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Sustainable Management of Green Corridors Below Overhead Lines in Europe

A Master's Thesis submitted for the degree of
“Master of Science”

supervised by
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Affidavit

I, **KIRUTHIKA VADIVU SWARNAMAHESWARAN B.SC. PME., MBA**, hereby declare

1. that I am the sole author of the present Master's Thesis, "SUSTAINABLE MANAGEMENT OF GREEN CORRIDORS BELOW OVERHEAD LINES IN EUROPE", 75 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted the topic of this Master's Thesis or parts of it in any form for assessment as an examination paper, either in Austria or abroad.

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Abstract

Overhead power lines (OPL) play a vital role in Europe's energy infrastructure, ensuring the efficient transmission and distribution of electricity across the continent. With the increasing emphasis on Clean energy and the necessity to transition to a low-carbon future. The implementation of green corridors below OPLs further enhances their importance in Europe's sustainable development. Green corridors refer to the strategic integration of ecological corridors or linear green spaces below or adjacent to OPLs. These corridors provide crucial connectivity for wildlife, support biodiversity conservation, and contribute to ecosystem resilience. By incorporating green corridors below OPLs, Europe can maximize the co-benefits of energy infrastructure development and ecological conservation. These green spaces can serve as habitat networks, facilitating the movement of species across fragmented landscapes. This thesis aims to assess the potential for creating a network of ecosystems through the sustainable management of green corridors below OPLs in Europe. The success of these corridors depends on the selection of appropriate transmission lines, strategic planning measures and the implementation of legal regulations and Directives. The Legal framework requires all Member States in Europe to establish a network of protected areas and communities, and to ensure that installation of OPLs do not negatively impact the ecosystem. This thesis employs a qualitative approach that complements existing literature on OPLs and green corridors, using existing data derived from the European Network of Transmission System Operators for Electricity, as well as ongoing projects that implement these infrastructure corridors. The aim of this thesis is to outline, through the example of the LIFE Elia-RTE project, the execution and strategic planning initiatives for the successful implementation of green corridors below overhead power lines in Europe. This selection process places a strong emphasis on the necessity of stakeholder involvement, and collaboration in strategic planning measures. Furthermore, the research highlights the significance of considering variables such as height, voltage, and location when choosing transmission lines. On the other hand, the thesis establishes the requirement for the implementation of regulatory frameworks to protect the biodiversity.

Keywords: Biodiversity, Connectivity, Ecosystem, Fragmentation, Green Corridor, Landscape Ecology, Overhead Power Lines

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List of Abbreviations

AAC	All Aluminium Conductor
AAAC	All Aluminium Alloy Conductors
AASR	Aluminium Alloy Conductor Steel Reinforced
ACAR	Aluminium Conductor Alloy Reinforced
ACSR	Aluminium Conductor Steel Reinforced
DEMNA	Département de l'Etude du Milieu Naturel et Agricole
EC	European Commission
EEA	European Environment Agency
EEC	European Energy Community
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
ENTSO-E	European Network of Transmission System Operators for Electricity
EU	European Union
FSC	Forest Stewardship Council
ft	feet
HV	High Voltage
HVDC	High Voltage Direct Current
HVAC	High Voltage Alternating current
IEA	International Energy Agency
IUCN	International Union for Conservation of Nature
IVM	Integrated Vegetation Management
kV	Kilo Volts
LV	Low Voltage
MV	Medium Voltage
OPL	Overhead Power Lines
PCI	Projects of Common Interest
PMI	Projects of mutual Interest
PEFC	Programme for the Endorsement of Forest Certification Schemes
ROW	Rights-of-Way
SPA	Special Protection Areas
TEN-E	Trans-European Networks for Energy
TSO	Transmission System Operator
UGI	Urban Green Infrastructure

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1. Introduction

Overhead power lines (OPL) are extremely complex infrastructures that cover many climatic zones, spanning across several kilometers in urban, suburban and forest landscapes. According to a report by the European Network of Transmission System Operators for Electricity (ENTSO-E), over 301,000 kms of OPLs managed by the TSOs traverse across the European countries (ENTSO-E, n.d.). The following voltage levels in Kilo Volts (kV) are employed in Europe's expanding electrical grid as a result of the availability of electrical energy: 0.4 kV for Low Voltage grid, 10–20–30/0.4 kV for transformers to low voltage network, 10-20-30 kV for medium voltage grid, 110/10-20-30 kV for transformers to medium voltage network, 110 kV for high-voltage grid in regional utilities, 380-220/110 kV for main transformers to the high-voltage grid and 380/220 kV for transmission grid, interconnected grid and extra high-voltage grid. There hasn't yet been a voltage level higher than 380 kV installed in Europe (Brauner, 2022). According to estimates, there were approximately 65 million kilometers of MV and HV OPLs in operation worldwide, and that number has been growing at a pace of 5% annually (Jenkins et al., 2010).

The energy transition taking place in Europe involves OPLs to a great extent. An effective and dependable electrical transmission and distribution infrastructure is essential as the continent works to lessen its reliance on fossil fuels and move toward cleaner and more sustainable energy sources. Connecting renewable energy producing sites to urban centers and commercial hubs across large distances is made possible by OPLs, which are both affordable and frequently used (Holt, 2023). The ability of OPLs to make the integration of renewable energy sources easier is one of their major benefits in the EU's energy transition. Europe has been making considerable investments in wind, solar, and hydroelectric power, which has led to a rapid expansion of its renewable energy capacity. These energy sources are frequently found in far-flung locations, including offshore wind farms or mountainous areas with excellent wind and solar potential (Moretti et al., 2020). The electricity produced by these sources is efficiently transported to urban regions where demand is highest by OPLs. The efficient and long-distance transportation of electricity is made possible by their HV transmission capabilities, which also minimize energy losses during distribution.

The placement of OPLs is typically based on a strategic plan that considers various terrain and geological factors. When there are no conservation restrictions, these OPL corridors are normally built following least-expensive routes, which typically have the least amount of change in slope and height. Because the placement of power lines is non-random and is influenced by various terrain factors, it can be challenging to evaluate the effects of power lines on nearby habitats due to correlations between vicinity, elevation density, slope, and hydrology (Vajjhala and Fischbeck, 2007). Mitigation hierarchies should be followed for the best chance of preventing environmental effects caused due to OPL grid development. The ecological significance of power-line corridors depends on their capacity to support various levels of biodiversity.

Green corridors have the potential to significantly increase biodiversity due to their large size and potential for improved connectivity between green spaces (Bennett, 2003). Undoubtedly, maintaining natural connectivity below OPLs is an effective measure for protecting flora and fauna. Therefore, vegetation management along these corridors should complement these strategies. Furthermore, these corridors offer significant land space for wildlife that require early successional ecosystems. To enable movements in the distribution of species owing to a fragmented environment, a network of corridors is created across Europe (Opermanis et al., 2012). Where these pylons span for thousands of kilometers, the EU's most significant Natura 2000 sites are among the most important SPAs. The need to secure OPLs in the has led to the creation of green corridors.

1.1. Overview

The underlying line of research in this thesis analyses how green corridors below OPLs can be used to create a network of ecosystems, and how they can aid in enhancing biodiversity when they are sustainably managed in the European context. The focus lies, on one hand, on developing green corridors below different types of OPLs and, on the other hand, on the strategic planning required to ensure their effectiveness. The analysis was carried out based on data issued by ENTSO-E. As the research subject, the main aim of this thesis is to understand the biodiversity below OPLs and to what extent infrastructure corridors are effective. Through the use of Pan-European initiatives, an effort has been made to assess the implementation of corridors beneath OPLs. The thesis includes a case study, using the LIFE Elia-RTE project as an example of an effective initiative for managing the green corridors.

The final goal of this thesis is to analyze the implementable frameworks for how Europe can approach the development of green corridors along with the implementation phase of an OPL. For the protection of biodiversity, the emphasis is on the sustainable management of these corridors. The framework will consider the Biodiversity Strategy for 2030 and other relevant policies and initiatives at the European Union (EU) level. In this context, the Environmental Impact Assessment (EIA), Bird, and Habitat Directives are the basis of the EU's biodiversity policy and establish guidelines for environmental factors to be considered when evaluating private and public infrastructural projects as well as the conservation of species.

1.2. Research Question

The central research question asks: Can infrastructure corridors below overhead lines be used for creating a network of ecosystems?

As part of this question, this thesis will also consider the below mentioned underlying lines of research:

- What kinds of transmission lines and strategic planning are required to ensure the success of such infrastructure corridors in Europe?
- What are the EU directives and regulations that can be implemented to promote Biodiversity below OPLs?

1.3. Methodology

The key findings of this research paper were drawn from an internet-based study that included academic papers, regional and EU level policy papers, past and present regulations, annual and termly reports, and articles published by the European Commission, ENTSO-E, EEC, and the European Environment Agency (EEA), as well as reports and articles published by regional and international stakeholder groups. When planning the scope of this study on OPL projects for green corridor management, the estimated energy transmission levels and the size and height of the pylons were based on average data, and assumptions were derived from state-of-the-art levels. Provisions for constructing green corridors typically involve guidelines and regulations aimed at minimizing the negative environmental impacts of overhead lines. Online research papers, studies, and articles were valuable sources of information on the regulations for building transmission lines with green corridors in Europe. These resources can be accessed on acdemic and commercial websites, industry portals, and research databases. To study the impacts of transmission lines on flora and fauna, the geographical area where the transmission lines are located and where the impacts on flora and fauna are likely to occur are taken into consideration. To identify any patterns or trends in species abundance or diversity that may be related to the presence of transmission lines, data was collected from multiple sources, including existing databases such as the databases on biodiversity and ecosystems on the EU and national levels, reports on endangered species from Natura 2000 sites, International Union for Conservation of Nature (IUCN) and Bird Life international.

1.4. Structure of the thesis

This thesis begins by providing a brief overview of OPLs and their role in Chapter 2. The chapter describes the various components and designs of overhead power lines such as conductors, insulators, and pylon and crossarm, and the configuration and types currently in use in the European power grid system. It also contextualises the role of OPLs in the energy transition, and how they make it possible. Additionally, the chapter highlights the risks to be considered while planning infrastructural projects like OPLs.

Chapter 3 defines the concept of a ‘green corridor’ in the context of this thesis, provides an overview of its benefits, particularly in terms of connectivity, and explains the rationale for the idea of implementing them below overhead power lines. It discusses the potential benefits they can offer in helping maintain and enhance biodiversity of ecosystems and in effectively managing vegetation through a ‘rights-of-way’ approach. It then suggests measures to keep in mind while planning for the implementation of green corridors to ensure their success and leverage the benefits they can offer.

While green corridors have huge potential in maintaining and enhancing the biodiversity in various ecosystem, their success is largely determined by how they are implemented and managed. Several legal frameworks in Europe offer guidelines for their implementation. Chapter 4 outlines relevant legal frameworks - such as the Birds Directive, Habitats Directive, the Convention on the Conservation of European Wildlife and Natural Habitats, and the Environmental Impact Assessment Directive – and discusses in detail how Transmission System Operators comply with the planning and permitting procedures established by such legal frameworks at the European and national levels.

Chapter 5 illustrates how green corridors can effectively be implemented in Europe with a project undertaken by TSOs in Belgium (Elia) and France (RTE). This chapter discusses the measures that LIFE Elia-RTE has taken in their project to successfully support the enhancement and restoration of wildlife and landscapes in Overhead power line zones. The thesis concludes by summarising the key findings of this study and reinforces how the green corridor concept aids in enhancing the flora and fauna under OPLs by establishing a network of ecosystems.

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2. Overhead power lines and their role

OPLs are structures set up to move electric energy throughout the power supply systems that has transcended international borders. Since they serve their purpose for an extended period, they require long-term planning. These Systems for supplying energy with high reliability rates have attained an exceptional level of technological advancement in Europe. The fundamental components that make up technology for overhead power lines have long been understood and are generally regarded as developed. Therefore, advancement in technology evolves progressively. In order to properly address the interdependence with the ecosystem, landscape orientation, and effectively manage limited natural resources while providing electricity at affordable prices, OPLs have undergone constant improvements within the rights-of-way (ROW).

2.1. Components and design

2.1.1. Conductors

The Conductors that are attached to the tower crossarms by insulators and then secured therein carry the electricity. Spanned between two towers are the conductors.They are often bundled to enhance the quantity of energy delivered. The linear relationship between conductor temperatures, current, and cable sag distinguishes conventional conductors from other types .The key technological variables are related to the conductor's buildup and material: All Aluminium Alloy Conductors (AAAC), Aluminium Alloy Conductor Steel Reinforced (AASR), Aluminium Conductor Steel Reinforced (ACSR), All Aluminium Conductor (AAC), Aluminium Conductor Alloy Reinforced (ACAR) and high temperature low sag conductor . Even with the numerous potential advancements that are to be achieved utilizing High voltage direct current (HVDC) technology, high voltage alternating current (HVAC) technology still make up for the majority of OPLs in Europe i.e., for lines exceeding 220 kV today (ENTSO-E, n.d.). There are conductor standards in numerous developed countries as well as worldwide ones set by the International Electrotechnical Commission (IEC). The European Norms (EN) have been in use today in most European countries and have replace national norms. Whether or not they are functioning, conductors are the wires that make up an OPL that might be naked, bare, insulated, or grounded. Bundle conductor cables are combinations of multiple sub conductors used in place of just one conductor and are typically maintained at a relatively consistent spacing over their entire length. According to the criteria provided, conductors might be cables, stranded conductors, or cables constructed of electrically conductive materials (Kiessling et al., 2003). The international standards IEC 61089 (which replaces IEC 207, 208, 209, and 210) and EN 50182 and 50183 cover the majority of conductor types for OPLs. A bigger conductor size makes the AAAC option more appealing from a material standpoint, but the decision between the two is less clear. For some projects, AAAC results in reduced sag and/or lower tower heights and may yield substantial strength/weight ratios. ACSR is far less prone to have long-term relaxation. As long as standard conductor cleansing and general preparation for design are followed, linking neither ACSR nor AAAC types of conductors poses insurmountable obstacles. It is a little simpler to link AAAC than ACSR.

Table 1: Different of types of conductors used in OPLs in Europe (Edvard,2013).

Standard	Title	Comment
IEC 61089	Round wire concentric lay overhead electrical stranded conductors	Supersedes IEC 207 (AAC), 208 (AAAC), 209 (ACSR) and 210 (AACSR)
EN 50182	Conductor for overhead lines: round wire concentric lay stranded conductor	Supersedes IEC 61089 for European use. BSEN 50182 identical
EN 50183	Conductor for overhead lines: aluminium–magnesium–silicon alloy wires	
BS 183	Specification for general purpose galvanized steel wire strand	For earth wire
BS 7884	Specification for copper and copper–cadmium conductors for overhead systems	

Mass-impregnated (MI) HVDC conductors are a well-established and conventional technology that are mostly used for subsea applications. Line-commutated converters were initially used with MI cables. Currently, Extra High Voltage Direct Current are situated beneath the surface of the sea are where this technology is most commonly used (ENTSO-E, n.d.). Polymeric insulations have replaced mass-impregnated insulations in Medium Volt (MV) and Low Volt (LV) power cables. Even though a significant portion of the European TSOs still uses mass-impregnated cables, they are no longer manufactured other than for replacement and maintenance. The technique of polymeric insulation is used in all new MV and LV cables (Europacable, 2014).

2.1.2. Insulators

The insulators, which are situated between active conductors and earthed elements of the OPLs and are susceptible to both mechanical and electrical stresses. Therefore, it is essential to design the insulators performance to withstand the most severe operating conditions impacted by environmental influences, such as ambient temperatures, precipitation patterns, and pollution. Every event load should be sustained with sufficient operational security attributable to a mechanical resistance that is sufficiently high. To sustain the subsequent forces, disruptive strength and electrical resistance should be sufficiently high (Kiessling et al., 2003). Proper insulator installation is crucial for the efficient operation of OPLs. Insulators come in an array of designs. Type A and type B overhead line insulators are the two categories into which they fall. Type A insulators are distinguished by the fact that the shortest puncture route through the insulation is at least half as long as the path of a flashover on the insulation surface. Such insulators are regarded as impermeable to punctures. Type B insulators, such as cap-and-pin insulators and line post insulators, are defined as having the shortest puncture path through the body that is less than half the length of the transitional path. They are regarded as not being Puncture-proof (Kiessling et al., 2003). Generally, the materials used for making these insulators are porcelain and glass; however, porcelain is the most commonly used material. It is a ceramic made from a mixture of feldspar, kaolin, and quartz. Due to its high malleability, it is mechanically stronger than any other type of insulator and also has higher adaptability to any temperature condition.

Pin type, suspension type, strain and shackle are the most common types of insulators used in OPLs (electricaleasy, n.d.) (Figure 1). The term "pin type insulator" refers to an insulator that separates a wire from an external support. It was the first type of insulator created, and OPLs employ it. The pin insulator is attached to the cross-arm of the pole. Nonconducting materials mostly porcelain, make up pin type insulators. Power distribution at voltages up to 33 kV make use of pin type insulators. Suspension insulators are used to protect OPLs and overcome the limitations of pin insulators. They are suitable for voltages above 33KV. In low voltage OPLs, shackle insulators are used. Sharp corners in the power line experience high tensile loads, which are sustained by strain insulators. These insulators are positioned upwards to handle the stress. Meanwhile, the suspension insulator string is horizontally aligned to support the conductor's weight and manage lateral forces. In summary, suspension insulators address the drawbacks of pin insulators, strain insulators handle corner stresses, and shackle insulators are suitable for low voltage OPLs. (Agarwal, 2020).

