Background paper

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Agrophotovoltaics (agri PV)

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Note

This background paper summarises significant key statements and discussion points from various workshops held on this topic between March and September 2022 under the leadership of the aforementioned authors and with the participation of external stakeholders. This is not a Bioeconomy Council position paper. Its contents, views and conclusions do not represent recommendations for action or the results of studies carried out by the German Bioeconomy Council, rather they exclusively reflect the contents of the discussions conducted by and with experts.

Summary

Agrophotovoltaics (agri PV) is the term used to describe specially developed photovoltaic systems that are installed above or on agricultural land and that, through specific technical modifications, enable agricultural or arable production to continue underneath or in conjunction with them. This combined use of agricultural land for generating energy and growing food can result in agrophotovoltaics boosting land productivity. Whereas the electricity yield per area rises as the density of the photovoltaic modules in operation increases, the amount of light available for plants drops, which, in turn, may result in fluctuations in agricultural yields. These may decrease if the amount of light available is the limiting factor for plant growth, but also rise if the particular limiting factor is availability of water. Furthermore, the elevation of agri PV systems results in losses of land, which can vary depending on the system design and what is being farmed underneath. This can amount to 10-15% according to DIN SPEC 91434 "Agri-photovoltaic systems – requirements for primary agricultural use". Consequently, great potential for the rapid expansion of photovoltaic systems in agriculture is offset by the possible reduction in agricultural output. Finding ways to expand agri PV in such a way that as many synergies with agricultural production as possible can be achieved without

leading to a critical reduction in the amount of arable land and production volumes is therefore important – protection against weather extremes (e.g. hail, drought) is a prime example of this.

1. How much does agri PV actually contribute towards achieving land management diversification goals?

Reducing the input dependency of farming systems

Agri PV enables farms to generate their own electricity, meaning they are not reliant on purchasing power externally and, in view of technical developments (e.g. electrification of agricultural machinery), offers the potential to increase the degree of agricultural self-sufficiency in the future, while also reducing CO_2 emissions.

Resource-efficient production of electricity

By producing agricultural products and generating energy on the same land, high-mounted agri PV with high elevation systems can typically increase the land equivalent ratio (LER) for exclusive agricultural use in Central Europe from 1 to between 1.6 and 1.8. Depending on the climate zone, crops grown and how the area is cultivated, LER values of over 2 can also be achieved. The better the synergies between agri PV and agricultural production are harnessed, the more productive the agricultural area and productivity will be. These can even lead to an increase in agricultural productivity – for example, agri PV systems can provide plants in hot and dry regions with shade. Given the current climatic conditions in Germany and the farming methods prevalent here, it must, however, be assumed that the use of conventional agricultural machinery will result in the loss of land, underneath the modules, that cannot be cultivated using large equipment (in the case of the system in Heggelbach, this land loss amounts to 8%). Moreover, it can be assumed that agricultural yields will fall by an average of approx. 20% due to changes in the microclimate and light availability in German arable farming and PV coverage of between 20% and 40%.

Enhancement of income in agriculture

The electricity produced can be used on-site for the farm's own requirements or sold at a profit. This can result in new business areas. Examples include further processing (e.g. drying) of harvested products into goods of higher quality or pooling the manufacturing of products that require a lot of energy to produce, e.g. hydrogen (power-to-X).

2. How far is agri PV technology in achieving these goals?

The following figure shows a variety of possible agri PV technologies that can be applied depending on the context. It should be noted that, according to DIN SPEC 91434, only open-space photovoltaic systems are classified as agri PV.

