COLLECTION
PRACTICAL GUIDE

INSTITUT DE L'ELEVAGE idele

Agrivoltaism applied to breeding ruminants

Guide for breeders
and managers of ground-based photovoltaic plants

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TO

the Pluriannual Energy Programming (PPE), the French government has set an ambitious target for the development of photovoltaic solar energy, which can only be achieved if it is accompanied, alongside solar development on roofs and degraded land, reasonable access to agricultural land. The idea of agrivoltaism then takes on its full meaning. The agricultural world can, once again, play its part in the development of renewable energies. Enabling low-cost electricity production, the installation of
Ground-based photovoltaic power plants constitute a means of consolidating agricultural activity in search of diversification insofar as these plants are designed to ensure the best possible cohabitation with agricultural production, including sheep grazing.
By adapting the height of the panels, to let the ewes pass, and the spacing between them to allow the passage of agricultural machinery, the impact of the installation of a photovoltaic plant on the ground on the sheep grazing activity is minimal or even beneficial for grass growth in drying areas. For sheep farmers, this represents an opportunity for diversification and therefore income consolidation while maintaining their production capacity for the sector. This is an opportunity for the installation, the reinforcement of farms in delicate situations or prospects for farms which do not have the necessary dimensions for transmission in good conditions.

In 2017, the FNO decided to take up the issue of agrivoltaism by signing an experimental partnership with the developer Neoen. Today, this work has resulted in the drafting of a charter defending our vision for the development of virtuous agri-solar projects. This charter is made available to professional agricultural organizations to enhance their thinking and allow the development of projects based on implementation and monitoring conditions that ensure a win-win framework.

This guide proposed by the Institut de l'Élevage constitutes the technical basis of this reflection and provides a good number of answers or at least some insights for an informed construction of projects: from the design of the power plant to the evolution of the agricultural production system through the partnership component which constitutes the basis of the sustainability of the project. There is also a collection of unresolved questions which shows us the value of experimenting with projects in order to finally have documented and shareable references. We would like to thank the Institut de l'Élevage and the partner developers of this guide, for this work of synthesis and transparency which will serve, we are sure, a good number of breeders, technical support structures, managers of ground-based photovoltaic plants and decision makers.

SUMMARY Agrivoltaism applied to ruminant breeding

500 ha

It is the surface of land of agricultural origin which would today be covered by ground-based photovoltaic parks in France, without it being possible to go further in the qualification of the land concerned, for lack of a dedicated observatory.

Data obtained by extrapolation of areas qualified as agricultural land and occupied by ground-based photovoltaic parks as part of the CRE3 call for projects to all calls for tender.
(Source: Decrypter Energy, 2021)

Sheep grazing in the Canadel power station (83) (© Voltalia)

PART 1

Context of the emergence and challenges of projects combining photovoltaicism and ruminant breeding

Boosted by a favorable national strategic framework, renewable energies are booming in France, particularly ground-based photovoltaic production.
As access to degraded land is more and more complicated, managers are now turning to agricultural land, seen as development opportunities to extend the photovoltaic park to the ground. As the use of agricultural land for development projects is highly regulated, developers of photovoltaic power plants have started to set up agrivoltaic projects combining electricity production activities and agricultural activities. The co-activity requires taking into account the issues of the different actors and a reflection on the arrangements to be planned from the design of the project.

A NATIONAL POLICY IN FAVOR OF RENEWABLE ENERGIES

The French energy and climate strategy was presented by the President of the Republic in November 2018. The government then set itself the ambitious objective of achieving carbon neutrality by 2050, relying to do so on two strategies: the National Low-Carbon Strategy (SNBC), France's roadmap to reduce its greenhouse gas emissions, and the Pluriannual Energy Programming (PPE), which sets priorities for actions in the field of energy for the decade 2020-2030.

The PPE is the tool for steering French energy policy in which all the pillars of energy policy are dealt with, with, among other things, on the one hand the reduction in energy consumption, particularly of fossil origin (oil, gas, coal), and on the other hand the diversification of the energy mix by mobilizing renewable energies and reducing the share of nuclear power. While the previous multi-year energy program published in 2016 had set an objective for 2018 of 10.2 GW, the PPE presented in 2018 goes further, since the ambitious objective is to double photovoltaic capacities by 2023 (for reach 18.2 to 20.2 GW) and multiply them by 3 or 4 by 2028 to reach 35 to 45 GW (Figure 1).

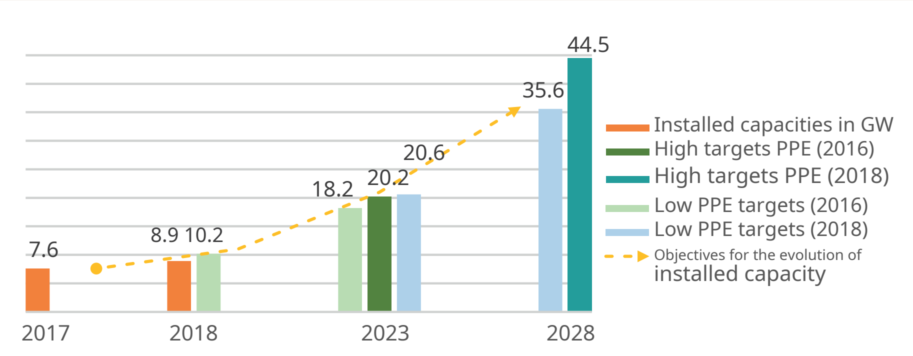
The PPE therefore directs towards an acceleration of the development of the photovoltaic sector compared to the rate of development of previous years and emphasizes competitive solutions such as photovoltaic installations on the ground, while locating projects in priority on artificialized or degraded spaces. so as to preserve natural and agricultural spaces.

TO KNOW !

To achieve the PPE targets, the projected solar power by 2023 must be between 18.2 GW and 20.2 GW.

Assuming that 1 to 2 ha of photovoltaic panels are needed to produce 1 MWp (the production potential varies greatly depending on the technologies and equipment), it would then be a question of mobilizing between 20,000 and 40,000 ha of agricultural land for solar energy production, which would therefore amount to devoting around 0.1% of French agricultural land to photovoltaic production if the photovoltaic parks were to fulfill the PPE objectives on their own. The surface that could be taken up by ground-based photovoltaic parks therefore remains relatively limited compared to other land uses. The impact of these installations would also be quite limited due to the reversibility of the installation after dismantling.

FIGURE 1 : INSTALLED PHOTOVOLTAIC CAPACITIES AND OBJECTIVES (IN GW) SET BY THE MULTI-YEAR ENERGY PROGRAM (PPE) - (SOURCE: ADEME, 2019)



EMERGENCE OF AGRIVOLTAISM

National guidelines are pushing developers of photovoltaic installations to target primarily and as a priority non-agricultural areas without conflicts of use, and in particular old industrial sites (technical landfills, brownfields, quarries, landfills, etc.).

The development of photovoltaics on roofs is also a priority, but roofing alone will not be sufficient to achieve the objectives of the PPE, all the roofs not being able to support the load of the photovoltaic equipment or not having a favorable orientation. With the rapid development of ground-based photovoltaic power plants, the availability of degraded land very quickly decreased, thereby increasing their land value. The potential land still available today has a high cost due to its remoteness from the network and / or its rugged nature. Developers are turning to agricultural land, seen as major opportunities to develop the photovoltaic production area.

In this context, and inspired by agroforestry approaches, managers have thus started to set up agrivoltaic projects combining photovoltaic production activity and agricultural activity. After several disappointing experiences on the combination of photovoltaics and agricultural greenhouses (market gardening, horticulture, arboriculture, nurseries) in which the yields and quality of agricultural production had deteriorated, the concept of agrivoltaism emerged, in particular *via* the Innovation call for tenders from the Energy Regulatory Commission, as being the coupling of an agricultural activity and a photovoltaic activity, in an operating synergy.

