Ecovoltaics in Sweden

Views on integrating measures for biodiversity in solar parks

Master's Thesis in Industrial Ecology

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SUMMARY
In line with the process of society converting to renewable energy sources and the increasing levels of electrification, solar power becomes a more important and prevalent energy source. One part of the development in Sweden is the growth in size and numbers of solar parks. Another issue facing humanity is the looming biodiversity crisis addressed in COP 15. In Sweden the ground mounted solar parks might pose a risk to biodiversity, but also presents an opportunity with the implementation of ecovoltaics. Ecovoltaics is the dual land use principle of combining measures for biodiversity and solar power. This study therefore aims to investigate how solar parks in Sweden utilize ecovoltaics in their design and what the industry needs to implement ecovoltaics more widely as well as investigating existing and potential incentives for increasing ecovoltaics in Sweden. The methods utilized in this thesis were a literature search and an interview study, with the methodology of Systematic Text Condensation used to analyze the interviews. The study reached the following conclusions: the use of ecovoltaics has grown in recent years, all interviewees reported the use of some measures, the most prominent categories being aiming to avoid, minimize or offset impacts on biodiversity. The industry reported three actions as essential: *the development of more research and best practices examples*, *clear and national regulations* and *a standardized measurement system for biodiversity*. There are no subsidies for ecovoltaics specifically. Further, it was found that there is an opportunity to align investor and landowner interests with biodiversity through the use of economic incentives.

Keywords: ecovoltaics, biodiversity, solar power, solar parks, ground mounted PV

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Måns Ljungström and Johanna Hörnelius

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Glossary

English	Swedish
Agricultural Subsidies	Gårdsstöd
Agrivoltaics	Agrivoltaisk
Amphibian hotel	Groddjurshotel
Bathouse	Fladdermusholk
Birdhouse	Fågelholk
Building permit	Bygglov
Cairn	Stenrös
Construction trailer	Arbetsbod
Consultation Application	Samrådsansökan
Detail development plan	Detaljplan
Ecovoltaics	Ekovoltaisk
Environmental impact assessment	Miljökonsekvenbeskrivning
Insect hotel	Insektshotel och mulmholk
Meadowlike grassland	Ängsmark
The Swedish National Board of Housing, Building och Planning	Boverket
Wildlife fence	Viltstängsel

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1. Introduction

In modern times, it is clear that global warming is affecting the earth as a result of greenhouse gas emissions. A major portion of these consist of CO2 emitted from energy generation and transportation. In an attempt to combat this, society is going through a period of electrification, meaning not only does electricity generation need to shift from fossil fuels to sustainable sources, but also more electricity needs to be generated in total.

One of the proposed ways to meet these new challenges is by expanding our society's potential for solar energy. The most prevalent technology in the field is currently the photovoltaic system, often abbreviated PV (IEA-PVPS, 2021). PV-cells can be mounted almost anywhere and generate electricity, but one of the more prevalent arrangements are ground mounted power cells in concentrated areas called solar parks. Since the cells are usually mounted on poles, the ground in the parks is unutilized.

Another issue facing our society and planet is the loss of biodiversity. Biodiversity loss is one of the most pressing issues today and one that is strongly linked to climate change (United Nations, n.d.). In the Swedish context, when discussing biodiversity, one of the more pressing issues is the loss of meadowlike grassland (Naturskyddsföreningen, 2023). Meadowlike grassland are areas very rich in species and the loss of meadowlike grassland disproportionately affects the biodiversity in the area, mainly pollinators, which in turn impacts the Swedish ecosystems. One way to combat this is adapting solar parks to create a similar habitat to meadowlike grasslands by implementing measures for biodiversity. This practice of combining solar parks with measures to preserve or increase biodiversity is called ecovoltaics (Pettersson et al., 2022).

Combining solar parks with measures for preserving or promoting biodiversity has the potential to create positive impacts on two of the most pressing challenges that society is facing, minimizing CO2 emissions and at the same time minimize biodiversity loss. However, the concept of ecovoltaics is rather new in the industry. According to a study made in 2021 by Björnsson et al., (2022), where actors developing large-scale solar parks in Sweden, parks producing over 1 megawatt (MW), were asked about their parks, half of the respondents had implemented measures to promote biodiversity. One fourth of the respondents had also used sheep grazing for managing the vegetation in the park. There are still rather few large-scale solar parks in Sweden. In 2022, there were 64 solar facilities producing over 1 MW, connected to the electricity grid, compared to the total amount of solar facilities which were 147 691 (Energimyndigheten, n.d.). In 2021, ground mounted solar facilities contributed with 8 % of the total grid-connected solar energy production in Sweden (Lindahl & Oller Westerberg, 2021). A number that will most likely increase when the demand for renewable energy rises. To minimize the negative impacts on biodiversity from land use changes and increase biodiversity in Sweden, it is important that biodiversity becomes a natural part of the development of large-scale solar parks in Sweden.

Measures for biodiversity could potentially be associated with additional costs, more maintenance or be more time-consuming which profit focused energy corporations might not necessarily be interested in. To understand how the industry views the subject and investigate how ecovoltaics could potentially be more widely implemented in Sweden, this study analyzes the industry's attitude towards the subject, to understand what measures are used today, what barriers there might be for a higher implementation and what incentives, regulation or subsidies that potentially could be implemented to incentivize the adoption of ecovoltaics in Sweden.

1.1. Aim and objectives

The aim of the study is to investigate how solar parks in Sweden utilize ecovoltaics in their design and what the industry needs to implement ecovoltaics more widely. Also, the study aims to investigate existing and potential incentives for increasing ecovoltaics in Sweden.

To achieve the aim, the study set out to answer the following research questions:

- How is ecovoltaics implemented in solar parks in Sweden?
- What barriers does the industry see with implementing ecovoltaics?
- What additional costs occur when implementing ecovoltaics in solar parks?
- Which economic incentives that are in place to preserve or increase biodiversity can be applied to ecovoltaics in Sweden?
- What does the solar energy industry see as necessary for a higher implementation of ecovoltaics? What incentives or actions, from academia, authorities and the energy sector, are seen as necessary?

1.2. Scope and Delimitation

The report will be limited in scope, with the following major delimitations:

- This study will only investigate ground-mounted solar parks and will not include solar facilities on buildings or floating PV.
- This study will be focusing on ecovoltaics which includes grazing but excludes other forms of agricultural activity.
- This study will only investigate ecovoltaics in parks located in Sweden. Additionally, the study will only include economic incentives that could potentially be available for Swedish solar parks, including subsidies from the state, the European Union and potentially other organizations. However, good examples and potential incentives from across the world will be included for a deeper understanding of the subject and inspiration.

2. Background

In this section, background information about biodiversity, solar energy and solar parks are supplied in more detail. Also, information on the potential impacts from solar parks on the environment and the mitigation hierarchy is provided.

2.1 Biodiversity

Biodiversity is a term that describes a wide range of different diversities. The United Nations defines it as “The variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems”, from "The UN Convention on Biological Diversity : Follow-up in EEA Member Countries 1996" (1997). These broad descriptors can be broken down to mean the need for genetic diversity within species, species diversity within ecosystems and a broad range of different environments defining these ecosystems, both aquatic and terrestrial. Biodiversity is essential for the health of the planet and the human race (Final Text of Kunming-Montreal Global Biodiversity Framework Available in All Languages, 2022). Under current business as usual scenarios, biodiversity is set to decrease going into the future, mainly as a result of climate change and over exploitation. To combat this, the UN has negotiated the COP 15, agreeing to the final vision of “living in harmony with nature”.

To combat the loss of biodiversity, the European Union has enacted the “EU Biodiversity Strategy for 2030” as part of the EU’s “New Green Deal”, which contains four main strategic approaches, protect nature withing the EU, restore nature within the EU, enabling transformative change and supporting biodiversity globally (European Commission, 2021). Sweden, as part of the EU, is obliged to contribute to these goals.

Three of the EU’s biogeographical regions are today part of Sweden, “continental” mainly in and around Skania, “alpine” in the Scandes and the rest being “boreal” (Naturvårdsverket, 2020). Sweden has a number of Natura 2000 areas, roughly 4000, spread over each of these biogeographical regions. The most threatened type of habitat within Sweden is currently by far grassland, followed by costal dunes, marine habitats and forests.

Grasslands in Sweden are today assessed as having an overall unfavourable outlook on preservation. Additionally, most grassland habitats preservation status seem to have a negative development curve (Naturvårdsverket, 2020). The main factor driving this development is the modernisation of both agriculture and forestry. Due to a lack of profitability, natural pastures have become less attractive to use in animal husbandry. Without the grazing of animals or other management, open fields are threatened by overgrowth. To combat this trend, the management of open fields need to increase and the mosaic these areas create in the landscape need to be more connected.

Wetlands in Sweden are not in an as bad shape as the grasslands, with a majority of the habitats in this category having an inadequate preservation status as opposed to the unfavourable status. However, outside of the alpine areas, wetlands all show a negative development trend. This is, just as with grasslands, mainly caused by a lack of grazing or other vegetation management, causing overgrowth (Naturvårdsverket, 2020).

2.1.1 Ecosystem services

Biodiversity is essential for humanity in the sense that it contributes to creating ecosystem services. The EU defines ecosystem services as “Ecosystems services are the contributions of ecosystems to economic, social, cultural and other benefits that people derive from ecosystems” (Maes et al., 2021, p. 9). Ecosystem services can be categorized into four types of services, regulating, supporting, provisioning and cultural services (Millennium Ecosystem Assessment, 2005). The regulating services include, inter alia climate regulation, water and air quality regulation, pollination as well as pest and disease control. Provisioning ecosystem services include products that the ecosystem provides e.g, food, fresh water, medicine, materials and fuels for energy. Ecosystems also benefit humans through cultural services such as providing educational and aesthetic values, inspiration, space for recreation and increased social relations or eco-tourism. There are also supporting services which include photosynthesis, soil formation and nutrient and water cycling. These services do not directly affect humans but support the other categories which in turn provide services to humans (Millennium Ecosystem Assessment, 2005).

Changes in land use, climate change and biodiversity loss are all strongly connected to the decline of ecosystems and in turn also the reduced supply of ecosystem service. Globally, ecosystem services are estimated to be worth between 125-140 trillion US dollars each year (OECD, 2019). However, between 1997 and 2011 the economic losses from reduced ecosystem services due to land-cover changes and land degradation were estimated to USD 4-20 trillion and USD 6-11 trillion respectively, and the declining of ecosystems and biodiversity it still ongoing.

