Electrocutions & Collisions of Birds in EU Countries: The Negative Impact & Best Practices for Mitigation

An overview of previous efforts and up-to-date knowledge of electrocutions and collisions of birds across 27 EU member states

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Raptor Protection of Slovakia
Since 1974, our mission has been to improve conditions for birds of prey and owls in wild nature all over Slovakia with a special emphasis on endangered species. We study the breeding biology, threats, habitats and carry out actions to create and/or conserve safe nesting conditions, suitable foraging habitats and roosting sites for birds of prey, owls as well as other bird species.

Nature and Biodiversity Conservation Union/BirdLife Germany (NABU)
Founded in 1899, NABU (Nature And Biodiversity Conservation Union), is one of the oldest and largest environment associations in Germany. The association encompasses more than 820,000 members and supporters, who commit themselves to the conservation of threatened habitats, flora and fauna, to climate protection and energy policy. NABU's main objectives are the preservation of habitats and biodiversity, the promotion of sustainability in agriculture, forest management and water supply and distribution, as well as to enhance the significance of nature conservation in our society.

Colophon
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Electricity has become part of the standard of living, posing a fatal risk to birds at the same time. It is our job to find the best solution for bird safety on power lines. Mutual communication and knowledge exchange between experts of EU countries is necessary, as the birds do not know the borders.

Foreword

Electric power is still regarded to be a major benefit for humankind, but it is also turning out to be a significant threat for wildlife. Transmission and distribution electricity grids are expanding rapidly worldwide with significant negative impacts on biodiversity. Unfortunately, the routes of Eurasian migratory birds are often concentrated in the regions where mankind has erected the most elaborate networks of electric power lines.

In recent years, awareness has risen surrounding the dangerous interactions of birds and electric power lines. Electrocution and collisions are substantial mortality factors for numerous bird species, despite the increasing number of mitigation measures implemented worldwide. The risk of power lines for birds is still an underestimated reason for mortality in some countries and regions and, overall, the data are either missing or absolutely insufficient. Hence, there is neither a legal setting for the mitigation of collisions with power lines, nor for electrocution. In some countries, only sporadic data are recorded by local experts and the wider public. Nevertheless, despite the fact that greater investment in scientific research aimed at bridging gaps is needed - current knowledge already offers a solid basis for actions to improve the safety of electric power lines.

This document provides a general overview of the current handling and knowledge of the 'birds vs. power lines' issue at national level in all 27 European (EU) member states through responses to a questionnaire prepared by Raptor Protection of Slovakia. The questionnaire was sent to a number of non-governmental organisations, BirdLife International offices, and electric utility companies. Unfortunately, low-quality information was retrieved from some countries. This possibly reflects the fact that available information on the subject of bird-power line interactions is genuinely limited and/or that relevant stakeholders are just not aware of the topic. Nevertheless, some of the missing information could be retrieved from scientific (and other) publications and documents. Through these sources, it was possible to prepare this document to present an up-to-date account of the scale and impact of electrocution and collision of birds with power lines. It also provides recommendations for actions and examples of best practices to reduce bird mortality.

We hope that this short overview can serve as a framework for implementing best practice standards to reduce bird mortalities, to document utility actions, to improve service reliability, and to comply with bird protection laws in the EU. An EU-wide implementation can set the ground for adaption in flyway regions with extraordinary demand for effective practical measures like the Balkans, Middle East, or East Africa.

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1 Introduction

Collisions and electrocutions on power lines have been known to kill large numbers of birds on a global scale for more than 130 years [1, 2] . Most powerlines constructed so far pose potential fatal risks for birds and significantly affect the habitats of large birds (in their breeding, staging, and wintering areas). Bird mortality from interaction with power lines and other electric-utility structures has been documented for over 380 species of birds, including critically endangered and threatened species. Interactions between birds and power lines are a complex mixture of biological, environmental, and engineering factors [3] . Power lines that span water bodies over more than 100 meters or that are located Natura 2000 sites represent the first priority for the implementation of protection measures [4] .

[1]: Haas (2005), *Protecting Birds from Powerlines: Convention on the Conservation of European Wildlife and Habitats (Bern Convention)*
[2]: Derouaux et al. (2012), 'Reducing Bird Mortality Caused by a High-and Very-high-voltage Power Lines in Belgium'

[3]: APIC (2012), *Reducing Avian Collisions with Power Lines: the State of the Art in 2012*

[4]: Ferrer (2012), 'Aves y tendidos eléctricos'

Depending on the type of construction, power lines may cause fatal injuries and death to birds due to electrocution or collision. The 'birds vs. power lines' issue is dealt with in a large number of reports and publications from various European countries. Although huge attention has been given to this issue in the past, there are still regions and types of power line infrastructures for which data are either missing or insufficient. In several countries, the problem has only recently begun to receive attention and efforts to prevent this threat are just developing. In many countries (such as Belgium, Germany, Czech Republic, Slovakia, Hungary, Bulgaria, Spain, Sweden and Portugal) different methods, efforts, and solutions for bird safety are being studied and their efficiency monitored, in order to obtain proper mitigation meaures (e.g. line marking...).

