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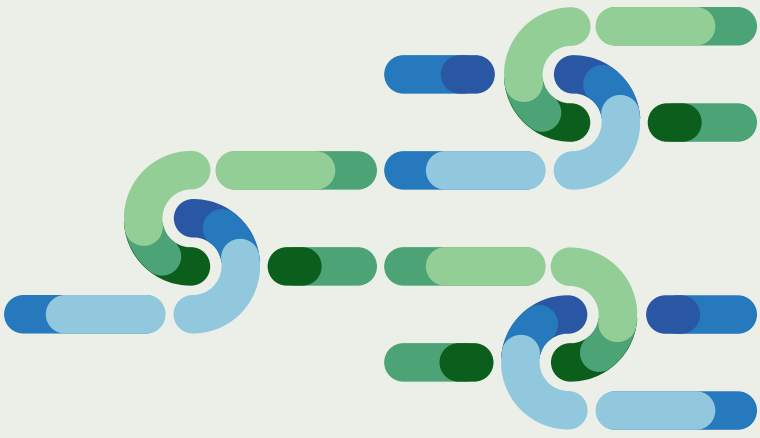
PlanToConnect

GBI-network: Land use conflicts for RE production and other threats

Alpine space

Mapping report outlining GBI network elements and areas of land use conflicts for renewable energy production and other major developments that may threaten GBI connectivity function



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PlanToConnect

GBI-network Land use conflicts

Mapping report outlining GBI network elements and areas of land use conflicts for renewable energy production and other major developments

Activity 2.4 Case Studies 3rd step: Identify unsuitable locations/mitigation measures for impact assessment of renewable energy systems and other major developments that may threaten GBI connectivity function

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Chambéry, February 28th 2025

Reference in AF: D2.4.1

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EXECUTIVE SUMMARY

The report focuses on the components of the green and blue infrastructure (GBI) network and highlights areas where the implementation of renewable energy production and other major developments may lead to land use conflicts threatening ecological connectivity inside the Alpine Space.

Following the presentation of the main features of the pilot region, the report explains the methodological approach and the steps followed for the analysis. This includes an overview relevant data and national/regional frameworks to identify spatial pressures and threats related to renewable energy (RE) production and the development of new installations. The document includes cartographic analysis and thematic maps that illustrate the current and medium-term status of RE infrastructure development in the pilot area.

Exclusion zones for unsuitable locations for a selection of relevant infrastructures (hydro, wind, solar and biomass) are described. Based on this analysis, general mitigation measures are proposed to preserve ecological connectivity at the regional level. The findings of the report are summarized in the conclusions, recommendations regarding the implementation of RE in the pilot area are outlined.

REPORT

1 Introduction

The aim of the PlanToConnect project is to develop and test an Alpine spatial planning strategy for ecological connectivity in cooperation with stakeholders in pilot areas. Proposals for the adaption of spatial planning systems and territorial policies will be developed.

As part of the PlanToConnect project, ALPARC Is conducting a case study on the GBI connectivity network in the pilot area “Alpine space”. The design of a GBI network for connectivity in the pilot region has been developed and described in the report D2.3.1. Potential planning areas for biodiversity protection were identified, and within these areas, four categories were elaborated to illustrate the most suitable zones for improving ecological connectivity. These areas form the basis for integrating ecological connectivity at a transalpine level and provide a starting point for prioritizing planning actions at the regional level. Ecological connectivity in the pilot region “Alpine space”, is considered as a broad ecological network featuring key structural components such as core zones, stepping stones and corridors (see report D2.3.1).

This report (D2.4.1) focuses on the land-use conflicts arising from renewable energy facilities and other infrastructural developments that may threaten the GBI network for connectivity in the pilot region. The objectives are:

- to assess potential impacts of renewable energy infrastructures that may threaten the GBI network for connectivity,
- to assess evaluation criteria for unsuitable locations for the various types of infrastructures with a focus on renewable energy,
- to map the land use conflicts for renewable energy production and
- to suggest possible mitigation measures.

This report covers all spatially relevant infrastructures that have already had a negative impact on connectivity (pressures) as well as those that pose a potential threat to ecological connectivity in the future (threats)[1].

As a thematic delimitation, this report focusses on renewable energies and excludes urban/industrial development and infrastructures. While agricultural land use also affects ecological connectivity (see report D1.2.1), it is not addressed in the scope of this report as it is mostly driven by market conditions and agricultural practices. Spatial planning and its instruments virtually have no mandate or steering influence.

The report is structured as it follows:

Chapter 2 shortly describes the pilot region “Alpine space”.

[1] Pressures are factors that have affected habitats and species, threats are factors that are anticipated to be likely to have an impact in future (European Environment Agency 2020).

Chapter 3 explains the methodological approach, the steps followed, and the data sources used for analysing the implementation of RE in the pilot region “Alpine space”

Chapter 4 shows the major pressures and threats to ecological connectivity in the pilot region.

Chapter 5 discusses opposing factors for major developments / renewable energy facilities (exclusion zones) in the pilot region.

Chapter 6 describes the possible mitigation and compensation measures for the existing and planned infrastructures in the pilot region.

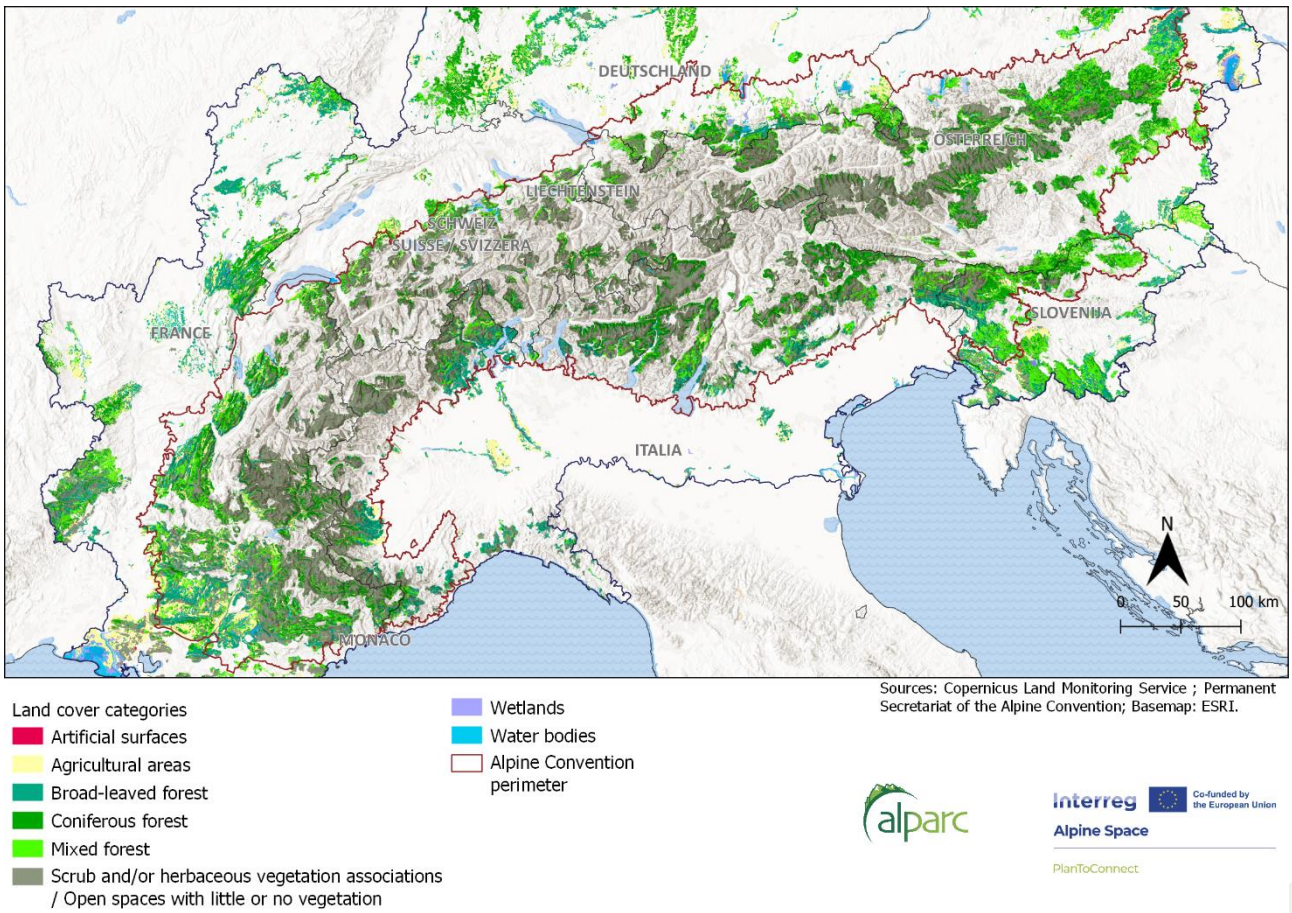
2 Pilot region Alpine Space

The Alpine space case study covers a selection of surfaces within the Alpine Convention perimeter and the interface with the EUSALP area, to elaborate a spatial planning proposal that allows to enhance ecological connectivity among landscapes with high relevance for biodiversity protection considering the 30% goal.

The analysis focuses on spatial planning areas for biodiversity protection, these are described as effectively conserved, ecologically representative, and well-connected areas. These areas cover around 3.828 municipalities and a surface of 72.048 km^2 inside the Alpine Convention perimeter.

The objective this case study is to analyse ecological connectivity linked with the current land use in the selected zones, identify the major barriers and threats to connectivity and provide recommendations to protect and restore ecological connectivity on the Alpine arc.

Map 1 Potential Planning Areas for Biodiversity Protection



3 Methodological steps

3.1 Description of the approach/ working steps

The following table shows the steps followed for the analysis of RE development in “Alpine space”

Table 1 Working steps

Working Step	Description
1 **General threats of infrastructures and land uses posed to GBI ecological networks**	Identification, harmonisation and selection of relevant datasources compiling renewable energy infrastructure, selection of geodata for the geographical scope of the case study.
2 **Definition of relevant infrastructures**	Identification of existing and planned RE infrastructure projects, with the selection of relevant locations based on thresholds for each power source
3 **Existing pressures and expected major threats in the pilot region**	spatially relevant existing and planned infrastructures in the pilot region are compiled on the basis of • search for official, publicly available lists of planned projects. • Proximity or overlapping with spatial planning areas for biodiversity conservation
4 **Criteria for unsuitable locations in the pilot region (exclusion zones)**	Exclusion zones, in this context, areas where certain infrastructures are not allowed to be built (unsuitable areas). For the definition of exclusion zones, spatial planning areas for biodiversity protection are already considered as areas that must remain free from any infrastructure development. Proximity impacts are also considered. • Current regional standards or guidelines for determining unsuitable areas for specific types of infrastructure are reviewed to assess potential formal concepts. • A compilation of national strategies regarding renewable energy (RE) implementation, emphasizing on considerations for protected areas and sensitive ecosystems.

Working Step	Description
5 **Mapping the land use conflicts for renewable energy production**	With regard to ecological connectivity a map of the exclusion zones including relevant type of RE infrastructure (biomass, hydropower, wind power, solar power) is generated (using overlay, buffering functions). High voltage transmission lines, roads, railways and urban/industrial development are not being considered in this report.
6 **Possible mitigation and compensation measures**	General proposals for possible mitigation or compensation measures for existing and planned renewable energy facilities in the pilot region of the "Alpine Space" are presented.

3.2 Data used

The following table shows the data sources and provides a short description of the data used and available for analysing the implementation of RE, identification of land use conflicts and definition of unsuitable locations for RE development inside the “Alpine space” pilot region.