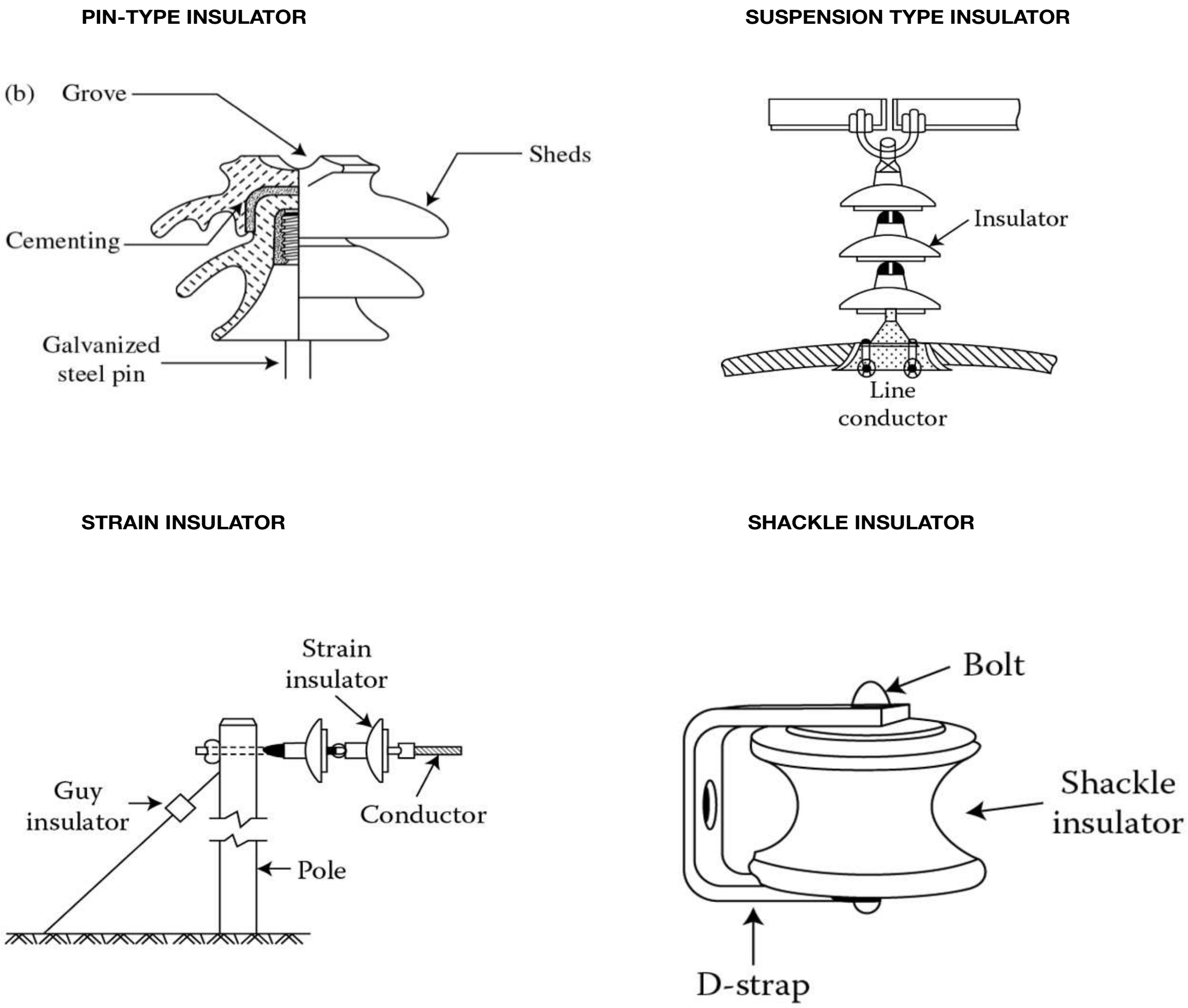


Figure 1: Types of Overhead line insulators (electricaleasy, n.d.).

2.1.3. Pylons and crossarms

There are several types of pylons, based on various factors. The accessibility of corridors has an impact on the OPL construction. If there is a barrier, the OPL must divert from the path that is closest to it. There might be several deviation points. The various tower types are employed depending on the angle of deviation (Table 2). HVAC OPLs are utilized for transmitting AC power at extremely high voltages, typically ranging from 110- or 115-kV and above. In modern systems, these voltages are commonly 132- or 220-kV and higher. The towers are specifically engineered to support three or multiple of three conductors, ensuring safe and efficient power transmission. HVDC OPLs use one conductor on each side of the tower or only one conductor.

Some towers are specifically designed for the River, Railway and Highway crossing zones. The design mainly depends on the tower height, foundation width, cross arm's light. Typically, the heigh of the tower ranges between 50-180 ft (Electrical Volts, 2022).

The height (H) of the tower can be calculated by (Figure 2):

$H = H_1 + H_2 + H_3 + H_4$

Where,

H_1 =Minimum permissible ground clearance;

H_2 =Maximum sag;

H_3 =Vertical spacing between conductors;

H_4 =Vertical spacing between earth wire and top conductor; (Electrical Volts, 2022).

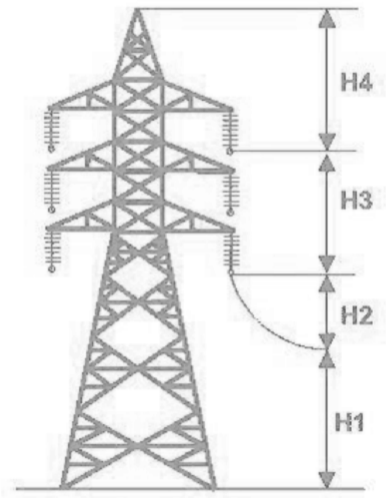
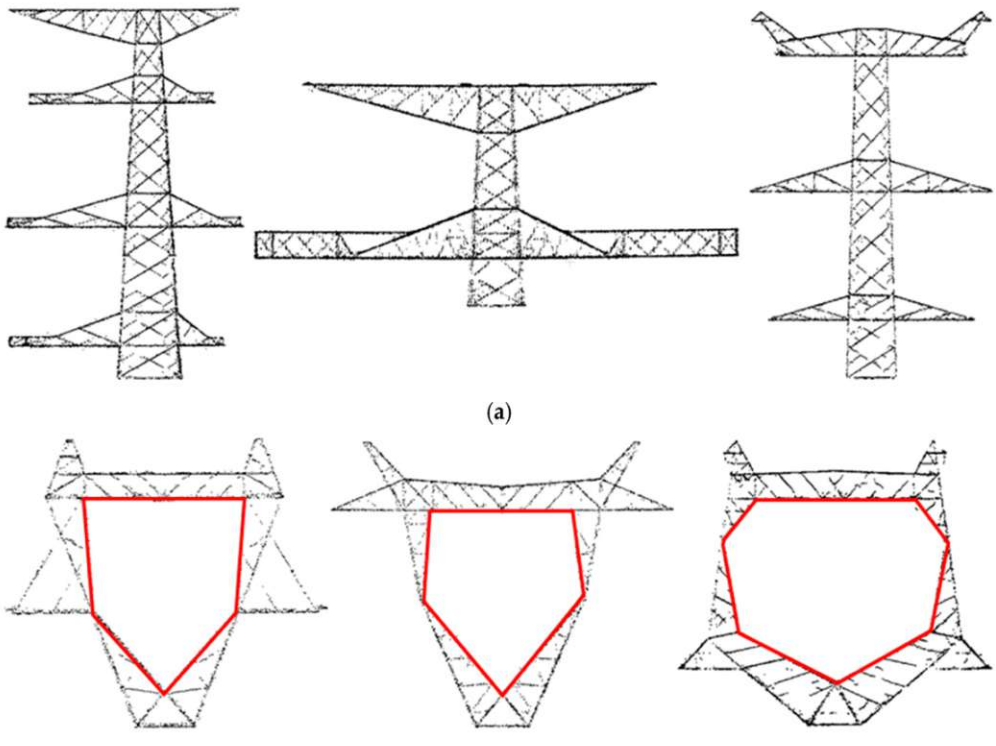


Figure 2: The height of the tower classified as H1,H2,H_3,H_4 (Kehang, 2018)

Table 2: Types of towers classified based on the Angle of Deviation (Electrical Volt, 2022).

Type of Tower	Angle of Deviation
A- Type	0^o to 2^o.
B- Type	2^o to 15^o
C-Type	15^o to 30^o.
D-Type	30^o to 60^o.

Depending on the kind of line, tower tops may be of several types. Structures can be simple construct as wooden poles that are buried in the ground and supported by a few to multiple cross-arm beams, or they might be "armless" with conductors supported by insulators that are fastened to the pole's side. Urban areas frequently employ tubular steel poles. Lattice-style steel towers are frequently used to support high-voltage wires (Edvard, 2020). The inverted triangle pyramid structure, the quadrangular frustum pyramid structure, and the complex structure are the three components that make up a pylon. Complex structures can be categorized as type-T or type-O structures (Chen et al., 2019) (Figure 3). The typical foundation in normal ground is a gravity foundation of reinforced concrete slabs.



(a) (b)

*Figure 3: The type of complex structure: (**a**) Type-T structure; (**b**) Type-O structure (Chen et al., 2019).*

2.2. Configuration and types for Europe

When it comes to electricity and transmission the power grid system is a complex one. Power stations require a variety of equipment in order to deliver electricity to all of its customers at a consistent frequency and voltage. The grid infrastructure has components from practically every area of technology. It is very essential to also consider, the components that is most visible, the pylons and the cables that make up the grid itself (Cockfield, 2019). In Europe there are different types of pylons depending on the geographical location they expand in. The vertical and Danube designs are among the most prevalent types. Depending on the topography, the towers are built at a distance of roughly 400 meters apart. Below the lines, 60 m to the ROW of the lines, there are patches of cleared vegetation. In contrast to cables, the lines that bridge the space between the towers don't have an insulating coating. They have the ability to immediately discharge heat created by transmission of electricity (EMF-Portal, n.d.). Different types of pylons are required depending on the level of voltage, the conductor arrangement, and the surrounding environment (figure 4). The Danube mast is a tower that supports two circuits of three-phases. The conductors are always set up in a triangular configuration. Each circuit has two conductor bundles on the lower cross-arm and one on the top cross-arm. For high-voltage towers with two electrical circuits, the two-level pylon design is most frequently employed since it offers favorable characteristics in terms of height, construction expenses, and ROW clearance width. A single-level tower has all of its conductors organized on a single level. The towers may be built at a lower height, but ROW clearance width is also broader. A design for OPLs with three cross-arms is a tower with a vertical double configuration. This circuit with electricity has three conductors that are arranged vertically (50 hertz, 2020).

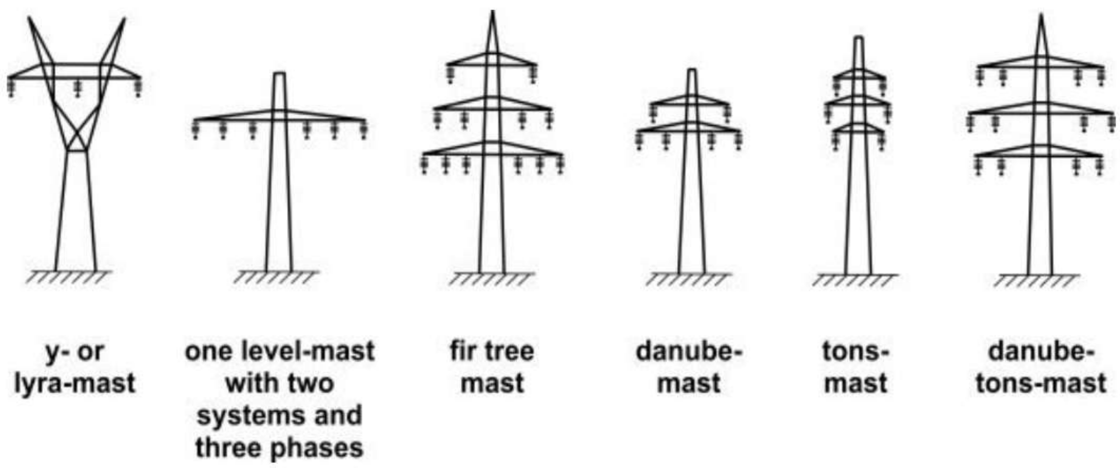


Figure 4: Different types of tower configurations in Europe (EMF-Portal, n.d.).

2.3. Overhead Power Lines for the Energy Transition

OPLs link the electrical infrastructures for a number of countries, allowing for the exchange of power across international borders and the sharing of renewable energy sources. The EU's intent to promote a more integrated energy sector is evidenced by its intention to enhance capacity. Countries may make greater use of renewable energy sources, guarantee a steady and consistent supply of electricity, and aid in transitioning to cleaner and more sustainable energy sources via improving interconnectivity (Holt, 2023). The TSOs play a significant part in creating solutions and demonstrating that they are scalable and effective (Leleu, 2021). By 2040, the EU wants to increase capacity by 128 gigawatts.

The Clean Energy for All Europeans package adopted in 2019, places residents at the forefront of the energy sectors tremendous development. The energy infrastructure in Europe is becoming increasingly made up of several dispersed resources of different dimensions and intensities that are all connected to one another. Energy infrastructure initiatives, such as PCIs (projects of common European interests), PMIs (Projects of Mutual Interest) and national grid projects, are frequently hailed for their contributions to Europe or for addressing local demands and interests. Stakeholder engagement methods are planned to be carried out at various stages of grid design and construction in most European country's regulations (Leleu, 2021). Around the globe, residences, firms, and entire populations are supplied with electricity by technologies including hydropower, wind power, and solar energy. According to the International Energy Agency's (IEA) most recent data, energy output must increase 92% by 2030, in order to achieve net zero emissions (Holt, 2023). Favorable changes in the energy distribution industry throughout the world, particularly in terms of the need for a resilient network technology and clean energy generation. The rapid and sustainable energy shift that is taking place throughout the world is what is driving these breakthroughs.

The Trans-European Networks for Energy (TEN-E) Regulation of 2022 aims to supersede the older regulations and encourage the upgrading of Europe's transnational energy networks while also supporting the goals of the EU Green Deal. In order to identify PCIs that support the EU's energy and climate policy objectives relating to energy supply security, the TEN-E Regulation specifies a criterion. These initiatives must be situated along priority corridors that have been upgraded to reflect the goals of the EU Green Deal (European Commission, n.d.). The regulations also broaden the definition of these priority corridors to cover PMI, which are initiatives linking the EU with non-EU nations. An EU based list shall provide PCIs and PMIs preferential status, guaranteeing quick bureaucratic and judicial processing. The goal of this prioritizing is to speed up the execution of significant infrastructure initiatives. The TEN-E regulation has allocated and designated 11 energy infrastructure priority corridors. The 11 priority corridors for electricity, offshore grid, and hydrogen infrastructure span across the European countries and regions. Financing from the EU for the construction of these corridors will link regions that are presently cut off from the European energy markets, reinforcing present trans-national networks, and aid in the integration of renewable energy (European Commission, n.d.).

Energy distribution must be done efficiently as nations work to lessen their reliance on fossil fuel-based energy and switch to energy sources that are sustainable. The transmission of this clean energy from these locations of production to populated areas and industrial sites is made possible by OPLs. In order to ensure that clean energy can be distributed to customers, they build the necessary facilities to connect renewable energy sources to the grid. With regard to electricity production and centralized heat generation, coal, which is well-known for having a high carbon content, was responsible for around 25% of emissions and 72% of the sector's total CO_2 emissions. The balance of energy generation in the EU has, however, undergone significant changes during the previous 25 years. While the production of electricity from renewable sources more than quadrupled from 13% to 30%, the proportion of coal in the mix fell from 39% to 24% (Agora Energiewende, 2019). Within the whole economy, the electricity sector offers the biggest opportunity for carbon neutrality at a reasonable cost. In order to do this, the industry wants to cut its emissions in half between 2015 and 2030 and reach almost carbon neutrality by 2050. This may be done by increasing the proportion of low-carbon power sources, such as nuclear and renewable energy, from 55% to 76% by 2030, while lowering the production of fossil fuels, mainly coal, by the same percentage. By 2030, solar, wind turbines– onshore and offshore will likely control the majority of the electricity production (Agora Energiewende, 2019). By 2030, it is anticipated that Europe would use 57% more renewable energy than it did in 2015, with solar and wind electricity generation seeing increases of nearly three times that amount, from 12% to 37%. By 2030, onshore and offshore wind energy will continue to take precedence and account for 26% of all power generated. While biomass production is predicted to increase by almost 50%, hydropower will stay steady. By 2030, the capacity of wind and solar installations will make up 53% of the total, driven by the need to satisfy carbon-free energy demands across a range of industries (Figure 5). Europe aspires to reach even greater levels of renewable energy by 2050, with a target of 81% to 85% (Agora Energiewende, 2019).

The conventional system has undergone substantial modifications as a result of the deregulation of electricity industry in Europe and the extensive use of clean sources of energy. A decentralized approach is emphasized in the projected model, where electricity are produced at different grid sectors by energy providers. By implementing distributed electricity demand applications, it becomes possible to effectively integrate variable wind and solar power into the power grid. This decentralized system empowers users to actively engage in the energy transition process, with the success of the transition relying on their choices to invest in renewable energy, embrace new technologies and mobility services, and accept the development of energy infrastructure (Leleu, 2021). The transmission of this renewable energy from the locations of generation to communities and industrial centers is made possible by OPLs. In order to ensure that clean energy can be distributed to customers, they build the required infrastructure to connect renewable energy sources to the grid. In addition, OPLs make it easier to integrate sporadic renewable energy into the system. The grid needs flexibility to balance supply and demand since the production of wind and solar energy varies depending on the weather. Long-distance electricity transmission is made possible by OPLs, allowing surplus clean energy to be sent to areas with high demand (Leleu, 2021).