According to current knowledge, it is possible to reduce the risk of electrocution and collision significantly, and within the boundaries of 'acceptable' inputs on the part of electric utility companies. Technical solutions against bird collisions exist and can reduce mortality by 60–95% [5, 6] . Although some of those measures have been implemented in more than half of the countries, the risk of power lines for birds is still an underestimated reason for mortality in some countries, local habitats and migratory corridors. However, one positive fact is that only certain parts of potentially dangerous lines and utility poles are responsible for the majority of killed birds. These most dangerous lines and poles should be fully identified and adapted by the responsible electriity utility companies. In various parts of Europe, different technical solutions for bird safety were/are being tested and evaluated. While many of them are not effective, some turn out to be highly effective. A transnational approach is necessary to achieve adequate results and share knowledge between experts on this issue, in order to prevent mistakes and adopt best practice methods and standards.

[5]: Barrientos et al. (2011), 'Meta-analysis of the Effectiveness of Marked Wire in Reducing Avian Collisions With Power Lines'
[6]: Gális et al. (2019), 'Monitoring of Effectiveness of Bird Flight Diverters in Preventing Bird Mortality from Powerline Collisions in Slovakia'

The following chapters present a source of information gathered through a questionnaire, which was sent to a range of parties across all 27 EU member states, and through literature review of published material.

2 Electric Grid Infrastructure

Electric power transmission is the movement of electrical energy from a generating site (power plant, wind turbines etc.) to an electrical substation (transformers reduce the voltage to a lower level) via a transmission and distribution power line network to the end consumers (Figure 2.1).

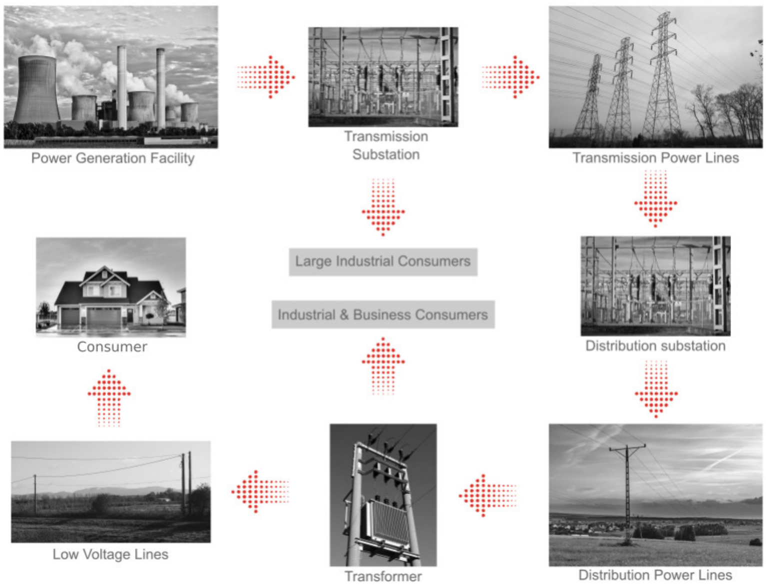

Figure 2.1: Schematic of the electric power system from the generation facility to the consumer.
Source: Raptor Protection of Slovakia

Power lines are rated and categorised, in part, by the level of electrical voltage they carry. In the European area of application, power lines are mostly divided into three basic categories: high voltage, medium voltage, and low voltage (Annex A).

High and Extra-high voltage power lines (60–750 kV) or "transmission lines" carry electricity at high voltages from generating facilities to substations for importing and exporting electricity from and to neighboring countries. The high-voltage grid is the backbone of the electricity transmission system. Transmission lines transport electricity from large production centers (thermal, hydroelectric, and nuclear power stations, or from renewable sources) to the main centers of consumption (e.g. cities and heavy industry) and to substations, which feed the energy into the distribution lines and onto the smaller centres of demand. Even to laymen, the differences in the different types of lines are apparent. Transmission lines mostly use high-voltage three-phase alternating current (AC), that deliver large amounts of power over long distances [3] . Electrical power may be transmitted through overhead lines or underground cables.

[3]: APIC (2012), *Reducing Avian Collisions with Power Lines: the State of the Art in 2012*

Transmission lines (Figure 2.2) loop between large pylons, over 30m high that, aside from the conductors, often have another cable on top - usually referred to as groundwires or earth (shield) wires, that protect the power line from lightning.

Figure 2.2: Pylons of transmission power grid carry electricity at high voltages from generating facilities to substations over long distances.
Source: Raptor Protection of Slovakia

Due to the voltage they carry, these types of lines have long chains of insulators and normally three conductors/cables per circuit [7] .

[7]: Ferrer (2012), 'Birds and Power Lines. From Conflict to Solution'

Medium-voltage power lines (1–59 kV) or "distribution lines" carry electricity to residential and business consumers [8] . The poles/pylons on distribution lines are much smaller than those used on transmission lines and are normally only 8-12m high (Figure 2.3). They are made, depending on the country, of metal, concrete or wood mainly as central mast – with metal crossarms [7] and in many variations of type and positions of cross-arms, pin insulators, exposed jumper wires, and other energised elements. In some countries and by some electric utility companies, the whole medium voltage power network has been laid underground. However, worldwide the majority are still overhead powerlines.