Table 2 Overview of data used

Data	Source	Description
Potential planning areas for biodiversity preservation	ALPARC	Effectively conserved, ecologically representative, and well-connected areas
Alpine Protected Areas	ALPARC	Compilation of a selection of protected areas: - National parks - Nature reserves - Natural/regional park - UNESCO biosphere reserves - UNESCO world heritage – natural
Natura 2000	EEA	Natura 2000 is an ecological network of protected areas, set up to ensure the survival of Europe's most valuable species and habitats.
Emerald Network	EEA	The Emerald Network is an ecological network made up of Areas of Special Conservation Interest. The objective of the Emerald Network is the long-term survival of the species and habitats.

Data	Source	Description
CORINE Land Cover	EU	Areas which protect the ecosystem and its functionality, the diversity and beauty of the landscape and its recreational value.
Natura 2000 and emerald network	EEA	Areas of protected animal and plant species and habitats as well as the biodiversity in an EU-wide NATURA 2000 network of protected areas
Hydropower plants	OSM	Hydropower plants Dams large and small
	Global Energy Observatory (GEO)	
Wind power infrastructure	Global energy monitor, Global wind power tracker	Wind farms projects categorised by their current advancement stage
Solar power infrastructure	Global energy monitor, Global solar power tracker	Solar projects categorised by their current advancement stage
	Alpine PV competence	Solar projects in Switzerland categorised by their current advancement stage

4 Major pressures and threats to ecological connectivity

4.1 General threats to GBI ecological networks posed by infrastructure and land uses

Table 3 Infrastructures and land uses with their impact on connectivity

Sector	Type of infrastructure/ Land use	Comments on Connectivity
Renewable energy	Hydropower - hydroelectric reservoir (dam)	high impact on structural and functional connectivity by producing blockages in water flows and changes in water quality. They represent barriers to species migration, causing habitat fragmentation. Require large land take
	Hydropower - Run-off-river power plants	low impact on structural connectivity because of minimal land take
	Windpower - windmills	low impact on structural connectivity because of minimal land take high impact the construction of turbines and infrastructure disrupts wildlife corridors, isolating habitats. Additionally, species face mortality risks due to turbine collisions or electrocution
	Solar Power - Photovoltaics: Ground-mounted solar panels	small scale photovoltaic projects mostly low impact on structural connectivity because of usually low soil sealing and marginal barrier effects. Effects depends on the design practices and spatial planning practices large area photovoltaics: high impact due to extensive land intake, habitat loss through clearance when development is built on a non-artificialized area, fragmentation effects and bird mortality.
	Bioenergy - Biomass	Bioenergy plants: Mostly low impact on ecological connectivity because of usually low land take and marginal barrier effects. The negative impacts will depend on the facility size and locations. Possible changes on land uses and management, especially in natural and agricultural areas:

Sector	Type of infrastructure/ Land use	Comments on Connectivity
Transport	roads/ highways	high impact on structural and functional connectivity because of usually large land take, barrier effects, wildlife mortality due to traffic and impacts due to noise, dust and pollutants
Transport	railway	high impact on structural and functional connectivity because of land take (habitat loss), barrier effects, wildlife mortality due to traffic and impacts due to noise, dust, pollutants and vibrations
Urban /industrial development	Urban/ industrial development	high impact on structural and functional connectivity because of land take (habitat loss), barrier effects and impacts due to noise and other pollutants

4.2 Definition of relevant infrastructures

The scale and design of certain infrastructures can have negative impacts on the biodiversity. Therefore, it is essential to first analyse which types of infrastructures generate pressures or constitute a threat to ecological connectivity and are relevant for spatial planning. Are there significant negative effects expected on the environment from the infrastructure listed below? Additionally, how can we identify which infrastructure projects are relevant at an Alpswide level and should therefore be considered in the context of this report?

The EU's Environmental Impact Assessment Directive provides specifications for which projects an Environmental Impact Assessment (EIA) are obligatory. These specifications can be interpreted as an orientation for the spatial planning significance of different infrastructures. In the EU's Environmental Impact Assessment Directive relevance thresholds are not specified for all project types. EU Member States can provide further details with regard to the necessity of an environmental impact assessment or a preliminary environmental impact assessment (on a case-by-case basis or by setting specific criteria such as the location, size or type of project).

The following table shows the project types that are considered to be spatially relevant and thus may have negative impacts on the environment and connectivity.

Table 4 Identification of projects thresholds for spatial planning

	Relevance for spatial planning
Hydropower	Any construction and operation of a hydropower plant Any river canalisation and stream correction work (run-of-river and pumped storage projects) Micro and small hydropower projects Projects located in a protected area
Windpower (windmills)	Wind farm with wind turbines with a total height of more than 80 metres each and over 10 MW in capacity Projects located in a protected area
Solar power (ground mounted photovoltaic systems)	ground mounted photovoltaic system with a surface area larger than 2 ha and over 5MW in capacity Projects located in a protected area
High voltage transmission line	transmission line with a voltage of 110 kV or more Projects located in a protected area
Roads/ highways	Highways and primary roads continuous length of 100 km or more Projects located in a protected area
Railways	railway track associated operating facilities with more than 2000 m² Projects located in a protected area

4.3 Existing pressures and expected major threats in the pilot region

The Alps are a region with significant biodiversity hotspots, but they are also under threat from different pressures, including tourism, landscape fragmentation driven by urbanisation and other infrastructure development. These phenomena are particularly important in the main valleys and along the edges of the perimeter of application of the Alpine Convention. The report D2.3.1 of the case study "Alpine region", provides a more detailed analysis of these barriers.

Besides the development of traditional infrastructure, the current energy and climate targets adopted by Alpine countries involve new developments in renewable energy production infrastructure, which could have potential impacts on valuable biodiversity hotspots in the Alps areas that, aside from hydropower, were not previously considered for such developments.

The European countries have set different goals for 2030 and 2050 regarding the development of renewable energy, decarbonization and energy independence. As illustrated in the table below, each Alpine country starts from a different baseline and have also different potentials for renewable energy development.

Table 5 Share of energy from renewable sources in gross final energy consumption

	2015[2]	**2020**	**Target 2030**[3]
Austria	33,49%	36,5%	57%
France	14,8%	19,1%	33%[4]
Germany	14.9%	19,1%	38,1%
Italy	17,5%	20,3%	39,4%
Slovenia	22,79%	25%	33%
Switzerland[5]	2 830,5 GWh (without hydropower)	4 710,2 GWh (without hydropower)	17 000 GWh (Without hydropower - 2035) [6]

[2] Data from 2015 obtained from the progress report “Towards renewable Alps” (Permanent Secretariat of the Alpine Convention, 2017)

[3] National Energy and Climate plans 2021-2030 - (National energy and climate plans 2021 - 2030 - Austria, Germany, Italy and Slovenia)

[4] Renewable energies 2030 target France (Ministère de la transition énergétique, 2023)

[5] Swiss Renewable Energy Statistic – 1990 - 2023 (Office fédéral de l'énergie OFEN, 2023)

[6] Swiss Renewable Energy Statistic - (Office fédéral de la statistique OFS, 2024)

The energy and climate strategies proposed by each country include measures to improve efficiency and accelerate the development of renewable energy. These efforts are translated into economic incentives, identification of areas for new developments and the exploration of potential alternatives to deploy renewable energy infrastructure on a larger scale across different landscapes, including mountain areas and, consequently, the Alps.

Currently, hydropower and windpower are the main renewable energy power sources in Europe. For some Alpine countries, hydropower has nearly reached its main potential and windpower presents some major technical challenges for a large-scale implementation. Solar power, however, has one of the biggest increases among the renewable sources in the different Alpine countries. For this reason, a dedicated analysis regarding this power source is developed below, the other RE power sources are also analysed in chapter 5.

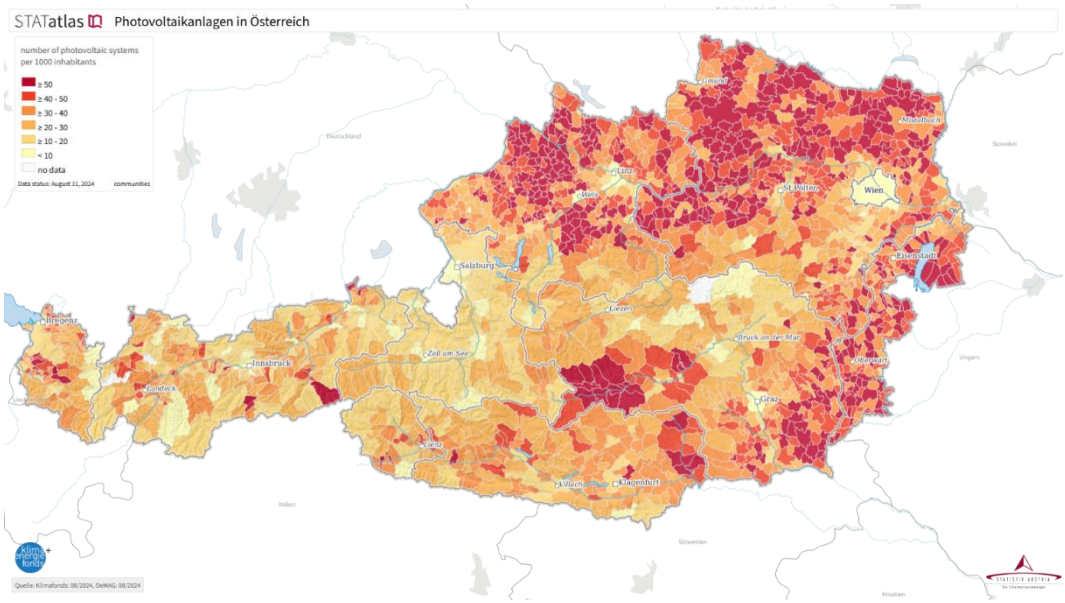
4.3.1 Solar power

4.3.1.1 Austria

The 2021 Electricity Industry and Organization Act (ElWOG) provides the main framework for energy supply in Austria, the federal and the provincial level have also their own Electricity Act. The developments of renewable energy have been implemented trough different amendments on the EIWOG, for instance, the Renewable Energy Extension Act describes the vision and strategies Austria will follow to meet both national and European Union goals for renewable energy implementation, aiming to achieve climate neutrality. (Federal Chancellery)

The government is supporting the development of PV installations through incentives and subsidies, the share of PV is steadily increasing as this power source plays a key role in the national goals of decarbonation and RE energy production.

Map 2 Number of PV plants per 1,000 inhabitants - Austria

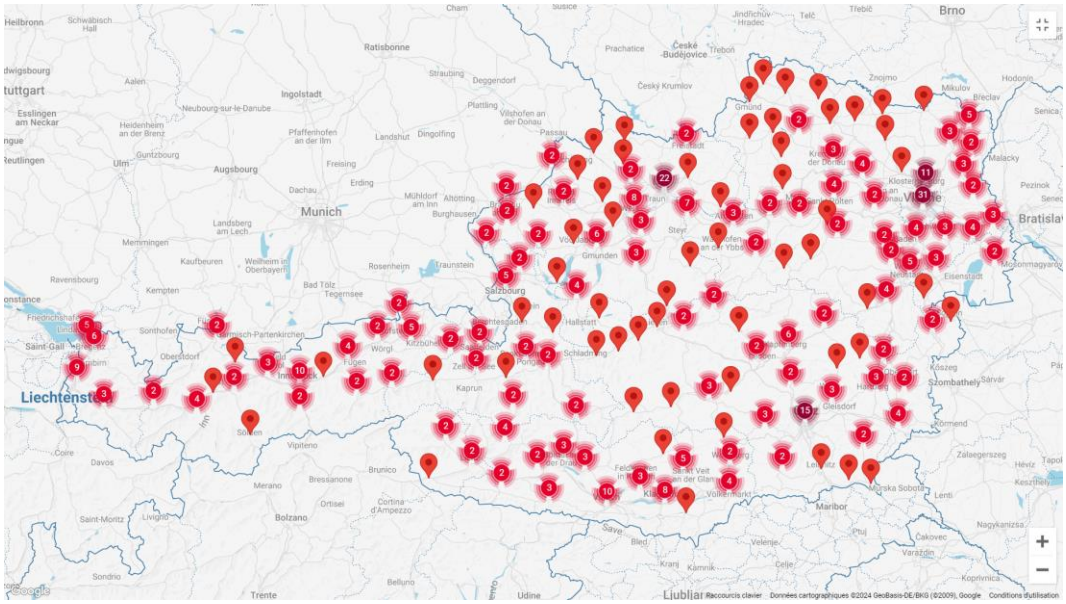


Source : (Climate and Energy Fund; OeMAG, 2024)
https://www.statistik.at/atlas/?mapid=them_energie_klimafonds

The acceleration of the implementation involves also the identification of potential areas to develop this power source, responding to the Electricity Industry and Organisation Act (ElWOG) "Transparency in the event of insufficient capacity", network operators must publish the available and booked capacity (MVA) per substation.