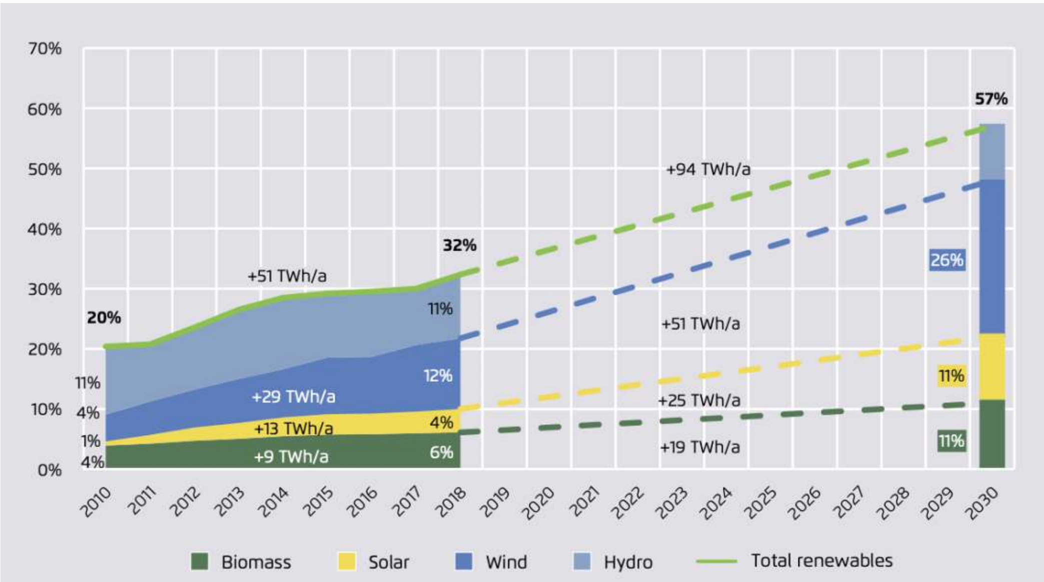


Figure 5: The European Commission's projections in Terawatt hour per annum (Twh/a) for the share of renewable electricity (Agora Energiewende, 2019).

As OPL networks work to make the switch to sustainable energy possible and achieve climate goals, grid integration is a key component. New technologies and solutions have the potential to open up possibilities and advantages by creating trans-national PCIs and PMIs. Through this integration, renewable energy resources may be used effectively, and power output can be optimized. It encourages international cooperation, which results in the dissemination of best practices and the execution of collaborative initiatives. Grid integration also makes it easier to create regional energy markets, which encourages competition and improves market effectiveness (Moretti et al., 2020).

3. The Green Corridor Concept

Despite the growth in the number and size of SPAs and conservation forest areas, biodiversity still remains under threat. While protected areas are crucial for biodiversity conservation, they are insufficient. Planning and implementing mitigation measures across large regions is necessary to protect biodiversity, especially considering the high rate of environmental disturbances. This requires structuring ecosystems in relation to adjacent conservation areas and larger land and seascapes. Protected areas that are part of an ecosystem chain are more effective in preserving biodiversity. To achieve this, it is essential to manage areas that facilitate interactions among these zones, ensuring connectivity is sustained or restored (Opermanis et al., 2012). The rapid growth of infrastructure developments and landscape changes caused by humans over the past few centuries is the main cause of habitat loss and related biodiversity loss. A landscape consists of geographically diverse regions that vary in size, form, material, and chronology. Considering geographical variation, dimension and hierarchy play a significant role. Landscape ecology is a scientific discipline that explores the connections between geographical patterns and ecosystem functions at different organizational levels. It is both a research area and a school of thought, encompassing multiple disciplines from the natural and social sciences. The concept of Landscape ecology originated in Europe (Wu, 2012). The European landscape ecology approach may be regarded as having a more comprehensive and society-focused outlook. The extent to which a landscape promotes or hinders the movement of life forms, materials and energy between landscape features is called Landscape connectivity. Landscape connectivity is only a measurement of how spatially interconnected a landscape's components are without consideration of any specific biological phenomenon. Landscape ecology aims to comprehend the relationship and actively shape it in order to promote landscape sustainability (Naveh, 2007). To encourage linkages between different points of view that are mutually beneficial for the biodiversity and habitat, a pluralistic and hierarchical framework has been suggested. This paradigm aims to bring together ecological viewpoints with holistic and ethical methods. In the mid 20th century, the concept of "Green Corridor" emerged from discussions among scientists and policy makers about environmental preservation. Regulations were developed based on in-depth research on animal migration and population distribution to mitigate and regulate the environmental effects of human activities. The long-term conservation of biodiversity across the globe is seriously threatened by habitat fragmentation brought on by rising human activity. Green Corridors are crucial since they provide connection between bigger core areas of habitat, which can be a mechanism for preserving biota populations in fragmented environments (Bolger, et al., 2001).

3.1. Definition of Green corridor

The large stretches of land surface areas that receive coordinated interventions to maintain biological diversity are known as green corridors. They connect sections of forests or SPAs that have been split up by development, such as construction of cities, transmission lines roads, the agricultural sector, or forestry operations (Gregory et al., 2021). Their primary goals are to promote seed distribution, increase the amount of vegetation, and allow for unrestrained mobility of Animals, Birds, insects, and pollinators. Researchers believe that habitat loss and the resulting fragmentation are the biggest risks to conserving global biodiversity and a key factor in current extinction rates. The distinction between naturally altered and intentionally fragmented landscapes is one of the biggest gaps in our knowledge topic. Although certain species may be able to evolve in response to natural fragmentation, it appears that many are negatively impacted by human-caused factors. Generally speaking, the mosaic of a landscape that is created by human-caused fragmentation, such as when forests have been cut down, pastures are plowed, dams are built, and agricultural and urban structures are developed (Wu, 2012). By connecting fragmented regions continuously, green corridors reduce the negative consequences of habitat fragmentation and make it easier for species to move across the natural environment. These corridors might be in the shape of hedgerows, woodland strips, riparian areas along rivers or streams, or even submerged paths. They are often made to allow a variety of creatures, from small insects and amphibians to bigger mammals and birds, to travel through safely.

It is important define the two terms, structural connectivity, and functional connectivity. These two concepts are necessary to understand the various types of Green Corridors. Functional connectivity addresses the extent to which landscapes completely assist or impede the migration of species across regions of habitat, whereas structural connectivity refers to the physical interaction between landscape features. Landscape structure and the way creatures react to it behaviorally, both influence functional connectivity. As a result, functional connectivity varies depending on the species and the geography. Because structural connectivity can sometimes contradict functional connectivity, it is crucial to differentiate between these two kinds of connectivity (LandScope America, n.d.). In certain environments, like agricultural regions in Europe where forests are interspersed with pastureland and meadows connected by hedgerows or corridors, structural connectivity serves as functional connectivity for species dependent on forests. However, there are instances where structural linkage exists without functional connectivity. For example, a corridor that is visually apparent on a map may be too wide for a plant species with limited dispersal abilities to traverse between physically connected core regions. Additionally, certain species may have functional connectivity between habitat patches even in the absence of apparent landscape connections (Hilty et al., 2019).

The development of green corridors depends heavily on the ecology of landscapes. Landscape ecology aids in comprehending the natural systems, such as the geographic distribution of habitats, connectivity patterns, and species interactions, prior to the establishment of green corridors. Landscape ecology sheds light on the pros and cons of adopting green corridors by examining the structure and operation of the landscape (Naveh, 2007) (Figure 9). Project developers may evaluate current connection via landscape ecology and pinpoint crucial regions where green corridors might improve functional connectivity. To enhance their efficiency in allowing species migration and supporting biodiversity conservation, they may assess the ecological relevance of various landscapes and choose the best areas for building green corridors. Landscape ecology also aids in foreseeing the possible effects of green corridors on a variety of ecological processes, including gene flow, species dispersion, and nutrient cycling. It enables the identification of possible roadblocks or restrictions, such as urbanization, infrastructure, or natural obstacles, that can obstruct the success of green corridors. Decision-makers, stakeholders and project managers may plan, develop, and maintain green corridors in a way that maximizes their ecological efficacy and long-term viability by taking landscape ecology concepts and information into account. Overall, landscape ecology offers a complete knowledge and a scientific foundation that are crucial for the effective implementation of green corridors (Hilty et al., 2019).

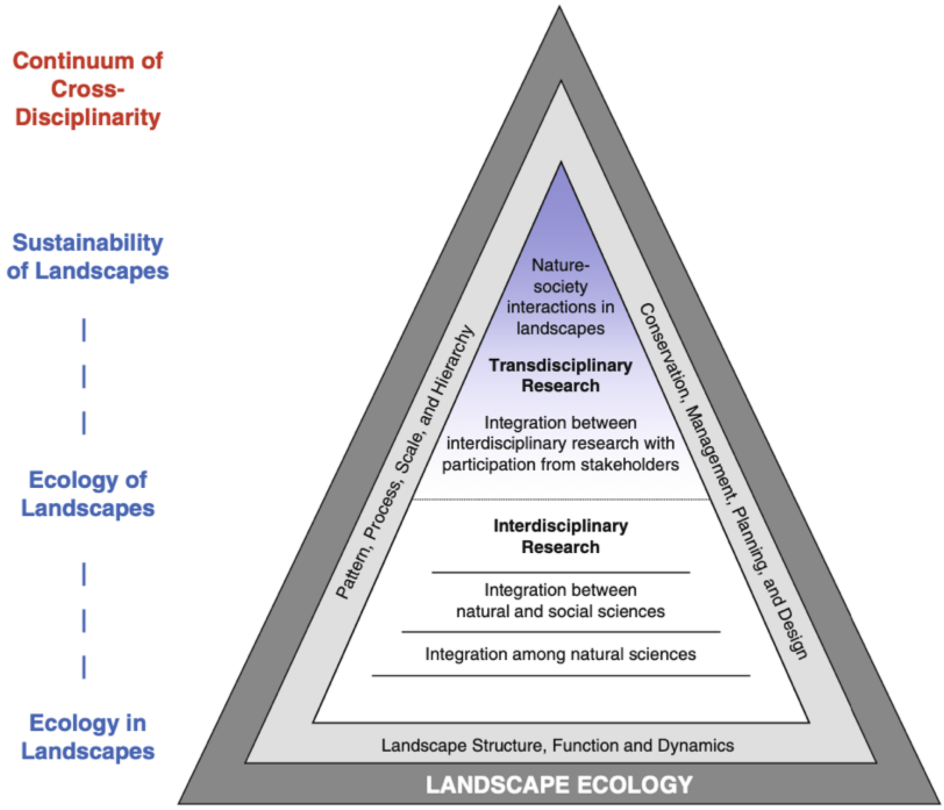


Figure 6: A schematic representation of a hierarchical perspective of landscape ecology (Wu, 2012).

Connectivity is improved by several landscape features. Numerous features, such as greenways, hedgerows, and vegetation, act as corridors even if they were not specifically intended to do so. Therefore, Green corridors are preserved, designed, and managed to enable connectivity for ecological communities. There are two different kinds of green corridors: planned and unplanned. Plans for creating or restoring connectedness within a landscape are referred to as planned corridors. These corridors are thoughtfully planned and put into place using scientific understanding and ecological values. They are often set up to lessen fragmentation of habitat brought on by human-induced activities like infrastructure development, agriculture, or urbanization (Hilty, et al, 2012). The intentional construction of linear elements like hedgerows, riparian buffers, or wildlife corridors is a common component of planned green corridors, which are intended to assist the movement of animals and advance biodiversity conservation. To optimize their ecological usefulness and longevity, they are carefully planned and managed. Unplanned green corridors, on the contrary, appear naturally or unexpectedly without human interference. These corridors for species migration and ecological connectedness come from existing landscape features like waterways, woods, or undeveloped geographic areas. Ecological processes, past trends in land use, or the existence of naturally occurring structures that serve as pathways for wildlife can all lead to the formation of unplanned green corridors. They might not have been created with connectivity in mind, but they nonetheless have a big impact on the spread of species communities and the preservation of ecological interactions (Hilty, et al, 2012).

3.2. Rationale for green corridors below OPLs

The 20th century saw a sharp increase in the amount of natural habitat and landscape by human-induced changes, which had a constant adverse effect on wildlife. Biodiversity has been driven to contend with infrastructural development–highways and OPLs. A prevalent approach to enhance conservation efforts is the establishment of interconnected ecosystems that enable species to adapt to changing land use patterns, thereby reducing the risk of extinction among various species communities (Naveh, 2007). The EUs OPL network comprises approximately one million towers, Since the towers are typically placed 400 m apart and has a base of 10 x 10 m resulting in a field below the pylons spanning about 100 million m^2. This expansive field encompasses every EU country, offering the potential to connect species communities with limited dispersal ability in fragmented environments. EU Natura 2000 sites alone encompass 15% of the OPL towers (Ferrer et al., 2020). The European OPL network demonstrates the extensive interconnectedness of the regions through transmission lines (Figure 7). The establishment of green corridors below the OPLs in Europe offers an effective solution to address habitat fragmentation and restore connectivity among fragmented ecosystems. This allows species to enjoy unrestricted movement, access novel habitats, and establish crucial corridors for dispersal and migration. Creating Green corridors below OPLs can add more linear attributes to a landscape. This enables the wildlife species to move around the landscape, locate sources of water and food, and enlarge their territorial ranges. Green corridors encourage species migration, which benefits genetic diversity and adaptability. Additionally, Green corridors below OPLs offer a practical solution to conserve and protect endangered species. These corridors can provide critical habitat and safe passage for rare and endangered species in the Natura 2000 sites, enabling them to access suitable habitats. By connecting isolated populations, green corridors enhance the chances of successful breeding, genetic exchange, and overall species recovery. The diversity of plants and the health of the environment depend substantially on pollinators (Russell, 2005). The provision of adequate habitats and food sources for pollinators in green corridors below OPLs can help to ensure their protection and the pollination services that are crucial for crop yields and the overall wellness of natural ecosystems. The presence of vegetation can assist to signal birds on the existence of the towers by establishing green corridors below OPLs, lowering the possibility of accidents. The vegetation can serve as a visual obstruction, allowing birds to see the power lines more clearly and modify their flight trajectories as a result. Employing bird-safe methods like perch deterrents, bird diverters, and installing warning spheres can lower the danger of electrocution is possible while implementing Green corridors (Sielicki et al., n.d). The vegetation along the corridor can also act as a natural barrier, preventing birds from perching on the supports of OPLs and therefore minimizing their exposure to electricity hazards (Hrouda and Brlík, 2021).

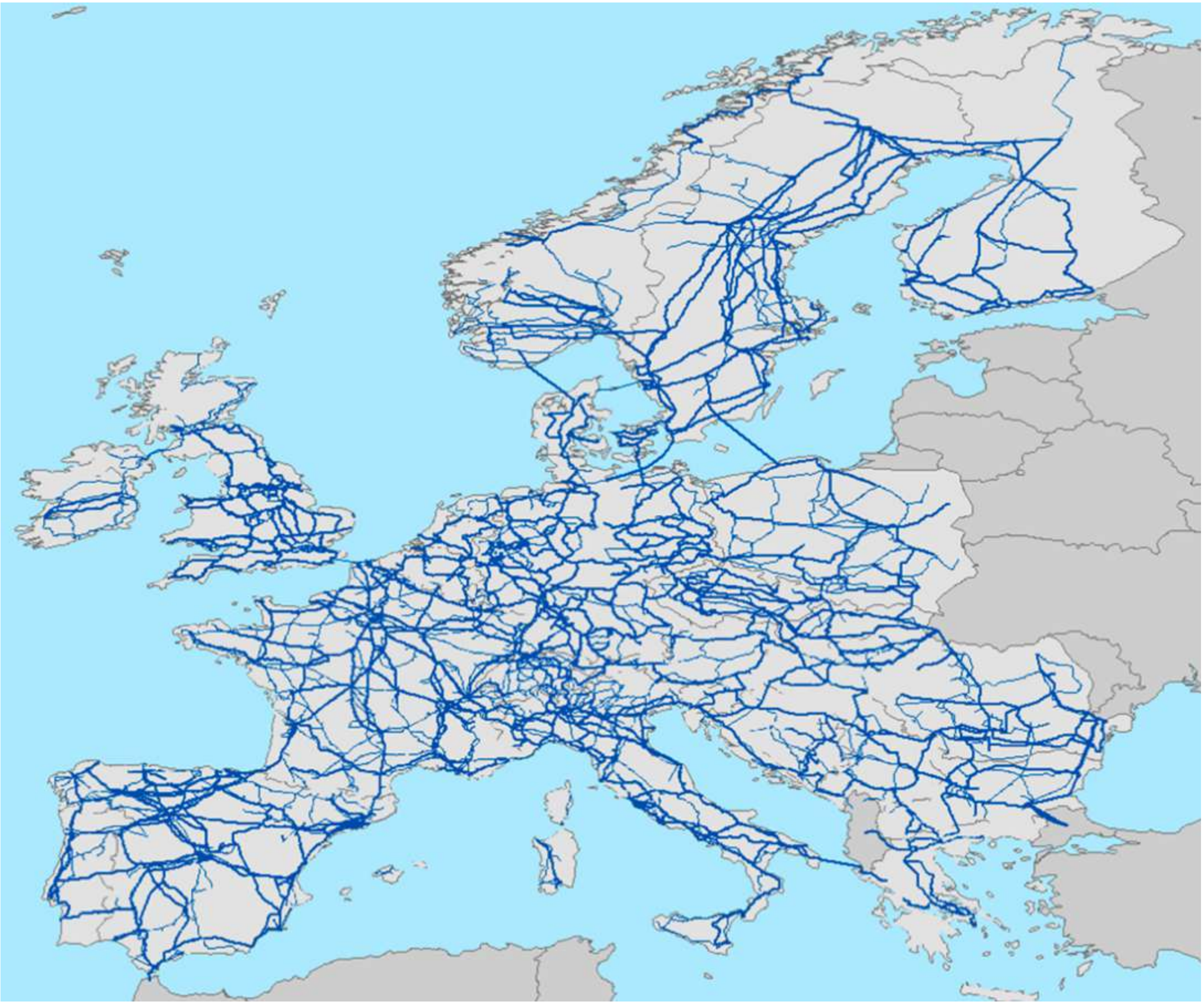


Figure 7: Schematic representation of OPL network in the EU (Ferrer et al., 2020).