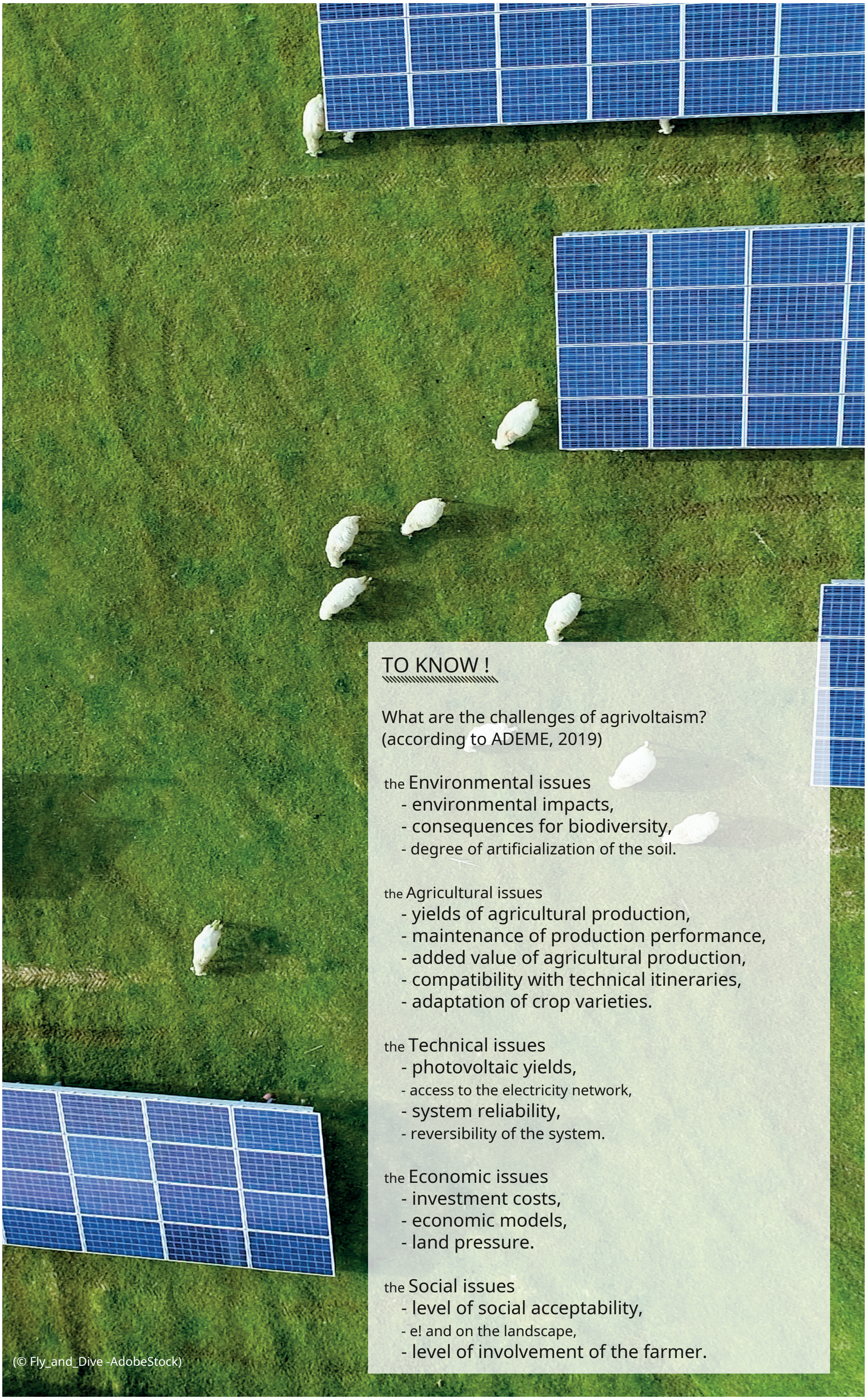
At present, in France and abroad, various agricultural productions have been the subject of experiments within the framework of photovoltaic park installation projects: market gardening, viticulture, arboriculture, field crops, and in a to a lesser extent, breeding (photos 1 to 4).

Photo 1: Photovoltaic shades installed above market garden crops (© Voltalia)

Photo 2: Sheep grazing in a photovoltaic plant with fixed tables (© TSE)

Photo 3: Photovoltaic tables installed above arable crops (© Jeson / AdobeStock)

Photo 4: Mobile photovoltaic shades installed above vegetable crops (© Jeson / AdobeStock)



TO KNOW !

What are the challenges of agrivoltaism?
(according to ADEME, 2019)

the Environmental issues
- environmental impacts,
- consequences for biodiversity,
- degree of artificialization of the soil.

the Agricultural issues
- yields of agricultural production,
- maintenance of production performance,
- added value of agricultural production,
- compatibility with technical itineraries,
- adaptation of crop varieties.

the Technical issues
- photovoltaic yields,
- access to the electricity network,
- system reliability,
- reversibility of the system.

the Economic issues
- investment costs,
- economic models,
- land pressure.

the Social issues
- level of social acceptability,
- e! and on the landscape,
- level of involvement of the farmer.

(© Fly_and_Dive -AdobeStock)

SUPERVISION OF THE PRACTICE OF AGRIVOLTAISM IN FRANCE

Regulatory framework for the use of agricultural land for development projects

The use of agricultural land for agrivoltaic projects is particularly regulated in France by the law of the future for agriculture, food and forestry of October 13, 2014. According to this law, public development projects and private sector likely to have significant consequences on the agricultural sector must be the subject of a preliminary study including the measures envisaged to avoid and reduce their significant negative effects, as well as compensation measures aimed at consolidating the agricultural economy of the territory.

In addition, the town planning code clearly indicates that *" ground-based power plants can only be authorized when they are not incompatible with the exercise of an agricultural, pastoral or forestry activity on the land on which they are located and that they do not undermine the safeguard natural spaces and landscapes! ".*

Case law established by the Council of State in February 2017 *(Board of state, 2017)* indicates, moreover, that agricultural, pastoral or forestry activity must be *"Significant on the site of the project, with regard to the activities that are actually carried out in the area concerned or, if applicable, would be intended to develop there, taking into account in particular the area of the plot, the 'influence of the project, the nature of the soils and local uses ".*

Photo 5: Sheep grazing in a photovoltaic power plant in the Allier (© E. Mortelmans)

Working groups, guides and charters to supervise the practice of agrivoltaism

The subject of agrivoltaicism brings together many actors in the form of working groups which organize themselves to propose a shared definition of agrivoltaic practices and to formulate recommendations on their uses, beyond the regulatory framework for the use of agricultural land for agricultural purposes. development projects. On the one hand, Ademe is leading an initiative to produce a guide to "support and facilitate the implementation of agrivoltaic projects while identifying the means to support this sector". On the other hand, the Green Platform (professional association dedicated to the energy transition created in 2018) offers a guide providing an operational and interdisciplinary vision of the issue (see page 77). At the same time, different organizations

farmers take a position on this subject *via* charters, with on one side a charter bringing together Chambers of Agriculture France, FNSEA (organizations representing farmers) and EDF Renouvelables, developer and producer of solar and wind energy. On the other hand, the FNO (Fédération Nationale Ovine) has established its own charter as part of its partnership with the developer and producer of solar energy Neoen. These charters have the common point of making the preservation of agricultural activities and land a priority. The activity of agricultural production must prevail wherever it can be maintained. In both charters, the signatories clearly set out the idea that agrivoltaism is above all an agricultural tool consolidating the income of farms and offering possibilities of adaptation to climate change, and not a tool for producing electricity in the first destination. For these actors, agrivoltaism can only be virtuous if the farmer and agricultural production are at the heart of the system.