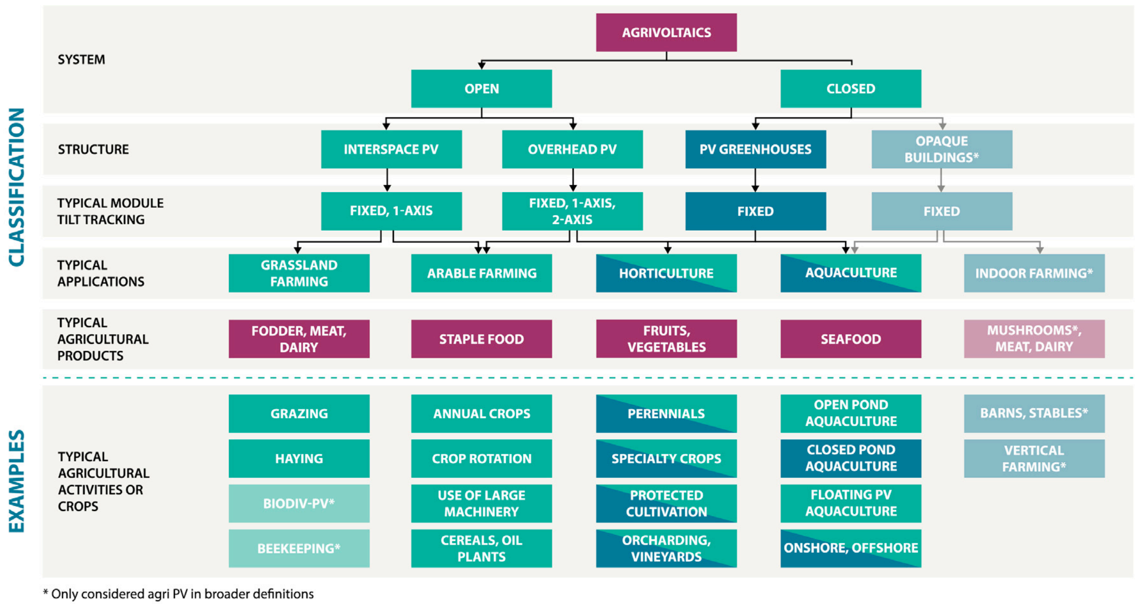

Figure 1: Overview of market development and legislation for agri PV

At present, mainly open-space systems, i.e. ground-mounted, are in the planning stage or have been installed. As of summer 2022, systems with a capacity of just under 20 MW have been installed in Germany.

In comparison, China has installed agri PV systems with a capacity of 15-60 GW (depending on how agri PV is actually defined).

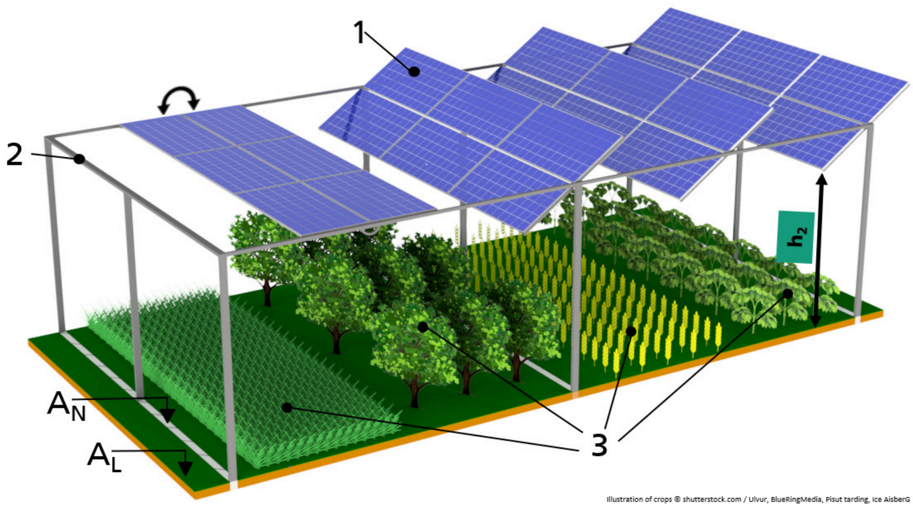

Figure 2: Example of a high-mounted agri PV system

In Germany, high-mounted systems (with clearance of more than 2.10 m) are more expensive than ground-mounted systems, due primarily to the higher costs incurred for the substructure. Nevertheless, they have a higher LER (1.4-1.8, Fig. 2), are easy to manage with sufficient row spacing and offer a higher range of possible synergies due to the partial canopy, even though rain distribution must be ensured.