3.3. Vegetation Management and planting Rights-of-way

The high voltage transmission lines in Europe form a network that transport electricity from power generation facilities to local distribution substations. These power lines often traverse regions with abundant vegetation, necessitating the need to maintain vegetation at an appropriate level to ensure uninterrupted energy distribution (First Energy, 2020). A strip land known as the ROW is used for construction, develop, operate, and maintain transmission lines. ROW is maintained with the transmission line in the middle. All trees, structures, and building that obstruct the OPLs are removed by the ROW. When determining the maximum width of ROW, safety factors such as the voltage, velocity of the which the wind travels, sag, tower design and other parameters are considered. Usually,In rural and forested areas, where overhead power lines (OPLs) pass through, a straight line clearance of approximately 50 meters is typically maintained for tower placement Federal regulations presently mandate that TSOs maintain clear OPL corridors by removing large trees and tall vegetation. It's not necessary to use herbicides carelessly or to routinely mow the entire area down to grass. As a substitute, several utilities have embraced Integrated Vegetation Management (IVM), which entails the precise application of herbicides to undesirable plants while permitting the establishment of wildflowers, sedge plants, ferns, and low-growing shrubs to create a diversified ecosystem below the pylons (Conniff, 2014). Generally, these project undertakers can use herbicides that are approved by the PEFC and FSC. Trees that grows tall enough to obstruct ROW corridors and prevent the secure, effective, and regulatory functioning of an OPLs must be removed. Wire zone/Zone 1 is a portion of the ROW that lies directly below the OPLs and extends 10 ft past every cable on both sides of the tower (Protheroe, 2021). Border zone/ Zone 2 is the remaining ROW which is not within the wire zone. The intervals from the boundaries of the wire zone and the outer limits of the ROW are the widths of the border zones. OFF ROW zone/zone 3 is generally the Zone 50 ft away from the tower. Priority Zone is the region surrounding each cable. The spacing extends starting from 14 ft from the cable for an OPL; this length is shorter for LV lines. The priority zone will sag around the cables between masts and be closer to the surface as the cables droop within masts (Con Edison, n.d.) (Figure 8). Targeting trees and shrubs, natural low-growing plant communities with a mature height less than 3 ft are created in the cable's zone. However, while suitable native trees and shrubs with a mature height less than 15 ft may be fostered. To the OPL ROW, pruning trees along distribution cables frequently involves cutting from tower pole to pole. While planting within 20 ft of an OPL, tall shrubs or low-growing trees that don't reach a height of 15 ft are typically chosen. Trees shouldn't reach taller than 40 ft if they are planted 20 to 50 ft away from a power line. Additionally, trees that reach a height of 40 ft or more should be placed more than 50 ft away from the OPLs (Figure 9).

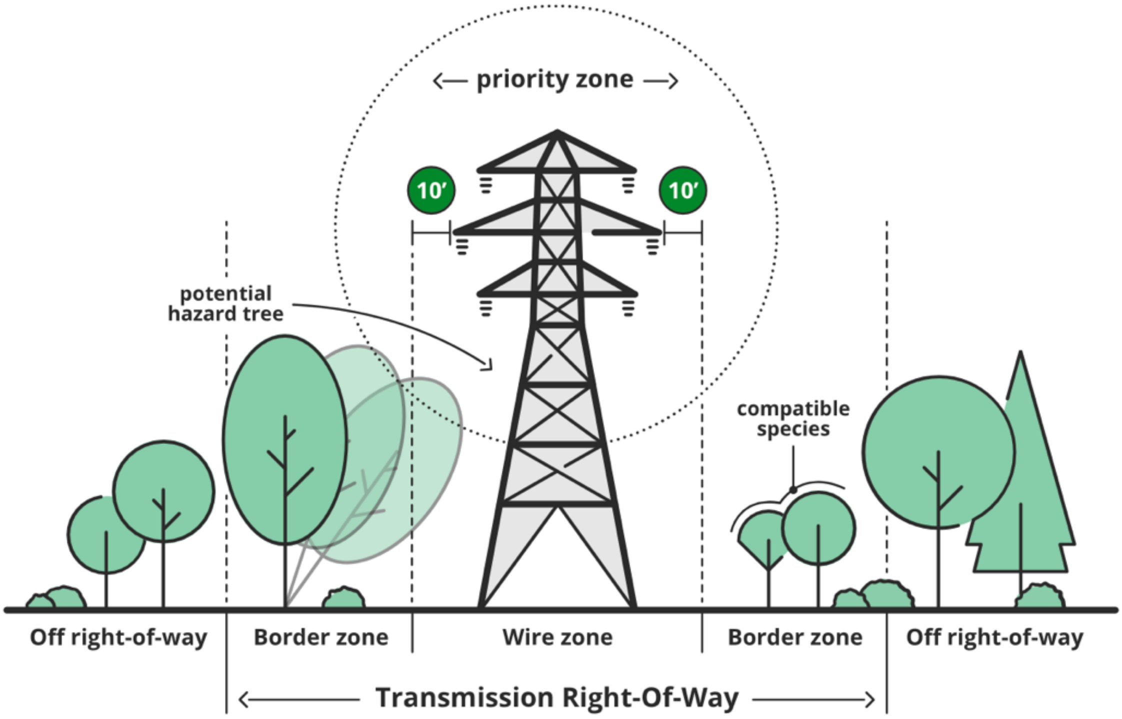


Figure 8: A Schematic representation of a OPL Corridor ROW vegetation Management (Con Edison, n.d.).

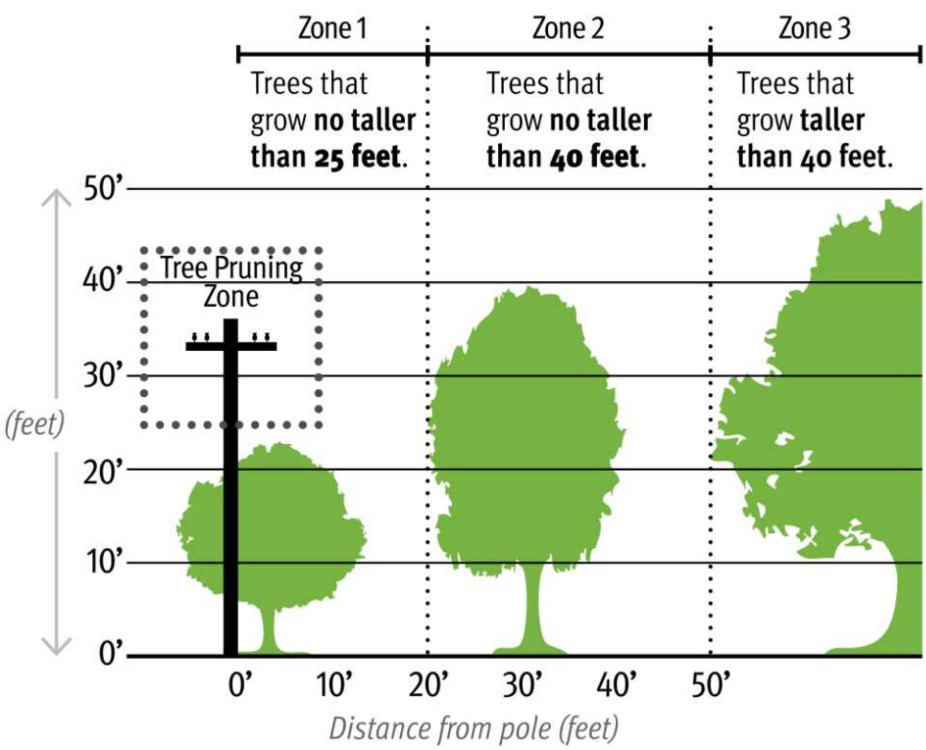


Figure 9: A schematic representation depicting the typical height of trees at various distances from the pole in the ROW (First Energy, 2020)

Blackouts brought on by trees striking electric cables are more than just an inconvenience. The safety of the public in urban region and to biodiversity in the rural and forest OPL corridor zones may be at risk in such circumstances where there are downed cables with vegetation ROW. If no action is taken, trees in forested areas might suddenly pose a serious threat to network security as they continue to grow (Berger, 2010). TSOs will monitor all aspects of the OPLs in order to ensure the protection of the network in forested regions and, by extension, the safety of the electrical supply. For TSOs it important to choose plant species that are suitable with the particular type of OPL and the area. Aspects like height constraints, growth patterns, maintenance requirements, and pest and disease resistance must be overlooked. To reduce possible interference with the cables, it is frequently desirable to use local species that are slow growing. When vegetation may interfere with the masts in the following circumstances, the pylons are at danger. TSOs must also make sure the plant species chosen won't rise above the permitted height limits for the electricity cables (Askins et al, 2012). To prevent any possible risks or power supply disruptions, it is imperative to abide by the clearance standards. By including a variety of floral plants to support pollinators, natural grasses to prevent erosion, and suitable shrubs to provide habitat, the ROW can enhance aesthetics and offer year-round visual appeal. Incorporating a range of plant heights, blooming periods, and leaf varieties further contributes to its overall visual and ecological value. Grasses, herbaceous plants, and indigenous shrubs, particularly those that spread through clonal growth, are allowed to thrive without competition from trees. As a result, they form a compact plant community with a short stature that is less susceptible to encroachment by trees in the closer zones to poles. Regular Maintenance procedures, which can take place every 3 to 12 years based on the growth of the plants, are the best approach to maintain the vegetation at a minimum (LIFE Elia-RTE, 2018). Vegetation species, height, soil composition, and climate patterns of a region are just a few variables that may have an effect on how much vegetation grows. Based on their typical definitive height, a list of prevalently growing plant species ROW to the OPL is documented for Europe (Table 3).

Table 3: The most prevalent plant species found across the EU (LIFE Elia-RTE, 2018).

Specie	Latin Name	Final height (m)
Poplar	*Populus x canescens*	30
Black Alder	*Alnus glutinosa*	25
Black Cherry	*Prunus serotina*	15
Black Locust	*Robinia pseudiacacia*	25
Downy Birch	*Betula pubescens*	25
English Elm	*Ulmus glabra*	30
English Walnut	*Juglans regia*	25
European Ash	*Fraximus excelsior*	40
European Aspen	*Populus tremula*	20
European white Birch	*Betula pendula*	30
Eurpean Beech	*Fagus sylvatica*	40
Fiel Maple	*Acer campestre*	20
Hornbeam European	*Carpinus betulus*	25
Large-leaved Lime	*Tilia platyphyllos*	30
Norway Maple	*Acer platanoides*	30
Norway Spruce	*Picea abies*	40
Pedunculate Oak	*Quercus robur*	35
Sessile Oak	*Quercus petraea*	40
Small-leaved Lime	*Tilia cordata*	30
Sweet Chestnut	*Castanea sativa*	30
Sycamor Maple	*Acer pseudoplatanus*	30
White Poplar	*Populus alba*	30
White Willow	*Salix alba*	25
Wild Cherry	*Prunus avium*	25
Wych Elm	*Ulmus minor*	30

3.4. Integrated Planning for Green Corridors and its Benefits

Green Corridors below OPLs are green spaces that have the ability to promote biodiversity in rural, SPAs and urban environments. Uncertainty exists regarding the extent to which these corridors offer unique habitats in comparison to the surrounding terrain. To sustain animal population growth in fragmented environments, mobility of animals between fragments is crucial. Without this, productivity may drop due to environmental and ecological variability. It is projected that wide-ranging ungulates would be particularly sensitive to habitat fragmentation. Movements of migratory species may increase the growth of wildlife populations, presumably aided by the utilization of seasonal environments. Additionally, increased area utilization via migrations may make up for diminished resources brought on by habitat loss, such as a decline in food supply and habitat production. Corridors frequently undergo vegetation management; their biodiversity can be compared with that of "natural" environments. Additionally, by facilitating species mobility in suburban and urban settings, these spaces may promote biodiversity. Birds are impacted by changes resulting from infrastructure developments, affecting their resting, feeding, roosting, and nesting habitats. These changes include the loss of vegetation structure, volume, and composition, increased fragmentation and decreased patch sizes, and an increased proportion of cover provided by constructed towers. Green corridors below OPLs foster nesting birds, both local and migratory species, as well as pollinators, seed predators, and ground-foraging insects. Over time, these corridors promote species richness, increase population sizes, and enhance the connectivity between natural landscapes (Hilty et al., 2020). The Green corridors below OPLs for conservation is optimized to accommodate these aims while also considering their geographical arrangement. The objectives for conservation may include target species, vital habitats, and ecosystems. In a methodical conservation strategy, political and socioeconomic factors may also be considered. In order to improve the effectiveness, sustainability, and resilience of terrestrial regions and SPAs in fragmented systems and make them fewer susceptible to all risks (Bennett, 2003). Habitat enhancement along green corridors can increase species populations, necessitating mitigation measures to address risks of bird electrocution and collisions.

3.4.1. Proactive Measures at the planning level to Avoid Electrocution

Across the countries within the EU, a variety of mitigating strategies and solutions have been looked at to prevent bird collisions. Some TSOs with in-house expertise sought to remedy for the electrocution issue by using exclusion barriers, sometimes known as perch deterrents. Since birds will still try to perch on structures where space is restricted, they have a greater likelihood of coming into correspondence with energized cables and components. Many of these proved to be ineffectual. To ensure the safety of the Avifauna, equipment’s employed to reduce the likelihood of electrocution should be durable, effective, and placed securely. A "Bird-safe" mast is a configuration intended to reduce the likelihood of bird form getting electrocuted, by providing enough space between grounded devices and energized phase conductors (Avian Power Liner Interaction committee, 2006). In order to lessen the risk of electrocution, exposed portions are encased. On a network that is already in use, upgrading the design can reduce the risk of electrocution. A long-term option is to use insulated and twisted conductors. It entails using insulated and twisted conductor cables in order to completely eliminate the possibility of electrocution. Only lines with a voltage lower than 35 kV are suitable for using twisted conductor cables. Separate insulated conductor cables can be used for higher Voltage levels. In order to reduce bird mortality, OPL modifications should consist of enough space conductors and grounded cables. At the distribution system's intersections and switch towers, there are frequently minimal distances connecting the conductors. In order to lessen the risk of electrocution, OPLs in Europe must be at least 1.4 m apart, and there must be more than 0.6 m between a potential perch and the energized components (Endangered WildLife Trust et al., 2012). These separations ought to be higher in regions where Accipitridae groups are common. Another long-term solution is to create crossarm provisions that minimize risk to Avians, called supports in cross-arms in pylons. Safe configurations should always be adopted when constructing new OPLs, because altering current setups can be highly expensive. The safe provision that provides fundamental elements must adhere to the minimal safety distances. It is extremely important to employ supports with hanging insulators that shift the phases away from the perching region whenever feasible (Vajjhala, 2007). It is important to note that the classification and measurements provided in this context specifically apply to metal crossarms. Bird collisions are generally less likely to occur with wooden or fiberglass crossarms because these materials have low conductivity and are often not grounded. Additionally, the position of a support structure must be taken into account when assessing its level of danger. Supports with very narrow spacing between conductors such as those with pin insulators or jumpers above the insulators on anchor supports, or when a crossarm lacks a ground connection, pose a significant risk of Bird electrocutions(Janss, 1999). Horizontal crossarms with suspension insulators are considered less hazardous as long as there is a minimum distance of 1.5 m between the side of the cross arm and the conductor hanging from the arm above. Similarly, vault layouts with suspension insulators are not highly dangerous if there is more than 1 m of space between the central conductor and the resting area for birds. Towers with any type of devices pose an increased risk of electrocution for birds of all sizes due to the close proximity of the device phases to the ground and to one another (Table 4). The biggest raptors that are sensitive to electrocution determine the most significant cross arm spacing levels (IUCN, 2022). One other method to ensure Bird-Safe measures is by diverting birds away from the OPLs is to install Visual/sound Deterrents and Strobe lights.

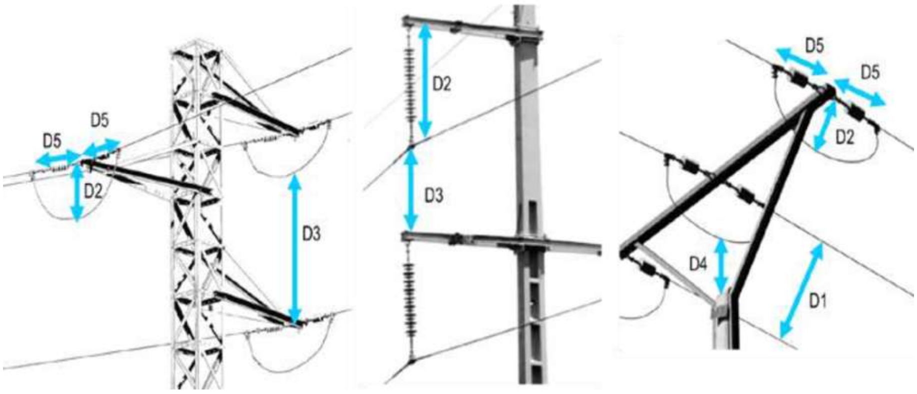


Figure 10: Representation of distances from various cross arm configurations (IUCN, 2022).