FOCUS ON BREEDING AND PHOTOVOLTAISM COUPLING

Ruminant breeding co-activity
Photovoltaism: what are we talking about?
In general, the practice of maintaining photovoltaic parks by grazing ruminants is starting to be widespread in France, spurred on by many eco-grazing companies offering their services by providing ruminant troops (mainly sheep, often hardy breeds with small numbers). In most cases, these are photovoltaic power plants that have already been built, generally in non-agricultural areas, on which has been organized

a posteriori maintenance of the plant cover through grazing. These breeding-photovoltaic coupling projects, which can be described as eco-grazing without a truly productive aim, are distinguished from agrivoltaic projects strictly speaking, for which there is a real desire for synergy between the breeding activities (meat or milk production) and electricity production. Agrivoltaic power plants take into account the agricultural dimension from their development phase and aim to promote agricultural production performance, in synergy with electricity production.

There are still few agrivoltaic projects in France today, as defined above, involving professional breeders in partnership with managers of photovoltaic plants. Most of the agrivoltaic systems, combining breeding and photovoltaicism, present today in France, concern suckler sheep farmers.

Breeding and photovoltaicism, a win-win combination?

In principle, projects combining photovoltaicism and ruminant breeding can present interesting synergies and benefits for the various actors involved.

the **For developers,** co-activity with livestock farming first of all allows access to agricultural land while preserving their primary nature of agricultural production. In addition, vegetation management, usually carried out mechanically, is in these projects ensured by animals, which reduces the cost and ecological impacts of maintenance as well as the risk of damage to equipment (stone throwing, etc.) . The regular presence of the breeder also allows a watch on the park, the latter being able to report any malfunction to the plant operator. Finally, agrivoltaism conveys a rather positive image with the general public and local authorities, which can facilitate the acceptance and ownership of development projects at the local level.

the **For breeders,** photovoltaic power plants can represent
new grazing opportunities in a context where tensions on fodder resources are increasingly present, thus contributing to the resilience of livestock farms vis-à-vis climate change. The use of fenced areas can also allow breeders practicing guarding to reduce their workload or even the labor cost associated with guarding the herd. As the maintenance of the fences is the responsibility of the plant manager, the farmer is relieved of this costly and time-consuming activity. Secure fences also offer peace of mind to the breeder in a context of increasingly significant predation.

Finally, the remuneration of the practice of grazing in a photovoltaic park allows the diversification and securing of income in the context of a sector in difficulty. Consolidation of income can secure installation projects, strengthen active farms in their development or even facilitate transmission (in the context of a transmission, access to land for the new installation can be facilitated by the fact that the owner will have no interest in selling his land and will therefore rather seek to rent it).

the **For the herd,** photovoltaic infrastructures can provide shelter in the event of hot weather, cold wind or bad weather (photo 6). The fences of the plants, high and sometimes semi-underground, also offer an interesting protection of the herd against predators.

Photo 6: Photovoltaic plants generate shade for animals (© Voltalia)

Factors conditioning the success of projects combining breeding and photovoltaicism

Three essential factors condition the success and sustainability of projects combining livestock farming and photovoltaicism:
- respect for animal welfare;
- the maintenance of the performance of agricultural production (in connection with the productivity of the breeding, the time and the ergonomics of the work of the breeder);
- maintaining the performance of electricity production (controlled management of vegetation).

It is important that these three conditions are met for a project agrivoltaicism involving ruminant breeding is viable and sustainable and that all the actors involved are involved. In addition, it is essential that these conditions are incorporated from the design of the project.

Scientific references available concerning the impact of photovoltaic activity on ruminant farming activity

As the practice of agrivoltaics grows and becomes an important subject, more and more experimental work is being done to assess the impacts of photovoltaic activity on agricultural activities. However, this work mainly affects the sectors of plant production (market gardening, arboriculture, viticulture). The effects of grazing under photovoltaic panels are not well studied. The main bibliographical references analyzing the impacts on animal welfare and the performance of the breeding activity are presented below.

Impacts of grazing under photovoltaic panels on the welfare of farm animals

Few studies document the impacts, both positive and negative, of the presence of photovoltaic panels on grazing ruminants, while animal welfare, as defined by the AA" NSES in 2018 and by the Farm Animal Welfare Council (see box "Definitions" on page 16), is however a fundamental prerequisite for the existence of these activities.

On the one hand, some studies show that photovoltaic installations improve animal comfort, especially in extreme weather conditions.

(strong wind, strong heat). The shading of photovoltaic panels is especially appreciated by animals during days with a high intensity of solar radiation. *Payen (2017), Maia et al. (2020)* have for example shown that thanks to the shading provided by the tables of the photovoltaic park, the ewes have a shelter which they actively seek with the increase in temperatures and radiation

solar. Experimentation *by Sharpe et al., (2021)* also showed, by monitoring of internal temperature and respiratory rate, that the shading of photovoltaic panels seems to reduce the intensity of thermal stress of dairy cows on pasture in summer.

Conversely, several experimental works show that the configuration of infrastructures and their installation conditions can be detrimental to the welfare of animals (contiguous corners, equipment that is too low, electrical risk, etc.). *Dietmaier (2015)* notes in particular changes in the behavior of lambs linked to circulation difficulties

DEFINITIONS

! Animal welfare is the positive mental and physical state related to meeting its physiological and behavioral needs, as well as its expectations. This state varies according to the perception of the situation by the animal. "*(Anses, 2018)*

The methods for assessing the welfare of farm animals are based on the “five freedoms”, basic principles proposed by the Farm Animal Welfare Council:
1- The absence of hunger, thirst or malnutrition;
2- The absence of diseases, injuries or pain ;
3 - The absence of discomfort;
4 -The absence of fear and distress; 5 -The possibility of expressing normal behavior of the species;

These five freedoms make it possible to define the basic principles for ensuring the welfare of farm animals:

• Provide animals with free access to water and healthy food to maintain a good level of health and vigor.

• Regarding health aspects, apply preventive measures or rapid diagnosis followed by appropriate treatment.

• Provide an appropriate environment, including shelter and a comfortable rest area.

• Leave the freedom of expression of normal behavior to the species through sufficient space, suitable facilities and the company of other congeners.

• Guarantee living conditions and treatment of animals that avoid all mental suffering.

in a photovoltaic park with tables that are too low. Indeed, in certain parks where the tables were too low, only the lambs could pass under the panels, thus separating them from their mothers and causing a certain agitation among the ewes. In addition, several cases of sheep injuries to the back and thorax have been reported in parks where the minimum height of the photovoltaic tables was less than or equal to 80 cm.*(Dietmaier, 2015)*. These design and engineering obstacles can however easily be overcome by adapting the equipment to the presence of farm animals in the photovoltaic park (see Part 2). On the other hand, the question of the impact of the practice of grazing under photovoltaic panels seems to have possible impacts on the state of hygiene of ruminants. The study of

*Sharpe et al. (2021)*testifies, for example, to a deterioration in the state of hygiene of dairy cows grazing under photovoltaic panels in summer (dirtier legs and belly). Finally, the question of the effect from waves electromagnetic on animals breeding remains intact. The returns experiences of pasture practicing the breeders in a power plant photovoltaic do not have, to date, echoes problems concerning a any effect of signs on animal behavior or health. Electromagnetic radiation emitted by photovoltaic equipment (panels, cables, inverters) is*a priori* relatively weak.