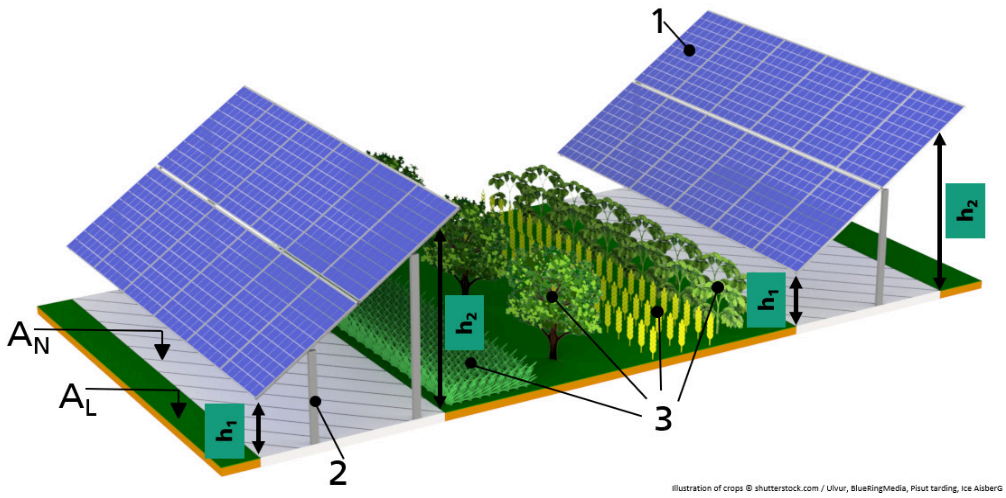

Figure 3: Example of a ground-mounted agri PV system

Ground-mounted agri PV systems with a clearance height of less than 2.10 m, where mainly inter-row cultivation is practised, typically have a lower LER of between 1.2 and 1.4. The main advantages of ground-mounted systems are their lower cost, potential wind protection for crops, and their tendency to have less of an impact on the landscape and rain distribution.

On the other hand, elevated photovoltaic systems use the land area more efficiently and can offer agricultural crops greater protection from adverse environmental impacts, for example:

- Protection against damage caused by droughts, i.e. against high soil temperatures, evaporation rates and drying out of the soil during hot weather periods through shading, thus saving on irrigation,
- Protects against heavy rain and hail,
- Protects against frost damage.

Considering the lower leverised costs of energy (LCOE) of ground-mounted agri PV systems compared to high-mounted ones, it is expected that the former are more likely to be installed within the context of competitive Renewable Energy Sources Act (EEG) tenders.

According to the classification in Figure 1, open-space agri PV systems do not always have to be located on arable land.They could also be designed to function as beekeeping or biodiversity PV systems. This does, however, make it difficult to distinguish them from open-space systems. No criteria currently exist to classify biodiversity PV systems.

Agri PV systems built on areas used to cultivate special crops, i.e. that require a lot of material such as films or nets for hail protection, for example, or that are particularly susceptible to adverse environmental impacts such as frost or heavy rain, have a particularly high synergy potential. This includes vegetables, fruit and viticulture.

3. What are possible conflicting goals and obstacles to sustainable implementation?

A significant conflict of objectives can be the impact on the landscape by agri PV systems as well as acceptance, or lack of it, by the public. A further conflict of objectives in agri PV system design is the goal of simultaneously generating additional energy or electricity from existing agricultural land and preserving agricultural land for food production. This means that, on the one hand, approx. 0.2-0.8 MW of electricity per hectare can be generated by agri PV under the current production conditions in Germany. At the same time, however, up to 10-15% of the area in German arable farming is occupied by PV system installations and can, therefore, no longer be used for agricultural production. Factors such as the type of crop, conditions of the area, weather and number of PV systems can reduce the productivity of crops located underneath the PV systems by up to 33%. By contrast, it is reported that, in dry years, productivity underneath the systems can be slightly higher than in unshaded areas.