Table 4: Recommended safe values for basic critical distances used to evaluate the level of danger associated with a crossarm (IUCN, 2022).

DISTANCE	CROSSARM CONFIGURATION	BASIC CRITICAL DISTANCE	SAFE VALUE
D1	ALL CONFIGURATIONS	Distance between the conductors. *Depends on the bird's wingspan.*	1.5 m
D2	ALL CONFIGURATIONS	Vertical distance between the point where the bird perches and the nearest live element at a lower level (conductor or jumper). *Depends on the risk caused by defecation and the distance between the bottom of the legs and the tip of a wing spread out downwards.*	1 m (0.7 m)*
D3	ALTERNATING (STAGGERED) CONFIGURATION VERTICAL CONFIGURATION	Vertical distance between the point where the bird perches and the nearest live element at a higher level (conductor or jumper). *Depends on the vertical reach of the bird, i.e. the distance between the foot and the tip of a wing spread out upwards.*	1.5 m
D4	VAULT CONFIGURATION	Vertical distance between the bottom of the crossarm and the nearest live element at a higher level. *Depends on the vertical reach of the bird.*	1 m
D5	ALL CONFIGURATIONS (ANCHOR SUPPORTS)	Horizontal distance between the point where the bird perches and the nearest live element. *Depends on the distance between the foot and the tip of a wing spread out sideways.*	1 m (1.5 m)**

**When configuration for vertical distances of 1m cannot achieved atleast 0.7 m distance must be employed.*
***In most cases, a horizontal safety distance of 1 m is considered adequate, as electrocution typically occurs when there is contact between the bare parts of a bird's wing and not with its feathers. In regions with high humidity or where large eagles or vultures are present, distance up to 1.5 can be employed.*

In order to prioritize mitigation measures against bird electrocution on OPLs in SPAs, it is necessary to categorize the OPL configuration into posing different risk levels and hence the need for protection in high-risk tower sections (Table 5). Cross arm configuration due to their complex structure are considered to be in the high-risk level. OPL units with vertical insulators, distribution transformers and switch disconnectors are considered in the medium-risk level and OPL units with horizontal support insulators and exposed jumper wires which allow for birds to perch safely are considered in the low-risk levels (Probst et al., 2019). For some countries in Europe Various other methods are also employed for mitigation.

Table 5: Matrix for prioritization of conservation measures against Electrocution on OPLs (Probst et al., 2019).

Prioritisation of conservation measures		Risk of electrocution		
		High	Medium	Low
Worthiness of protection	Open countryside in SPAs	Very High	Very High	High
	Woodland in SPAs	High	Situation-dependent	Situation-dependent
	Open countryside outside of SPAs	High	High	Situation-dependent
	Woodland outside of SPAs	Situation-dependent	Situation-dependent	Low

3.4.2. Proactive Measures at planning level to Avoid Collision

The most effective preventative technique is to avoid installing OPLs in high-risk regions. This is achievable with careful planning of the routes the OPLs traverse, including during the EIAs, the evaluation of several paths, and the selection of the most ecologically harmless, technically feasible, and cost-efficient Corridors. On a larger scale, OPL routing should be installed away from expansive wetland regions and other sensitive Avian habitats, key migration pathways, and SPAs designated for endangered species. collision rates can be substantially reduced by removing the grounded cables. This solution is often not practical, though, as the grounded cable is essential for ensuring stability and shielding the OPL from lightning strikes (Avian Power Liner Interaction committee, 2006). However, this method has been effective in parts of Hungary and Austria reduced the Collison rates of Bustard populations (Raab et al., 2011). Additionally, for the conservation of birds in the cold Nordic regions removing grounded cables was seen effective.

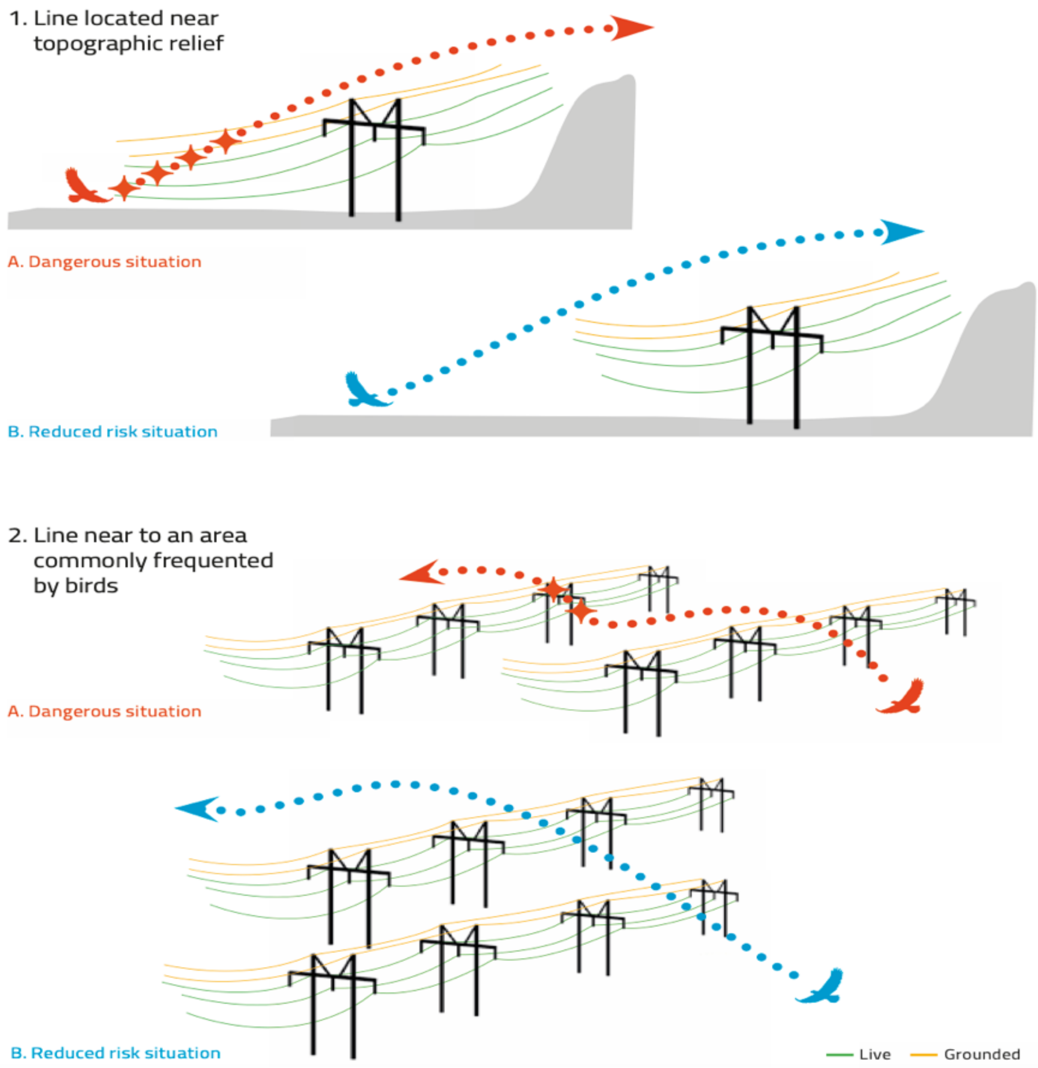


Figure 11: Route planning to minimize the risk of collision by avoiding hazardous situations (IUCN, 2022)

Marking the OPLs is one of the ideal options and has been the preferred mitigation strategy across Europe when dangerous power lines cannot be buried. Swinging plates, spiral vibration dampers, and crossing bands Bird. Mark Flapper, Swan Flight Diverter, Firefly Flapper are just a few of the numerous possible cables marking instruments that have come into existence over time (Figure 12). Investigations have found a broad range in the efficiency of marking lines, considering habitat, Avian species, seasonal patterns, and the kind and configuration of power lines among the main determinants (Bird Life International, 2022). Another option is to divert and deter Avians away from electrical wires. Others propose installing forage strips to entice birds to settle before coming into contact with a OPL or installing visual warning spheres the zones where the vegetation is present and alerting noises (to assist birds in changing their desired flying route) to take use of their high-resolution peripheral view. Limiting high-disturbance behaviors on OPL ROW may help decrease collisions brought on by frightened birds (Jenkins et al., 2010).

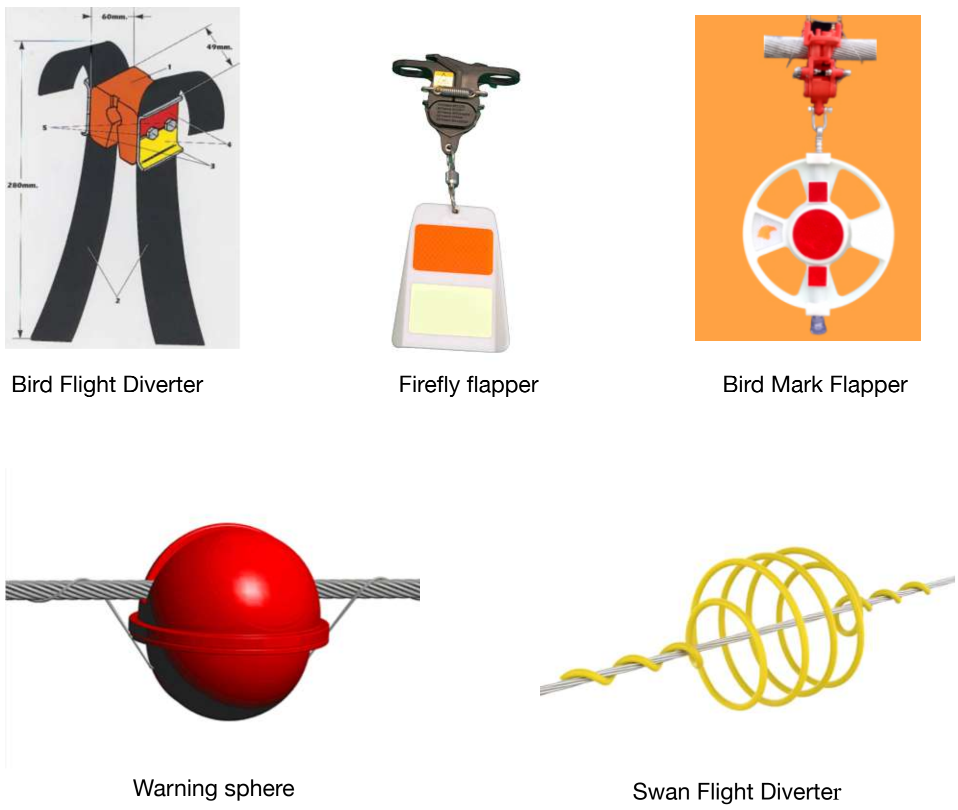


Figure 12: Some examples of Bird Diverters on Overhead power lines.

Since, most collision risks are higher on the aquatic birds around waterbodies that span for over 100 m in radius especially in the SPAs implementation of mitigation measures against collision is based on risk levels (Probst et al., 2019). OPLs crossing or spanning along the has high risk within the 100 m radius of the HV, MV AND LV lines. For OPLs further to the waterbodies generally HV and MV lines poses high risk. OPLs not spanning across or along waterbodies the risk is based on the surrounding habitat, lines are considered to pose low risk levels.

Table 6: Matrix for prioritization of conservation measures against Collison on OPLs (Probst et al., 2019).

Prioritisation of conservation measures		Risk of collision		
		High-voltage power lines	Medium-voltage power lines	Low-voltage power lines
Worthiness of Protection	Waterbodies in SPAs	Very High	Very High	Very High
	SPAs further than 100 m from waterbodies	High	High	Situation-dependent
	Waterbodies outside of SPAs	High	High	High
	Outside SPAs	Situation-dependent	Situation-dependent	Low

3.4.3. Benefits of Green corridors and Rights-of Way maintenance on Biodiversity

Birds and electricity lines can be physically deterred by planting and maintaining a variety of low-growing plants beneath the wires. By serving as a visual barrier, this flora may aid birds in recognizing the presence of OPL and avoiding colliding. Birds may be drawn to the green corridor, which can serve as a suitable habitat, and away from the OPL. The corridor encourages birds to spend time inside the safe zone, lowering their exposure to hazards of collision and electrocution, by offering food supplies, nesting locations, and shelter. By establishing a green corridor in OPL pathways, it gives birds an alternative route to fly, diverting their flight away from the dangerous zones. Birds may be better able to identify and avoid power cables if there is vegetation in the corridor since it can make the lines more visible to them. Birds may be warned to keep their distance by the contrast between the greenery and the power cables. According to surveys carried out in the Czech Republic, the most often seen bird species were the tree sparrow and lesser whitethroat, indicating the significance of these environments (Hrouda et al., 2021).

Narrow linear green corridors can serve as passages for animals, such as wolves, facilitating their movement and enabling hunting opportunities. These corridors also act as bridges, enhancing the movements of wide-ranging species like moose, bears, and deer. Corridors also enhance the habitat for small animals. In winter, when a ROW cuts through a dense forest, it can create a tunnel-like effect and result in snow drifts. On the contrary, this situation can offer better thermal protection for smaller animals that dig and burrow beneath the snow (Berger, 2010). Green corridors have been found to enhance floral diversity (Eldegard et al., 2015), attract pollinators, butterflies, and support abundant populations of small animals and birds in open farming areas Additionally, they provide nesting sites for larger bird species (Møller et al., 2014). Nesting boxes are also installed for enhancing bird nesting sites. A study carried out in Kärnten, Austria, found that nest boxes placed within the OPL project area, installed from 2015 to 2020, exhibited remarkably low rates of nestling mortality. This implies that in a location exposed to a high-voltage pylon, the nest box do not overheat and endanger the starlings (Sturnus vulgaris) ability to reproduce. On the other hand, the nest box may also be used to measure cooler temperatures that roughly match the outdoor temperature (Kleewien et al., 2021).

Green corridors and the maintenance activities associated with them are likely to modify the tree flora in the surrounding areas by affecting factors such as light availability, soil moisture, and temperature (Hrouda et al., 2021). As a result, there may be an increased density of dead trees, which can be advantageous for other organisms (Müller et al., 2010). Studies conducted in Saxon Germany, showed that flower strips enhance the growth of Butterfly species (Wix et al., 2019). Compared to semi-natural fields, butterfly species were more prevalent around OPL corridors. In semi-natural pastures, butterfly occurrence was highest in sections with tall vegetation, whereas in OPL corridors, butterfly occurrence was highest in sections with short or medium vegetation in the lower mast areas. The variable that influenced the abundance of the majority of species was the number of blooms. The majority of species have beneficial relationships with a variety of flower groups. The quantity of various butterfly species was positively correlated with the flowers of the plant families Apiaceae, Caryophyllaceae, Primulaceae, Rubiaceae, Scrophulariaceae, and Violaceae (Berg et al., 2013). In addition, natural structures in the mast foot area can contribute to achieving greater biodiversity and thus greater ecological value. The present results of the investigation of species diversity at the two selected locations in Carinthia Austria clearly showed that through succession and appropriate maintenance measures in the area of the mast foot, greater biodiversity can be achieved in comparison to locations used intensively for agriculture. Something similar could also be implemented for forest routes and for grassland management (Kleewein et al., 2019).

The foraging patterns of pollinators depend heavily on fragrances from the floral diversity. Some flowers emit scents in the form of volatile organic compounds (VOCs) in the natural pastures to entice bees. These pollinators take up the fragrances and search for the origin of the fragrance. This may be accomplished by using visual cues to track the gradient of fragrance released from the source. In the case of bees, after locating the source, the foraging pollinator will return to the colony and signal the other workers where the source is (Wang et al., 2021). Planting native vegetation along the corridor can provide a suitable habitat for pollinators. Native flowers, shrubs, and trees can attract pollinators by providing nectar and pollen resources. The green corridor can serve as a connected pathway for pollinators to move between fragmented habitats. By providing a continuous and accessible route, it enhances pollinator mobility and gene flow, promoting genetic diversity and population resilience. Creating a green corridor encourages the use of IVM practices that minimize or eliminate pesticide use. This reduction in chemical exposure benefits pollinators by preserving their health and reducing negative impacts on their populations (Russell et al., 2005). By carefully choosing a mix of plant species and employing well-designed engineering elements, it is perceived that TSOs can enhance the connectivity of habitats for pollinator insects in the OPL corridor. This, in turn, can boost the resilience of declining pollinator biodiversity.

Among the enchanting creatures found in the green corridors are the blue fritillary butterfly, known for its striking blue coloration. This butterfly adds a touch of natural beauty to the landscape with its delicate wings and intricate patterns. Another fascinating resident is the multicolored tiger beetle, which boasts vibrant hues and a remarkable ability to scurry across the open terrain (Cole, 2019).. The metallic blue and green bees add a touch of brilliance to the corridors. These bees exhibit shimmering colors, ranging from vivid blues to sparkling greens, making them a captivating sight for observers. Their presence underscores the importance of these corridors in providing suitable forage and nesting resources for pollinators.The avian life in power line cuts is equally noteworthy, featuring a variety of captivating species. The indigo bunting, with its deep blue plumage, contributes a splash of intense color to the surroundings. The eastern bluebird, known for its vibrant blue and rusty orange feathers, adds further visual appeal. The prairie warbler, blue-winged warbler, and yellow-breasted chat are also notable inhabitants, each possessing unique colors and patterns that enhance the diversity and beauty of the avian community in these corridors (Cole, 2019).