Photo 7: Sheep thatching in the shade of photovoltaic panels (© TSE)

The measures carried out on from photovoltaic installations of several hundred KW or several MW conclude to weak electric and magnetic fields *(Tell et al., 2012).* Beyond the intensity of the radiation, it is important to take into account the frequency and duration of exposure to this radiation. To date, there is no scientific consensus regarding long-term effects on human health from low but regular exposure. Little is known about the impact on animals.

Either way, the effects of electromagnetic fields largely depend on how far humans or animals are from the source of radiation, their strength being inversely proportional to the square of the distance. In the case of domestic photovoltaic panels, two or three meters are sufficient to find the level of the electromagnetic field emitted naturally by the earth. For very large installations of the ground-based central type, a separation of more than ten meters will be required to return to the natural level of terrestrial radiation.*(Deciphering energy, 2021)*. There is currently no scientific answer to this question, and experiments are necessary to evaluate this subject.

Photo 8: Castellet photovoltaic plant (© Voltalia)

Impacts of photovoltaic panels on plant cover

Feedback from field experience shows that the panels seem to provide shade favorable to grass production, especially in hot weather or to prevent frost. Even if the growth of the vegetation cover may be somewhat affected at certain times of the year, it would seem that the overall forage potential is maintained over the entire grazing period. The presence of photovoltaic tables would thus offer a spread over time of the growth of the grass (photo 9).

Photo 9: Protection of plant cover in drought conditions (Verneuil) (© E. Mortelmans)

Beyond from returns experiences, the impact of the presence of photovoltaic panels on the plant cover can be considered from several angles, through the impacts on the microclimate, on the quantity and quality of vegetation.

Impacts of photovoltaic panels in terms of microclimate

An important question for agricultural activity under a photovoltaic installation is the alteration of microclimatic conditions and consequences for crops or herbaceous cover. Different studies confirm that the presence of photovoltaic panels creates a microclimate, limiting radiation, reducing the maximum temperature of the ground and the air during the day, and limiting the temperature differences between day and night during the summer, and changing the wind speed*(Pang et al., 2017; Ehret et al., 2015; Marrou et al., 2013; Armstrong*

Photo 10: Grassland cover in an agrivoltaic plant (81) (© Idele)

Photo 11: Photovoltaic plant grazed by sheep (30) (© Idele)

et al, 2016; Adeh Hassanpour et al, 2018). In addition to this parasol effect, one might think that solar panels also have an umbrella effect. However, this is not the case, due to the interstices which separate each module constituting a panel. *Armstrong et al. (2016)*thus measured a localized precipitation three times more important under the panels because of a water runoff on the support frames, while *Adeh Hassanpour et al. (2018) and Madej (2020)*found wetter prairie soil longer under the panels, compared to the area in full sun which increased evaporation. Other effects on the exchange of gas and water vapor and on the distribution of precipitation in the solar park can finally be observed.*(Armstrong et al., 2014; Hernandez et al., 2014)*.

On the other hand, several studies carried out in France *(Cossu et al., 2017; Dupraz et al., 2011),* in Germany *(Fraunhofer Institute, 2018)* and in the United States *(Barron et al., 2019)* show that the impacts of photovoltaic panels on the microclimate vary depending on the location and the design of the infrastructure photovoltaic. First, the amount of solar radiation available for plants varies according to the technical design of the panels (distance of the panels from the ground, inter-row distance, orientation of the modules). The heterogeneity of the radiation on the ground is for example accentuated when the panels are close to the ground (photo 10). Second, studies have shown that the lower the altitude, the greater the microclimatic changes. Finally, depending on the orientation and design of the system, the wind speed can also decrease or increase, influencing plant growth.

Impacts of photovoltaic panels on the yield and quality of plant production

Modifications from conditions microclimatic generated by the photovoltaic panels induce modifications to the vegetation cover. Several studies document the impact of shading from photovoltaic panels on the production of plant cover, both in terms of quality and quantity.

the **Impacts on biomass production**

Studies on this subject present contrasting conclusions. Several experiments report a drop in biomass production under photovoltaic panels. *Armstrong et al. (2016)*thus measured a grassland biomass four times lower under the panels than between rows or in the control zone, with lower photosynthesis especially in spring and winter. *Kirilov et al. (2013)*also reported a drop in the production of plant cover under the panels. Conversely, the study carried out in meadows by*Adeh Hassanpour et al. (2018)* showed a biomass greater than + 90% under the solar panels compared to the control zone, and + 126!% compared to the inter-row.*Arsenault (2010)* also measured taller and lush vegetation in the shade of the panels. Finally, a study carried out in France in 2020

(in Allier and Cantal) does not measure the difference in biomass production under the panels compared to the inter-row or the control, in summer *(Madej, 2020).*
These differences in findings are linked to the diversity of the geographical and climatic contexts of the experimental sites. It seems that the negative effects on plant biomass have been noted in experimental situations where the summer water deficit remains moderate (experiments of*Armstrong et al. (2016)* conducted in England and *Kirilov et al. (2013)*carried out in Bulgaria), while the positive effects were noted in climatic contexts of low rainfall and marked water deficit in summer (experiment of*Adeh Hassanpour et al. (2018)*conducted in the United States, Oregon). Photovoltaic panels could therefore have a positive or negative effect on biomass production depending on the degree of aridity of the climate.

*Shemshenko et al. (2012)*measured the biomass production of 46 grassland species under different conditions shading. The results of this study show first of all that “light” shading (shade sail letting through 75% of solar radiation) has no impact on biomass production, compared to the control in full exposure. A "moderate" shadow

(shade sail allowing 50% of solar radiation to pass through) has a facilitating effect on biomass production. It is only with “strong” shading (shade sail allowing only 10% of solar radiation to pass) that the biomass produced by shaded plants is significantly lower. These experimental results make it possible to imagine what could be the impacts of mobile photovoltaic panels, forming partial shade during the day, on the plant cover.

Photo 12: Sheep grazing in an agrivoltaic park (Karoline Thalhofer / AdobeStock)

the **Impacts on growth dynamics**
Madej (2020), *Arsenault (2010)* and *Adeh Hassanpour et al. (2018)*note a growth dynamic of the vegetation more important under the panels compared to the sunny areas, thanks to the reduction of the hydric, light and thermal stress induced by the protection of the cover of the photovoltaic panels. This difference can also be explained by the higher water reserve over time under solar panels.

Madej (2020) however, specifies that this improvement in the growth of the cover under the panels was observed in particularly restrictive summer weather conditions. In
absence of thermal and water stress, the growth potential was indeed greater in the areas of full exposure, which did not present any radiation limitation, unlike the areas under the panels. This result is consistent with the hypothesis according to which the beneficial effect of panels on plant cover would be felt all the more under conditions of water and heat stress.

It is important to note that most studies on the impact of photovoltaic panels on the productivity of the vegetation cover focus on specifically isolating the effect of the panels on the canopy, apart from any other interaction. *Madej (2020)* offers a complementary analysis by evaluating the impact of panels on the plant cover in a context of sheep grazing. The study report qualifies the positive effects of panels on biomass: the positive signs related to grass growth (such as water use efficiency and radiation interception efficiency) are counterbalanced by sheep disturbances (trampling and compaction in particular), the percentage of soil naked reducing plant density.

the **Impacts on the quality of the vegetation cover**
Madej (2020) notes that, in summer, the state of the vegetation and its quality have benefited from solar panels, protecting against water, light and thermal stress. Vegetation under the panels remained greener than in sunny areas and exhibited superior forage quality, with higher nitrogen content and decreased fiber content due to delayed maturation and reduced stress.

the **Impacts on the evolution of the composition of the vegetation cover**
Several phenomena are at work. On the one hand, some plants adapt

Photo 13: Photovoltaic plant in Le Castellet (83) (© Voltalia)

their morphology to acclimatize to shaded conditions and compensate for the limitation in light by the panels. These plants then form thinner and elongated leaves to optimize the interception of the radiation.*(Marrou et al., 2013; Valle et al., 2017)*. On the other hand, all the studies observe a decrease in specific richness and a change in the floristic composition of the plant cover under photovoltaic panels. Indeed,*Kirilov et al.* (2013), *Armstrong et al. (2016), Montag et al. (2016), Adeh* *Hassanpour et al. (2018) and Madej (2020)* all report a decrease in grassland plant diversity under the solar panels compared to the inter-row, with a majority of grasses under the panels, compared to a majority of various plants and legumes in the inter-row and control zone.