In response to this requirement, a map of available grid connexion capacities has been published. The locations indicated on the map extend through all the country. With most areas with low PV share per inhabitant located in low artificialized areas. It will be crucial to follow the progress of PV infrastructure development in these areas.

Map 3 Available grid connection capacities - Austria

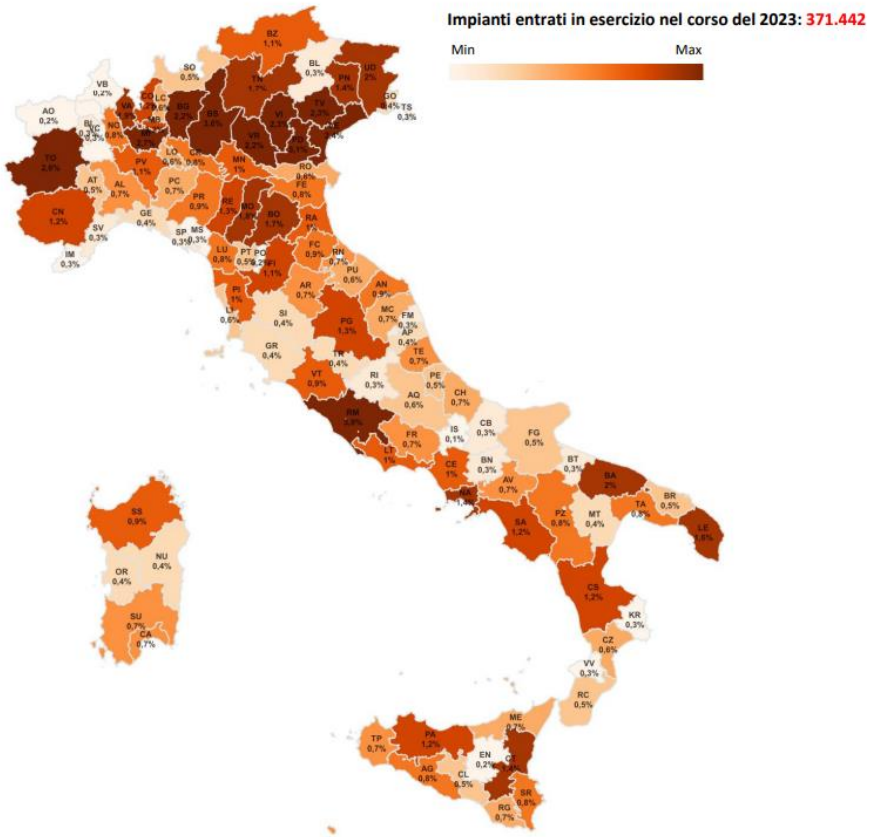


Source : https://www.ebutilities.at/verfuegbare-netzanschlusskapazitaeten

4.3.1.2 Italy

The renovation of the energy sector has been set as one of the objectives set on the energy and climate strategy 2030. As illustrated in Table 2, the country has committed to achieving more than doubling its production from renewable energy sources by 2030. The geographical characteristics of the country make of solar energy, one of the sources with the greatest potential to be developed.

Map 4 Provincial distribution of plants in operation in 2023 - Italy



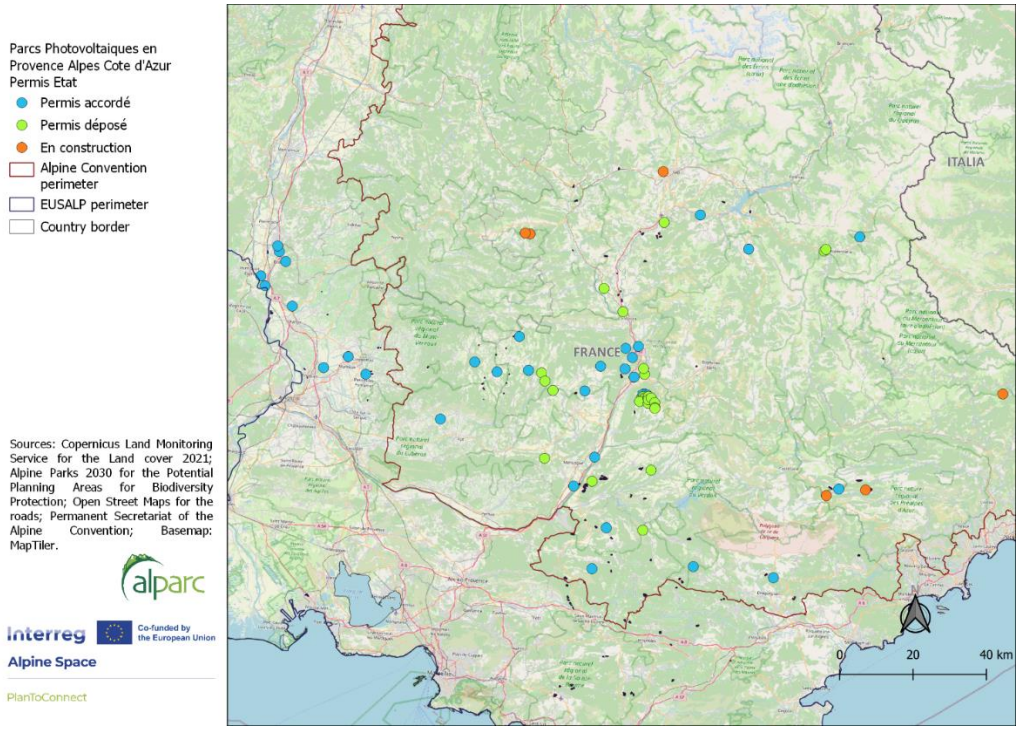
Source: (Gestore dei Servizi Energetici, 2023)

According with the report of the Energy services authority 2023, there were around 7800 installations with a capacity of 1MV or greater distributed across the country. The production levels of the regions located in the north of the country vary considerably. For instance, in 2023 Lombardy ranked second in terms of solar energy production while Valle d'Aosta ranked last. (Gestore dei Servizi Energetici, 2023)

In this context, the regions are called to improve their capacities and to implement measures to guarantee the development of new solar projects. The presence of solar power installations in the Italian Alps is less significative that other locations in the country. However, this trend may change with the increase of requests made through the implementation of the PAS (Simplified authorisation request) since 2022 and the developments promoted by energy production groups with experience in installing solar energy projects in mountain areas.

4.3.1.3 France

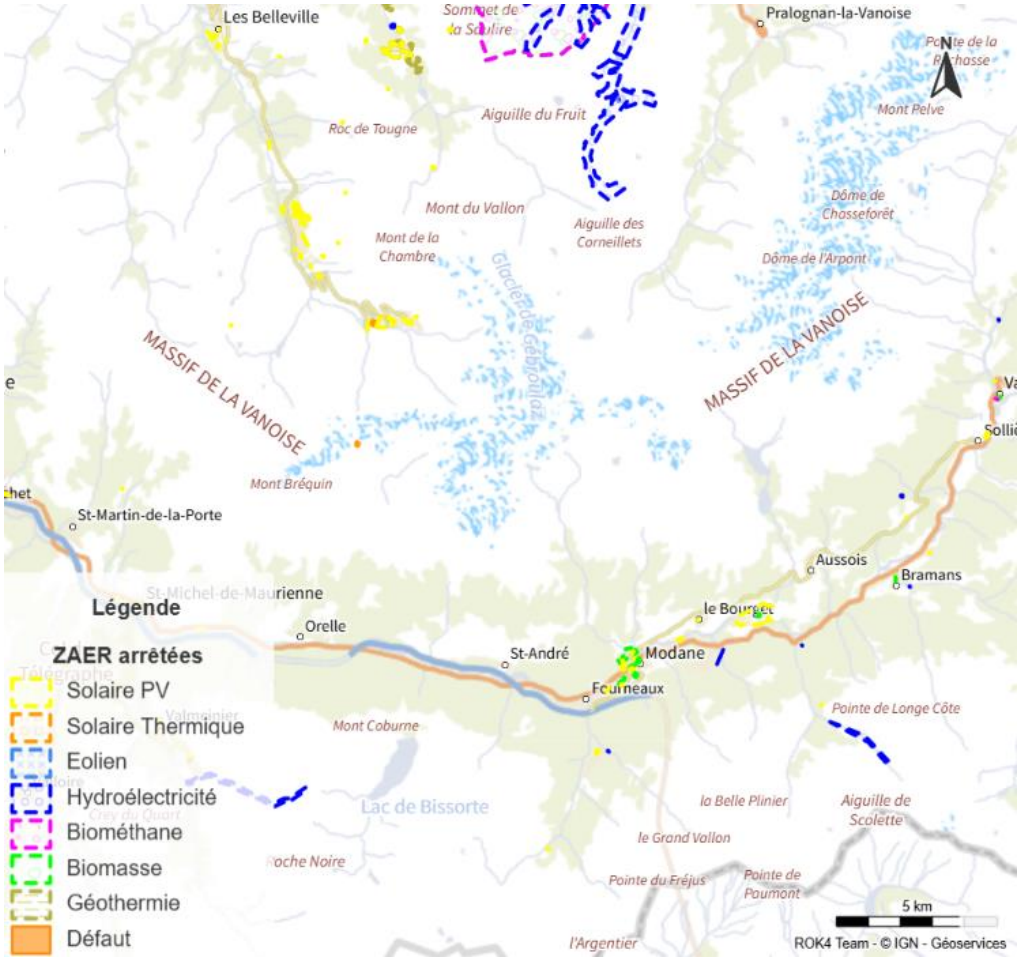
Map 5 Solar facilities permit state - Provence d'Alpes Côte d'Azur region



The French energy and climate strategy includes different actions oriented to reduce the dependence on fossil energies, the acceleration on the development, of renewable energies is one of the key actions to achieve this goal and the government. Solar energy is one of the renewable sources that is marked as a priority in the strategy. Today the production from this source accounts for 16 GW and the goal set on the strategy for 2030 is 54-60 GW.

The Alps hold considerable potential for the development of renewable energy infrastructure; however, this acceleration can constitute a threat for region's biodiversity. As illustrated on the map above, there are already projects that have obtained their permit to start their activity and there are more being presented to the authorities in the region, this phenomenon is expected to increase with the implementation of the ZAER (Acceleration zones for renewable energies).