2.1.2 EU Biodiversity strategy for 2030

The Biodiversity strategy for 2030 is a long-term plan from the EU with the aim of reversing degradation of ecosystems and biodiversity and will contribute to the protection of nature and the recovery of biodiversity by 2030 (European Commission, 2021). For this aim, the EU has set out targets for 2030 including reversing decreasing levels of pollinators, creating protected areas out of 30 % of EU’s land- and 30 % of the sea areas, restore degraded ecosystems and create biodiversity-rich landscapes out of 10 % of the European farmland. The strategy was introduced on the 20th of May 2020 and has since then launched actions to help create a path towards the targets (European Commission, n.d.-a). One of the key actions within the Biodiversity Strategy for 2030 is the launch of the EU Nature Restoration Plan (European Commission, 2020)

The EU Nature Restoration Plan is a plan that aims to restore ecosystems and nature (European Commission, 2020). The plan includes a variety of commitments including strengthening the legal framework of the EU on nature restoration to minimize regulatory gaps for restoration, increase sustainable practices within agricultural land and bring back nature in these areas. Another focus is on soil ecosystems and restoring areas that have been poorly managed e.g., areas where there has been unsustainable farming or overgrazing. The EU Nature Restoration Plan also focuses on energy generation and how to find win-win solutions that can fight both climate change and at the same time biodiversity loss. One solution that is mentioned in (European Commission, 2020) is solar farms which implement biodiversity-friendly soil cover.

As one part of the Biodiversity strategy for 2030, the European Commission are proposing to establish a new law called the *Nature restoration law* which will aim to restore ecosystems that has been degraded and increase biodiversity, secure ecosystem services, limit global warming and increase resilience (European Commission, n.d.-b). The proposed law is a continent-wide law which will contain targets for a variety of ecosystems, habitats and species, from agricultural ecosystems to forest ecosystems to pollinating insects among others. With the Nature restoration law, Member States will have to submit national restoration plans for their country and are expected to report their progress to the European Commission.

2.2 Solar energy

To minimize the effects on global warming and climate change, greenhouse gas emissions have to be limited. For this to happen the world needs to reduce the use of fossil fuels and make a transition towards using renewable energy sources. This transition plays an important role in tackling the environmental problems that society is facing today. To tackle this, the Swedish parliament has decided upon energy targets for the future. This includes that 100 % of the electricity production should come from renewable sources in 2040 (Regeringskansliet, n.d.). This goal necessitates an expansion of renewable energy systems like solar power, wind power and hydropower.

Solar power is increasing every year in Sweden. Since 2016, grid-connected solar cell facilities have increased more than 14 times from 10 000 to over 147 000 facilities in 2022, from 140 MW to over 2,3 GW (Energimyndigheten, n.d.). Looking at large-scale solar cell facilities, the expansion went from 3 facilities producing over 1 MW in 2016 to 64 facilities in 2022. In 2022, solar power increased by 75 % compared to 2021 to a production of 2 TWh (Energimyndigheten, 2023b). However, the total electricity production from solar power still only contributes approximately 1 % of Sweden's total electricity production. With the goal of 100% electricity from renewable sources in 2040, the Swedish Energy Agency made a report with a proposed strategy where the scenario showed that 5-10% of the Swedish demand for electricity could potentially come from solar power (Energimyndigheten, 2022). However, for this scenario to be true, actions have to be implemented to promote solar power.

2.3 Solar parks

Larger solar facilities are becoming more common within the energy sector. These large-scale installations of photovoltaics, working as large generating stations which can produce high amounts of power to the electricity grid are called solar parks (Wolfe, 2012). Ground-mounted solar parks are large-scale installations of solar PV with panels usually constructed in arrays. The panels can be attached to the ground through different mounting structures, for example piles driven into the ground, concrete blocks or piers, or through earth screws (Lammerant et al., 2020). Solar parks can be designed in many ways, with variations in array width and heights, the direction of the arrays, how the arrays are mounted and the tilt angel of the panels.

Large-scale solar facilities like solar parks are still relatively new in Sweden, the first solar park with an effect over 1 MW was built in 2014 (Stridh, 2016). In 2021, ground-mounted solar parks contributed with 8 % of the total grid-connected solar energy production in Sweden (Lindahl & Oller

Westerberg, 2021). However, the development of solar parks is increasing rapidly both in Sweden and across the world.

One factor that could possibly have had an affect the expansion of solar parks in Sweden are the lead time. According to a report made by the Swedish Energy Agency (2018), lead times for solar power is usually shorter than for other energy technologies where lead times for other technologies can range between 5-10 years. In addition to the shorter lead times, other factors that potentially could explain the expansion of solar facilities and solar parks are public acceptance, accessibility to areas with low economic value and more affordable prices for the technology (Energimyndigheten, 2019a). The falling prices for PV have enabled the technology to become a competitive technology for energy production and the prices are assumed to continue to fall in the future.

2.3.1 Choice of location

Large-scale solar parks require large land areas for their establishment. Some of the factors that are mentioned in the literature to affect the choice of location for solar parks are the solar radiation and shadowing effects, connection and distance to electricity grid and low costs for the land area.

Solar radiation
When deciding on the location for a solar park, one important factor is the proportion of solar radiation. The amount of solar radiation differs throughout Sweden, from 750 kWh/m^2 in the north to 1050 kWh/m2 in the south (SMHI, 2017). To maximize energy generation per area the width and height of the panel arrays has to be designed properly to fit the topography and latitude in the chosen location (Wolfe, 2012). Another important factor is that the location is an open area to reduce the risk of shadowing the panels. According to Björnsson et al., (2022), when mapping solar parks over 1 MW in Sweden in 2021, the general rule was to use open areas with high solar radiation.

Connection and distance to electricity grid
From the study by Björnsson et al. (2022), according to the respondents, the two most important factors when choosing the location for a solar park were the price for buying or leasing land area and the distance to the electricity grid. To minimize the costs for the project, it is important that the park is located close to the grid. Long distances from the electricity grid can lead to high additional costs for the project (Energimyndigheten, 2019b; Wolfe, 2012). Also, it is important that the chosen site is located where the electricity grid has the capacity for the planned installation. If the electricity grid does not have capacity, there is a risk of additional costs from reinforcement of the electricity grid.

Price and type of land
In addition to the proportion of solar radiation and the distance to the electricity network and its capacity, another factor that affects the choice of location is the price of land. The price of buying or leasing land was one of the main factors when choosing location for large-scale solar parks, according to Björnsson et al. (2022). To make the solar park profitable, it is important that the economic value of the area is low (Energimyndigheten, 2019b). The choice may also depend on the current land use, which could affect the development of the project (Wolfe, 2012). The study by Björnsson et al. also showed that 65% of the large-scale solar parks in Sweden were built on agricultural land. Other land types that were used were open areas alongside roads or by closed airports, on industrial land or pastures.

2.3.2 Permits and regulations

There is usually no requirement for a building permit for solar parks in Sweden as long as the installation is not legally seen as a building (Energimyndigheten, 2019b). Usually, the only requirement is to apply for consultation with the County Administrative Board, according to the Swedish Environmental Code 12th chapter 6§ (12:6). The consultation is needed for measures done in nature that could substantially change the environment. However, there are a few elements that need a building permit even if the panels themselves do not need one. For example, there is a need for a building permit for transformer stations (Boverket, 2018). It can also be required to have a building permit for construction trailers (Boverket, 2022a).

If there is a risk that the solar park substantially affects or changes the environment, which includes damage to e.g., materials and natural resources, biodiversity or valuable environments, the developer has to apply for consultation according to 12:6 in the Swedish Environmental Code (Energimyndigheten, 2019b). The Consultation Application is submitted to the County Administrative Boards in the county where the park is planned. The application, according to 12:6 in the Swedish Environmental Code, refers to measures or activities which are not covered by any other permits or obligations within the Environmental Code (Naturvårdsverket, n.d.-c). The County Administrative Board have the right to demand that the developer prevent or limit the damage to the environment by taking necessary measures or they can decide to prohibit the activity if the damage to the environment is too high.

2.3.3 Potential negative impacts on biodiversity

One common foundation option for ground-mounted solar facilities are pile systems where panels are held up by piles driven into the ground. If using piles, the area being directly affected by the structure is minimal. This creates good opportunities for mitigating the impact on nature where biodiversity can be preserved or even increased. However, if solar parks are not planned or managed properly, there is a risk of negative impacts on the environment and the biodiversity in the area. Some negative impacts that may occur include loss or degradation of habitats, habitat fragmentations due to fencing and disturbance for wildlife (Lammerant et al., 2020).

One common consequence from land use changes is habitat loss and by occupying land for solar parks, there is a risk of negative impact on habitats and species in the area (Blaydes et al., 2021; Lammerant et al., 2020). Aside from the direct consequence of habitat loss from changes in land use, habitat may also be degraded or transformed when the environment is changed into a solar park. According to New Jersey Department of Environmental Protection (2017) some potential consequences from solar parks on the environment are reduced vegetation and infiltration, increased runoff, lower air and water quality, lower soil activity and compaction of soil. Furthermore, the panels may also lead to changes in microclimate by affecting shadowing, rainfall distribution as well as changing the temperature, which could impact the growth of vegetation (Lammerant et al., 2020). Furthermore, by habitat loss or degradation, solar parks may create barriers for species to reach suitable habitats in other areas.

Barriers can be created by fencing off areas, commonly done around solar parks, which can lead to fragmentation of habitats (Lammerant et al., 2020; Lovich & Ennen, 2011). It can also create barriers for genetic exchange between populations through obstructing movement (Lovich & Ennen, 2011). Also, because of fencing and fragmentation, there is a risk of reduced feeding and resting places for wildlife (Lammerant et al., 2020).

In addition to habitat loss, degradation and fragmentation of habitats and species, other consequences that may occur in solar parks, mainly during the construction phase, could be disturbance from noise emissions (Lovich & Ennen, 2011). The consequences from noise emissions may include increased levels of stress in wildlife, changes in their behaviors and habitat use and reduced immune systems and reproduction. Another potential negative impact on the environment from the construction phase could be that with clearance of vegetation or earth movements, habitats for invasive species may be created (Lammerant et al., 2020).

The potential negative impacts on the environment from solar parks creates a risk for reduced biodiversity in the area. This could in turn lead to effects on ecosystem services. According to Råberg et al. (2021) solar parks risk reducing supporting ecosystem services like photosynthesis or biogeochemical cycles due to changes in water or light access under the panels. Also, regulating ecosystem services may be endangered as a result of this. With changes in soil composition, biomass or reduced biodiversity in the area, consequences like weakened regulation of water and air quality, risk of poor water flow regulation or reduced carbon storage may occur. Solar parks could also have negative effects on pollinator populations through land use change and damaging of habitats for pollinators (Blaydes et al., 2021). Pollination is another important ecosystem service that provides benefits to humans through for example contributing to securing and improving food production, wild plant populations and helping preserve ecosystems.

Solar parks may also risk having an effect on cultural ecosystem services by creating barriers for pedestrians, changing the landscape view or affecting the esthetic or recreational value of an area.

2.3.4 Opportunities for biodiversity in solar parks

Despite the potential negative effects including habitat loss or degradation, fragmentation or disturbance, the characteristics of solar parks could potentially also create good opportunities for preserving or even promoting biodiversity in the area. As mentioned earlier, the area used for the construction is usually very small. According to (BRE, 2014), if piles are being used, 95% of the area in the park is not disturbed by the construction, where the piles and the additional infrastructure occupy less than 5% and 1% respectively. Meaning that 95% of the area could be utilized in other ways, for example by vegetation growth or other measures for biodiversity. In addition to the large area unutilized by the construction, creating good opportunities for vegetation to grow under and around the panels, solar parks usually have relatively low human activity that creates an environment without disturbance for wildlife. Also, because of the long operation time of solar park, at least 20 years, the area will be protected from other disturbance over a long time. This creates good opportunities to establish habitats for wildlife which could work as havens (Parker & Monkhouse, 2022).