Impacts of grazing under photovoltaic panels on the productivity of the livestock activity

There are very few references concerning the impacts of grazing in a photovoltaic power plant on the productivity of the ruminant breeding activity.

The study conducted by *Andrew (2020)* compares the growth of lambs in a solar-paneled pasture setting compared to open pastures in Oregon. Preliminary results report that the live weight production (in kg ha / day) and the live weight gains of lambs were comparable in the two types of pasture. The study did not show a significant difference in the average daily water intake of the lambs. More broadly, the study concludes that the grazing of lambs under photovoltaic panels allows the maintenance of a higher load towards the summer and that the productivity of the land could be increased to 200% by combining sheep grazing and the production of sheep. solar energy on the same site.

Another study conducted by *Sharpe et al. (2021)* on dairy cows grazing under photovoltaic panels has also shown that the panels have no influence on milk production, or on the quality of the milk (fat content, protein level), or on watering periods.

Back on the bibliography: experiments to be multiplied and questions still to be explored

The studies on the impacts of Agrivoltaism on livestock activities is still in its infancy. Scientific references concerning the impact of grazing in photovoltaic power plants on the welfare of ruminants, on the plant cover or on the productivity of the livestock activity are indeed few and mainly carried out outside France. Some study protocols present weaknesses (in particular *Maia et al. (2020), Armstrong et al. (2016)*), which makes the conclusions moderately reliable. It is therefore imperative to continue this investigative work and to multiply the experiments in France, in different pedoclimatic contexts, with different species of ruminants and in different configurations of photovoltaic equipment. Regarding the fields of investigation, it is important to continue the analysis of the impacts of agrivoltaism on animal welfare, on the plant cover, on the maintenance of the performance of the breeding activity (in quantity and in quality) and to produce references that are currently missing, on the socioeconomic impacts of the practice (profitability of the practice, working time in particular).

To date, beyond the knowledge resulting from experimental results and the lack of knowledge pointed out on certain specific questions, more and more agrivoltaic projects involving ruminant breeding are being set up in France and the practice is becoming more democratic. . It is important to continue the experiments in order to continue producing references on this practice and its impacts.

At the same time, it is still possible to formulate simple recommendations so that the projects that are set up are the most suited to the co-activity between photovoltaic production and ruminant breeding. This is the whole purpose of this guide, which aims to disseminate recommendations that can be mobilized when setting up projects combining ruminant breeding and photovoltaics, in order to increase the chances of success of the project. The recommendations put forward in this guide are based on feedback from several breeders currently grazing in photovoltaic parks, on visits to several plants currently maintained by ruminants in different pedoclimatic contexts and on the expertise of the Institute of Livestock in grazing management.

IN PRACTICE

The Institut de l'Élevage can support management companies in their project, by carrying out experiments in the following areas:

the Agronomy: Quantity and quality of fodder resources under the panels, variation of the floristic composition with grazing, variation of the composition of the soil with grazing, effect of grazing vis-à-vis the management objectives, choice of plant cover (in case of 'implantation).

the Zootechnics: Risk of equipment for animals, evaluation of animal welfare, maintenance of the "productive" character of the breeding.

the Socio-economic: Impact of the practice from an economic point of view and impact on the farmer's working time.

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Sheep grazing in the agrivoltaic plant of Castellet (83) (© Voltalia)

PART 2

Adapt photovoltaic equipment and think about their location to a co-activity with breeding

The equipment conventionally used in photovoltaic parks is not always suitable for the presence of grazing animals: tables that are sometimes too low, contending objects, presence of manholes and / or unprotected electric cables, etc.
It is therefore necessary to integrate the constraints linked to the presence of farm animals from the design of the park, through the choice, sizing and installation conditions of photovoltaic equipment.

The first returns experiences show that agrivoltaic projects in which the breeding activity was associated after the design and establishment of the park often reveal problems that could compromise the maintenance of the co-activity: negative impacts on animal welfare, too much fodder resources. poor, too much time spent by the breeder ... The photovoltaic breeding co-activity therefore requires a new reflection on the arrangement and installation of photovoltaic infrastructures.

These specificities of course are preferably integrate upstream of the installation of the photovoltaic park.

CHOOSE A STRUCTURE PHOTOVOLTAIC ADAPTED TO CO-ACTIVITY WITH BREEDING

Behind the concept of "photovoltaic power plant" hides a variety of infrastructures whose common point is to produce electricity using modules made up of photovoltaic cells.

The different technologies available

Different technologies are available today, some already on the market and others still in prototype state: fixed tables (oriented to the south at an angle of 25 to 30 °) (photo 14), mobile panels equipped with a motor allowing them to follow the course of the sun to optimize their exposure and therefore their output (1-axis trackers allowing to follow the sun from east to west (photo 15) or 2-axis trackers allowing both a modification of the orientation and the inclination (photo 16), photovoltaic “hedges”, or even photovoltaic shades placed in height (photo 17), and so on.
The most commonly encountered equipment in French parks currently grazed by ruminants are fixed tables and more secondarily 1-axis trackers.

Photo 14: Sheep grazing in a photovoltaic park with fixed tables in Torreilles (66) (© Neoen)

Photo 15: 1-axis tracker panel photovoltaic park in Le Castellet (83) (© Voltalia)

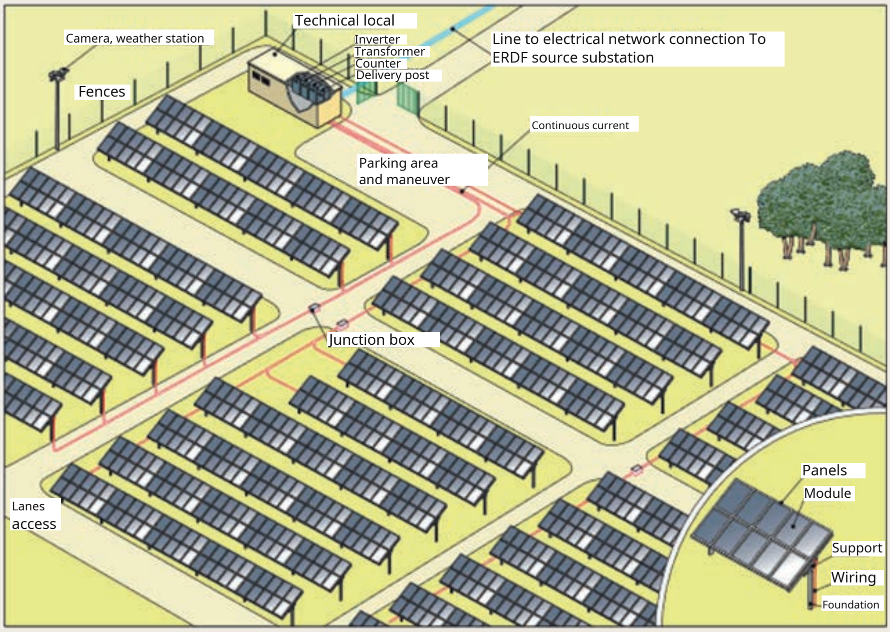
Photo 16: 2-axis tracker photovoltaic panels in Grabels (34) (© Idele, park managed by Neoen)