Overall, this raises the question of how agricultural land in Germany is best used. The answer also primarily depends on the quality of the land and the prevailing climatic conditions. In high-yielding agricultural areas with fertile soil the focus should be on maintaining agricultural productivity, while areas with low soil quality and, hence, lower potential for successful agricultural production are more suitable for generating solar power. Regardless of the soil quality, agri PV may also help to maintain agricultural productivity in the future by improving the microclimate, especially in areas where it is becoming increasingly dry. Overall, when it comes to competing uses of land, the compensatory measures that currently have to be taken when building an agri PV system and the goal of 4% land that has been set aside are counterproductive. Instead, ways should be found to make proactive use of non-cultivable areas created during the construction of agri PV systems for increasing biodiversity. To minimise the risk of problem weeds taking foothold and to reduce the use of herbicides, active measures such as the targeted sowing of flower strips are necessary. This may also require financial support.

To reduce the risk of partially tying up agricultural land by installing agri PV, PV for built-up or sealed areas (motorways, roofs) should be prioritised. However, these type of PV systems are generally more expensive than open-space systems and/or more difficult to implement under building law. At the same time, there is not enough potential for achieving the targets associated with expanding renewable energy, meaning that the energy transition cannot succeed based on these measures alone. Consequently, rapid development of alternative technologies, such as agri PV, is needed.

Nevertheless, agri PV systems are more complex and more expensive than purely ground-mounted systems that are not integrated into agricultural production. It must therefore be ensured that facilities approved and installed as agri PV are not actually managed as ground-mounted systems without any agricultural activity occurring. Due to their low electricity production costs, ground-mounted systems are particularly popular among investors, as they achieve a much higher return on leased land than do agri PV systems. Indeed, there is currently a tendency for more ground-mounted systems to be built independently of the tenders under the EEG, meaning that the steering effect of EEG on the protection of agricultural land no longer applies, and lease prices can rise disproportionately in some regions.

Agri PV systems could also be attractive options for permanent grassland, which is already used extensively, as well as in combination with livestock farming. Whereas the latter has not yet been clarified conclusively, the installation of agri PV systems on grassland has been taken into account in the new EEG. The decisive factor here is ensuring a clear distinction from conventional open-space systems (e.g. with sheep grazing).

Smaller agri PV systems (less than 500 kWp) are probably more realistic for use on farms, as systems of this size can be built, financed and managed by the farm itself. In addition, the farm can benefit from the added value using the system, e.g. by generating and using its own electricity. In the case of larger agri PV systems, it can be assumed that external investors are involved, while electricity generated on farms will probably only be used for upkeeping the land, meaning the proportion of added value they contribute is minimal.

Direct payments from the EU play an important role for agricultural businesses. Where agri PV expansion is concerned, it therefore makes sense if areas do not lose their eligibility for financial support if they implement such projects. Another advantage is that the arable land remains under the control of local agricultural offices. The point to be made here is the extent to which agricultural activity is actually restricted by solar use. Depending on which agri PV system is installed, at least 85% of an area can continue to be used for agricultural purposes. However, the current wording of Germany's Direct Agricultural Payment Ordinance (DirektzahlDurchfV), which excludes agricultural land with any type of system for generating solar power from direct payments, leads to considerable legal uncertainty for farms, thereby inhibiting the expansion of agri PV. Since this is not the case in other EU countries, such as France, this is not only a direct competitive disadvantage for German agriculture but also for the economy surrounding the planning, construction, maintenance and operation of such systems. Consideration of agri PV within the framework of the Germany's Direct Agricultural Payment Ordinance would eliminate this legal uncertainty. This is planned with the introduction of the new CAP regulations starting in January 2023 or January 2024, which will make grants of up to 85% of direct payments possible for the dual use of land with agri PV.