Solar parks, if planned and managed properly, also have the chance to not only preserve the existing biodiversity, but if built in an area with low biological values, increase biodiversity as well. One common type of land that is often used for solar parks in Sweden is agricultural land (Björnsson et al., 2022). Agricultural land that has been used for production and where fertilizers have been commonly used usually has very nutritious soil that often only suits a small variety of species (Pettersson et al., 2022; Råberg et al., 2021). Turning agricultural land into solar parks could reduce intensively managed land with few species into less nutritious land, by not using fertilizers and herbicides, with conditions that suit a variety of species instead of monocultures.

The characteristics of solar parks create good opportunities for biodiversity. By preserving or creating a high plant diversity in a park, valuable habitats could be developed which could provide a large range of species, for example insects, reptiles, birds and small mammals, with benefits like shelter and feeding areas (Parker & Monkhouse, 2022). With higher biodiversity, ecosystems could become more resilient to adverse effects from climate change and also enhance ecosystem services.

2.4 The Mitigation Hierarchy

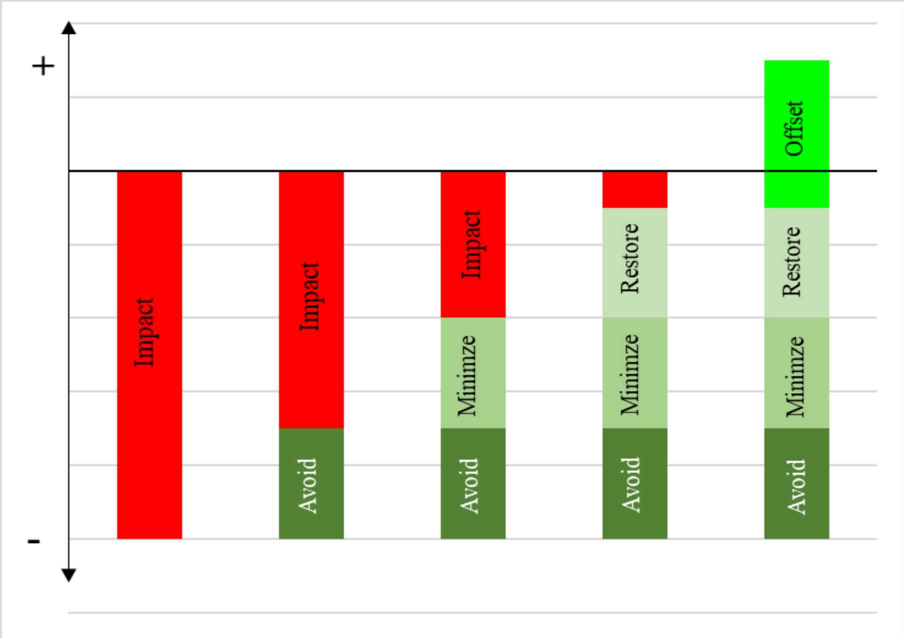
The mitigation hierarchy is a useful tool for contributing to biodiversity and preventing its loss. For maximum effect Pettersson et al. (2022) recommends that the tool should be utilized early in the process of constructing a solar park, as early as the planning stage if possible. Through its use, the mitigation hierarchy minimizes the environmental impact of a construction project and aims to potentially provide a net gain.

The principles of the mitigation hierarchy, in order of importance: firstly, vulnerable areas and ecosystem features should be avoided to as large an extent as possible. Secondly, any impact should be minimized. Thirdly, any damage incurred should be restored. And lastly, any residual impacts should be offset. This is illustrated in Figure 1.

Avoidance is most effective when implemented early in the planning stage but can be utilized during construction and end-of-life as well. It is based on identifying and avoiding, both spatially and temporally, potential impacts from the project on the environment (Bennun et al., 2021). The second principal, minimization, generally refers to the possibility of reducing the duration, intensity or extent of impacts. Minimization can be applied during several steps of the project cycle of the solar park, from the project design phase to the end-of-life phase. The principle of restoration, in the context of the mitigation hierarchy, refers to the restoration of habitat and ecosystem features that were damaged by the project, despite the application of avoidance and minimization, to their pre-project state. In this context, it only refers to the repair of features on their original location, not compensatory measures in other locations. Restoration is performed during construction or during the end-of-life phase.

The offset measure differs from the other principles, in that it is not only meant to compensate for the damages created but create additional biodiversity (Bennun et al., 2021). It is meant to offset any impact not mitigated by the other principles. Offset aims to achieve this by creating new habitats in the same, or another, location as the project. Additionally, offset measures can be implemented at any time during the project's lifetime.

Figure 1. Graph illustrating the temporal flow of the 4 principles of the mitigation hierarchy, avoidance, minimization, restoration and offset. The impact on biodiversity is on the X-axis and time is on the Y-axis. Modified from "Figur 4" in Pettersson et al. (2022).



2.5 Best practise guides for ecovoltaics

Guidelines and best practice reports can work as incentives for increasing biodiversity in solar parks where stakeholders and actors within the solar industry can get inspiration and knowledge in how solar parks can benefit biodiversity and what measures are suitable to implement in parks. Some reports and manuals are presented below.

Ecovoltaics and agrivoltaics – a manual on solar parks that benefit biodiversity and ecosystem services

Ecovoltaics and agrivoltaics – a manual on solar parks that benefit biodiversity and ecosystem services (original title "*Ecovoltaics och agrivoltaics - en handbok om solcellsparker som gynnar biologisk mångfald och ekosystemtjänster*" translated by the authors) is a manual created by the Research Institutes of Sweden (RISE) together with Ecogain AB and was published in October 2022 (Pettersson et al., 2022). It is a manual with guidelines for how to create solar parks with no impact or a positive impact on biodiversity, ecosystem services or cultivation. The manual is part of the project Eko-Sol which was preformed between 2020 and 2022 by RISE and Ecogain AB and was financed by The Swedish Energy Agency (RISE, n.d.). Except for the manual, the project also includes a mapping of solar parks in Sweden, a survey about large-scale solar parks, a literature study and a case study.

The manual was created to help actors working with large-scale solar parks to create parks that can have a positive effect on biodiversity and ecosystem services such as cultivation or animal husbandry (Pettersson et al., 2022). It includes guidelines for both ecovoltaics and agrovoltaics, combining solar parks with measures for agriculture. According to Pettersson et al. (2022), the guidelines are primarily written for entrepreneurs in the solar energy industry, but also actors working with biodiversity and ecosystem services within County Administrative Boards and municipalities, interested land or property owners could use the guide for building biodiversity positive solar parks.

The manual offers guidelines and recommendations on how to work in the different stages of solar park development, from planning to building, managing and dismantling of a solar park to benefit biodiversity and ecosystem services (Pettersson et al., 2022). It also includes lists of actions and measures for ecovoltaics and agrovoltaics that are suitable to implement in solar parks. Furthermore, the manual includes a chapter on technical solutions for ecovoltaics and agrovoltaics.

Solar, Biodiversity, Land Use: Best Practice Guidelines

Solar, Biodiversity, Land use: Best Practice Guidelines (SolarPower Europe, 2022), is a report developed by SolarPower Europe together with co-author BirdLife and was published in October 2022. SolarPower Europe is a member-led association for the solar PV sector in Europe, representing over 280 organizations and works as the link between the solar PV sector and policymakers to work towards solar becoming the leading energy source in Europe (SolarPower Europe, n.d.).

The report is developed to work as a guide for stakeholders within the solar industry to provide information and recommendations about the synergy between solar PV and biodiversity. This, is done through providing information about EU regulations that are relevant for solar projects and also on environmental protection. The guide also includes how these are being applied in different EU Member States through case studies. The report identifies suitable land types for solar projects and provides a toolbox for stakeholders to help identify suitable land for solar projects. The guidelines also include best practices and examples from sites in Europe where measures have been used. Furthermore, the guide offers information about measures throughout the different phases of the project.

Realising the Biodiversity Potential of Solar Farms – A Practical Guide by Wychwood Biodiversity and Naturesave Insurance

Realising the Biodiversity Potential of Solar Farms – A Practical Guide by Wychwood Biodiversity and Naturesave Insurance is a guide developed by Wychwood Biodiversity and Naturesave Insurance (Parker & Monkhouse, 2022). It is written by Dr Guy Parker and Joseph Monkhouse from the consulting group Wychwood Biodiversity and the guide was edited and published in April 2022 by Naturesave insurance. The guide was developed through information gathering from many sources that includes experiences from the team at Wychwood Biodiversity, solar farm owners and communities, conservation NGOs, landscape companies, Wildlife Trust and Buglife.

The report is a practical guide for stakeholders owning or responsible for managing solar parks with the aim of providing guidance on how to enhance biodiversity within parks (Parker & Monkhouse, 2022). It provides information about how solar parks can benefit biodiversity and gives practical guidance in how to plan and design parks for increased biodiversity. Furthermore, it offers information on how to create and manage wildlife habitats within the park and includes information about monitoring biodiversity in solar parks.

IUCN - Mitigating biodiversity impacts associated with solar and wind energy development - Guidelines for project developers

Mitigating biodiversity impacts associated with solar and wind energy development - Guidelines for project developers is a book published in 2021 by The International Union for Conservation of Nature (IUCN) and The Biodiversity Consultancy and is a guide for project developers within solar and wind energy to mitigate their impact on biodiversity and ecosystems (Bennun et al., 2021). The guidelines are directed towards project developers, operators and investors of solar and wind energy projects. However, the guidelines could also be used by a variety of stakeholders within the field such as governmental authorities and policymakers or non-governmental organizations.

The aim is to provide information and knowledge through practical solutions and good practice approaches for mitigating impacts on biodiversity (Bennun et al., 2021). The guide uses the mitigation hierarchy as a basis and provides tools and approaches on how to work with the different stages of the hierarchy to minimize the negative impacts on biodiversity and ecosystems, through all phases of the project. The guide also supplies information about how projects within solar and wind potentially could impact biodiversity and how to work both proactively with measures for avoidance and minimization but also measures for restoration and offsets. Furthermore, the guide includes a list of case studies from solar and wind energy projects, which supports the guidelines.

3. Method

To be able to answer the research questions, a literature search and interview study was performed. The study was done in five parts. The first part was the literature search, collecting data for the background and result. The second part was constructing an interview guide, using the literature search and through meetings with experts on ecovoltaics. The third part was contacting actors within the field of Swedish solar parks. The fourth part was to conduct the interviews. The last part was to analyze the interviews using Systematic Text Condensation.

3.1 Literature search

A literature search was conducted to gather information complimentary to the results of the interview study. It also contributed to the background in the previous chapter. The literature gathered was on the topics of solar power, biodiversity, biodiversity in solar parks and ecovoltaics. The search was initially preformed using Scopus and Google Scholar. Thereafter, the snowball sampling, using the sources of found sources to find more information, was used to gather additional information. Grey literature and reports published by governmental authorities and intergovernmental organisations was also directly sought out.