Photo 17: Photovoltaic shades at the Cabanon (© Voltalia)

FIGURE 2:
DIAGRAM OF THE OPERATING PRINCIPLE OF A PHOTOVOLTAIC INSTALLATION
(SOURCE: MINISTRY OF ECOLOGY, SUSTAINABLE DEVELOPMENT, TRANSPORT AND HOUSING, 2011)

A ground-mounted photovoltaic plant is made up of several elements:

- assembly tables (or panels), made of metal (steel, aluminum or other) are fixed to the ground and organized in rows.
- photovoltaic modules composed of photovoltaic cells and oriented with an optimal inclination with respect to the sun's rays are placed on the assembly tables.
- all the overhead cables coming from a group of panels join a junction box from which the direct current returns in a single underground cable, to the technical room.
- the technical room houses the inverter stations, transformers, meters, electrical protection installations and the delivery station. Depending on the size of the project, there are often several transformer stations, or even several delivery stations.
- the electricity produced is then sent to the nearest electrical network connection point (Enedis source substation).
- The fencing of photovoltaic installations protects installations and people and makes it possible to limit acts of vandalism. Site security can be reinforced by surveillance cameras, an alarm system, permanent security or even night lighting with motion detection.
- access routes are required during construction, operation and decommissioning. A parking and maneuvering area is generally set up nearby. During operation, it must be possible to circulate between the panels for maintenance (cleaning of the modules, maintenance) or technical interventions (breakdowns).



Criteria for the choice of equipment by managers

From the point of view of managers, the choice of photovoltaic equipment is usually made on criteria such as performance, cost / price ratio, reliability and durability, mechanical properties, supply conditions, life cycle or again the carbon footprint. Each type of photovoltaic equipment has advantages and disadvantages. In a project of co-activity with livestock, other parameters are important to consider when considering the choice of photovoltaic equipment, among

which the possibilities of movement of animals and the breeder, the possibilities of installing mobile fences in the park to divide the space, the possibilities the passage of any agricultural machinery under the panels and between the rows, and the shading effects of the panels on the plant cover.

Photo 18: 1-axis tracker panel control bars that may possibly complicate co-activity with breeding depending on their height (if <80 cm from the ground) (© Idele)

Photo 19: The 1-axis tracker control bars do not pose a problem if the animals can circulate smoothly below, as in the Canadel power station (83) (© Voltalia)

IN PRACTICE

What equipment should be preferred in the case of a co-activity with breeding?

In general, all types of photovoltaic infrastructure can be used in co-activity with livestock.

A point of vigilance must still be asked regarding the tracker panels
1 axis. Indeed, certain types of 1-axis trackers have control bars installed perpendicular to the rows of panels which can make it difficult for the breeder and the herd to move around, increasing the risk of injuries, and which can complicate the use of agricultural machinery. or a mobile fence in the aisles if these control bars are positioned at a low height (less than 80 cm) (photos 18 and 19).

From an agronomic point of view, according to the experimental results available, it would seem that structures adapting their inclination are to be preferred to maximize the production of the plant cover, the vegetation zone receiving direct sunlight being more important than with fixed tables. An ideal compromise would be a structure bearing adjustable panels, but not employing force bars.

Beyond the very nature of the infrastructures, it is above all their installation conditions that will make them more or less suitable: minimum height of the lowest points, type of fixing in the ground, density of infrastructures, row spacing, space between the infrastructure and the exterior fence. As the modes of establishment condition the possibilities of co-activity, it is all the more important to integrate co-activity with livestock from the first reflections, upstream of the construction of the park.

TO NOTE !

From an animal welfare point of view, in the current state of knowledge and apart from the unknown field of the effect of electromagnetic waves on animals, all types of photovoltaic equipment can a priori be adapted to a co-activity with breeding.

DEFINE CONDITIONS IMPLEMENTATION OF EQUIPMENT FAVORABLE TO CO-ACTIVITY

Provide a minimum height of equipment allowing the "uid and safe movement of animals

The height of the equipment is the first factor determining the possibilities of co-activity with breeding (photos 20, 21 and 22). This is the first criterion mentioned by breeders with experience of grazing in a photovoltaic park. Indeed, a too low height of the infrastructures can of a hand to hinder the movement of animals, preventing them from expressing their natural behavior, especially for gregarious species.

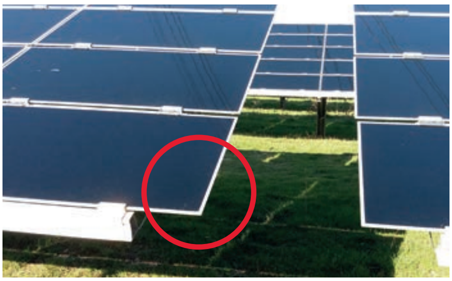
On the other hand, the equipment consists of corners and very angular metal supports that can present significant risk of injuries to grazing animals (photos 23 and 24). Abrasions on the contending edges can occur in particular during herd regrouping movements by a driving dog. The risk of injury to animals on photovoltaic equipment is indeed maximum during unexpected movements of the herd.

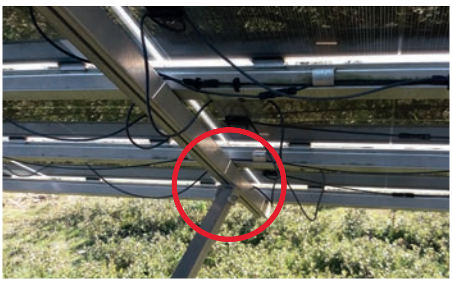
Finally, in the case of parks having panels installed too low, there is a risk of damage to the photovoltaic modules by animals, in particular in the case of thin-film modules. The risk of damage is increased when the grazing animals are goats or sheep able to stand up and rely on photovoltaic infrastructures.

Photo 20: Sheep that can pass entirely under the tables (© E. Mortelmans)

Photo 21: Sometimes very low table heights (<1 m) (© Idele)

Photo 22: Donkeys graze in a photovoltaic power plant with tables more than 1 meter away (© Jeson_AdobeStock)





Photos 23 and 24: Contendent supports and table corners that can injure animals (© Idele)

IN PRACTICE

The minimum height between the ground and the lowest point of the infrastructure must be adapted to the type of animal.

Taking into account the bibliographical references and experience feedback, a minimum height of 1 m is recommended for sheep. With regard to other ruminant species, the references and feedback are much less numerous. A dairy cow grazing experiment under photovoltaic panels is currently being carried out in Minnesota, with minimum heights between 2.40 m and 3 m. However, there has, to date, not enough perspective on the results of this experimental setup.

In all cases, whatever the type of ruminant, it is important to ensure that this is a minimum height at any point in the park and whatever the relief.

Provide a minimum height of equipment allowing the passage of agricultural machinery

Beyond the issues of animal welfare, the height of the photovoltaic equipment is a factor to be taken into account to facilitate the passage of agricultural machinery, to ensure the mechanical maintenance of the vegetation abandoned by the animals or to carry out operations. on the plant cover (reseeding in particular). Any mechanical maintenance that may be additional to the pasture is commonly done by the breeder using a brush cutter, which is very time consuming. The mechanization of weeding by the use of a tractor considerably reduces the on-call time compared to management with a brush cutter.

IN PRACTICE

The minimum height of 1 m between the ground and the lowest point of the panels recommended for sheep flocks leaves the possibility of a secure mechanical maintenance under the tables thanks to offset tools hitched to a tractor.