4. What are possible recommendations for overcoming these obstacles and for supporting the sustainable use of agri PV?

Legal framework

EEG

- Extension of the "technology premium" for high-mounted systems, including those less than 1 MW, and combinations described in the EEG innovation tender.
- For standard tenders: an increase in the "technology premium" for elevated installations to 2 cents/kWh in order to promote installations with a higher LER or a priority award volume.

Right of approval

- Link privileges to farm ownership (including e.g. energy cooperative). The aims here are income security and the preservation of agricultural land.
- Smaller photovoltaic systems should also be funded, in order to ensure that farms participate.
- Criteria for testing the minimum requirements defined in DIN SPEC 91434 should be established to distinguish them from conventional ground-mounted PV systems.
- Partial privilege for agri PV: less than 2 hectares, no planning permission required (excl. land use plan), and generally for horticultural businesses.

Research requirements

- Accompanying research on agri PV implementation must go hand in hand with the installation of the systems. Given the urgent need for a successful energy transition, we should not wait for further research before implementation; we should conduct this research and make implementation possible with greater funding.
- How can the use of steel be reduced during installation?
- Which plants react to PV module shading and how?
- Demonstrate feasibility of agri PV with paludiculture on rewetted peat soils.
- Development of semi-transparent PV modules for selective adsorption of light spectra and optimisation of agricultural yields.

- Arable use of ground-mounted agri PV systems.
  (trials to date have exclusively been carried out with high-mounted systems)
- Combination with farm robots and/or GPS guidance systems.
- Application in semi-arid and arid regions and coupling with intelligent irrigation systems.

Create synergies (how do we create them?)

- Agri PV must bring additional benefits for farmers (e.g. cover own electricity needs, fence function, hail protection, power-to-X, in the agricultural sector – energy, ammonia) -> approval and framework conditions to be adapted accordingly
- It is imperative that each site is viewed individually to ensure the best possible solution

DIN SPEC 91434

Redefinition is required, in particular:

- What criteria must be met to ensure that the main use is for agricultural purposes only? So far, the threshold is at least 66% of the productivity provided compared to the area that has not been built on. This could also be increased to 70-80%.
- Monitoring of compliance with DIN-SPEC. It has not yet been clarified who is allowed to carry them out. Either this has to be done by the agricultural offices or by private inspectors, who would require special accreditation to check compliance with the DIN SPEC.
- Dealing with non-compliance. Is it clearly defined in the DIN SPEC what happens if the criteria are not met? Unlike in Japan, where removal is a barrier to investment, penalties or the like would certainly make more sense (it should be the facility operator who is penalised, however, and not the farmer).
- Adjustment of land loss calculations: at present, in the case of a high-mounted system like the one in Heggelbach, the strip of land that cannot be cultivated would not count as a loss of land. Since this area can theoretically be cultivated again if done differently, only the space required by the post would ultimately count as a loss. In fact, however, there are always larger strips (regardless of the cultivation method) that cannot be cultivated in each respective year.
- The situation is similar for ground-mounted systems, where only the projected area of the PV module tables counts, whereas the 50 cm or more cultivation distance between agricultural machinery and PV module rows counts as usable arable land.
- Protect the term “agri PV” according to the definition in line with DIN SPEC. This is probably not possible within the scope of the DIN SPEC, but definitely necessary.

Communication

- Communicating the range of different agri PV systems.

It is necessary to view and design the systems individually, depending on the location!

- Generally speaking, no technology is favoured, the most suitable one is selected for the intended use.
- Climate relevance and environmental protection must be part of the equation.

International perspective

International perspective is very important!
“The agri PV world looks very different in a world where rainfall is only 200-300 mm”.

Sources

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