3.2 Interview guide construction

With the help of the information gathered during the literature search and the research questions, an interview guide was constructed. The guide was divided into 6 topics to help direct the flow of the interview. Interview questions were constructed and ordered within each of these topics. The chosen topics are as follows, introduction, choice of location, measures for biodiversity, barriers, economic incentives and closure. The questions were designed to be open ended, to facilitate a semi-structured interview. Two meetings with experts on ecovoltaics were held to get inspiration for the questions in the guide. The interview guide is provided in Appendix 1.

3.3 Contacting the interviewees

To get in contact with actors within the solar power industry two main strategies where utilised. The first was to target companies having produced solar parks with effects over 1 MW. To reach these actors their PR-departments or receptions were contacted through email or telephone and asked if anyone at the company wanted to be interviewed for the project. The second method used was to ask the ecovoltaics experts consulted during the interviewed guide construction for recommended contacts within relevant solar power actors. In total 17 actors were contacted and 13 actors agreed to participate.

3.4 The interviews

Thirteen semi-structured interviews were conducted as the primary means to gather information for the result. The interviews where all conducted remotely using Zoom except for two which were held via telephone. All interviews were held in Swedish and all interviewees where fluent in the language. The length of the interviews ranged from 30 to 75 minutes, with most falling in the 45–60-minute range. The interviewees where all given the option to remain anonymous. All the interviews were recorded and transcribed utilising the automatic transcription tool in Microsoft Word and was subsequently proofread and corrected manually.

The interviews followed the interview guide but as the main questions were formulated to be open ended follow up question where asked when deemed appropriate. A neutral stance was held through all interview to avoid influencing the interviewees.

Of the interviewees, seven had constructed a solar park and out four of them owned the park. Fiver interviewees had not yet constructed any solar parks, though they had projects in the development phase. One of the interviewees represented an organisation.

Of the 13 interviews that were conducted, seven of the participants had already constructed at least one solar park producing over 1 MW, where four of these owned their own park (A1, A2, A3, A4) and the remaining three had only built parks but did not own the parks themselves (B1, B2, B3). Five of the remaining participants had not yet constructed any solar parks in Sweden however, they had projects in the planning or development phase (C1, C2, C3, C4, C5). One of the participants represented an organisation (D1).

3.5 Systematic Text Condensation

In order to analyze the gathered material, the methodology of Systematic Text Condensation (STC), developed by Kristi Malterud (2012) was used. STC consists of four distinct steps, total impression, identifying and sorting meaning units, condensation and synthesis.

During the first step, total impression, all transcripts from the interviews were thoroughly reviewed individually, with no communication between the co-authors. There was no attempt at systematization of the material. Rather, a total impression of the material was developed, and common themes throughout the material were identified and compiled into a list. The themes identified by the co-authors were then compared and differences and commonalities were discussed, and a list of themes were finally compiled. Lastly, themes not deemed to contribute to the research questions were removed.

During the second step, identifying and sorting meaning units, all transcripts were read through again. This time the themes identified during step one were kept in mind and meaning units, parts of the text that contain some information about the research question, were identified and copied into lists associated with the theme or themes they were deemed to align with most closely. During this step, themes are kept loose. Similar themes were allowed to merge, and too broad themes were allowed to be broken up into new themes.

During the third step, condensation, the meaning units within each theme were sorted into subgroups that each have a different perspective on the theme and contributing to the research question. By reviewing each meaning unit within the subgroups their content and meaning can be combined into a condensate, an artificial quotation maintaining, as far as possible, the original terminology of the interviewees. The condensates are written in first person.

During the fourth step, synthesis, the condensates of a theme are synthesized into a final analytical text written in third person. The texts were meant to collect and encompass the interviewees experience and present it as the finalized result. These were accompanied by a title given to each synthesized text, which provided a quick overview of the findings of the study and are presented in Chapter 4. The synthesized texts were finally checked towards the original transcripts to make sure the texts accurately represented the interviews.

4. Result

In this chapter, the results from the literature search and the interviews are presented. For the subsections 4.1.1 and 4.4.1 the findings from the literature search are presented first, followed by the results from the interviews. All quotes were translated from Swedish to English by the authors.

4.1 Implementation of ecovoltaics in solar parks

In this section, measures for preserving or promoting biodiversity in solar parks are presented, both measures that can be found in literature and measures commonly used or mentioned by the interviewees. The measures discovered in literature are listed and described in Table 1-4. The measures have been grouped in accordance with the principles of the mitigation hierarchy. In Section 4.1.2, measures used by the interviewees has been analyzed and presented in the three subgroups in accordance with the principles of the mitigation hierarchy, avoidance measures, minimizing measures and offset measures. The third principal, restoration, was left out because no measure pertaining to this principal were mentioned during the interviews.

4.1.1 Inventory of measures for ecovoltaics

In this section, measures for biodiversity in solar parks discovered during the literature search are provided. The measures have been categorized in accordance with the principles of the mitigation hierarchy the authors deem the measure to align with most closely. All measures were sourced from the best practice guides in 2.5 and are displayed in Tables 1-4.

Table 1: Avoidance measures

Park design	Designing the layout of the park in a manner that avoids damage to ecosystem features (Bennun et al., 2021; Pettersson et al., 2022; SolarPower Europe, 2022).
Scheduling	Timing construction of the park to avoid disturbing natural cycles (Bennun et al., 2021; Pettersson et al., 2022).
Site selection	Avoiding sensitive areas early in the planning phase and potentially comparing viable alternatives from a biodiversity perspective (Bennun et al., 2021; Pettersson et al., 2022; SolarPower Europe, 2022).

Table 2: Minimization measures

Avoid temporal disturbances	Timing upkeep of the park to avoid disturbing natural cycles (Bennun et al., 2021; Pettersson et al., 2022; SolarPower Europe, 2022).
Protect sensitive areas within the park	Designing the park to keep construction and park equipment a safe minimum distance from vulnerable areas (Bennun et al., 2021).
Reduce compaction	Compact soil inhibits the growth of plants and can be caused by heavy machinery. Reducing the area or amount of compaction is beneficial for vegetation growth (Bennun et al., 2021).
Reduce output of light, noise and chemical pollutants	Reducing light and noise pollution creates a calmer environment for wildlife. Chemical pollutants are rare in solar parks, but potentially hazardous none the less. (Bennun et al., 2021; SolarPower Europe, 2022).
Reducing habitat fragmentation	Not dividing existing natural habitats, such as using fences that allows for wildlife passage (Pettersson et al., 2022; SolarPower Europe, 2022).

Table 3: Restorative measures

Post-construction restoration	Repairing biodiversity features damaged by the project as soon as construction of the park finishes (Bennun et al., 2021).
Post-use restoration	Restoring the park to its pre-developed state by repairing biodiversity features damage by the project (Bennun et al., 2021).
Restoring vegetation	Replanting of original vegetation to the extent possible, following decommission of the park (Bennun et al., 2021).
.Un-compact soil	Uncompacting the soil after the parks use-phase ends. Allows for plants to grow their roots more easily (Bennun et al., 2021).

Table 4: Offset measures.

Build amphibian hotels	Construct and deploy shelters for amphibians where amphibians can overwinter or find shelter (Pettersson et al., 2022; SolarPower Europe, 2022).
Build bird- and bathouses	Construct and deploy bird- and bathouses for the benefits of local bird and bat species respectively (Pettersson et al., 2022; SolarPower Europe, 2022).
Build insect hotels	Construct and deploy insect hotels for the benefit of local insect species (Pettersson et al., 2022).
Create sandy environments	Provides a habitat for plants, some fungi and insects, especially bees and bumblebees (Pettersson et al., 2022).
Establish flower beds	Relies on a meadowlike grassland having been established. Planting meadow flower appropriate for the region provides feedstock for pollinators, who are currently in low numbers in Sweden (Parker & Monkhouse, 2022; Pettersson et al., 2022; SolarPower Europe, 2022)
Establish grazing	Relies on a meadowlike grassland having been established. Grazing helps establish a natural cycle in the grassland and benefits all animals who has grassland as its primary habitat (Pettersson et al., 2022; SolarPower Europe, 2022).
Establish meadowlike grassland	Planting meadow grasses appropriate for the region and cutting and removing grass creates a habitat for animals who rely on meadowlike grassland, especially pollinators (Pettersson et al., 2022).
Leave old and dead wood	Placing a pile of wood pieces of various sizes in a non-obstructive location within the solar park (Pettersson et al., 2022).
Place cairns	Placing cairns creates habitat and shelter for reptiles, insects and other invertebrates (Pettersson et al., 2022).
Plant trees and bushes	Trees and brushes create habitats for insects and birds and can create a green corridor. Trees might however shade the installations and reduce output (Parker & Monkhouse, 2022; Pettersson et al., 2022; SolarPower Europe, 2022)
Restore ditches and streams	Creates an aquatic environment for aquatic plants, amphibians, insects and other invertebrates (Pettersson et al., 2022). Low lying wetter areas are usually not suitable for construction and highly suited for ditches or streams (Parker & Monkhouse, 2022).

4.1.2 Ecovoltaics in Swedish solar parks

The analysis from the interviews showed that all interviewees had worked with some measure for either preservation or promoting biodiversity. Most interviewees mentioned that biological values are important when screening for locations and where areas with high biodiversity usually are avoided. The interviewees also brought up minimizing measures with the most common ones being leaving trees and vegetation standing in the park if possible, keeping distance to sensitive habitats and working with wildlife fences that reduce the risk of fragmentation and creating barriers. For offset measures, sowing flowerbeds or establishing grasslands were often mentioned. Also, establishing sand dunes and log piles from old and dead wood were commonly mentioned measures. There is a desire to use sheep grazing in the parks for managing vegetation, however, some of the interviewees are uncertain about logistics and the feasibility of sheep grazing.

Avoidance
Most of the interviewees mentioned that they work a lot with site selection, either through an internal mapping tool or using GIS. Through these tools they avoid sites with public and national interests, such as Natura 2000 areas and other areas designated to have high biodiversity. The interviewees who did not use a tool like the ones mentioned above, reported that they only look for land in a very limited area. After a site has been selected an ecology consultant visits the site and determines if the site contains high biodiversity, or if there are red listed species present. If this is the case, then the development of the site is stopped. These measures ensure that areas with high biodiversity are avoided.

Minimizing
Most of the interviewees reported that they apply some sort of minimizing measures. These include leaving trees and other vegetation within the park to provide various habitats, or keeping a safe distance to other micro habitats, like cairns and ponds. This can create wildlife corridors through the park and minimize fragmentation. The use of wildlife fences or the lack of fences all together are also used to minimize fragmentation, and most interviewees reported one of the two. Often it was also reported that the timing of cutting and trimming the grass is adapted to avoid the breeding times of ground nesting birds and that of spawning amphibians. Grass is still not allowed to grow high enough to shade the PV cells.