Map 6 ZAER - Renewable Energy Production Acceleration Zone



Source: (Cerema; Institut National de l'Information Géographique et Forestière, 2025)

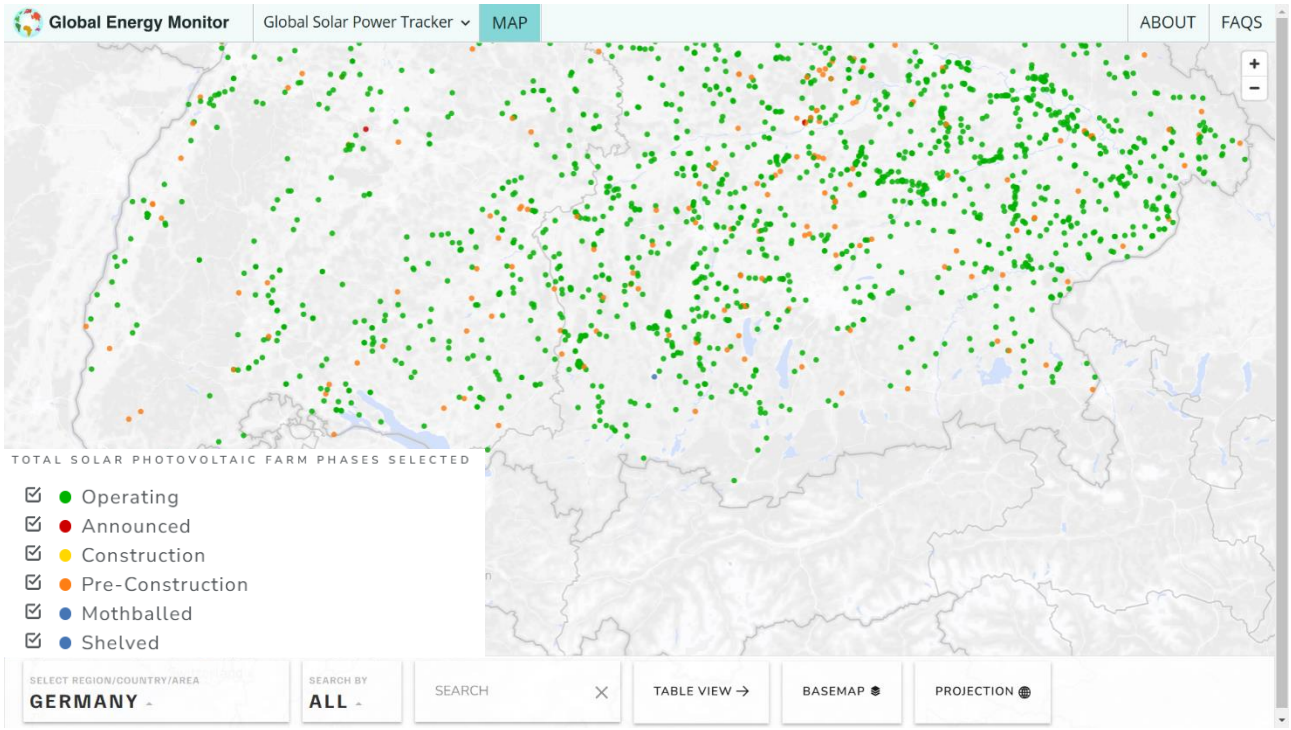
4.3.1.4 Germany

The German energy strategy “Energiewende”, has implemented different tools and incentives to facilitate the development of renewable energy in the country. Due the higher exposition to solar radiation, mountain areas such as the Alps have a high potential for solar energy, one of the main renewable energy sources promoted in the strategy.

The map below shows the operating projects and those in development in other states. Even though there may be other projects not included on the map, it provides a clear overview of the current situation. Solar energy has spread across the territory, but except for a few

operational projects, the German Alps remain with no major disruption from such installations.

Map 7 Solar photovoltaic facilities - Germany



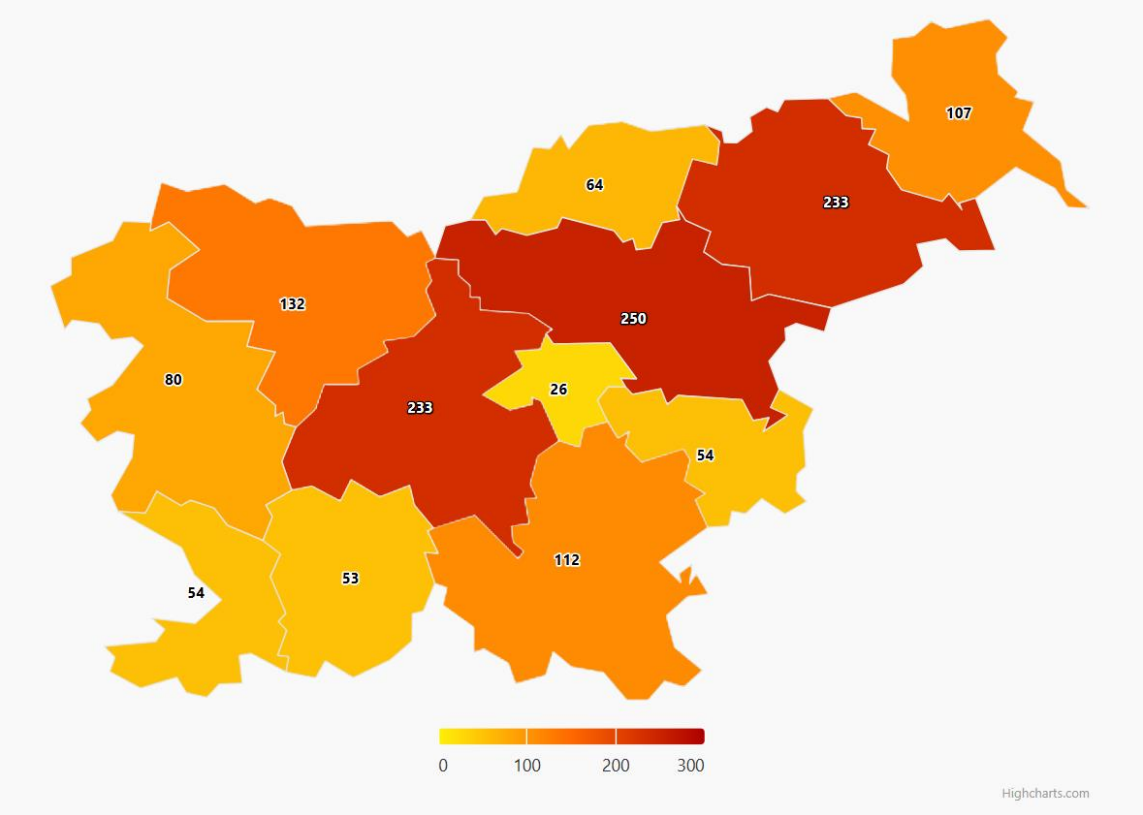
Source: (Global Energy Monitor, 2024)

4.3.1.5 Slovenia

The energy and climate plan highlights solar power as one of the highest potential renewable energy sources for Slovenia while maintaining environmental sustainability. As illustrated in the map, there are important differences in terms of solar energy production capacity between the municipalities of the country.

One major challenge, identified in the energy and climate plan is the capacity to integrate solar power into the electricity grid, which, along with the environmental implications and economic costs of power plants installation, represents a crucial factor in the development of solar power infrastructure and the achievement of the solar energy production goals for 2050. (Republic of Slovenia, 2020)

Map 8 Installed power capacity (MV) by statistical region



Source: (PVportal, UL FE, LPVO, 2025) - *Status as of 31/12/2024*

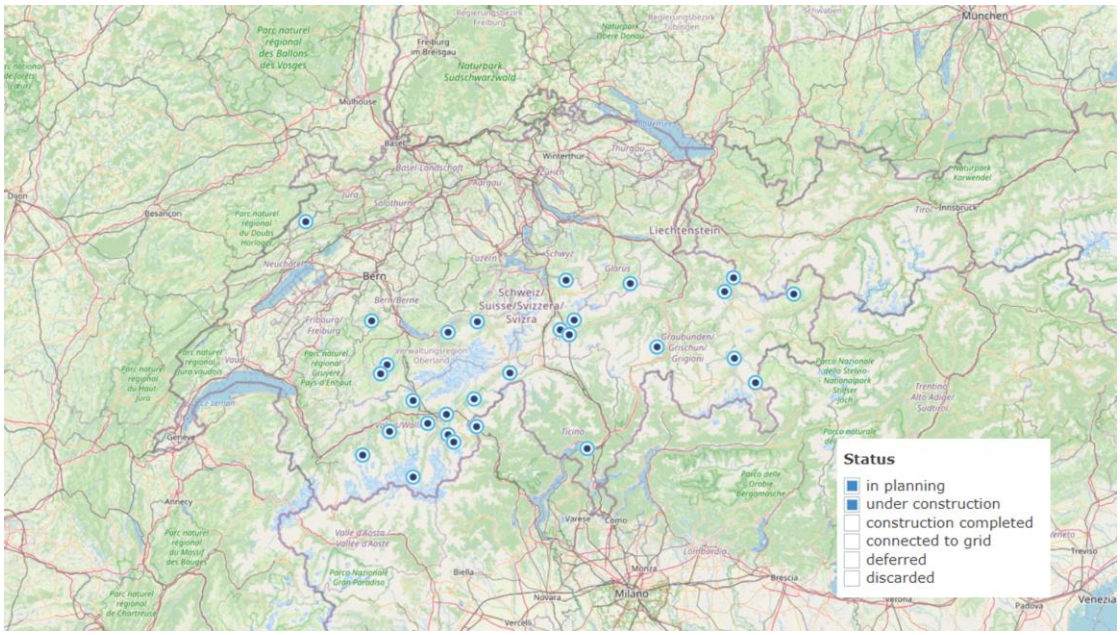
4.3.1.6 Switzerland

The implementation of the Sustainable development strategy 2030, particularly the priority Climate, energy and biodiversity, as well as the Energy strategy 2050, have boosted efforts to develop renewable energies in the country. Hydropower remains as the major renewable energy source, (48,2% of the total electricity production). However, solar energy, along with wate-to-energy and biomass, contributed to 95% of renewable energy sources production, excluding hydropower. Energy production official statistics, reports hydropower separately, while other renewable energy sources represent 10,5% of the production. (Office fédéral de la statistique OFS, 2024)

The map presented below, show the projects in planning or under construction state. This information, provided by the Alpine PV competence, offers an overview of how solar projects are starting to spread across the Alpine region. Some of these projects are subject to consultations with local communities, a few projects listed on the table have been refused. In terms of land use, 6 projects from the list are further developments of existing dam infrastructure. For the remaining projects, some focus on developing on giving a new purpose to abandoned facilities, such as ski resorts, while others are being developed on agricultural areas.

Ecological connectivity in the Alps is clearly concerned by these developments, as new infrastructures are being planned in higher altitudes. By comparing the approximative location of the projects listed in the table with the Spatial areas for biodiversity protection, the overlapping projects are indicated in blue. This indicates how areas with high biodiversity value are also being considered as possible locations for renewable energy development. For projects proposed on locations not yet artificialized, the assessment of potential threats and implications for biodiversity and landscape quality are crucial.