Photo 25: Too low control bars in a previous generation 1-axis tracker photovoltaic park (© Idele)

Photo 27: Invasive bushes not consumed by the ewes, ultimately harmful to the performance of the park (© Idele)

Photo 26: Damaged photovoltaic panel (© Andrei Merkulov / AdobeStock)

Photo 28: Meadow sown in a photovoltaic park (© Mortelmans)

Adapt the distribution of photovoltaic equipment in space

Row spacing of tables

An optimal photovoltaic plant (density of panels, piloting of trackers) is incompatible with normal agricultural production (except extremely rare exceptions). Managers must therefore accept a sacrifice in the design of the photovoltaic component. This sacrifice passes in particular by concessions on the density of panels *via* the spacing of the rows of tables in particular.

In the current state of knowledge, the ideal configuration is a sufficient spacing of the rows of photovoltaic tables to allow the passage of a tractor, in order to reseed a meadow if the repeated climatic hazards have damaged the vegetation (photo 29) or to weed mechanically with a rotary cutter if the maintenance by the tooth of the animal was not sufficient.

IN PRACTICE

Ideally, the spacing should allow the passage of a tractor of "medium" size so that the farmer does not have to buy specific equipment (mini-tractor, motor mower, etc.) for the mechanical maintenance of the machine. Park. The average width of a tractor with a hitched seed drill being about 3.50 m, considering a safety margin, the aisles between the tables should therefore have a minimum width of 4m.

Photo 29: Tractor traveling between the rows of a photovoltaic power plant in the United States (© Land Services - Now Monarch)

Positioning of the rows of tables in relation to the exterior fence

Still with the idea of allowing the passage of agricultural machinery, a minimum distance of 10 m is to be provided between the end of the row of photovoltaic tables and the exterior fence of the park. It is indeed important to leave sufficient space to allow the turning of agricultural machinery between two aisles.

Consider the location of equipment taking into account the grazing technique

The installation of the panels must also take into account the grazing technique envisaged for the maintenance of the park, namely dynamic rotating grazing (otherwise called techno-grazing or cellular grazing), classic rotating grazing or continuous grazing (otherwise called free grazing) (see description of techniques in part 6). Dynamic or classic rotating grazing techniques will in fact require redistributing the park with a mobile electric fence. The farmer must then be able to install fences without difficulty parallel and perpendicular to the rows of photovoltaic panels.

IN PRACTICE

In this objective of simpli "cation of the work of the breeder and to facilitate the division of the plots, the ideal is to add an alley perpendicular to the rows of tables every 120 to 150 m, in order to offer animals plots approaching the square shape to promote good use of space.

Stretched plots could indeed create differentiated zones: on the one hand an over-use and on the other an under-use of the space and hamper the maintenance of the vegetation. These new alleys do not need to be 4m wide because their purpose is only the passage of the breeder who may be equipped with a quad. The maximum width thereof being 1.50 m, an aisle width of 2 m is sufficient.

Choose a system for fixing the structures to the ground that has the least impact on the plant cover
Different types of ground assemblies are encountered in photovoltaic parks !: single-pile vs twin-pile tables, driven piles planted directly in the ground vs piles on a concrete base foundation (photos 30 to 32).

IN PRACTICE

The choice of technical ground mounting solutions depends on the nature of the soil, revealed by a geotechnical study of the site.

Ideally, if the ground conditions allow it, a ground mounting with single-pile tables is preferred. It provides flexibility in the maintenance under the tables, limiting the circumvention of the piles by the equipment.

When the situation is favorable, driven piles are also recommended rather than concrete footing foundations in order to limit the impact on the vegetation present.

Photo 30: Fixed bi-pile table on concrete slab (© Idele)

Photo 31: Single-pile double-tracker on a concrete slab (© Idele)

Photo 32: Fixed table on driven single-pile (© Idele)

PROTECT ANIMALS FROM ELECTRICAL EQUIPMENT

The protection of electrical equipment in the photovoltaic park is fundamental for the safety of animals.

Beyond the risk of electrocution by nibbling cables (photo 33), it is especially the problems of animal mortality by hanging that are mentioned by breeders. In fact, the link systems which allow the cables to be held together are degraded by the weather, the weather conditions and by the friction of the animals. Electric cables thus tend to hang down at many points in the pens, thus promoting mortality of lambs by strangulation (photos 34 and 35).

In addition, the presence of unsecured manholes on photovoltaic parks can cause injury problems on animals which would get a limb stuck in them (photo

37).

Photo 33: Electrical wiring left visible at low height that can be gnawed by animals (© Idele)

Photos 34 and 35: Electric cables tend to hang low behind panels, creating a risk of strangulation, especially in young animals. (© Idele)

At last, of made of lack of solid knowledge of the effect of electromagnetic waves on farm animals, it may be considered, as a precautionary principle, to maintain a distance of 2-3 meters between the main transmitting equipment waves (inverters, transformers) and grazing areas. This distance can possibly be established by means of mobile fences inside the park. It may also be advisable, if the surface of the park is sown, to avoid sowing near the main wave-emitting stations, so that the surroundings of these stations are not grazed areas.

IN PRACTICE

The greatest vigilance must be given to the protection of electrical equipment. All the cables of the system must be out of reach of animals or be protected with in particular as points of vigilance:

- the The sheathing of the electric cables at the installation of the park, with a fixing of the cables using cable ties and clips (photo 38).
- the The addition of screens to prevent the sheep from gnawing on any visible cables.
- the Before introducing the animals, check that there are no cabled installations in the shape of a "V". There should be no loops of cables hanging down.

Particular vigilance must also be given to the protection of manholes and other holes in the park.

Photo 36: Wiring left visible (© Idele)

Photo 37: Example of a manhole that may be present in a photovoltaic park (© Idele)

Photo 38: Example of fixing electric cables with cable ties at the back of a photovoltaic panel (© Idele)

LAY FENCES RELIABLE EXTERIORS AND ROBUST

Photovoltaic power plants are usually delimited on their perimeter by high metal fences, in order to limit intrusions (human or animal) into the park. By coming to graze in photovoltaic parks, breeders benefit from these fences. The delimitation and protection of the grazing area are indeed important issues for unguarded herds.

Pastoralists who already have experience of grazing in photovoltaic parks often notice problems concerning the fences of these parks. It is not so much the quality of the materials or the height of the fences that seem problematic, the fences having an average height of 2 m to 2.50 m. It is especially the solidity of the fences that is lacking, as well as their lack of waterproofing, in particular in photovoltaic parks with reliefs. Several breeders have thus encountered problems with “straight traced” fences, without going all the way to the ground in relief areas, allowing the entry of predators and / or the exit of farm animals (ewes or lambs).

IN PRACTICE

Fences with a minimum height of 2 m are to be preferred in order to protect animals from the risk of intrusion, in particular large predators.

The fences must match the relief, so that neither a predator nor the ewes can slip under the fence, i.e. a maximum ground-fence gap of 10 cm.

Arrangements for the passage of small fauna must be provided (photo 40). This equipment must allow the movement of small fauna, but must prevent the passage of potential predators (wolves, foxes).

Finally, the fence posts must be firmly anchored in a solid substrate, so that the fence remains effective at all points of the park.

Photo 40: Example of installation in the fence for the passage of small wild animals (© Idele)

Photo 39: DIY a breeder to fill the space under a fence to prevent animals from leaving the park (© Idele)

TO KNOW !