Offset measures
Out of the 13 interviews, 7 participants had already built larger solar parks in Sweden at the time of the interviews while many of the remaining interviewees were developing projects for large-scale solar parks. From the interviews with actors who have built solar parks today the most commonly mentioned offset measures were establishing flowerbeds or meadowlike grasslands, creating sandy environments and dunes, leaving old and dead wood and create log piles within the park as well as placing bird nests around the parks. The most common measure was to establish some type of flowerbed or meadowlike grasslands, but the choice of sown species might differ depending on the location. Leaving old and dead wood in the area or creating piles with dead wood was seen as one rather easy measure according to the interviewees. They argued that by leaving trees that had to be cut down for the installation or that the landowners had access to, this can be used to create a good offset measure. Except for the above-mentioned measures, other measures that some of the interviewees had implemented included planting hedgerows, creating insect hotels and placing beehives in the park.

For the interviewees that are developing projects and planning to build solar parks the most common measures are the same as for the ones that are already in place, establishing flowerbeds and grasslands, creating sand dunes and piles of old and dead wood. These measures are mentioned by the majority of the interviewees. A few of the interviewees also mentioned measures like bee hotels, insect hotels and birding nests as measures that are planned to be implemented. Also establishing wetlands and avoid fencing are measures that are planned in some parks. Except for these, some measures that were also discussed by a few interviewees are tree corridors to reduce barriers, creating ponds or place cairns.

Many of the interviewees discussed sheep grazing as a measure for biodiversity in solar parks. However, only a few of the interviewees mentioned that they use sheep grazing for managing the vegetation around and under the panels. Of the interviewees that discussed sheep grazing, there is a desire to be able to use it, however arguments like problems with logistics and transportation, need for careful planning as well as scheduling to fit with the vegetation growth are all mentioned as barriers for using sheep.

4.2 Identified barriers for a higher implementation of ecovoltaics

The barriers for a higher implementation of ecovoltaics that were brought up is the lack of knowledge about biodiversity, lack of clear rules and regulations, difficulties because of site specifics conditions and lack of prioritization for biodiversity within the industry. The interviewees see lack of knowledge as one of the main barriers for a higher implementation, for project developers, investors but also policy makers and county regulators. The lack of knowledge leads to uncertainties about implementing measures for biodiversity. The interviewees also see the lack of clear rules and regulations as one of the barriers, leading to differences in interpretations and uncertainties about what is expected of the project developers. Most interviewees mentioned specific conditions for each site as a barrier, creating uncertainties in how to create national rules that suit all locations. The last barrier discussed by the interviewees was the lack of prioritizing for biodiversity, that the industry is prioritizing other factors before biodiversity both within companies and their business models but also for landowners and investors.

4.2.1 Lack of knowledge

All the interviewees mentioned lack of knowledge as one of the main barriers for the industry to overcome. This deficiency is industry wide and on all levels of the project development chain, project developers, investors, and county regulators. Very few within the sector are biologists or ecologists, most mentioning that they are engineers and economists and therefore lack the expertise to work with biodiversity. The actors therefore must rely on external expertise.

"Most of us who work here are not biologists or experts in biodiversity, so the intent is to actually let people who are good at this stuff give suggestions"
- C3

Lack of knowledge results in uncertainties with regards to what measures to implement in what location. A few even expressed concerns about the effectiveness of implementing any measures at all. This was believed to be compounded by the inability to measure biodiversity.

The leading contributing factor mentioned is the relative youth of the industry, with very few effective Swedish examples demonstrating the success of implementing ecovoltaics. Some of the interviewees voiced a belief that with time the issue would resolve itself with one mentioning that most of the larger solar parks have been built within the last year and the long-term effects of the implemented measures in these parks have not yet been seen.

4.2.2 Lack of clear rules and regulations

Most interviewees see the lack of clear rules and regulations for solar parks as one of the major barriers for a higher implementation. These interviewees expressed their concerns about the absence of clear rules for solar parks as a cause for uncertainties in the planning process of solar parks. The absence of clear rules and regulations leads to different interpretations of the regulation that is in place today, which is the Swedish Environmental Code (12:6), both between different County Administrative Boards but also for the developers of solar parks.

"There are specific writings in the The Swedish Environmental Code, different regulations regarding wind, we lack that and that is precisely what causes County Administrative Boards in Sweden to have a little trouble interpreting the Environmental Code and the various regulations in a legally secure manner"

-B2

A few of the interviewees also mentioned the broad definitions of the words biodiversity and environment as a problem when trying to interpret the Environmental Code. Another argument that was brought up was the uncertainty about what should be included in the permit application when this can vary greatly between counties.

4.2.3 Importance of site-specific conditions

Some of the interviewees believe that another hindrance could be that every site has its specific conditions, making it difficult to have the same requirements for all locations and counties. What implementations suit the location depends on the site's specific conditions and the impact on the landscape. They believe that implementations should be selected according to the conditions and needs on the site and not just because of regulations, creating problems with too specific rules and regulations for biodiversity in solar parks.

"We want it [implementations] to be based on the needs or the possibilities that really exist, not what we think will be good"

-B2

4.2.4 Lack of stakeholder interest

Most of the interviewees also brought up the lack of interest or priority of biodiversity from the involved stakeholders as a barrier. Arguments that were mentioned are that biodiversity might not be as highly valued as profit, that some actors prioritize maximizing energy production and not biodiversity as well as the industry’s lack of knowledge because biodiversity is not their main focus.

“A whole chain is needed. The person who is responsible for the service must be able to offer these services in a way that creates biodiversity but those who buy must also understand that they have to pay for it because it is a very small amount of money to create a very large value”
- B3

Most of the interviewees lease land from landowners. Some interviewees expressed the importance of the landowners’ interest in the subject, where it is important to find landowners that are interested in creating biodiversity and biological values in the area. They also believe that the landowners could make demands for preserved or increased biodiversity.

In addition to the need for interested and willing landowners, another barrier that is mentioned is the lack of interest or knowledge from investors. A few of the interviewees also explained that there might be a risk that investors will not be interested in funding projects where the legal requirements for biodiversity are too high.

Some of the interviewees also brought up the structure of organizations and companies as a potential barrier for higher implementation of measures for biodiversity. They discussed how the business models or structure of the organizations might become a barrier if there is not a role or actor who can prioritize and make time for biodiversity within the organization or company.

At the same time as the organization's structure or priorities might become a barrier, many of the interviewees mentioned that they do have an interest and curiosity for the subject. They also work to increase their knowledge and want to invest in biodiversity in solar parks.

“It feels like the issue is very much relevant as of late. Not only for us but for others as well. People are talking more and more about, for example, sheep grazing or how it can be used. Also, pastures in parks and in general there is a great interest from others within the industry”
- A1

4.3 The costs of ecovoltaics

Most interviewees answered that there is little to no additional costs when adapting solar parks to ecovoltaics. This means that the costs for measures are extremely small compared to the whole project and revenue. One important factor to lower the costs for measures is to acquire the right knowledge, which can be done by consultation with ecologists or biologists who have the knowledge or by cooperating with non-profit organizations within biodiversity. One ecovoltaics measure that was mentioned as potentially adding costs is sheep grazing, depending on the logistics of transportation of sheep.

4.3.1 Negligible cost

Most interviewees agreed that the cost for implementing ecovoltaics in solar parks are negligible or marginal in comparison with the revenue of developing and running a solar park. Those that elaborated agreed that the low cost mostly came from having or having acquired the right knowledge. For example, adapting the time when the grass is cut to not interfere with the breeding times of birds does not cost more than cutting the grass at any other time, providing it does not grow to cover the solar panels.

The knowledge this requires was stated to be easy and cheap to come by. Most large solar parks projects perform an Environmental Impact Assessment during the planning as part of their Consultation Application and must bring in a consult to help them. The interviewees also claim that the cost of the extra hours the consultants would have to spend to investigate and provide recommendations for ecovoltaics measures would also be negligible. Many have also stated that they have tried to engage non-profit organizations within biodiversity or ornithology to help them appraise biodiversity before and after the park's construction.

In contrast to the statement about negligible costs, many interviewees said that they are interested in having grazing sheep in their parks. Few actually implement it however, because if the landowner or a neighbor to the solar park is not a sheep farmer the cost of transporting the sheep back and forth quickly grows very expensive compared to cutting the grass. The only other mentioned "cost" is the opportunity cost from leaving pockets of undeveloped land in the park and avoiding development of areas with high initial biodiversity.

4.4 Economic incentives for ecovoltaics

There is no financial support for implementing ecovoltaics in Sweden that can be found in the literature today. However, there are many organizations and authorities that can offer financial support for projects regarding biodiversity both for creating habitats, restoration of areas or through financial support for research. When asking the interviewees, a few of the economic incentives from the literature were mentioned however the majority of the interviewees do not have the knowledge about any economic incentives directly made for ecovoltaics or that they have not applied for any of the grants that are in place for biodiversity today. There are also uncertainties about if these grants will be available for the industry due to the main activity being energy production rather than conservation.

4.4.1 Economic incentives inventory

No grants or subsidies that are directly made for ecovoltaics can be found in the literature today. There are a variety of subsidies and grants that can be offered for biodiversity in Sweden including Agricultural Subsidies or financial support for investments for water conservation measures from The Swedish Board of Agriculture, the grant *Lokala naturvårdssatsningen* (LONA) from the County Administrative Boards as well as financial support for research, both from the Swedish Energy Agency, the governmental research council FORMAS and from the EU. The different grants and subsidies are explained further below.

Financial support from The Swedish Board of Agriculture

The Swedish Board of Agriculture have many different grants that can be offered to farmers and actors operating in Swedish rural areas. One of the grants is an Agricultural Subsidy. It is a financial support for farmers with an area of at least 4 hectare and can be offered for arable land used for crop cultivation, pastures managed with grazing, trimming or cutting or for meadows where grass or herbs grow that could be used as feed (Jordbruksverket, 2023). To get financial support, you have to be an active farmer and have to use the land for agricultural activities including crop production, animal husbandry or by actively preserving the area as agricultural land. However, according to The County Administrative Board of the County of Scania, farmers will not qualify for the Agricultural Subsidies for land where solar panels have been constructed (Länsstyrelsen Skåne, n.d.). The County Administrative Board means that by constructing solar panels, the land area does not meet the requirements for areas eligible for the support.

Except for the Agricultural Subsidies, The Swedish Board of Agriculture also offers financial support for investments for water conservation measures like investments for increasing water quality, building two-stage ditches or by establishing or restoring wetlands in the agricultural land (Jordbruksverket, 2022). The support is available for companies within agriculture activities, gardening as well as companies working with reindeer husbandry.

Lokala naturvårdssatsningen (LONA)

LONA is a financial support that is offered by the Swedish County Administrative Boards and is available for municipalities for projects within nature conservation (Naturvårdsverket, n.d.-b). Also, projects benefiting public health and outdoor life can be supported by LONA. Some types of projects that can be supported are projects for conservation and management, protection or restoration of specific areas, habitats or species. Municipalities applying for the support can be granted compensation for up to 50 % of the costs for the project. LONA can also be offered for projects aiming to create or restore wetlands, in this case LONA can subsidize up to 90 % of the cost. This financial support is only available for municipalities. However, other actors can initiate projects together with the municipality. LONA cannot be offered for projects that lead to profit but rather to projects locally initiated for nature conservation or benefiting outdoor life (Naturvårdsverket, n.d.-b).

Financial support for research

Except for grants and subsidies from The Swedish Board of Agriculture and LONA, another option is to find financial support for research projects. Three ways to get financial support for research projects is through the Swedish Energy Agency, the EU's research fund LIFE and support from the governmental research council FORMAS.