The wide stretches of vegetation below OPLs support a complex and diverse ecosystem that is distinct from the trees and forests that surround them (Cole, 2019). This unique habitat provides valuable resources and conditions for various forms of life.The open terrain receives more sunlight due to the absence of dense tree canopies. This increased light availability promotes the growth of different types of vegetation, such as low-lying shrubs, grasses, and herbaceous plants. These plants create a favorable environment for a wide range of organisms, including insects, reptiles, small mammals, and birds. The lack of towering trees in this area alters the microclimate and creates a distinct set of ecological conditions (Climate Policy Watcher, 2023). The open space allows for improved air circulation, temperature regulation, and exposure to sunlight, which can influence the behavior and distribution of species. Some organisms have evolved to thrive specifically in these open, sunlit areas, utilizing the available resources and adapting to the unique challenges presented by this habitat.In contrast, the trees and forests surrounding the open terrain provide a different set of ecological benefits. They offer nesting sites and shelter for arboreal species, support a diverse range of fungi and mosses, and contribute to the overall canopy structure of the ecosystem (Russell et al., 2005). These wooded areas may have a higher diversity of tree-dwelling species and provide different resources compared to the open terrain below the power lines.

4. Implementation of Green Corridors in Europe

Planning for urban green infrastructure (UGI) is an established method to create linked, multipurpose networks of blue and green areas that might help the environment, society, and economy while also making communities more resilient to landscape fragmentation caused by infrastructure developments . The European Commission (EC) encourages TSOs to enhance the supply of ecological services and the conservation of biodiversity and emphasises on strategic green corridor planning below overhead lines. Different forms of blue-green areas, such as woods, wetlands, agricultural land, solitary green components are included in the UGI. The EC established the Biodiversity Strategy for 2030 in a thorough, institutionalized, and comprehensive approach for preserving the environment and stopping the depletion of ecosystems. The Strategy outlines further mitigation measures, goals, targets, and governance systems in order to better execute the present legislation (European Commission, 2020). The Strategy presents an extensive plan by the EU for nature restoration through EIA. It includes developing a new legal framework, setting binding targets to restore damaged ecosystems. The aim is to improve the conservation status of 30% of EU protected habitats and species that are not currently in a favorable state. Additionally, the plan involves restoring 25,000 km of rivers to their natural flow, reversing the decline of farmland birds and insects, reducing chemical pesticide use and risk, promoting organic farming on 25% of agricultural land, decreasing nutrient losses from fertilizers, and planting 3 billion trees while protecting primary and old-growth forests. The Biodiversity Strategy 2030 includes a plan for creating green corridors below OPLs in the urban, suburban and Natura 2000 Sites. Natura 2000 is a network of protected areas in the European Union designated for the conservation of biodiversity (European Commission, n.d.). These corridors aim to promote biodiversity and ecological connectivity by utilizing the space below OPLs. The strategy involves implementing measures such as planting native vegetation, creating habitat structures, and managing the vegetation in a way that supports a diverse range of plant and animal species. The goal is to establish interconnected green corridors that enhance wildlife habitats, facilitate species movement, and contribute to overall biodiversity conservation.

4.1. Legal Frameworks

4.1.1. Birds Directive

The Birds Directive or the Directive on the Conservation of Wild Birds (Directive 2009/147/EC), is a piece of legislation enacted by the EU to protect wild bird populations and their habitats within EU member states as mentioned in Article 1. The directive aims to ensure the conservation and sustainable management of all species of wild birds that are naturally occurring or regularly visiting Europe. Article 2 of the directive states that

> *"Member States shall take the requisite measures to maintain the population of the species referred to in Article 1 at a level which corresponds in particular to ecological, scientific and cultural requirements, while taking*

> *account of economic and recreational requirements, or to adapt the population of these species to that level."*

Regarding OPLs, the Birds Directive includes provisions to mitigate potential negative impacts on bird populations caused by power lines and other linear infrastructure. These provisions require member states to take measures to avoid significant disturbance or direct damage to bird species and their nests resulting from the construction, operation, and maintenance of transmission lines. To comply with the directive, member states are expected to Assess the potential impacts of transmission lines on bird populations and habitats during the planning and permitting phases, Implement mitigation measures to minimize disturbance or harm to bird species and their nests, Consider the routing and design of transmission lines to avoid sensitive bird areas whenever possible, Apply measures to prevent bird collisions with power lines, such as marking and modifying the visibility of the lines, Regularly monitor and evaluate the effectiveness of mitigation measures and take necessary actions to improve their efficiency. Article 4 states, the bird species mentioned in Annex I of the Directive must be subject to special conservation measure concerning their habitat and their survival and reproduction must be guaranteed and this applies to those species that are present in the tower sites (Directive 2009/147/EC, 2009). It is significant to highlight that while each EU member state is responsible for adopting it into their own national legislation, the precise implementation and compliance to the Birds Directive could differ. As a result, several countries within the EU may have different specific laws and regulations governing transmission lines and bird protection.

4.1.2. Habitats Directive

The Habitats Directive aims (Council Directive 92/43/EEC) to protect and conserve natural habitats, including those supporting wild fauna and flora, across the European Union. It establishes a network of protected areas called Natura 2000, which comprises SPAs. As Article 3 states,

> *"A coherent European ecological network of special areas of conservation shall be set up under the title Natura 2000. This network, composed of sites hosting the natural habitat types listed in Annex I and habitats of the species listed in Annex II, shall enable the natural habitat types and the species'*

habitats concerned to be maintained or, where appropriate, restored at a favourable conservation status in their natural range.

The Natura 2000 network shall include the special protection areas classified by the Member States pursuant to Directive 79/409/EEC."

In relation to OPLs, Article 6 of the Habitats Directive indirectly addresses potential impacts on protected habitats and species that may occur as a result of their construction, operation, and maintenance. Member states are required to consider these potential impacts during the planning and permitting processes (Council Directive 92/43/EEC, 1992).

The Birds and Habitats Directives form the foundation of the EU's biodiversity policy. These directives provide a shared legal framework that allows EU member states to collaborate in conserving Europe's most threatened and significant species and habitats. The directives ensure that conservation efforts extend across the entire natural range of these species and habitats within the EU, disregarding political or administrative boundaries. Data on habitats and species provide valuable insights into their distribution, abundance, and ecological requirements. This information helps identify areas of high conservation value and areas where potential conflicts with human activities, such as transmission line construction, may arise. By analyzing habitat and species data, authorities can develop targeted mitigation measures to minimize negative impacts on protected habitats and species. Reports from Member States offer a baseline for assessing the condition of and changes in species and habitats over several observation periods using simplified monitoring methods.

4.1.3. Convention on the Conservation of European Wildlife and natural Habitats

Recommendation No. 110 (2004) is a guideline issued by the Council of Europe on minimizing the adverse effects of above-ground electricity transmission facilities on birds. It provides recommendations for member states to mitigate the impacts of power lines on bird populations. These recommendations are not legally binding but serve as guidance for member states in developing their own strategies and measures to mitigate the adverse effects of power lines on birds. Implementation may vary between countries, and additional measures beyond those recommended may be necessary based on local circumstances and bird species present in specific regions. It is important to determine and monitor the severity of impacts on bird populations in Europe caused by mortality resulting from electrocution and collisions with power lines across various bird families (Table 7) (The Council of Europe, 2004).

Table 7: List of bird families indicative of those that should tend to be focal species for environmental assessments where they are at risk as they are considered to be particularly sensitive OPLs (European Commission, 2018).

Bird families in Eurasia identified as vulnerable to electrocution and collision internationally	Casualties due to electrocution	Casualties due to collision
Loons (Gaviidae) and Grebes (Podicipedidae)	0	II
Shearwaters, Petrels (Procellariidae)	0	II
Boobies, Gannets (Sulidae)	0	I
Pelicans (Pelicanidae)	I	II-III
Cormorants (Phalacrocoracidae)	I	I
Herons, Bitterns (Ardeidae)	I	II
Storks (Ciconidae)	III	II
Ibisses (Threskiornithidae)	I	II
Flamingos (Phoenicopteridae)	0	II
Ducks, Geese, Swans, Mergansers (Anatidae)	0	II
Raptors (Accipitriformes and Falconiformes)	II-III	I-II
Partridges, Quails, Grouse (Galliformes)	0	II-III
Rails, Gallinules, Coots (Rallidae)	0	II
Cranes (Gruidae)	0	III
Bustards (Otidae)	0	III
Shorebirds/Waders (Charadriidae + Scolopacidae)	I	II-III
Skuas (Sterkorariidae) and Gulls (Laridae)	I	II
Terns (Sternidae)	0-I	I-II
Auks (Alcidae)	0	I
Sandgrouse (Pteroclididae)	0	II
Pigeons, Doves (Columbidae)	I-II	II
Cuckoos (Cuculidae)	0	I-II
Owls (Strigiformes)	II-III	II
Nightjars (Caprimulgidae) and Swifts (Apodidae)	0	I-II
Hoopoes (Upudidae) and Kingfishers (Alcedinidae)	I	I-II
Bee-eaters (Meropidae)	0-I	I-II
Rollers (Coraciidae)	I-II	I-II
Woodpeckers (Picidae)	I	I-II
Ravens, Crows, Jays (Corvidae)	II	I-II
Medium-sized and small songbirds (Passeriformes)	I	I-II

0 = no casualties reported or likely;
I = casualties reported, but no apparent threat to the bird population;
II = regionally or locally high casualties, but with no significant impact on the overall species population;
III = casualties are a major mortality factor, threatening a species with extinction, regionally or at a larger scale.

The convention suggests that a criterion for a thorough EIA should be applied to all OPLs that have the potential for damaging effects on birds. Consistency in applying standardized methods, specifically the Before-After Control-Impact approach, is crucial to ensure comparability. These methods should be consistently used before, during, and after construction near the power line, along with a reference area, for effective comparison.

4.1.4. The Environmental Impact Assessment (EIA) Directive

The EIA Directive (Directive 2011/92/EU) is a legislation that mandates that before any public or private project is approved, its potential environmental effects must be assessed. It applies to a variety of undertakings, including building out infrastructure like OPLs. The rule requires that the assessments consider, among other things, aspects including the impact on the environment and biodiversity. It states that a study must be conducted to identify, discuss, and assess the important environmental effects that the project is anticipated to have. The order also highlights the value of public participation, making sure that members of the public and other interested parties have the chance to voice their ideas and grievances during the decision-making process. The results of the EIA must be considered by the pertinent authorities that are in charge of issuing licenses or approvals. The EIA Directive has been incorporated into the national laws of every member state of the EU, thus there may be some variances in how it is put into practice at the national level. Establishing a methodical and open process for identifying, outlining, and assessing projects' possible environmental implications is one of the directive's key goals. This assessment considers a number of factors, including climate, soil, water, air, biodiversity, and cultural significance. Additionally, it considers how these variables interact as well as any possible synergistic effects (Directive 2011/92/EU, 2011).

The EIA process begins with the developer preparing an Environmental Impact Statement (EIS) that provides detailed information about the project, its potential impacts, and proposed mitigation measures. The EIS is then submitted to the competent authority responsible for granting permits or authorizations for the project. The authority, in turn, reviews the EIS, assesses its adequacy, and may request additional information if necessary. It ensures that the public and stakeholders have the opportunity to express their opinions, concerns, and suggestions regarding the project. The developer is required to make the EIS available to the public, and the public is given a reasonable time frame to submit comments and participate in public hearings or consultations. It ensures that the public and stakeholders have the opportunity to express their opinions, concerns, and suggestions regarding the project. The developer is required to make the EIS available to the public, and the public is given a reasonable time frame to submit comments and participate in public hearings or consultations. The competent authority considers the results of the environmental impact assessment, including the public's input, when making decisions on the project. It evaluates the significance of the potential impacts, considers alternative options, and weighs the overall benefits against the environmental costs. The EIA Directive also emphasizes the need for competent authorities to cooperate and exchange information during the assessment process, particularly in cases where projects may have transboundary impacts (Pan-European transmission line networks). It encourages coordination and collaboration among member states to ensure the effective assessment of cross-border projects. By requiring thorough assessments of potential impacts, encouraging public participation, and fostering cooperation among member states, the directive aims to ensure that development is sustainable and respects the environment (Directive 2011/92/EU, 2011).

4.2. Permitting Procedure for OPLs

ENTSO-E based in Brussels, Belgium, is an association of TSOs in Europe. It was established in 2008 in accordance with Regulation No. 714/2009–Conditions for access to the network for cross-border exchanges in electricity. with the intention of ensuring effective administration of the electrical transmission network and facilitating transnational power trading within the European Community. ENTSO-E succeeded the earlier organization of European TSOs, which was established in 1999 by local TSO groups (ENTSO-E, 2012). The goal of ENTSO-E is aimed at tackling issues with market integration and transparency, infrastructure adequacy, network efficiency and safety, and sustainable growth through the incorporation of renewable energy sources. Their primary tasks include creating generational adequacy outlooks, formulating European network regulations, and creating the Ten-Year Network Development plan (TYNDP). The TYNDP combines a top-down evaluation of Pan-European power line that are essential. The first thorough TYNDP, released in 2012, concentrated on the short- and long-term needs of the European electrical network. ENTSO-E works with TSOs from 42 European countries (ENTSO-E, 2012). Different methods are used by MS of the EU when planning projects. However, the selection and permission phases of OPL planning may often be separated (Figure 13). At the moment, the optimal planning period lasts between 5-7 years.

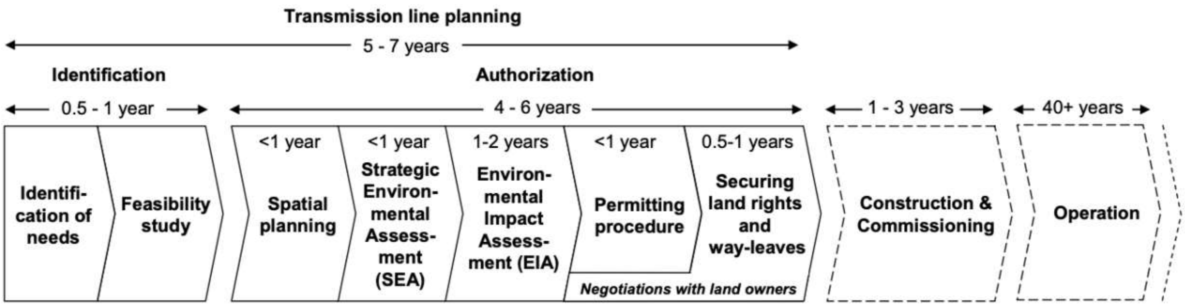


Figure 13: Planning process for overhead power lines (Perras, 2014).

TSOs start OPL projects by determining the need for grid extension, projecting future scenarios for electricity consumption and generation, and evaluating the current energy distribution network's capacity. Network developers may encounter difficulties due to uncertainties like regulatory changes and modifications to the power mix. To preserve supply security and prevent bottlenecks brought on by more frequent power trades, TSOs must assure adequate transmission capacity. TSOs must update existing transmission lines or construct new ones if the current grid is insufficient to handle potential situations (Perras, 2014). TSOs include generating and consumption scenarios, as well as information about their growth plans, in national TYNPDs that are submitted for assessment. The regulatory body keeps an eye on how the strategy is being carried out. To determine the reliability and financial sustainability of the investment and to set important project criteria, the TSO starts a feasibility study. Fundamental design possibilities are determined based on electricity requirement. Energy needs, system security and dependability, voltage level and energy flow are all included in this list of factors. To identify the overall course of the OPL, a preliminary route corridor is then drawn (Perras, 2014). The goal of spatial planning is to create equitable geographic growth and arrange the physical environment. When the TSO chooses the best path for a line, spatial planning becomes crucial in the context of OPLs. To determine if the proposed routes comply with the relevant official spatial planning legislation, which regulate land use, cooperation with authorities is required. If the plan is does not comply with Article 6 (3) (Council Directive 92/43/EEC, 1992), an Appropriate Assessment examines its effect on Natura 2000 network protected areas. The Appropriate Assessment evaluates adherence to the Directive 2009/147/EC, which pertains to the conservation of wild birds as well. To guarantee that conservation goals are met, precautions are taken.

According to Directive 2001/42/EC, a transmission networks proposed path must undergo a Strategic Environmental Assessment (SEA) if it traverses Natura 2000 site. The SEA is also required for initiatives that are part of energy-related plans or programs that regulate the subsequent approval for project undertakings (Sands and Galizzi, 2006). This category includes Lines that are predicted to have major environmental effects, are planned as OPL with a voltage level of 220 kV or more. The provisions of Directive 2011/92/EU, covering the evaluation of the adverse environmental effects of specific public and private projects linked to OPLs have been incorporated into the national level EIA Regulations. For OPLs satisfying the requirements of having a voltage of 220 kV or higher and a length exceeding 15 kms an EIS is required, as per the aforementioned regulations. Applications For 132 kV or higher OPLs in sensitive regions, also need to conduct an EIA if the development is anticipated to have substantial environmental consequences (Marshall and Baxter, 2002). The EIA Directive does not mandate public engagement during the scoping phase, although some Member States may permit it. Following scoping, the TSO carries out the EIA and EIS is prepared. After consulting with pertinent parties for a period of 1 month, the responsible TSO releases the report. The authority creates a Declaration and publishes its conclusion, together with any mitigating measures, based on the findings of the consultation. The EIA procedure normally lasts 12 to 18 months, although it may take longer if new alternatives are being investigated or if revisions are made. The decision can be valid for 2 to 5 years with additional EIAs (Perras, 2014). The TSO undertakes thorough technical planning of the OPL when spatial planning and environmental assessments are finished, taking the results into account. The TSO then completes lengthy application materials, which are subsequently sent to the appropriate authorities to start the formal permitting process. The authority assesses the application's completeness and, if required, asks a resubmission. The public can express their ideas and concerns through public consultation, which frequently takes the form of a public hearing. The authority decides whether to grant the permit, which may come with conditions and mitigation measures, after considering all submitted documentation, evaluations, and public concerns. Stakeholders who took part in the consultation phase have the opportunity to appeal when the final decision is released (Marshall and Baxter, 2002). The authority decides whether to grant the permit, which may come with conditions and mitigation measures, after considering all submitted documentation, evaluations, and public concerns. Stakeholders who took part in the consultation phase have the opportunity to appeal when the final decision is released. If the court dismisses the appeal, construction can start. The permitting procedures should take about

1 year generally if they meet all the aforementioned requirements (ENTSO-E, 2012). Additionally, TSOs in Europe can scope, plan, design, and develop green corridors below OPLs by following a systematic approach (Figure 14).