Map 9 Alpine PV projects in planning and under construction



Source: Alpine PV Competence https://alpine-pv.ch/

No	Project	Status	Type	Approval of Local Municipality
1	Albigna Solar	connected to grid	Dam Wall	Not necessary
2	Alpine Photovoltaikanlage Sidenplangg	in planning	Freestanding	Yes
3	AlpinSolar	connected to grid	Dam Wall	Not necessary
4	Bernina Solar	in planning	Freestanding	Yes
5	Caischavedra	connected to grid	Freestanding	Not necessary
6	Gibidum Solar	in planning	Freestanding	Yes
7	Gondosolar	in planning	Freestanding	Yes
8	Grengiols Solar	in planning	Freestanding	Yes
9	Lago di Lei	connected to grid	Dam Wall	Not necessary

No	Project	Status	Type	Approval of Local Municipality
10	Madrisasolar	in planning	Freestanding	Yes
11	MontSol	in planning	Freestanding	Yes
12	NalpSolar	in planning	Freestanding	Yes
13	Oberaar Staumauer	connected to grid	Dam Wall	Not necessary
14	Ovra Solara Magriel	in planning	Freestanding	Yes
15	Parc solaire des Grands Plans	in planning	Freestanding	Yes
16	Parco Solare Alpino Duragno	in planning	Freestanding	Yes
17	Prafleuri	in planning	Freestanding	Yes
18	PV Alpin Parsenn	in planning	Freestanding	Yes
19	PVA Hohsaas	in planning		Pending
20	PVA Punt dal Gall	connected to grid	Retaining Wall	Not necessary
21	Räterichsboden Stausee	connected to grid	Dam Wall	Not necessary
22	Schattenhalb Tschingel Ost	in planning	Freestanding	Yes
23	Scuol Solar	in planning	Freestanding	Yes
24	Sedrun Solar	under construction	Freestanding	Yes
25	Solaranlage Gries	in planning	Freestanding	Yes
26	Solaranlage Schwandfäl	in planning	Freestanding	Yes
27	Solaranlage Vorab	in planning	Freestanding	Yes
28	Solarfarm Bergbahnen Lenk (Hahnenmoosbärgli)	in planning	Freestanding	Yes
29	Solarkraftwerk Alp Hintisberg	in planning	Freestanding	Yes
30	Solarkraftwerk Samedan	in planning	Freestanding	Yes
31	Solarprojekt Morgeten	in planning	Freestanding	Yes
32	SufersSolar	in planning	Freestanding	Yes
33	Vispertal Solar Mäsweide	in planning	Freestanding	Pending
34	Vispertal Solar Wysse-Bode/Sattel	in planning	Freestanding	Pending
35	z'Opmisch Hubil	in planning	Freestanding	Yes

Source Alpine PV Competence https://alpine-pv.ch/

5 Choice of Locations for major developments / renewable energy facilities

5.1 General criteria for unsuitable locations

The general criteria for unsuitable sites are compiled in the following table. They are based on the corresponding chapters of the report D1.3.1.

Table 6: General criteria for unsuitable sites (D1.3.1)

	Unsuitable locations
Hydropower	• protected areas (e.g. Natura 2000 areas, nature reserves, …) • natural or semi-natural rivers • open spaces
Windpower	• protected areas (e.g. National parks, Nature reserves, Natura 2000 areas, nature reserves, …) • European bird protection areas with occurrences of wind energy-sensitive bird species • designated bird migration routes • density centers of collision-sensitive bird species • old natural or semi-natural forests • forested ridgelines because of high collision rates of birds and bats • areas with high perceived scenic quality (landscape quality)
Solar power	• protected areas (e.g. National parks, Nature reserves, Natura 2000 areas, nature reserves, …) • areas of high nature conservation value • riparian buffer zones, floodplains • natural watercourses and lakes • soil with very high significance for natural soil functions • agricultural soil with high degree of productivity • open spaces
Biomass (bioenergy plant)	• protected areas (e.g. National parks, Nature reserves, Natura 2000 areas, nature reserves, …) • areas of high nature conservation value • open spaces

	Unsuitable locations
High voltage transmission line	• European bird protection areas (Important Bird Areas (IBAs) or Special Protection Areas (SPAs)) • wetlands of international importance according to the Ramsar Convention • designated bird migration routes • near large bodies of water and reservoirs • protected areas specifically for landscape (UNESCO World Heritage Sites, Landscape conservation areas, priority areas for tourism) • other protected areas (e.g. Natura 2000 areas, nature reserves, core areas of national parks and biosphere reserves) • old natural or semi-natural forests • water protection areas of zones I and II (no construction of transmission poles in waterways or banks of waterways
Roads/ highways	• protected areas (e.g. National parks, Nature reserves, Natura 2000 areas, nature reserves, …) • areas of high nature conservation value like old-growth forests or wet- and peatland • soil with very high significance for natural soil functions • open spaces
Railways	• protected areas (e.g. Nature 2000 areas, nature reserves, core zones of national parks and biosphere reserves, water protection areas) • areas of high nature conservation value like old-growth forests or wet- and peatland • open spaces

5.2 Development of specific criteria for unsuitable locations in the pilot region (exclusion zones)

Exclusion zones in this context are areas where certain infrastructures are not allowed to be built or operated. Exclusion zones are the most common planning instrument to mitigate environmental impacts of human land-use, including the deployment of RE.

As can be seen from the table above, the unsuitable locations are often identical. They include mainly protected areas of various types: e.g. Nature 2000 areas, nature reserves, core zones of national parks and biosphere reserves, water protection areas or the developed GBI network for connectivity (including priority areas for conservation and restoration).

When defining exclusion zones, it is not enough to consider only the boundaries of ecologically valuable areas. Many infrastructure projects have far-reaching effects (for example wind turbines or roads), so that positioning them directly next to an ecologically valuable area can result in significative negative effects. As described in report D1.3.1 edge effects and barrier or fragmentation effects influence not only the habitats adjacent to an

infrastructure, but also the ecosystems and living conditions of wildlife in wider areas (see report D1.3.1).

Due the extension of the case study, it is not possible to provide general guidelines for buffer sizes to be applied to renewable energy infrastructure projects. Concrete and pertinent measures should be provided on the local level were more specific information regarding the habitat and species impacts can be measured. As outlined on the different cases studies from the project, each country has its own framework regarding the authority to define the distances, and these are most often defined on local urban planning documents.

The spatial planning areas for biodiversity protection are one instrument that illustrates one alternative to preserve biodiversity valuable land. However, the compatibility of these sensitive spots for biodiversity with RE projects most be studied in detail and for each potential project on the local level.

5.3 Mapping the land use conflicts for renewable energy production

5.3.1 Hydropower

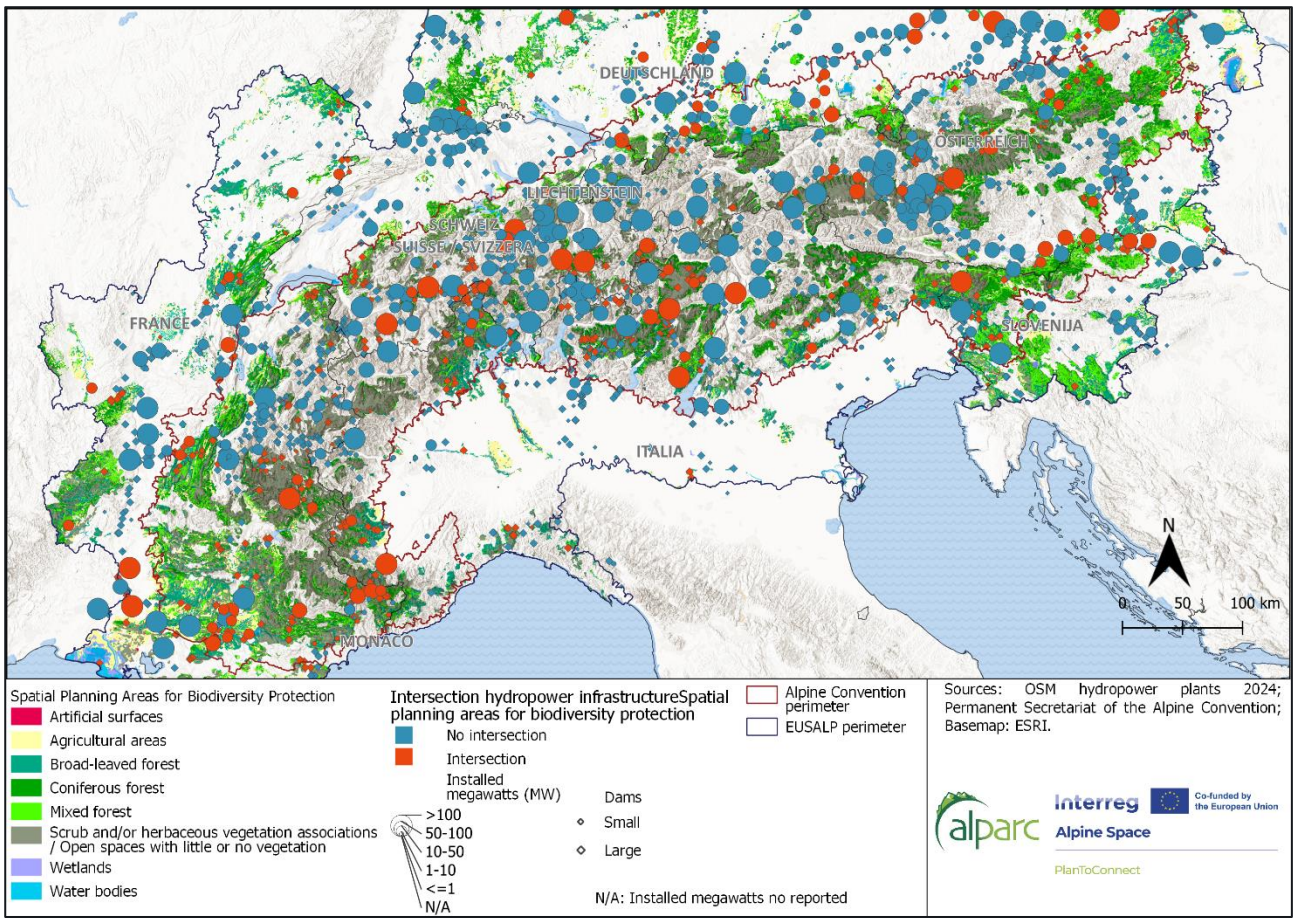
Hydropower generation is widespread and deeply established throughout the Alpine Arc, with most of the renewable electricity in the EUSALP region being generated from this source. (EUSALP, 2017) The potential for planning new projects varies from one country to another, there are land use and environmental factors that will determine the characteristics of new installations.

The development of this kind of infrastructure, has implications for both the current and future situation of nature protection. With the goal of increasing renewable energy production, countries are actively seeking alternatives to create new developments. In Europe, 28% of planned hydropower projects are located in protected areas. Specifically IN the Alps, although there is no exact figure, some reports indicate that most of countries (Austria, France, Germany and Switzerland) have reached an important amount of infrastructure for this energy source, the potential for further expansion quite reduced. (FLUVIUS, WWF, RiverWatch, EuroNatur, GEOTA, 2019)

Among the multiple effects to be evaluated. As described the recharge.green project, water diversions for hydropower, modifies the availability of water and land for local activities, such as for agriculture. Additionally, these installations can disrupt wildlife, negative phenomena such as reservoir flushing and fluctuations in water levels represent a potential harm to fish populations. (recharge.green project, 2015)

The map illustrates hydropower infrastructures, the dots represent hydropower plants (1312) and the diamonds, the dams (1729). The goal is to highlight the extent of the infrastructure required for energy production from water sources, which also involves water storage and diversion. Around 21,7% of the compilated hydroelectric power plants overlap with Spatial

planning areas, while the proportion for large and small dams is 31,1%. This demonstrates how these areas are essential for different land uses, which may not be necessarily compatible.