The Swedish Energy Agency is the leading governmental authority for the transition towards a sustainable energy system in Sweden and they work with increasing and spreading knowledge and facts about the subject, they are responsible for the official energy statistics in Sweden and also work with supporting research and innovation within the energy sector (Energimyndigheten, 2023a). The agency offers financial support for research projects within a variety of themes, both within technology development but also for knowledge-building projects (Energimyndigheten, 2023c).

FORMAS is a governmental research council working with sustainable development and financial support for research and innovation that contributes to sustainable development within their areas of activity, environment, agricultural science and spatial planning (FORMAS, 2023). Each year, Formas distributes around 1,8 billion SEK to projects for development of new innovative solutions and knowledge building projects. Formas is also responsible for four out of the 13 national research programs that the government has initiated: the national research program for Climate, Sustainable Spatial Planning, Food and Oceans and Water (FORMAS, 2022).

LIFE is a program from the EU that started in 1992 and is a funding instrument for financial support for projects within environment and climate actions (Naturvårdsverket, n.d.-a). The program includes four sub programs – nature and biodiversity, circular economy and quality of life, climate change mitigation and adaptation and clean energy transition. The program supports projects for protection, restoration and improvement of biodiversity and the environment as well as projects leading towards the transition to a sustainable, energy-efficient circular economy. LIFE supports projects with measures for restoration and protection, projects for best practices and knowledge building projects. Within the sub-program "Nature and Biodiversity", funding can be given to projects that include restoration of nature, projects that increase knowledge within the field or develop best practice solutions (Naturvårdsverket, n.d.-a)

4.4.2 The industry's view on economic incentives

The general view from the interviewees on economic incentives for ecovoltaics is that there are no specific incentives for solar parks that they know of. Some of the interviewees argued that there are some incentives but that they choose not to apply for financial support for implementations for biodiversity but instead planned on budgeting for this themselves. Some of the interviewees expressed doubts for the economic incentives that are in place today, meaning that there are difficulties for the industry to apply for financial support for biodiversity due to the main economic activity for the company being energy production and not conservation.

One economic incentive that was mentioned a few times by some of the interviewees is LONA. This financial support was discussed by a few of the interviewees to potentially be an incentive that could be used for measures for biodiversity within solar parks. However, none of the interviewees have been offered the support for a solar park yet.

Another financial support that was discussed by a few interviewees was subsidies from The Swedish Board of Agriculture, which could be applied to by farmers for agricultural land or pastures. A few of the interviewees believe that this could be an economic incentive that could be offered to landowners who want to work with implementations for biodiversity in their solar parks and on their land.

Except for LONA and The Swedish Board of Agriculture, one interviewee also mentioned the possibility to work together with researchers and get financial support for research projects in solar parks, creating an opportunity for implementing measures for biodiversity in the park.

4.5 Necessary actions for a higher implementation of ecovoltaics

The three main needs that the industry see as necessary for increasing ecovoltaics in Sweden is the need for clear and national regulations, standardized measurements for biodiversity, increased knowledge and more research about ecovoltaics and how solar parks effect biodiversity. To minimize the risk of different interpretations and uncertainties about what is expected of the developers, there is a need for clear regulations regarding solar parks. Policy makers have a large responsibility, and the interviewees see that regulations are a rather easy way to force developers to do more for biodiversity in parks. Except for clearer regulations, another thing that the industry is requesting is the ability to quantify biodiversity. Being able to measure biodiversity, or giving it a monetary value, could increase interest, knowledge and also work as a tool for policy makers. The last thing that was mentioned as necessary for a higher implementation is increased knowledge and more research to minimize uncertainties, create higher interest and may lead to faster and more secure decisions processes. One thing that was requested from the interviewees is more research within Sweden.

4.5.1 Clear and national regulations

Most interviewees believe that one of the most important factors for higher implementation of ecovoltaics is clearer rules and regulations for solar parks. They believe that creating rules would be the easiest way to give clarity of what is expected of them when planning and building solar parks. Also, by creating regulations that take biodiversity into account, this could be an easy way to force the industry to do more for biodiversity. They also expressed that the government, and the County Administrative Boards have a big responsibility, and they expect more guidance. Some of the interviewees also expressed the need for regulations and guidelines on a national level, wanting more general guidelines to minimize the differences in interpretation of the rules between the counties.

"There is a need for clearer laws and regulations. It should be easy to do the right thing"
- A2

Some of the interviewees expressed their concerns about having too strict rules for solar parks and biodiversity due to the site-specific conditions of each location. They believe that there is a risk that it could lead to difficulties if the rules are too strict and general and argue that the site-specific conditions have to be taken into account as well.

"Some of these things are quite simple to implement and then it is really reasonable, but if it turns out that there will be requirements that may be difficult to maintain, then it may be that it becomes negative. Actually, you have to find a good balance there".
- A3

4.5.2 Standardized measurements for biodiversity

One action that was mentioned by most interviewees is the need for standardized measurements for the quantification of biodiversity. They believe that a standardized system will facilitate the gathering of more knowledge about how solar parks affect biodiversity, to definitively be able to tell what measures work and what does not. Also, being able to put a price on biodiversity in solar parks is believed to increase interest from actors and may lead to higher implementations of measures for biodiversity. It is also believed that it may increase investor interest if you can show with numbers how their investment affects biodiversity.

"I think that many of the companies that we work with, they are interested as soon as it is possible to just measure things, it becomes like green buildings but green PV parks instead. And that, I think they will be super interested in being able to show this off"
- B3

Another argument that was brought up by some of the interviewees is that a standardized system for quantifying biodiversity could also be a tool for policy makers to use for regulations and demands for preservation or promotion of biodiversity.

4.5.3 Increased knowledge and more research

One of the most widely held opinions amongst the interviewees, as can be read in Section 4.2.1, is that there is a distinct lack of knowledge within the industry. To remedy this, most of the interviewees requested that the industry needs to gain more experience and knowledge and academia needs to provide more research. They expressed a belief that as park sizes increase with time, more knowledge will be necessary to not become damaging to local biodiversity. What the interviewees request is not very specific with some claiming that some basic research would help a lot.

The interviewees stated that one of the main problems with existing research is that it has been performed abroad. Measures for biodiversity are believed to be very site specific, as is detailed in Section 4.2.3, and most research has been done in other countries, especially Germany and the Netherlands. The interviewees agree that Sweden is far behind the rest of the world. With examples of best practice within Sweden it would be easier to mimic as the ecosystems would be more similar.

As was mentioned in Section 4.2.1, there is a belief that the lack of knowledge will remedy itself with time. Despite this, a lot of cooperation with Swedish University of Agricultural Sciences has been mentioned, to both help the interviewees gather information and contribute to research. The interviewees also expressed a belief that these investments will pay themselves back with time.

5. Discussion

In this chapter, the chosen method and potential limitations of the study is discussed, as well as the implications of the results and potential future studies.

5.1 Potential limitations

The utilized methods were a literature search and an interview study. The literature search was done to investigate what views and information could be found about ecovoltaics, what measures were the most common and what incentives exist for increasing ecovoltaics in Sweden. In the literature search, both research articles and grey literature were used, this was to compensate for the relatively small amount of research done on the subject. The grey literature was mainly from authorities and organizations working with biodiversity.

For the interview study, 13 actors within the industry were interviewed. A qualitative interview study was chosen because it is more flexible than a quantitative study and focuses more on the interviewees' view of the subject and what they think is relevant which suits the aim of the project. The interviews were done in a semi-structured manner which creates an opportunity to adapt the interview depending on the interviewee's interests, experiences and knowledge, allowing for more information to be extracted. It makes the replication of the methodology harder, but the benefits were considered to outweigh the disadvantages.

One potential limitation with the study could be the choice of actors for the interviews. Most interviewees are actors working either with already built parks, in the process of building parks or in project development of large-scale solar parks. This could potentially cause the results to be biased due to the possibility that the participants have a similar outlook. With a larger variety of actors interviewed, the results could possibly have been more extensive and include a wider range of perspectives which could be of interest. The study included mainly actors working with development of parks, from actors building, installing, managing and owning parks. Some of the actors could potentially have worked with the same parks, creating another uncertainty in the results. Also, a higher number of participants could give more validity to the results. Furthermore, with semi-structured interviews there is a risk that interviewees interpret the questions in different ways, for example when asked about what measures they had worked with, some interviewees listed their measures that they had used in existing parks while others talked more freely about what could be done. Lastly, another potential limitation is reduced transparency due to enabling the participants to be anonymous. However, by enabling the participants to be anonymous, they might be more open to answering the questions truthfully, due to not having to concern themselves with their company's image.

5.2 Growing interest and increasing implementation

The results show a broad inventory of possible measures for preserving or increasing biodiversity when it comes to solar parks, from all principles of the mitigation hierarchy. For the first two principles, avoidance and minimization, some of the measures mentioned in the literature were also mentioned in the interviews. However, the variety of measures presented from the literature search were higher than the measures that had been used by the participants. When looking at the offset measures, the results from the interviews show that there are a few measures that reoccur both already existing parks as well as in the plans for parks under development. However, for the parks under development, a larger variety of measures were mentioned compared to what was already implemented in existing parks. Also, the measures discussed or mentioned as planned included larger and more difficult measures to implement such as creating wetlands and ponds.

The variety in number of measures mentioned between what has been implemented in existing compared to planned parks could potentially be explained by higher knowledge and interest in biodiversity within the industry today. According to a study done by Björnsson et al. (2022), about 50 % of the solar parks that participated in the study had by 2021 implemented some type of measure for benefiting biodiversity in their park. On the other hand, in this study, when asking the interviewees what measures they had implemented alternatively planned on implementing, almost every participant mentioned one or more offset measures. This could potentially be explained by a higher awareness and focus on biodiversity now compared to early years of large-scale solar parks being built in Sweden. This raised focus on biodiversity can be seen on a European level with the new EU Biodiversity strategy for 2030 (European Commission, 2021), which aims to reverse degradation of ecosystems and increase biodiversity, as well as the EU Nature Restoration Plan and the proposed Nature restoration law. These strategies and law indicate a higher focus on biodiversity and measures for minimizing biodiversity loss has become more important. Also, more guidelines like the ones presented in Section 2.5 are being published each year as well as good examples from around the world, giving the industry inspiration for measures and guidance on how to work with ecovoltaics.

Except for more knowledge and guidance, another explanation could be that the industry believes that it will help in the consultation process with the County Administrative Board, creating a more positive attitude towards the parks if it does not damage to the environment and instead increase biodiversity. With higher focus on biodiversity from the European Commission, the Member States will have to step up their work for minimizing biodiversity loss. This may in the end affect the consultation process for solar parks and by creating parks with high biodiversity, it may become easier to get acceptance from the County Administrative Board.

