparity.ag

About the author

Dr. Erich Merkle, together with Almaden Glas, developed the first transparent PV double glass modules with thin 2 mm glass as early as 2006. These have since been installed by GridParity AG in more than 1,000 building-integrated PV systems. Among the first AgriPV applications are two systems installed in Cairo and in the Wahat Desert in Egypt already from 10 years ago. Since then, he has been lecturing and writing papers on these topics, which have received too little attention for too long, and have now gained significant momentum. GridParity is currently developing a large number of plants totaling over 20 MWp.