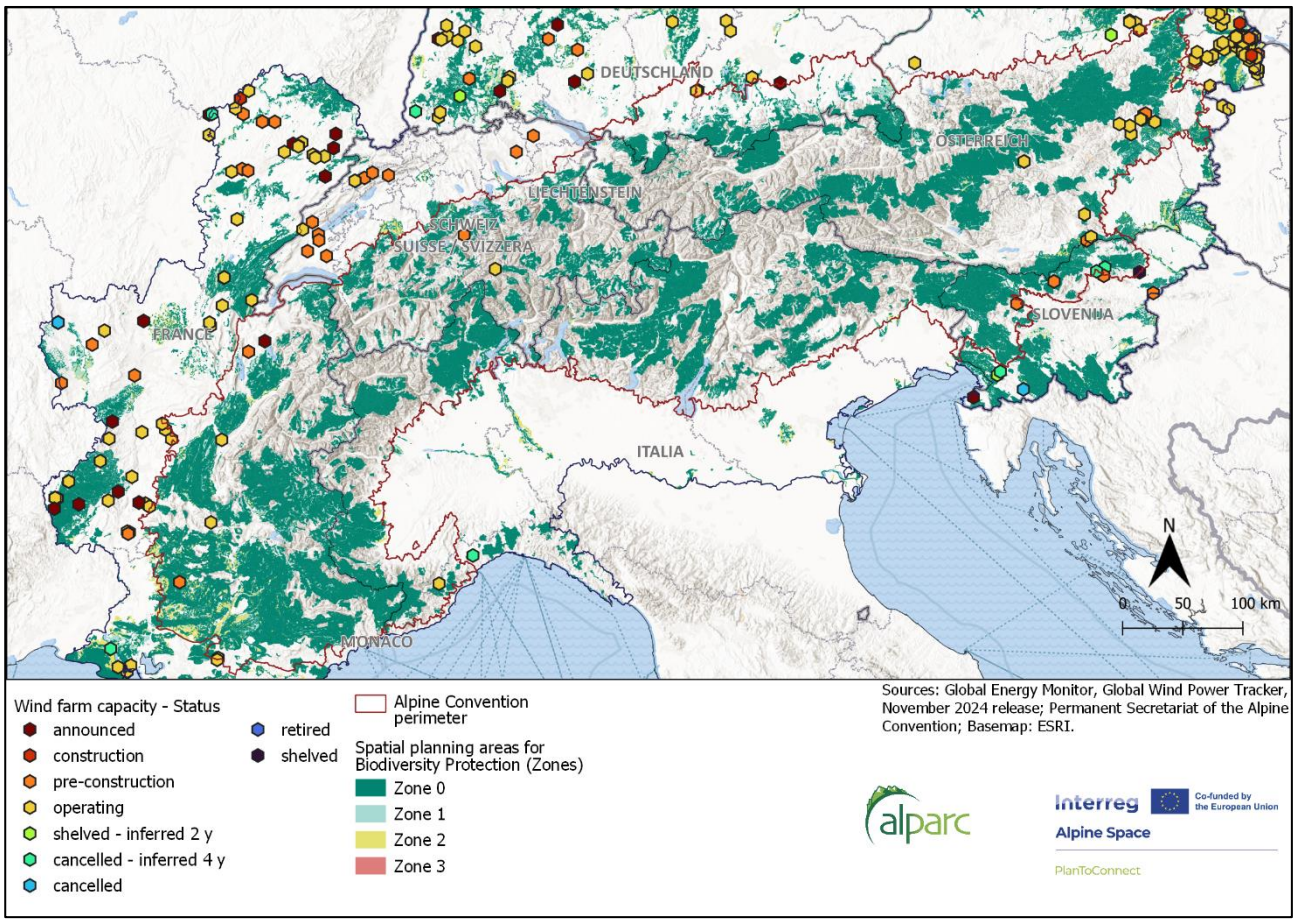
The map was elaborated with available data from OSM, which does not cover all infrastructure related to hydropower production. Nevertheless, it provides an overview of the widespread presence throughout the Alps. The Alpine Convention (2005) accounted 550 large hydropower stations (output greater than 10 MW) and thousands of smaller plants with lower production capacity. (Permanent Secretariat of the Alpine Convention, 2011)

5.3.2 Windpower

The presence of wind power installations is less prominent compared to other renewable energy sources included in this report. Most of these projects are located in the peripheral areas to the west and east of the Alpine Arc. According to the EUSALP energy survey, wind power represents 3% of total power production in the EUSALP region.

Some of the wind power infrastructure overlays with spatial planning areas for biodiversity protection, particularly in the southwestern region. These projects are on different stages of development and due their location they are subject to French environmental regulations, which require the preparation of an environmental impact assessment as part of the application process for review by the relevant authorities. (Section 11 : Eoliennes (Articles L515-44 à L515-46) from Code de l'environnement)

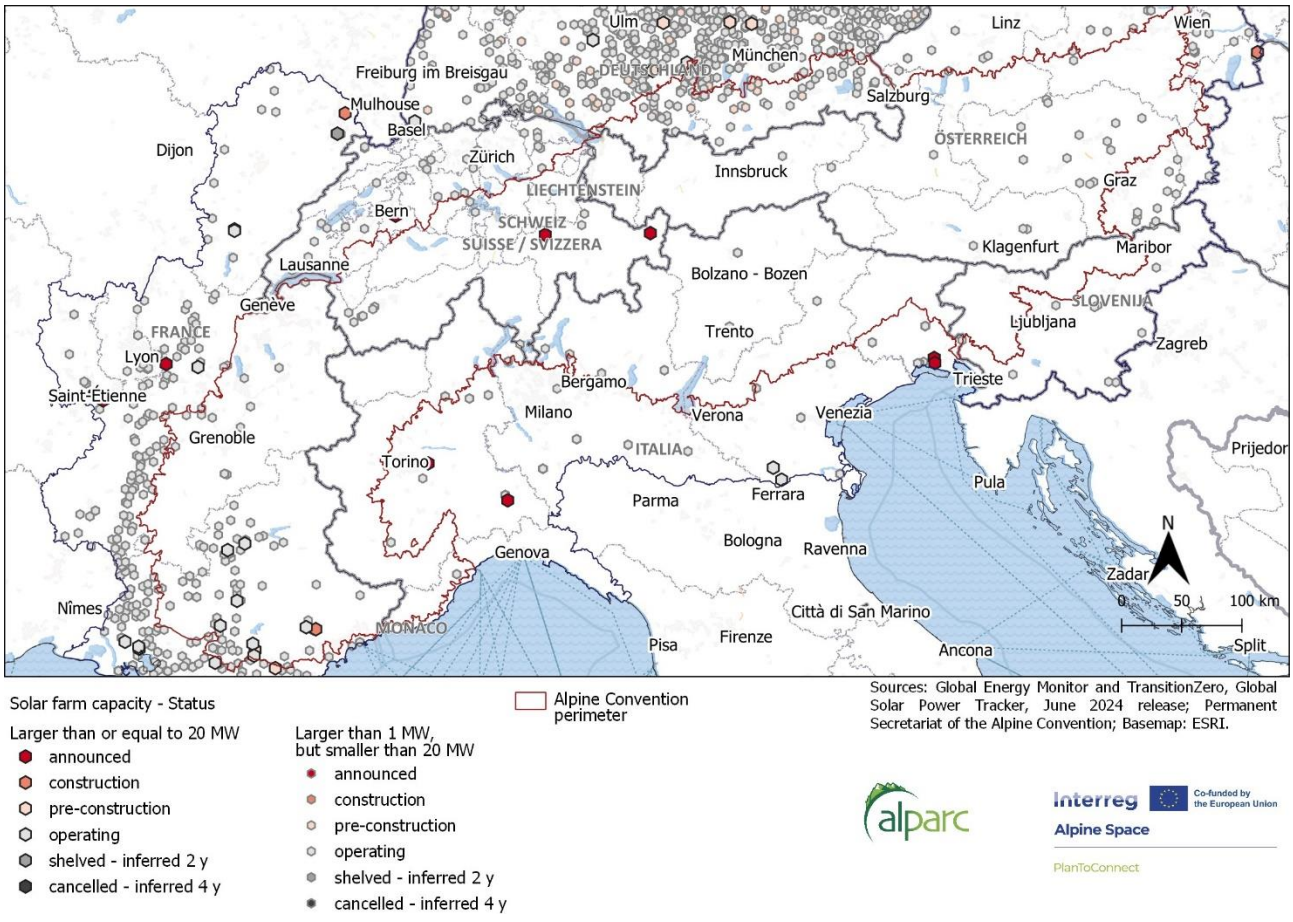
The development progress of windpower in the areas concerned by the case study is less significant compared to other renewable energy sources identified on the report. No major threats were identified from the projects and installations on the map. However, attention should be given to upcoming developments at the interface of the Alps and its periphery, where as shown on the map, there is a higher concentration of such installations.



5.3.3 Solar power

This section summarizes the current projects in various tables, the analysis is focused on projects that are either announced, under construction, or in the pre-construction phase. Projects located within or near Potential Planning Areas for Biodiversity Protection will be highlighted in blue. Additional information about potential threats to these projects will also be provided.

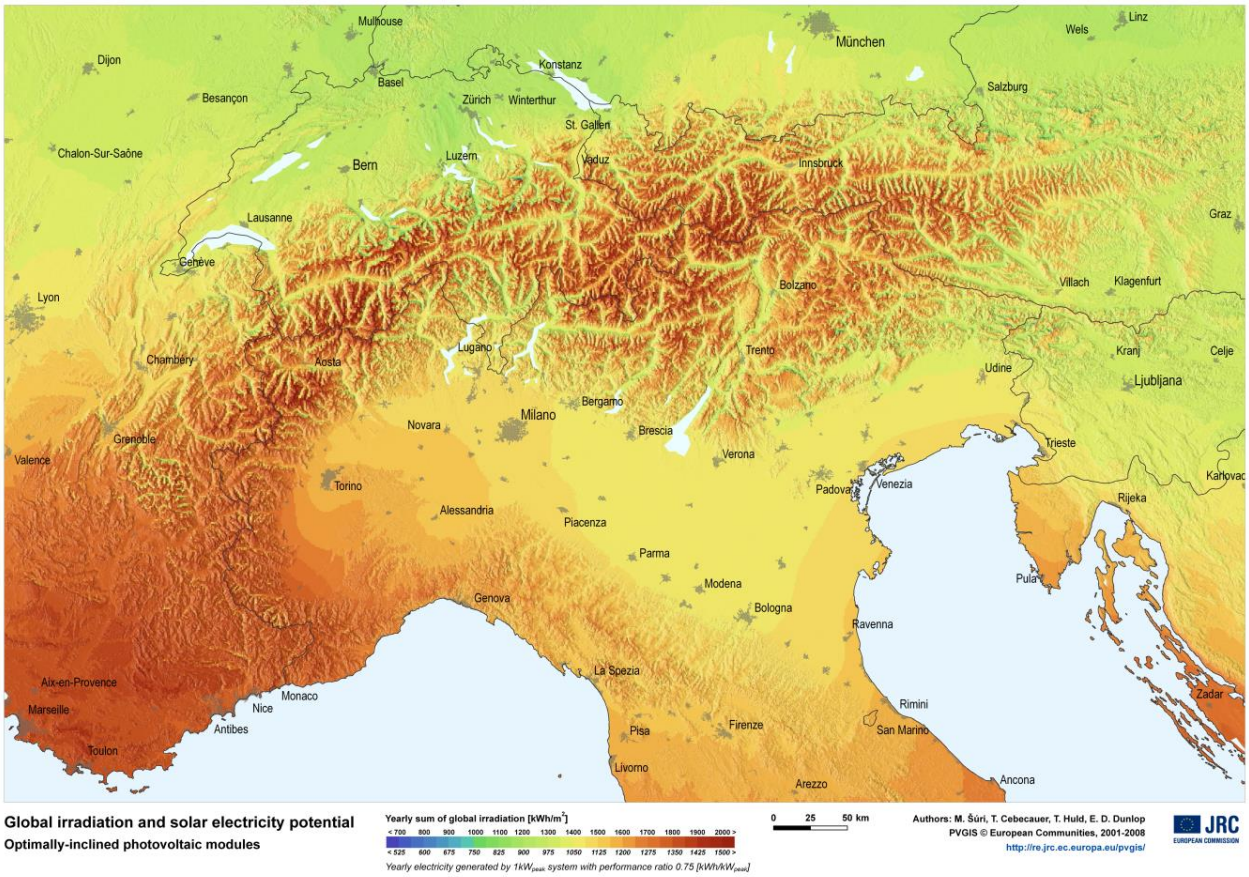
The map provides an overview of solar projects from the list compiled by the Global Solar Power Tracker. It highlights a selection of projects of different scales (level of production in MV) in and around the Alps, the locations expressed on the map are approximative. Any solar project in announcement status with an estimated production larger than1MV was included on the map.