5.3 How can the industry overcome the identified barriers?

The results show that the industry see four main barriers for higher implementation of ecovoltaics, a lack of knowledge about biodiversity within the industry, the lack of clear rules and regulations for solar parks leading to differences in interpretation, that biodiversity is not prioritized within the sector as well as difficulties because of site specific conditions. All of the mentioned barriers could probably be consequences of the industry' being relatively young in Sweden. There is a lack of knowledge within the sector but also policy makers lack the knowledge to create clear regulations. There is also an absence of good examples of ecovoltaics in Sweden, which the interviewees also request. To overcome the barriers, the interviewees saw the need for three main actions: clearer regulations, having a standardized tool for quantifying biodiversity and increased knowledge for the whole sector, more research and good examples. As will be explored in this section, the only identified obstacle not addressed by these actions would be “Lack of priority for biodiversity”.

5.3.1 Increased knowledge, research and more good examples

The increase of knowledge, research and more good examples works against two of the identified obstacles provided by the interviewees, the lack of knowledge and site-specific conditions. Increased knowledge will help solar park planners and constructors to select measures from an inventory and apply them to the park effectively as well as help with the expressed concern that preforming any offset measures might be detrimental. In a similar manner it will help with site specific conditions, as more knowledge will help with adapting to varying locales. This will be especially effective with good examples of best practice, allowing solar parks to adopt similar measures as solar parks in their proximity.

More knowledge might also help with the obstacle of a “lack of clear rules and regulations”. One of the problems for the industry is lack of knowledge on all levels and increased knowledge in companies and institutions would help communication between them and therefore make receiving permission for solar parks easier.

5.3.2 Local guidelines and national regulations

Some of the interviewees mentioned that there is a lack of national regulations and guidelines to help the industry to implement measures for biodiversity. This works in tandem with the great differences in site specific conditions to make highly specific criteria hard to implement, what works in one location may not be a good option in another. One possible solution to this is to have national regulations enforced through local guidelines on a municipal or county level. This would create a twofold problem. The first is that this creates pressure on institutions to have sufficient knowledge to handle their own local regulations. A lack of knowledge in the industry and institutions is a problem already highlighted by the interviewees and this risk to exacerbate that problem. The other is that there is a distinct risk of varying interpretations across Sweden and does therefore not address the main obstacle sought to be addressed.

Another way to address the lack of knowledge, one that the industry has noticed, would be to have loose national regulations with demands rather than mandatory actions. The decision on how to conform to them is then up to the planner and constructor of the solar park. This relies upon one major advancement and another obstacle highlighted by the interviewees, the ability to quantify biodiversity. Institutions will not be able to enforce loser rules and regulations without this ability and companies and other actors will not be able to measure the success of their own measures. As a standardized measurement system for biodiversity has yet to be developed, this means the only current option is to have inefficient and project specific requirements, in the vein of other energy industries, such as wind power.

5.3.3 Standardized tool for measuring biodiversity

A standardized tool for measuring biodiversity has not yet been established in the industry nor in any other industry within the EU. It is being worked on by both companies and academia's and would help to regulate and increase biodiversity in all industries. Specifically for solar parks it would help to combat three of the main obstacles identified by the industry. For the obstacle lack of knowledge it would make it easier to determine which measures work and which do not. It would make regulations on solar parks easier to legislate, enforce and follow. And it would make it easier to adapt to site specific conditions. It would not however combat the obstacle that biodiversity is not the main objective.

The Swedish standard for Inventory of nature conservation value, or NVI, is a standardized process for investigating and documenting natural values. NVI fulfills many of the criteria that the interviewees have requested. It was also mentioned in a majority of the interviews, so it is clear that the interviewees are aware of this tool. It seems that the problem with NVI might be that it does not yield a numerical value, and therefore it is hard to give biodiversity an economic evaluation, e.g., being able to show that X amount of money created Y amount of biodiversity in the solar park.

5.3.4 Economic incentives can encourage actors to collaborate

During the interviews it became apparent that the interviewees are not aware of any economic incentives that are in place today and are specifically made for ecovoltaics, with the literature search reaching the same conclusion. Most interviewees also agreed that measures for biodiversity generally are not expensive if the correct measures are chosen, something possible with the right knowledge. This cost, compared to that of the whole project, is described as neglectable. Most interviewees had therefore not applied for any subsidies for biodiversity or believed that there was a need for such subsidies.

Economic incentives for biodiversity could help with the last and unaddressed obstacle observed by the interviewees, a "lack of prioritization for biodiversity". As is described in Section 4.2.4, different stakeholders have diverging interests. Landowners can make demands for the parks installed on their land, highlighting the benefits of an interested landowner. Today, there is a large amount of uncertainty about some grants for landowners, e.g., that Agricultural Subsidies is not offered to plots of land if there are solar parks installed (Länsstyrelsen Skåne, n.d.). If this was possible or expanded when in combination with solar power, landowners would be more likely to demand and respond positively to implementing measures for biodiversity.

In Section 4.2.4 there are two additional issues regarding prioritization for biodiversity. Investors are mentioned as sometimes being uninterested in spending money on biodiversity, even if the sums are small, and opt out if the landowner does not require it. A lesser problem is that some producers of solar parks mention that they are energy producers first and the creation of biodiversity is a secondary, or even lower, objective. An option to combat this would be the availability of green loans, loans with better rates due to having requirements on environmental benefits. This would encourage both investors and planners to adopt ecovoltaics. One way to achieve this is through the usage of the EU taxonomy. The taxonomy allows for classification of sustainable and environmentally friendly activities and gives investors and financial establishments the terminology to make sustainable investments (European Commission, n.d.-c). In this way ecovoltaics could be classified and given the benefit from the taxonomy, creating access to the aforementioned green loans and widening its implementation.

5.4 Future studies

The study does, as discussed in Section 5.1, have some limitations including the number of participants and the choice of actors interviewed. The results still give an indication of the attitude and view of ecovoltaics but risk excluding valuable perspectives. Further studies with a greater variety of stakeholders including landowners, nearby residents, investors, policy makers and ecologists, could therefore be of interest to see how biodiversity and ecovoltaics is valued throughout the whole value chain.

A follow up study regarding the development of biodiversity in solar parks using ecovoltaics would also be of interest. There is a lot of solar parks in development in Sweden right now, with a large portion of the large-scale parks completed in recent years. To investigate, on an industry wide level, how biodiversity in the parks grew and developed depending on the measures implemented would be highly valuable to the field.

One of the actions that the interviewees saw as necessary for a higher implementation was a standardized measurement or a way to quantify biodiversity. However, how this tool is desired to work or be designed was not investigated further. For future studies it could therefore be of interest to investigate the industry's wishes and opinions about such a tool more in-depth. The study could also be used to determine how the new tool would differ from NVI and therefore contribute to the development of the new tool more suitable for solar parks and ecovoltaics.

Also, doing a more in-depth investigation of ecovoltaics from other countries and their legislations for solar parks could be of interest for further research and contribute with knowledge and inspiration to the Swedish governmental authorities.

6. Conclusion

The purpose with the study was to investigate how solar parks in Sweden utilize ecovoltaics in their design and what the industry sees as necessary to implement ecovoltaics more widely. Also, the study aimed to investigate existing and potential incentives for increasing ecovoltaics in Swedish solar parks. This was done by investigating the industry's view of the subject through an interview study as well as investigating views found in literature through a literature search. The findings from the interview study and the literature search resulted in the following conclusions:

- Most of the interviewees work with measures from the mitigation hierarchy for their solar parks, mostly with avoiding areas with high biodiversity and minimizing measures such as leaving vegetation and sensitive micro habitats within the park.
- Almost all the interviewees have or plan to implement offset measures in their solar parks. The most common one being the establishment of meadowlike grasslands and flowerbeds.
- For further implementation of ecovoltaics three actions are needed:
    - More research from academia, knowledge accumulation within the industry and more best practice examples within Sweden.
    - Clearer national regulation specific for solar parks.
    - A standardized measurement system for biodiversity.
- While there are economic incentives for biodiversity, no incentives are specifically aimed at ecovoltaics.
    - The absence of subsidies was not found to be a highly detrimental factor for the industries implementation of ecovoltaics, due to the negligible costs of implementations.
    - The economic incentives in place for biodiversity can work effectively as an incentive for research and should be kept in place or expanded for this purpose.
- The concept of ecovoltaics is still very young, especially in Sweden, which also can be seen in the noneconomic incentives that are in place.

The study shows that there is an increasing awareness and interest for biodiversity and a desire to work towards increasing biodiversity in Sweden. The interviewees see solar parks as a good possibility to enhance biodiversity. However, the concept is still very young, and the industry needs more research and good examples to reach a higher implementation of ecovoltaics. Also, it will be important to follow up and investigate how existing parks affect biodiversity and to spread knowledge within the industry. In the last two years many major best practice documents have been published internationally and in Sweden. This is showing an increased focus on biodiversity and how solar parks can be a good option to minimize the impacts on two of the greatest challenges that society faces today, climate change and biodiversity loss.

The obstacles identified by the industry in the interview study were all effectively countered by the proposed actions, except for the obstacle “lack of prioritization for biodiversity”. We propose that this can be countered through economic incentives, especially geared towards landowners and investors. All the obstacles are also countered to some extent by implementing a standardized way to measure biodiversity and we therefore suggest that the development and adoption of such a tool should be a priority for public as well as private interests.

References

Bennun, L., van Bochove, J., Ng, C., Fletcher, C., Wilson, D., Phair, N., & Carbone, G. (2021). *Mitigating biodiversity impacts associated with solar and wind energy development: guidelines for project developers*. Gland, Switzerland: IUCN and Cambridge, UK: The Biodiversity Consultancy.

Björnsson, L.H., Pettersson, I., Morell, K., & Van Noord, M. (2022). *Solcellsparker i Sverige 2021-en kartläggning*. RISE Rapport 2022:64, ISBN 978-91-89711-04-4, RISE Research Institutes of Sweden.

Blaydes, H., Potts, S. G., Whyatt, J. D., & Armstrong, A. (2021). Opportunities to enhance pollinator biodiversity in solar parks. In *Renewable and Sustainable Energy Reviews* (Vol. 145). Elsevier Ltd. https://doi.org/10.1016/j.rser.2021.111065

The UN convention on biological diversity : follow-up in EEA member countries 1996 (1997) Institute of Terrestrial Ecology, Copenhagen.