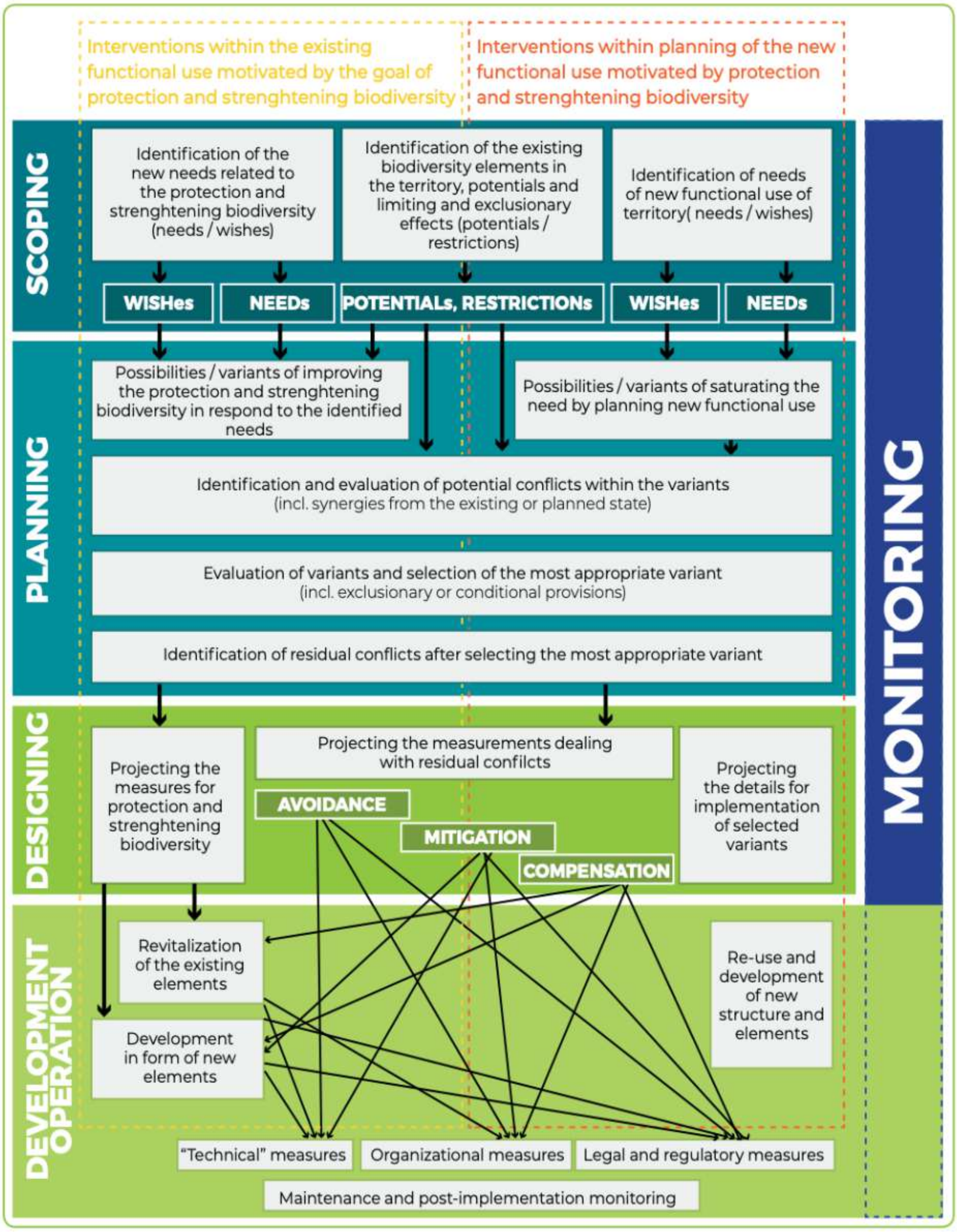


Figure 14: Steps for spatial planning that are relevant to the sustainable management of green corridors (Danube Transnational Programme, 2021).

Scoping involves conducting a preliminary assessment to identify and evaluate the potential environmental impacts associated with the installation of OPLs. This includes considering factors such as ecological disturbance, visual impact, the potential for habitat fragmentation and impacts on wildlife. Establish the boundaries of the assessment, including the specific locations where the green corridors will be implemented, and identify the key issues to be addressed during the assessment. Identify and engage with stakeholders, such as local communities, environmental organizations, and relevant government agencies, to gather their input and concerns regarding the project. Planning defines the objectives of considering the intended purpose of the green corridors, such as enhancing biodiversity, providing wildlife habitat, or green spaces to enhance the flora below OPLs (Danube Transnational Programme, 2021). Develop an assessment plan that outlines the methods, data requirements, and timeline for conducting the assessment. Determine the appropriate assessment techniques to be used, such as ecological surveys and landscape design principles. The data requirements for the assessment and plan the collection of relevant data. Designing the green corridors to minimize environmental impacts and maximize ecological benefits. This includes selecting appropriate plant species that are native to the area, considering wildlife habitat requirements, and incorporating landscape design elements that blend with the surrounding environment. Identify and incorporate mitigation measures to address potential environmental impacts. The development process involves implementing the planned green corridors by carrying out the necessary construction activities (Danube Transnational Programme, 2021). Further identifying and understanding the legal and regulatory requirements that need to be followed during the project. This includes considering any permits or environmental guidelines that may apply to the creation of green corridors. This may involve clearing vegetation, installing fencing or barriers, and preparing the ground for planting below and ROW to the transmission lines by plant native vegetation in the green corridors, following the designated design plans. Consider the appropriate spacing, plant diversity, and establishment techniques to promote successful growth and biodiversity. The final step is to establish a monitoring and maintenance plan to ensure the ongoing health and functionality of the green corridors. This may include regular inspections, maintenance of vegetation, and addressing any unforeseen environmental issues that may arise (Danube Transnational Programme, 2021).

Once permits have been granted for a transmission line project, the TSO needs to secure the ROW land rights from the landowners along the proposed route. Instead of purchasing the land outright, the TSO typically negotiates easements with the landowners. Easements grant the TSO the right to operate the transmission line across the landowners' property while the landowners maintain their property rights. Directly affected landowners, whose properties are directly impacted by the transmission line, receive one-time compensation for granting the easements (Kiessling et al., 2003). This compensation covers factors such as the impact on property value and limitations on land use due to the transmission line's presence. The specific amount of compensation is typically determined through negotiations between the TSO and the landowner. In addition to easements, the TSO may also require temporary access rights to the land for construction and maintenance purposes. These rights are granted for a limited duration and allow the TSO to access the land as needed during the construction and ongoing maintenance of the transmission line. Landowners granting temporary access rights are compensated by the TSO through annual rent payments for the agreed-upon duration of access. It's important to note that if a property with an existing ROW agreement is sold, the agreement becomes void, and a new agreement needs to be negotiated with the new property owner. This ensures that the TSO has the necessary rights to continue operating the transmission line across the property. However, there may be cases where landowners refuse to sell or grant easements to the TSO. In such situations, as a last resort, the TSO may pursue expropriation. Expropriation is a legal process that allows the TSO to acquire the necessary rights over the land, following national and EU level regulations (Perras, 2014). Expropriation is typically considered a measure of last resort and is subject to specific legal procedures and requirements.The process of identifying relevant landowners and negotiating agreements for easements and access rights can be time-consuming. It typically takes about 2 years, and negotiations often start in parallel with the spatial permitting procedure for the transmission line project. However, in the case of expropriation, additional legal proceedings may be required, which can further delay the overall process (Kiessling et al., 2003). It's worth noting that the specific details and regulations surrounding easements, access rights, and expropriation can vary between countries and jurisdictions. Therefore, it's important for the TSO and landowners to adhere to the applicable national and EU level regulations throughout the negotiation and expropriation processes. (Perras, 2014).

The TSO starts the constructing phase after all necessary permits have been approved and moves forward with a thorough design evaluation. The TSO concludes contractual negotiations, awards licenses for the constructions, and tenders out the OPL construction operations. Construction normally takes between 1 and 3 years, depending on the transmission line's length and other factors. OPL installations can be completed at a rate of 1-2 weeks per kilometer. HVDC networks could require a little more time because converter station installation is required. The wire is activated after installation is finished, and extensive electrical tests are performed. The TSO personnel receives instruction on how to operate and maintain the line. (Kiessling et al., 2003). For the transmission line to operate effectively over an extended period of time, regular upkeep and maintenance is essential. TSOs create maintenance inspections agendas, and the vast majority of service labor includes monitoring and inspection. Aerial and ground monitoring, as well as climbing to examine line and pylon structures, are used to inspect the towers. OPL requires ROW clearing, including trimming of vegetation. Inspection intervals vary; earthing system inspections are performed every 5 years, grounded cable checks every 10 years, and cleaning and mowing of the ROW is done every 5 to 10 years (Perras, 2014).

5. Case Study

5.1. Elia-RTE’S Green Corridor initiative

By establishing green spaces beneath HV OPLs and utilizing a multi-partner strategy, the LIFE Elia-RTE project blends the electrical safety of OPLs with green corridor management. Between 2011 and 2017, it was operated in collaboration with the French TSO RTE, the Belgian TSO Elia, and the environmental consulting firm Ecofirst. The Belgian HV network is administered by ELIA. The HV network's main function is to deliver the power generated by generators to distribution network operators and significant industrial customers. All of the OPL infrastructure in Belgium between 150 and 380 kV and about 94% of the infrastructure between 30 and 70 kV are owned by ELIA. The Électricité de France Group subsidiary company RTE is in charge of running the French electricity distribution network. RTE distributes electricity between French and European electricity providers and consumers. The network run by RTE is the biggest in Europe, with 100,000 km of lines ranging from 63,000 to 400,000 volts and 46 cross-border lines. ELIA and RTE, collaborated on a 5-year initiative from 2011 to 2017. The project aimed to oversee and rehabilitate more than 300 hectares of land situated below MV and HV lines in Wallonia (Belgium)–(155 km and 15 sites) of electrical corridors and France–7 Sites in various biogeographic locations (Atlantic–Finistère, Seine-et-Marne, Continental–Aube, Ardennes, Doubs, Mediterranean–Drôme, Alpine–Hautes-Alpes) (Figure 15) (European Commission, 2018). The joint effort of the LIFE Elia-RTE tproject aimed to introduce a novel approach to managing vegetation below OPLs. Their strategy involved restoring forest boundaries, preserving natural habitats, creating natural ponds, planting orchards for conservation, sowing meadows, and establishing grazing facilities for local farmers. The overall cost of implementing this project was 3.2 million Euros. The innovative approach not only proved to be more favorable for biodiversity by avoiding traditional methods of clearing vegetation under grid lines but also demonstrated cost savings ranging from 1.4 to 3.9 times over a 30-year period compared to conventional vegetation management practices.This initiative involved collaboration among various stakeholders, including TSOs, authorities, forest owners, non-governmental organizations (NGOs), and academic institutions. The impressive outcomes include the restoration of 20 hectares of natural habitats and the enhancement of the biodiversity network through the creation of connecting zones between key conservation areas. Furthermore, by fostering local partnerships, the project successfully improved public acceptance of high-voltage grid lines (Renewables Grid Initiative, n.d.).

Figure 15: LIFE ELIA-RTE's green corridor sites in Belgium and France (Renewables Grid Initiative, n.d.).

5.1.1. Strategies for the Green corridor initiative

The main concept behind creating forest edges along HV line green corridors involves selecting tree species that are short in height when fully grown. This ensures that the trees in the forest edge do not pose any issues for the HV lines. Additionally, this approach effectively limits the growth of problematic tree species that have a greater height at maturity, by utilizing selected species that occupy space and reduce light penetration to the ground. The strategy of selective tree cutting implemented by the ELIA-RTE's project undertakers aimed to establish gradual and natural habitat interfaces, known as ecotones, by creating forest edges. These ecotones are highly beneficial for numerous species, particularly reptiles, small mammals, invertebrates, and plants (Renewable Grid Initiative, n.d.). The approach focuses on restoring ecologically functional edges in a "V-shape" corridor by carefully choosing which tree species to selectively cut, ensuring their long-term stability. This approach stands in contrast to traditional vegetation management techniques that maintain a "U-shaped" forest corridor (Figure 16).

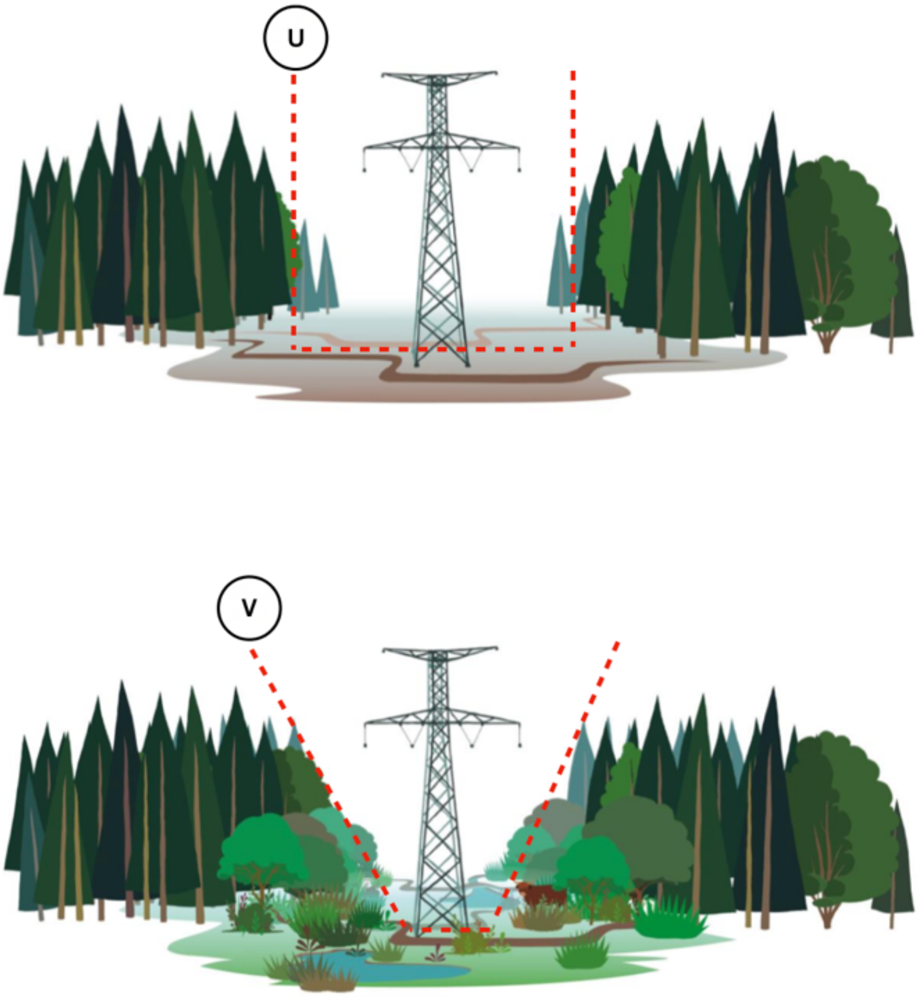


Figure 16: Schematic representation to show a shift from U-shaped corridor to a V-shaped corridor (LIFE Elia-RTE, 2018).

The plant species that were selected that were not towering too high, had a capability to adapt the local conditions and bore flowers to attract the fauna (Table 8). Additionally, the project acknowledges the presence of invasive species listed by Walloon authorities, including black cherry, summer lilac, giant hogweed, Himalayan balsam, Japanese knotweed, narrow-leaved ragwort, and black locust. The configuration of corridors and power line networks facilitates the spread of these vegetation types. Heavy machinery used in the management of the network and forests can further damage the soil, worsening the problem of invasive species along forest access routes. Additionally, the management activities themselves may inadvertently contribute to the spread of these species. Efforts were made to identify effective methods for combating the growth of these plants. Experiences and techniques from other LIFE projects in different Member States will be leveraged to develop strategies for eradicating invasive species populations underneath high-voltage power lines (LIFE Elia-RTE, 2018).

Table 8: Some plant species selected in Belgium corridor (LIFE Elia-RTE, 2018).