The development of solar energy projects in mountain areas has gained increased interest in response to the new challenges emerged since 2022. In response, different governments have elaborated initiatives and strategies to accelerate the energy production, exploring new sources and locations to guarantee the energy supply.

The Alps are an attractive territory for the development of solar plants, mountain areas benefit from a higher solar irradiance and the current technology developments allow to better capture the solar radiation reflected by snow.

Map 10 Solar irradiation and solar electricity potential - Alps



About the current trends regarding the development of solar parks inside the Alps, there are different types of landscapes that are being targeted and also different types of installations and extensions. Two additional considerations should be taken into account:

The first consideration about the landscape, concerns the land use conflicts. The two projects in announcement phase, listed below are in proximity to ski and agricultural areas setting favourable conditions in terms of new development work. Solar energy projects located on already artificialised areas, allow to preserve untouched natural landscapes from new developments and to prevent land use conflicts.

The type of solar installation can vary depending on the location and the project's production goals. Most of the current solar projects within the Alps are either ground-based or installed on dam walls. The first option corresponds to large-scale solar panel systems which involves the modification of a considerable amount of land but a larger production potential. The

second option, the wall-mounted projects, cover a smaller and already in use areas and offer a lower production potential. (Đukan, Gut, Gumber, & Steffen, 2024)

5.3.3.1 Announcement phase

The projects listed on this category *"have been described in corporate or government plans or media releases but have not yet taken concrete steps such as applying for permits"* (Global Energy Monitor, 2024).

The detailed information resumed on the tables only include the projects with an estimated production greater or equal to 20MW. The projects indicated on this category are large-scale ground-based photovoltaic systems, both were subject to vote from local population and were set to start energy production from 2025.

Scuol solar farm - Scuol Solar AG[7]	
Country	Switzerland
Municipality	Scuol
State	Announced
Surface	57 Ha
Description	The photovoltaic system planned at the municipality of Scuol is set to be one of the largest developments of its kind in the country. Located near a ski area, the project announces different commitments such as minimizing visual impacts and ensuring no disruption to protected areas. On September the population approved the project led by the municipality of Scuol, Energia Engiadina (EE) and Engadiner Kraftwerke (EKW). (ScuolSolar, 2024)

Ovra Solara Rueun solar farm - Axpo Holding AG[8]	
Country	Switzerland
Municipality	Ilanz/Glion
State	Rejected
Surface	50 Ha

[7] Scuol solar farm project - https://www.gem.wiki/Scuol_solar_farm; https://www.scuolsolar.ch/

[8] Ovra Solara Reum project - https://www.axpo.com/ch/en/energy/generation-and-distribution/solar-power/ovrasolara-rueun.html

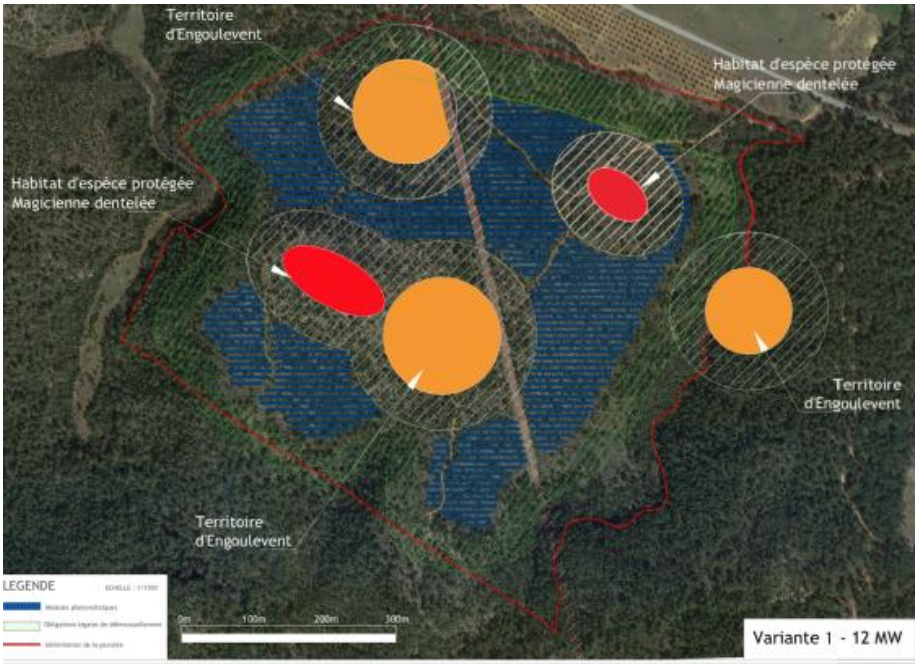
Ovra Solara Rueun solar farm - Axpo Holding AG[8]	
Description	The photovoltaic system located on Alp da Rueun was announced as a development where multiple uses could coexist on an elevation of 2000 ma.s.l.. The project, proposed by Axpo company working on the development of solar energy developments in the Swiss mountains, was rejected by vote of the population of the municipality of Ilanz/Glion in November 2023. (Municipality of Ilanz/Glion, 2023)

5.3.3.2 Pre-construction phase

The projects listed on this category *"are actively moving forward in seeking governmental approvals, land rights, or financing."* (Global Energy Monitor, 2024). The detailed information resumed on the tables only include the projects with an estimated production >20MW.

Aups solar farm - Tenergie[9]	
Country	France
Municipality	Aups
State	Pre-construction
Surface	16-22 Ha
Description	The photovoltaic system located on Aups, Provence-Alpes-Côte d'Azur, the project started with a call for proposals made by the municipality in 2020. This participative project involved different stakeholders, including the municipality, citizen representatives, the National Forest Office, the Verdon Natural Regional Park and the project development consortium with different companies covering different stages of energy production and distribution. Three variants of the development were proposed for concertation with the population, the differences are based on the surface covered by the project, the annual production, the challenges regarding energy transition and environmental protection. No further information regarding the advancement of the project has been published since the project concertation announcement call in 2021.

[9] Aups solar project further information : https://www.concertiis.fr/medias/20210421-aups-livret-habitants-e1308798.pdf;https://www.concertiis.fr/medias/20210308-aups-panneaux-permanence-e1282695-e1308800.pdf

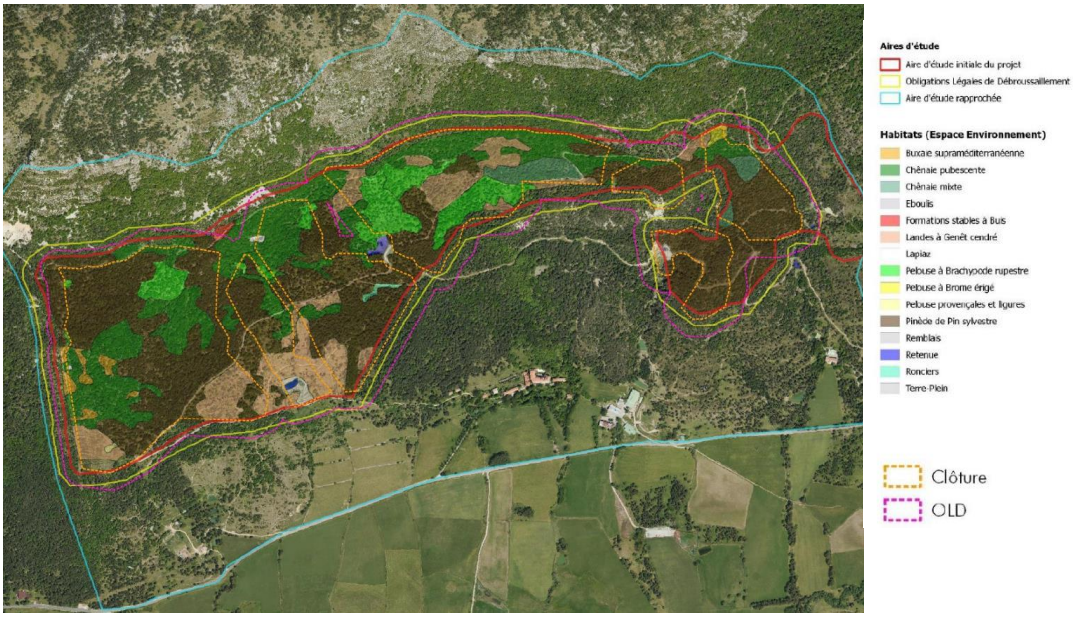
Aups solar farm - Tenergie[9]	
Further information	 Map 11 Aups (France) solar project proposal *Source : AUPS projet photovoltaïque participatif -Variante 1 Environnement privilégié*

5.3.3.3 Construction phase

The projects listed on this category have already started the *"site preparation and equipment installation."* (Global Energy Monitor, 2024). The detailed information resumed on the tables only include the projects with an estimated production >20MW.

Andon solar farm - Photosol Group[10]	
Country	France
Municipality	Andon
State	Construction
Surface	91 Ha (including 30 Ha - ground clearance area)

[10] Andon solar project further information : https://www.paca.developpement-durable.gouv.fr/06-andon-parc-photovoltaique-du-bas-thorenc-a12020.html

Andon solar farm - Photosol Group[10]	
Description	The photovoltaic system in Andon, is located in a forestry area categorised as a remarkable natural space (ZNIEFF) and a biodiversity reservoir on the regional schema of ecological coherence (Regional urban plan – implementation of ecological connectivity – Trame verte et bleue). The project was rejected (avis défavorable) by the National Council for Nature Conservation, the project was reconducted after proposing additional compensation measures and obtained the approbation of the Alpes maritimes prefect in 2019. The project is currently under construction.
Further information	 Map 12 Andon (France) solar farm project extension and habitats 2018 *Source: Photosol ; Réponses à l'avis du Groupe Régional d'Experts (GREx) DREAL PACA ; 2018*

Andon solar farm - Photosol Group[10]	
	 *Source: ©Google Earth 2024 – Andon solar farm current development*

6 Possible mitigation and compensation measures

A list of all possible mitigation and compensation measures can be found in the Annex 2. The chapter highlights the possible mitigation and compensation measures for the RE infrastructures in the pilot region Alpine space. They are based on the corresponding chapters of the report D1.3.1.

The particularity of the areas identified on the case study is that they integrate both protected areas and other biodiversity valuable areas, which have also been identified as key for ecological connectivity. In consequence, the first mitigation measure to implement for any infrastructure project planned on these areas should be focused on avoidance, by modifying the location of the projects preventing possible disturbances on these priority areas. When considering other possible mitigation measures for renewable energy infrastructures, the following considerations should be taken into account:

Mitigation measures for solar power projects should prioritize the repurposing of already developed land, for example abandoned ski resort sites. This approach can help minimize land clearance activities. Additionally, existing artificial structures, like dam walls, could be multi-purposed to accommodate photovoltaic installations, further reducing the environmental impact.

Dam on the Grimselsee, Switzerland © G. Plassmann

Hydropower project planning should focus on preservation of natural and semi-natural water sources by preventing new developments in these areas.

For projects under development, it is essential to implement measures that facilitate the movement of aquatic biodiversity. Additionally, a specific assessment of water quality maintenance should be conducted for each case to ensure the project's environmental compatibility.