Boverket. (2018). *Transformatorstationer*. https://www.boverket.se/sv/PBL-kunskapsbanken/lov--byggande/anmalningsplikt/bygglov-for-anlaggningar/transformatorstationer/

Boverket. (2022a). *Nybyggnad*. https://www.boverket.se/sv/PBL-kunskapsbanken/lov--byggande/anmalningsplikt/byggnader/nybyggnad/

Boverket. (2022b). *Solfångare och solcellspaneler*. https://www.boverket.se/sv/PBL-kunskapsbanken/lov--byggande/anmalningsplikt/byggnader/andring/sol/

BRE. (2014). *Agricultural good practice guidance for solar farms.* Ed J Scurlock. https://files.bregroup.com/solar/NSC_-Guid_Agricultural-good-practice-for-SFs_0914.pdf

Energimyndigheten. (n.d.). *Grid connected photovoltaic power systems, number and installed capacity, 2016 -*. Retrieved May 22, 2023, from https://pxexternal.energimyndigheten.se/pxweb/en/Nätanslutna solcellsanläggningar/-/EN0123_1.px/table/tableViewLayout2/

Energimyndigheten. (2018). *Vägen till ett 100 procent förnybart elsystem Delrapport 1: Framtidens elsystem och Sveriges förutsättningar*. https://energimyndigheten.a-w2m.se/Home.mvc?resourceId=104686

Energimyndigheten. (2019a). *100 procent förnybar el Delrapport 2 – Scenarier, vägval och utmaningar*. https://energimyndigheten.a-w2m.se/Home.mvc?resourceId=133470

Energimyndigheten. (2019b). *Solcellsparker*. https://www.energimyndigheten.se/fornybart/solelportalen/lar-dig-mer-om-solceller/solcellsparker/

Energimyndigheten. (2022). *Solceller*. https://www.energimyndigheten.se/fornybart/solenergi/solceller/

Energimyndigheten. (2023a). *Hållbar energi för alla*. https://www.energimyndigheten.se/om-oss/

Energimyndigheten. (2023b). *Minskad elanvändning under 2022*. https://www.energimyndigheten.se/nyhetsarkiv/2023/minskad-elanvandning-under-2022-i-sverige/

Energimyndigheten. (2023c). *Så arbetar vi med forskning och innovation*. https://www.energimyndigheten.se/forskning-och-innovation/sa-arbetar-vi-med-forskning-innovation/

European Commission. (n.d.-a). *Biodiversity strategy for 2030*. Retrieved May 16, 2023, from https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en

European Commission. (n.d.-b). *Nature restoration law*. Retrieved May 16, 2023, from https://environment.ec.europa.eu/topics/nature-and-biodiversity/nature-restoration-law_en

European Commission. (n.d.-c). *EU taxonomy for sustainable activities*. Retrieved June 9, 2023, from https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en

European Commission. (2020). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the regions.* https://eur-lex.europa.eu/resource.html?uri=cellar:a3c806a6-9ab3-11ea-9d2d-01aa75ed71a1.0001.02/DOC_1&format=PDF

European Commission. (2021). *EU Biodiversity Strategy for 2030, Bring nature back into our lives*. Luxemburg; Publication Office of the European Union.

Final text of Kunming-Montreal Global Biodiversity Framework available in all languages, (2022). https://www.cbd.int/conferences/2021-2022/cop-15/documentsasdocument:CBD/COP/15/L25

FORMAS. (2022). *Nationella forskningsprogram*. https://formas.se/om-formas/vad-vi-gor/nationella-forskningsprogram.html

FORMAS. (2023). *Finansiering*. https://formas.se/om-formas/vad-vi-gor/finansiering.html

IEA-PVPS. (2021). *Trends in Photovoltaic Applications 2021*. www.iea-pvps.org

Jordbruksverket. (2022). *Investeringsstöd för vattenvårdsåtgärder*. https://jordbruksverket.se/stod/jordbruk-tradgard-och-rennaring/vatmarker-vattenvard-kalkfilterdiken-och-bevattningsdammar/vattenvardsatgarder

Jordbruksverket. (2023). *Gårdsstöd 2023*. https://jordbruksverket.se/stod/jordbruk-tradgard-och-rennaring/jordbruksmark/gardsstod

Lammerant, L., Laureysens, I., & Driesen, K. (2020). *Potential impacts of solar, geothermal and ocean energy on habitats and species protected under the birds and habitats directives.*Final report under EC Contract ENV.D.3/SER/2017/0002 Project: "Reviewing and mitigating the impacts of renewable energy developments on habitats and species protected under the Birds and Habitats Directives", Arcadis Belgium, Institute for European Environmental Policy, BirdLife International, NIRAS, Stella Consulting, Ecosystems Ltd, Brussels.

Länsstyrelsen Skåne. (n.d.). *Jordbrukarstöd*. Retrieved May 20, 2023, from https://www.lansstyrelsen.se/skane/natur-och-landsbygd/stod-till-jordbruk-och-landsbygd/jordbrukarstod.html

Lindahl, J., & Oller Westerberg, A. (2021). *National Survey Report of PV Power Applications in Sweden 2021 Task 1 Strategic PV Analysis and Outreach*. IEA: International Energy Agency. www.iea-pvps.org

Lovich, J. E., & Ennen, J. R. (2011). Wildlife Conservation and Solar Energy Development in the Desert Southwest, United States. *BioScience*, *61*(12). https://doi.org/10.1525/bio.2011.61.12.8

Maes, J., Teller, A., Erhard, M., Condé, S., Vallecillo, S., Barredo, J. I., Paracchini, M. L., Adbul Malak, D., Trombetti, M., Vigiak, O., Zulian, G., Addamo, A. M., Grizzetti, B., Somma, F., Hagyo, A., Vogt, P., Polce, C., Jones, A., Carré, A., & Hauser, R. (2021). *EU Ecosystem Assesment: Summary for policymakers*. EUR 30599 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-30423-4, doi:10.2760/190829, JRC123783.

Malterud, K. (2012). Systematic text condensation: A strategy for qualitative analysis. *Scandinavian Journal of Public Health*, *40*(8), 795–805. https://doi.org/10.1177/1403494812465030

Millennium Ecosystem Assessment. (2005). *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, DC,

Naturskyddsföreningen. (2023). *Varför behövs det fler blomsterängar?* https://www.naturskyddsforeningen.se/artiklar/varfor-behovs-det-fler-blomsterangar/?fbclid=IwAR0mbZCqUutHR6s6adFdxMnk0u8gNaX8vlmr1Cmp9x1JJm5DXC0NfDnfndQ

Naturvårdsverket. (n.d.-a). *LIFE-programmet 2021-2027*. Retrieved May 17, 2023, from www.naturvardsverket.se

Naturvårdsverket. (n.d.-b). *LONA – Lokala naturvårdssatsningen*. Retrieved May 16, 2023, from https://www.naturvardsverket.se/bidrag/lona/

Naturvårdsverket. (n.d.-c). *Samråd vid ändring av naturmiljön*. Retrieved May 17, 2023, from https://www.naturvardsverket.se/vagledning-och-stod/samhallsplanering/samrad-vid-andring-av-naturmiljon/

Naturvårdsverket. (2020). *Sveriges arter och naturtyper i EU:s art- och habitatdirektiv : resultat från rapportering 2019 till EU av bevarandestatus 2013-2018.* ISBN 978-91-620-6914-8

New Jersey Department of Environmental Protection. (2017). *Solar Siting Analysis Update 2017*. https://www.state.nj.us/dep/aqes/SSAFINAL.pdf

OECD. (2019). *Biodiversity: Finance and the Economic and Business Case for Action*, report prepared for the G7 Environment Ministers' Meeting, 5-6 May 2019.

Parker, G., & Monkhouse, J. (2022). *Realising the Biodiversity Potential of Solar Farms - A Practical Guide by Wychwood Biodiversity and Naturesave Insurance*. Nature Insurance. ISBN 923-1-912393-23-5

Pettersson, I., Morell, K., Råberg, T., van Noord, M., Zinko, U., Ghaem Sigarchian, S., Sandström, A., & Unger, M. (2022). *Ecovoltaics och agrivoltaics - en handbok om solcellsparker som gynnar biologisk mångfald och ekosystemtjänster.* ISBN 978-91-89711-96-9, RISE Research Institutes of Sweden.

Råberg, T., Van Noord, M., Björnsson, L.H., Pettersson, I., & Zinko, U. (2021). *Solcellsparker, biologisk mångfald och ekosystemtjänster-Påverkan och möjligheter för multifunktioner.* RISE Rapport 2021:52, ISBN 978-91-89385-93-1, RISE Research Institutes of Sweden.

Regeringskansliet. (n.d.). *Mål för energipolitiken*. https://www.regeringen.se/regeringens-politik/energi/mal-och-visioner-for-energi/

RISE. (n.d.). *Planering av solcellsparker för biologisk mångfald och ekosystemtjänster*. Retrieved May 16, 2023, from https://www.ri.se/sv/vad-vi-gor/projekt/planering-av-solcellsparker-for-biologisk-mangfald-och-ekosystemtjanster

SMHI. (2017). *Normal globalstrålning under ett år*. https://www.smhi.se/data/meteorologi/stralning/normal-globalstralning-under-ett-ar-1.2927

SolarPower Europe. (n.d.). *Our story: Leading the Energy Transition*. Retrieved May 17, 2023, from https://www.solarpowereurope.org/about/our-story

SolarPower Europe. (2022). *Solar, Biodiversity, Land Use: Best Practice Guidelines*.

Stridh, B. (2016). *Sveriges första MW-solcellspark och dess forskningssystem*. Akademin för ekonomi, samhälle och teknik

United Nations. (n.d.). *Biodiversity - our strongest natural defense against climate change*. Retrieved January 25, 2023, from https://www.un.org/en/climatechange/science/climate-issues/biodiversity?gclid=EAIaIQobChMIuN397of0_AIVZhoGAB3n7ABPEAAYAiAAEgKlu_D_BwE

Wolfe, P. R. (2012). *Practical Handbook of Photovoltaics: Solar Parks and Solar Farms*, 943–962. https://doi.org/10.1016/B978-0-12-385934-1.00030-1

Appendix A

The interview guide includes the main questions that were asked to the interviewees. The questions were translated from Swedish.

Introduction

1. Could you tell us a little bit about yourself, your background and role in the company?

2. Could you briefly tell us about the solar parks that you have built and/or are responsible for?
   a. Alternatively solar parks that are in the project phase.

Choice of location

3. What type of land are you using for solar parks?
   a. What does the process look like when choosing a location?
   b. What factors are important when deciding on the location for a solar park?
   c. What is the ownership structure of the park?

4. How do natural values affect the choice of location?
   a. When choosing a location, are the natural values in the area explored?
   b. Are these values taken into account when choosing a location?

5. How would you say that the construction of a solar park affects the environment?

Measures for biodiversity

6. How are the solar parks managed?
   a. Who is responsible for managing the park?
   b. How is vegetation under and around the panels managed?
   c. Do you collaborate with other actors for the management of the solar park?

7. Have you worked with measures for preserving or promoting biodiversity in the parks or in the nearby area? Which measures have you worked with?
   a. In what way do these measures affect biodiversity?
   b. How have these measures been implemented?

8. Have you had any follow-up to evaluate the effectiveness of the measures implemented?
   a. What results have you gotten from the follow up?

9. Have you worked specifically with biological values in your parks?
    a. Have you worked specifically with consultants for biodiversity, biologists or ecologists?

10. What benefits could be seen by implementing measures for biodiversity in solar parks?

Barriers

11. What reasons are there to why measures aren’t implemented more widely in solar parks in Sweden today?
    a. What barriers or obstacles are there for a higher implementation?

12. What permits are needed for building a solar park?
    a. Are there any requirements or regulations for solar parks?

Economic incentives

13. How do ecovoltaics measures affect the costs for a project?

14. Are there any economic incentives that are in place that can be applied for ecovoltaics?

15. What actions or incentives are necessary/would be needed for a higher implementation of measures for preserving or promoting biodiversity in Swedish solar parks?

Closure

16. How do you think the development of ecovoltaics will look like in the future in Sweden?

17. Anything you would like to add or you´ve come to think of?

18. Do you have any questions for us?

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