Common name	Latin name	%	Advantages	Max. height (m)
Single-seeded hawthorn	Crataegus monogyna	20	Good resistance to grazing thanks to its thorns	10
Common hazel	Corylus avellana	20	Good ground coverage, rapid growth, good resistance to grazing, no thorns	4
Alder buckthorn	Frangula alnus	10	Rapid coverage, ability to multiply by root suckers	5
Common dogwood	Cornus sanguinea	10	Rapid coverage, very low species	5
Blackthorn	Prunus spinosa	10	Rapid coverage, resistance to grazing thanks to its thorns, ability to multiply by root suckers	4
Eared willow	Salix aurita	10	Rapid coverage, adapted to wet soils, can propagate by cutting and natural layering	3
Rowan	Sorbus aucuparia	5	Tree of moderate height with flowers and fruits	10-20
Black elder	Sambucus nigra	5	Rapid coverage, shrub with flowers and fruits	10
Red elderberry	Sambucus racemosa	5	Rapid coverage, shrub with flowers and fruits	4
Guelder rose	Viburnum opulus	5	Rapid coverage, shrub with flowers and fruits	4
European crab apple	Malus sylvestris	Depending on opportunity	Tree of moderate size with flowers and fruit. Produces small high-quality logs and is genetic reservoir of a species in decline.	6-10
European wild pear	Pyrus pyraster	Depending on opportunity	Tree of moderate size with flowers and fruit. Produces small high-quality logs and is genetic reservoir of a species in decline.	8-20

Extensive grazing was seen to be highly effective and biodiversity-friendly method for managing the wettest and most open areas in valley bottoms, typically inhabited by wet grassy environments. To encourage biodiversity conservation and management, the project developers encouraged the establishment of these grazing areas near publicly accessible paths. By introducing traditional and robust cattle breeds, we aim to raise awareness and foster a greater understanding of nature conservation and biodiversity management. As part of vegetation management, herbivorous animals are employed to graze along HV line green corridors within forests (European Commission, 2018). Their grazing behavior helped control the growth of young tree shoots, resulting in a grassier vegetation composition. Typically, robust animals with minimal maintenance requirements and a simple diet are selected for this grazing practice. Grazing is a versatile management method that can be implemented in various conditions along forest corridors, including wet, stony, or steep terrain. It is particularly suitable when other methods are not feasible. To ensure effective grazing, it is important to have sufficiently large areas in close proximity to villages and easily accessible. Wide corridors are recommended for grazing, with parallel double lines offering an advantage by providing a spacious safety corridor. For containing animals, fixed fences made of fine-meshed type materials are commonly used, while mobile fences with electrified meshes connected to generators offer flexibility for quick relocation. Mobile fences have minimal long-term landscape impact and can be an alternative if there are concerns about installing permanent fences (LIFE Elia-RTE, 2018).

Moors and peatlands that are endangered habitats in Western Europe, are crucial for declining plant and animal species. Forest corridors of HV OPLs often intersect these habitats, resulting in damaged areas and smaller, better-preserved islands. Restoration of these unique environments beneath the power lines is achievable through sod removal, which uncovers the dormant seed bank and promotes the growth of pioneer species and associated biodiversity. Local water levels can be restored by sealing drains, revitalizing wet moorlands and peatlands, and providing habitat for flora and fauna. Replanting with indigenous species like cotton grass, sphagnum, and heather is also planned. In Belgium, some sections of the forestry lines are located in regions where peatlands have been extensively restored through other LIFE Elia-RTE's corridor initiative. These restored peatlands will now serve as vital biodiversity corridors, enabling plants and animals from the moor and peatland areas to move and recolonize new sites (Life Elia-RTE, n.d.).

The use of fertilizers and phytosanitary products in agriculture has caused the disappearance of natural meadows and a decline in insect populations. The access routes near forested areas where HV OPLs traverse provide an opportunity to establish meadows as refuges for rare flora and insects (Renewable Grid Initiative, n.d.). These meadows will also preserve local plant seeds lost due to agricultural practices. Regular mowing and soil depletion can promote the return of rare plant species, and flower meadows can be recreated through local seed sowing. Farmers, hunters, beekeepers, and local nature conservation associations can benefit from management contracts for these areas during and after the project (Life Elia-RTE, n.d.).

A network of ponds spanning nearly 130 km of HV line project zones was seen to create favorable habitats for amphibians, dragonflies, and damselflies. These ponds will prevent population isolation and support the spread of biodiversity along the power line corridors. The project aimed to create approximately 100 ponds, forming a dense network of these specialized habitats. Ponds were established in suitable areas with impermeable soil. Priority will be given to locations with potential for rare species, such as certain dragonflies, amphibians, and wetland birds. The minimum size for the ponds were designed to be at least 25 m^2 to ensure long-term sustainability and prevent rapid filling. The pond creation process should be planned early in the project timeline, as it may involve a laborious permit application procedure (Life Elia-RTE, n.d.).

5.1.2. Stakeholder Engagement

The LIFE ELIA-RTE project involves active stakeholder engagement to ensure the success and effectiveness of the project. Stakeholders and their shares include The European commission (38%), TSOs (35%) (ELIA and RTE), authorities (27%) (Directorate General of the Walloon Public service), non-governmental organizations (SOLON and CARAH), consultancy (Ecofirst), academic institutions–Département de l'Etude du Milieu Naturel et Agricole (DEMNA), locals, and local nature conservation associations (Office National des Forêts and the Department of Nature and Forests). These stakeholders are actively involved in various aspects of the project, such as planning, implementation, and monitoring. Their input and expertise are sought to ensure that the project aligns with local needs and conservation goals. Stakeholders contribute to decision-making processes, provide valuable knowledge and insights, and help identify potential challenges and solutions (Renewable Grid Initiative, n.d.).

During the preparatory phase of the LIFE ELIA-RTE project, permanent scientific monitoring was implemented to assess the conservation status of selected high-value habitats. This monitoring will provide a baseline understanding of the areas under the power lines before the project's management interventions and track the progress achieved during and after the project. Monitoring tools and techniques were developed, tested, and validated to ensure optimal monitoring throughout the project. The monitoring process was aligned with the existing monitoring approach of DEMNA, which oversees the monitoring of the entire Walloon Natura 2000 sites to assess site conservation status. Annual checks were during the project, and efforts will be made to continue monitoring in the post-project phase through the involvement of Walloon administration services or local volunteer naturalist organizations. The implementation of biodiversity actions in the LIFE ELIA-RTE project follows a systematic approach. It began with an initial mapping to assess risks and identify alternative management actions. Development proposals were then prepared and shared with the vegetation management teams for review. Consultation with owners and managers took place to involve them in decision-making. Agreements were signed to formalize the implementation of developments. Specifications were written, and contractors were selected through a competitive process. Site work was carried out, monitored, and aligned with the specifications. Finally, long-term management plans are created to guide vegetation maintenance and protect the HV lines and the landscapes they traverse in. This comprehensive method ensured the effective planning, stakeholder engagement, and ongoing monitoring for successful biodiversity conservation.

5.1.3. Outcomes of the Project

Once the project was completed in 2017 a total area of 528 hectares (ha) where the corridors were implemented, and 175 ponds were dug (Table 9). The results obtained were promising and showed a long-term positive impact on the HV line corridor network. To see how the actions impacted the biodiversity, different species of plants and animals using specific methods were monitored. It was found more than a dozen species that are important and will benefit from the corridor initiative. For example, in the French Ardennes, saw the Inundated Clubmoss come back in peat bogs, and in Belgium, the Mouse-Eared Bat now hunts in grassy areas that are kept trimmed (Layman,2018).

Table 9: Total Areas (in ha) covered at completion of the project (Layman, 2018).

	Results obtained
Forest edges	273 ha
Orchards	24 ha
Natural habitats	100 ha
Combating invasive species	28 ha
Grazing and mowing	68 ha
Flowering meadows	34 ha
Total	**528 ha**
Ponds	175 ponds

In 2023, a comprehensive analysis was published, covering 10 years of biological monitoring conducted on the restored sites. This monitoring specifically targeted various animal and plant species to assess the effectiveness of the new management approach. The analysis aimed to evaluate the overall outcome and impact of the implemented measures on biodiversity. According to the report by Godeau et al. (2023), the restoration actions in the LIFE ELIA-RTE sites have demonstrated a commendable success rate, with approximately 70% of the sites achieving their objectives. Among the 68 sites evaluated, only a single small site has experienced clear failure. The evaluation of restoration success takes into consideration the effective attainment of goals set for the LIFE actions implemented at each site, as well as the implementation of sustainable management practices to ensure continued progress. The recently managed sites within Elia's Ecological corridor strategy have shown promising initial outcomes, with 5 out of the 11 sites evaluated displaying positive advancements. In general, the biological improvement achieved in 82% of the sites surpasses their previous state in terms of biological quality. While it is still premature to evaluate all of the Ecological corridor's sites, initial findings indicate positive progress in 4 out of the 17 sites (Figure 17).

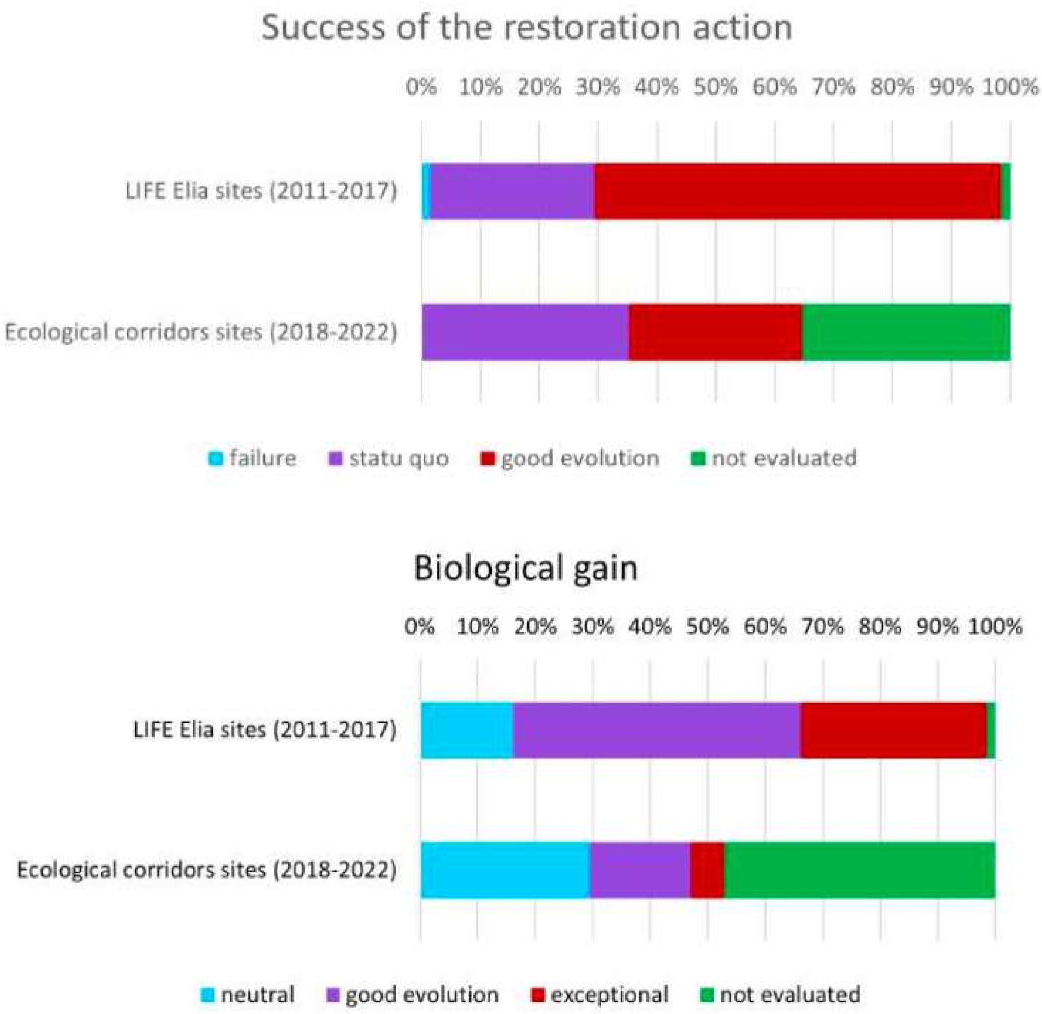


Figure 17: Success rates of restoration action and biological gain on the ELIA-RTE-sites (Godeau et al., 2023)

The practical solutions offered by the LIFE Elia-RTE project address a significant issue by improving the landscape, enhancing biodiversity habitats, and fostering societal acceptance of OPL projects.

Conclusion

The importance of transmission line configurations, the necessity of OPLs for the energy transition, the possibility for managing green corridors for efficient energy distribution, and how they contribute to biodiversity enhancement were all extensively addressed in this thesis. OPLs are essential to Europe's energy transition because they allow for the efficient distribution of electricity from sources of clean energy to fulfill the rising energy needs of Europe. They enable trans-national energy trading, make it easier to include renewable energy, and help to diversify the energy supply. However, it's crucial to talk about the proactive mitigation strategies that ensure the smooth integration of OPLs into the natural landscape and assist alleviate negative effects. The mentioned strategies include strategic placement, insulation devices, and the creation of green corridors. Europe can pave the way for a sustainable and resilient energy future by finding a balance between energy infrastructure development and environmental concerns. The configuration of OPLs plays a critical role in determining their impact on the surrounding environment. By adopting appropriate designs, such as compact and low-profile configurations, the size of transmission lines can be minimized, reducing disruption to natural habitats. Strategic placement of OPLs can also help preserve important habitat connectivity, enabling species populations to move and disperse across landscapes. Compact configurations of OPLs offer several advantages. Firstly, they require less land for transmission line infrastructure, resulting in fewer disturbances and reduced habitat fragmentation along the corridor. Occupying a smaller area, compact configurations have a lesser impact on the natural environment, contributing to the preservation of ecosystems and biodiversity. To ensure the safety and integrity of power infrastructure, effective vegetation management practices are essential. It is crucial to select plant species that can thrive beneath overhead lines, considering factors like soil type, moisture availability, and climate conditions. Regular monitoring and maintenance through IVM methods are necessary to control vegetation growth and ensure the sustainability of green corridors. The successful establishment and management of these corridors depend on collaboration among power companies, environmental organizations, and local communities. Moreover, green corridors beneath OPLs provide habitat and resources for various species, including birds, pollinators, and small mammals. The vegetation beneath OPLs offers cover, nesting sites, and foraging opportunities, supporting the survival and reproduction of diverse wildlife. Continued research, collaboration, and engagement with stakeholders are crucial to optimize the benefits of OPLs and promote a clean energy transition in Europe.

The Birds, Habitats, and EIA directives have a crucial role in evaluating the environmental impacts of OPL projects in Europe. These directives require a comprehensive assessment process, including the identification and evaluation of ecological factors, to ensure that projects are conducted in an environmentally responsible manner and to find effective solutions for the conservation of threatened species due to infrastructure development. By considering the potential impacts on birds, habitats, and ecosystems, the EIA process helps identify suitable mitigation measures to minimize negative effects and promote sustainable development. The Bern Convention, also known as the Convention on the Conservation of European Wildlife and Natural Habitats, is another significant instrument for safeguarding European wildlife and their habitats. The Bern Convention is an international agreement that aims to protect flora, fauna, and their natural habitats through cooperation among participating countries. It provides a framework for conserving endangered species and their habitats, including those impacted by infrastructure development like overhead transmission lines. Parties to the convention are obligated to take appropriate measures to conserve and sustainably utilize these natural resources. The integration of green corridors beneath overhead lines aligns with the goals of both the EIA directive and the Bern Convention. These corridors contribute to habitat conservation and facilitate the connectivity of wildlife populations, ensuring the preservation of biodiversity and the maintenance of viable species populations. By incorporating green corridors into the planning and design of transmission line projects, power companies demonstrate their commitment to environmental sustainability and adherence to conservation obligations. Collaborative efforts among transmission system operators (TSOs), environmental organizations, and local communities are essential for the successful establishment and management of green corridors, as well as the implementation of effective conservation measures. Involving stakeholders throughout the process facilitates the exchange of knowledge, improves transparency, and increases public participation. This collaborative approach ensures that conservation initiatives are well-informed, socially accepted, and mutually beneficial for all parties involved.

Lastly the LIFE Elia-RTE green corridor project highlights the importance and effectiveness of implementing green corridors below OPLs in promoting biodiversity conservation and ecological connectivity. The project, jointly undertaken by Elia in Belgium and RTE in France, demonstrates a successful collaboration between power companies, conservation organizations, and stakeholders to mitigate the negative impacts of transmission infrastructure on the environment. The LIFE Elia-RTE green corridor project aimed to establish a network of green corridors below OPLs, spanning across both countries, to create ecological connectivity and provide additional habitat for wildlife. Through the careful selection of appropriate vegetation and management practices, the project successfully enhanced the ecological value of the transmission line corridors. The project's significance lies in its positive impacts on biodiversity conservation. The establishment of green corridors provided new habitats and ecological pathways for various species, facilitating their movement and dispersal across the landscape. The presence of these corridors helped counteract habitat fragmentation caused by infrastructure development, contributing to the preservation of biodiversity and the maintenance of viable populations. Moreover, the project demonstrated the successful integration of environmental considerations into transmission line planning and design. By incorporating ecological expertise and conducting thorough environmental assessments, the project implemented bird-friendly measures, vegetation management practices, and monitoring protocols to minimize the impact on avian species and their habitats. This approach exemplifies the importance of incorporating environmental considerations early in the project lifecycle and ensuring ongoing monitoring and adaptive management to ensure the long-term sustainability of green corridors. The case study also highlights the significance of stakeholder engagement and collaboration. The involvement of local communities, conservation organizations, and experts fostered knowledge exchange, raised awareness, and ensured the project's social acceptance. Such collaboration is vital for the successful implementation and long-term management of green corridors, as it fosters a sense of ownership and shared responsibility among stakeholders. The solutions offered by the LIE Elia -RTE can be modified and applied with necessary adaptations to be replicated throughout Europe, making them appropriate responses to the identified challenge. In summary, green corridors below OPLs have the potential to create a network of interconnected ecosystems. By providing habitat, promoting species movement, and supporting biodiversity conservation, these corridors contribute to the formation of ecological networks and enhance the resilience of ecosystems.

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