Windpower can also benefit from repurposing existing infrastructure, for instance, abandoned industrial sites, which could help to minimize the environmental impacts of construction and operation. Since birds and bats are among the most threatened populations, all dissuasion measures should be implemented to reduce the possible mortality produced by the operation. The environmental assessment includes the identification of habitats and species affected by the project, a continuous monitoring of their evolution and declines should be implemented to take the corrective measures.

7 Conclusions

The report has focused on current and future projects for three main renewable energy sources: solar, wind and hydropower. As explained on previous chapters, there are some of this projects that overlay with the spatial areas for biodiversity protection. It is also important to mention that in most cases, the overlap is only partial and some comparisons are limited by the lack of precision regarding the scale - as some of the data is only available on point format and availability on the precise location data of the projects – only approximative locations. Nevertheless, the analysis of the three energy sources allows to identify the increasing interest of renewable energy projects within the Alps and how these developments do not exclude areas of high biodiversity value.

Multipurposing land could be a viable solution to address land use restrictions. As discussed in previous chapters, some developments are being proposed on already artificialized land, which helps mitigate the impact on natural or semi-natural ecosystems. This approach minimizes the need for further land modifications, reducing potential harm to biodiversity. Additionally, it's crucial to assess the compatibility of certain agricultural activities with the installation of renewable energy (RE) infrastructure.

Renewable energy projects should be supported by decision making tools addressed to different stakeholders. As illustrated in some cancelled projects, local population acceptance plays a key role to the success of these developments, clear information regarding the benefits and impacts on the territory is essential.

Alpine countries have developed acceleration areas and are starting to elaborate planning tools to better identify suitable land for these projects, and this should also include the identification of the key environmental challenges of the territory. This will help to clearly define the potential for each RE source and, when necessary, restrict future developments to protect key habitats and species incompatible with any kind of development.

8 Glossary

Connectivity" (structural and functional)	"Connectivity comprises two components, structural and functional connectivity. It expresses how landscapes are configurated, allowing species to move. Structural connectivity, equal to habitat continuity, is measured by analysing landscape structure, independent of any attributes of organisms. […]. Functional connectivity is the response of the organism to the landscape elements other than its habitats (i.e. the non-habitat matrix). This definition is often used in the context of landscape ecology. A high degree of connectivity is generally linked to low fragmentation." (EUROPEAN COMMISSION - Technical information on Green Infrastructure (GI), 6.5.2013, Glossary) (Definition of connectivity see also Deliverable 1.1.1, chapter 8)
Fragmentation	Set of processes by which habitat loss results in the division of continuous habitats into a greater number of smaller patches of lesser total and isolated from each other by a matrix of dissimilar habitats. Habitat fragmentation may occur through natural processes (e.g. forest and grassland fires, flooding) and through human activities (forestry, agriculture, urbanisation). (IPBES, 2025)
GBI – Green and blue infrastructure	Green infrastructure (GI) is a strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas. On land, GI is present in rural and urban settings." (EUROPEAN COMMISSION - Green Infrastructure (GI) — Enhancing Europe's Natural Capital, 6.5.2013) (Definition of connectivity see also Deliverable 1.1.1, chapter 6)
Potential Planning Areas for Biodiversity Protection	According to the Alpine Parks 2030 project, these areas are a spatial planning proposal of protected areas, distributed in nine categories combining the criteria of low fragmentation, low spatial development, and a high level of ecologically favourable areas creating the framework, along with the identification of already existing areas with strong protection.
Renewable energy	Definition by the European Environment Agency - Glossary *"Energy sources that do not rely on fuels of which there are only finite stocks. The most widely used renewable source is hydroelectric power; other renewable sources are biomass energy, solar energy, tidal energy, wave energy, and wind energy."*
Hydropower (dams, weirs, run-off-river power plant)	power derived from the energy of falling water or fast running water to generate electricity Hydropower generation including development and use of associated infrastructure (e.g. building dams or weirs, changes of hydrological functioning rivers or chemical and thermal properties of water due to operation of dams and weirs). Definition by the European Environment Agency - Glossary "The renewable source of energy provided by falling water that drives the turbines. There are two types of hydroelectric power plants: a) run-of-river power plants for the use of affluent water; b) storage power plants (power stations with reservoir) where the influx can be regulated with the help of a reservoir. Mostly greater differences in altitudes are being used,like mountain creeks. Power stations with reservoirs are generally marked by barrages with earth fill dam or concrete dams. Though hydropower generally can be called environmentally acceptable, there exist also some problems: a) change of groundwater level and fill up of the river bed with rubble b) risk of

	dam breaks c) great demand for land space for the reservoir d) diminution,but partly also increase of value of recreation areas."
Hydroelectric dam	a barrier that stops or restricts the flow of water; used to create energy in the water flow that can be captured by a turbine to generate electricity
Pressures and Threats	Definition by the European Environment Agency 2020 (State of nature in the EU - Results from reporting under the nature directives 2013-2018): *"Pressures are considered to be factors that have affected habitats and species within the current reporting period, while threats are factors that are anticipated to be likely to have an impact during the subsequent two reporting periods."*
Solar power	Definition by the European Environment Agency - Glossary *"The energy transmitted from the sun in the form of electromagnetic radiation. The most successful examples of energy extraction from the sun are so far solar cells used in satellites and solar collectors used to heat water."*
Solar PV panel	an arrangement of PV materials that absorbs and converts sunlight into electricity
Solar farms	Large-scale PV installations often ground mounted for production of significant amounts of electricity
Dam wall solar installation	Integration of solar energy to existing dam infrastructure
Transmission lines	power lines used to move electricity from a generating site (e.g., a power plant) to an electrical substation, which often transforms the voltage from high to low before reaching consumers
Wind energy	*"Harnessed from moving air, transformed into electricity using wind turbines located onshore (land) or offshore (sea)."* (Bennun L. , et al., 2021)
Wind farm	a group of wind turbines used to produce electricity

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ANNEXES

Annex 1 Identification of projects thresholds for spatial planning

	Relevance for Environmental Impact Assessment (EIA)	Relevance for spatial planning
Hydropower	According to the EU's Environmental Impact Assessment Directive dams of a certain capacity must be assessed for their impact on the environment (Environmental Impact Assessment - EIA).	Any construction and operation of a hydropower plant Any river canalisation and stream correction work
Windpower (windmills)	In the EU's Environmental Impact Assessment Directive windpower is not mentioned as a subject to an obligatory Environmental Impact Assessment (EIA).	Wind farm with 3 wind turbines with a total height of more than 50 metres each
Solar power (ground mounted photovoltaic systems)	In the EU's Environmental Impact Assessment Directive solar power is not mentioned as a subject to an obligatory Environmental Impact Assessment (EIA).	ground mounted photovoltaic system with a size of at least 2 hectares
Biomass (biogas plant)	In the EU's Environmental Impact Assessment Directive bioenergy plants are not mentioned as a subject to an obligatory Environmental Impact Assessment (EIA).	Biogas plant with more than1.2 million standard cubic metres of raw gas per year
High voltage transmission line	In the EU's Environmental Impact Assessment Directive transmission lines are not mentioned as a subject of an obligatory Environmental Impact Assessment (EIA).	transmission line with a voltage of 110 kV or more
Roads/ highways	According to the EU's Environmental Impact Assessment (EIA) Directive motorways and express roads must be assessed for their impact on the environment (Environmental Impact Assessment - EIA).	four-lane or multi-lane federal road with continuous length of 5 km or more
Railways	According to the EU's Environmental Impact Assessment (EIA) Directive long-distance railways must be assessed for their impact on the environment (Environmental Impact Assessment - EIA	railway track

Annex 2 Mitigation /compensation (see D1.3.1)

	Mitigation / Compensation
Hydropower	• Upstream and downstream fish passage facilities (fish ladders, bypasses) to allow migration • intelligent turbine design or turbine shutdown on a fixed schedule decreasing turbine related mortality • ecologically effective minimum flow of water • bed-load management • morphological enhancement measures: ➢ improvement of the riverbank structure (unsealing the riverbank) ➢ introduction of gravel banks ➢ introduction of disturbance elements (stones, deadwood) • New hydropower technologies with less environmental impacts
Windpower	• turbine design optimization • switch off systems at times of increased bird/bat activity to prevent/avoid collisions (Automatic anti-collision systems) • unattractive design of the environment at the base of the mast and in surrounding fields for wind energy-sensitive birds (red kites)
Solar power	• landscape-oriented design of the facility, visual integration into the environment: suitable arrangement of the solar panels (e.g. “Solar biotope network”) • sufficiently large (wide) open spaces between the rows of solar panels (sunlit strips at least 3 m wide between the rows) • elevation of the solar panels (panel distance to the ground at least 0.8 m) • no fencing or at least permeable for small and medium-sized mammals (15 cm distance between the fence and the ground), migration corridors as crossing aids for large-scale facilities • development and maintenance of extensively used species- and flower-rich grassland in the solar park ➢ using seeds from local species or locally obtained mown material ➢ no fertilization, no use of pesticides ➢ up to 2 mowing intervals (use of insect-friendly mower, cutting height 10 cm) with removal of mowed material or/and site-adapted grazing • no mulching
High voltage transmission line	• bundling of linear infrastructure, appropriate route alignment • appropriate design of the pylons to reduce fragmentation including spanning above the forest canopy • marking transmission lines to reduce bird collision risk • ecological rights-of-way vegetation management creating and connecting new habitats

	Mitigation / Compensation
Roads/ highways	• appropriate route alignment • traffic management measures: reducing traffic volume or speed • fencing combined with wildlife passages • wildlife passages as overpasses (e.g. green bridge, fauna overpass, multiuse overpass) or as underpasses (e.g. viaduct, fauna underpass, multiuse underpass, small fauna underpass, adapted culverts, fish passage, amphibian passage) reducing the barrier effect and providing a safe crossing • embankments to mitigate noise and provide new habitats for endangered flora species • adapting infrastructure verges • mechanical methods for vegetation control or grazing as alternative methods to the use of chemical substances in the management of green areas • adapting road lighting for mitigating light pollution • noise screens, placing the road between cuttings or earthen mounds, silent pavements for mitigating noise • runoff water management: Retention ponds
Railways	• appropriate route alignment • fencing combined with wildlife passages • wildlife passages as overpasses (e.g. green bridge, fauna overpass, multiuse overpass) or as underpasses (e.g. viaduct, fauna underpass, multiuse underpass, small fauna underpass, adapted culverts, fish passage, amphibian passage) reducing the barrier effect and providing a safe crossing • embankments/ earthworks to mitigate noise and provide new habitats for endangered species • adapting infrastructure verges • mechanical methods for vegetation control or grazing as alternative methods to the use of chemical substances in the management of green areas • noise screens, placing the road between cuttings or earthen mounds, rail noise absorbers for mitigating noise • runoff water management: Retention ponds

	Mitigation / Compensation
Urban /industrial development	• appropriate location of new urban/industrial development (avoid areas of high nature conservation value including ecological corridors) • preservation of large, undissected open spaces, safeguarding inner-urban trees (particularly large/mature trees) • minimizing the road infrastructure associated with urban/industrial development, keeping vehicle speeds low • reducing use of fertilizers and pesticides in maintenance of public and private green • minimizing artificial lighting • good pet ownership to reduce domestic animal damages to wildlife • runoff water management: minimize water runoff into streams • Integration of connectivity elements in zoning plans / optimising connectivity planning and interfaces between regional concepts and municipal planning

PlanToConnect
Mainstreaming ecological connectivity in spatial planning systems of the Alpine Space

Project partners:

Urban Planning Institute of the Republic of Slovenia (SI)
Veneto Region (IT)
ALPARC – the Network of Alpine Protected Areas (FR)
Asters, organisation for the conservation of natural areas in Upper Savoy (FR)
Eurac Research (IT)
ifuplan - Institute for Environmental Planning and Spatial Development (DE)
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