Photovoltaic parks are subject to landscape integration requirements, sometimes leading to the planting of plant hedges on the perimeter of the power plant. The movable fences put in place to intersect the park must rest on the fence around the park. In this case, it is strongly recommended to install the hedges outside the photovoltaic park to facilitate their maintenance and not to hinder the installation of mobile fences in the park.

(© Mike Mareen - AdobeStock)

Sheep grazing in the agrivoltaic plant of Parroc (© Voltalia)

Part 3

Equip the photovoltaic park with additional equipment specific to the livestock activity

The presence of animals in the photovoltaic park implies equipping the park with specific infrastructures necessary for the breeding activity (feeding, watering, restraint).
This equipment is mainly used to meet the basic needs of the animals and to guarantee their safety and well-being.

THE PANELS PROVIDE ANIMAL SHELTER

A photovoltaic park gives access both to very sheltered spaces but also to more open spaces at the edge of the tables. This diversity of solutions is conducive to the comfort of animals.

In addition, by limiting the temperature differences between day and night during the summer and by modifying the wind speed, photovoltaic tables induce a microclimate quite similar to that of a tree or a hedge, planting allowing animals to take shelter. The effect of photovoltaic panels is also sometimes assimilated to that of trees in agroforestry systems. The panels can therefore act as a shelter against cold winter winds and against strong summer heat (photo 41). So there is *a priori* no need for specific equipment in terms of shelter for animals.

TO KNOW !

Several managers build shelters or sheepfolds within or on the edge of the park to facilitate the breeding activity: distribution of food supplements, care, etc.

Arranging real shelters under certain sections of panels is also possible *via* waterproofing of the photovoltaic surface and closing the face exposed to the prevailing winds with a windbreak net.

Photo 41: Sheep grazing in the shade of the photovoltaic panels of the Verneuil plant (03) (© E. Mortelmans)

PROVIDE FORAGE POSSIBILITIES IN THE PARK

The aim of grazing in a photovoltaic plant is that the animals feed mainly on the vegetation available in the park, in order to ensure its maintenance.

However, the addition of additional fodder may prove to be necessary in the event that the grass is scarce and the photovoltaic park is far from other pasture plots (photo 42). However, it should be noted that fodder in photovoltaic parks remains a relatively rare practice, the breeders preferring to adapt the load (number of ewes in the park) to avoid the constraints linked to fodder.

Finally, it is also common to use troughs or a feeder to feed the animals with concentrates, in particular during the growth phase of lambs. These supplementation practices are quite feasible in a photovoltaic power plant and do not require any adaptation or special equipment.

Photo 42: Example of a feeding system found in a photovoltaic park (© B. Morel)

Photo 43: Haystack (© Lucca Mallone / Unsplash)

PROVIDE POINTS WATER SUPPLY FOR DRINKING

Farm animals need to be watered daily.

Depending on the number of animals and their physiological stage, the need for water may be substantial. For example, an untracked ewe drinks on average 3 liters of water daily and twice as much when it sucks a lamb (Table 1). For a flock of 100 ewes, the daily water requirement therefore varies from 300 to 600 liters.

In most cases, the photovoltaic parks currently in operation do not have a water point, it is the breeders who manage the water supplies to the animals by means of tanks, which generates a very important on-call workload. , reinforced when the photovoltaic park is far from the farmer's operating headquarters.

TO KNOW !

Rainwater collection systems flowing over the photovoltaic panels can be envisaged with gutters installed on a few tables (photo 44).

However, rainwater harvesting must not completely deprive the plant cover of the water supplies necessary for its development. Vigilance with regard to water quality must be increased in the case of rainwater harvesting intended for watering.

Photo 44: The runoff water flowing from the photovoltaic panels can constitute a resource for livestock (© Mariana Proenca, Pan Xianhze / Unsplash)

TABLE 1:
ESTIMATED AVERAGE WATER REQUIREMENTS FOR PASTURE ANIMALS * (SOURCE: MARTIN, 2019)

Animal type	Consumption mean	Consumption at the summer peak
Dairy cow (35 kg milk / day)	100 L / D	125 L / D
Suckler cow + calf	35 L / D	75 L / D
Broutard (200 kg)	15 L / D	20 L / D
Dry cow, pregnant cow, beef	35 L / D	70 L / D
Heifer (350-450 kg)	30 L / D	50 L / D
Dairy sheep	7 L / D	15 L / D
Suckler ewe + lambs Ewe	6 L / D	12 L / D
not monitored	3 L / D	6 L / D
Dairy goat	5 L / D	12 L / D
Dry goat	3 L / D	6 L / D
Adult horse	20 L / D	45 L / D
Lactating mare	30 L / D	55 L / D

* Daily water consumption considering a diet composed exclusively of grass.

IN PRACTICE

The issue of watering and access points to water should ideally be taken into account from the design of photovoltaic parks, in order to ensure the sustainability of the co-activity.

It is recommended to install a water line that crosses the photovoltaic park with connections at different points to have drinkers distributed in the different plots. It is recommended to install a water outlet for a maximum of 2 hectares, i.e. a water point 150 m away for animals. The valves to manage the arrival of water must be accessible to the breeder, as well as a water meter to assess the herd's water consumption and inform of any leaks. The drinkers can be placed at the interface between two plots to optimize their use.

Watering being an essential element of breeding, in quantity as in quality, it is recommended to have a water supply with a minimum flow of 4 to 5 liters / min. In addition, a control of the bacteriological and physicochemical quality of the water is advised if it comes from a private catchment.

Finally, it is imperative to check that no electrical current interferes with the water (electrical voltage of the water less than 150 mV).

Photo 45: Different factors influence water consumption by animals: it increases if food is dry, if the weather is hot, depending on the physiological stage and milk production of the animal (© Fabian Schneidereit / Unsplash)

PLAN A SYSTEM CONTENTION

In breeding, monitoring the herd requires frequent interventions with the animals, whether by the breeder or by outside workers.

To carry out these manipulations, which can be delicate, breeders need effective restraint to work in complete safety and to avoid accidents (photo 46). This containment yard can also serve as a loading / unloading yard for animals.

Photo 46: Sheep in a containment yard (© Isidoro Martinez / Unsplah)

IN PRACTICE

A fixed restraint makes it possible to build a solid park with inexpensive recovery materials (motorway barriers, railway ties, etc.). However, once in place, it will no longer be flexible.

A mobile restraint will be more adaptable. The photovoltaic parks are not always in one piece and can be far from other areas of the farm, the ideal is to provide for the provision of a mobile containment park.

The ideal for a good restraint is for the restraint pen to be made up of a waiting area, a restraining lane (with a cage or a blocking door) and an assembly pen. The containment pen must be adapted in its design and in the choice of materials to the type of ruminant animals grazing in the photovoltaic park.

Animals may feel frightened when approaching the park. It should therefore be positioned preferably on the usual circuits of animals !: close to watering points, the feeding area, the entrance to the park.

TO KNOW !

The interests of a containment pen are multiple, for the breeder as for the herd.

- the The animals are calmly controlled and maintained, which allows safe interventions for humans and animals.
- the This device is appreciated by external stakeholders (inseminators, veterinarians, etc.) for the safety it provides (the breeder being responsible for the good safety of these people during handling).
- the Since the interventions on the animals are simple to perform and less painful, the farmer is less reluctant to intervene on the animals, which has an impact on his technical results.
- the Grouping of animals is facilitated for loading or moving between the different islands.
- the The breeder does not need to hire someone from outside to help maintain the animals.
- the Handling in the pasture saves time and money, no need to use the livestock trailer to bring the animals back.

The restraint can also be used to temporarily remove the herd in the event of intervention by the maintenance service of the photovoltaic park.

(© Olexandr - AdobeStock)


Bioule (81) agrivoltaic plant (© Idele, plant managed by Neoen)