[8]: Bernardino et al. (2018), 'Bird Collisions with Power Lines: State of the Art and Priority Areas for Research'

Figure 2.3: Single-phase 22 kV utility pole — most common for distribution power lines in Slovakia.
Source: Raptor Protection of Slovakia

Low-voltage power lines (>1 kV) are used in a number of countries to transport the electricity directly to consumption points such as residential homes, public lighting or industrial areas. Often, low voltage lines use well-insulated thick black cables, directly attached (as suspended) to poles without additional cross-arm construction. Collision risk is minimised, because the well-visible black thick cable replaces a number of conducting wires. On low voltage overhead power lines, the risk of electrocution is limited, because of the relatively low voltage and the high electric resistance of birds (Figure 2.4).

Figure 2.4: Low voltage lines often use well-insulated thick black cable.
Source: Raptor Protection of Slovakia

Other power line constructions such as overhead power lines of railways typically transmit electricity at typically 10,000 V to 15,000 V (Figure 2.5). This corresponds to the medium voltage range of the electric utility companies, and similar aspects of bird safety must be thus taken into consideration. Railway poles also use different constructions of cross-arms, and many "killer poles" are in use [1] .The problem itself is almost unknown; only recent studies have started to reveal the dangers involved to birds. In the past, these dangerous power lines received little attention.

[1]: Haas (2005), *Protecting Birds from Powerlines: Convention on the Conservation of European Wildlife and Habitats (Bern Convention)*

Figure 2.5: Poles of electric railway lines correspond to the medium voltage poles, and similar aspects of bird safety must be thus taken into consideration.
Source: Raptor Protection of Slovakia

2.1 National Grids

The split of competencies is geographical, or by the voltage range. There are grids of distribution and transmission power lines in each country. Transmission system operators (TSO) are often state-owned and are responsible for the operating network of high and extra-high voltage lines for the entire country. Distribution system operators (DSO) are mainly small or larger private companies, they operate on the level of the whole country or are divided based on the regions, provinces, municipalities, etc. Especially in some smaller countries, only one company is in charge of the transmission and the distribution grid.

Austria: Extra-high voltage grid is administered at the federal level (APG, Austrian Power Grid), whereas lower networks are often administered at the state level or by certain companies (railway companies, etc.). Austrian Power Grid AG operates the largest [1] supra-regional high-and ultra-high voltage grid in Austria with voltage levels of 110, 220, and 380 kV. Electricity also flows at high and medium voltage levels in the nine regional distribution networks before continuing to the local low voltage networks, where it comes out of the socket at 230 V. (www.apg.at). There are more than 130 electricity suppliers in Austria. Some offer their products across Austria, others only at a local level. The following companies are the dominant players in the supply market: Verbund, Wien Energie, KELAG, Salzburg Netz, Linz Strom and EVN. DSOs operate distribution grids generally from 110 kV to 0.4 kV. The 110 kV grids are connected to the TSOs 220/380 kV grids. The majority of the end-consumers are provided with electricity from the 230/400 V grids (www.cms.law).

1: approximately 6,970 km and 12,000 pylons

Belgium: TSO Elia (www.elia.be) is responsible for the entire network of high voltage (30 kV to 400 kV) power lines in Belgium, operating over 8,781 km overhead lines and underground cables. Elia owns the entire Belgian very-high voltage grid (150 to 380 kV) and around 94% (ownership and user rights) of the Belgian high voltage grid (30 to 70 kV). Elia's grid comprises 5,614 km of overhead lines and 2,765 km of underground cables (www.renewables-grid.eu). DSO Ores (www.ores.be) and DSO Resa (www.resa.be) manages medium (>70 kV) and low voltage lines in Wallonia. DSO Eandis and DSO Infrax are distributors in Flanders; while DSO Sibelga is active in Brussels. Such companies ensure the operation of their members' distribution grids.

Bulgaria: The split of competencies is geographical, as well as by the type of power line – there are Distribution and Transmission power lines. The state-owned National Electricity Company is responsible for high tension power lines Three private electric distribution companies (EVN, Energo-Pro, and CEZ) are operate medium (20 kV) and low voltage power lines, each operating in a different geographically region.

Croatia: The split of competencies is geographical, as well as by the type of power line – there is one distribution and one transmission grid operator. Low and medium voltage lines are managed by HEP-Distribution system operator Ltd. and high voltage power lines by HOPS-Croatian Transmission System Operator Ltd. They both operate in the whole of Croatia. The electricity infrastructure of transmission lines includes 1,247 km of 400 kV power lines, 1,210 km of 220 kV power lines and 5,013 km of 110 kV power lines (www.cms.law).

Cyprus: The Electricity Authority of Cyprus (EAC) is responsible for the generation, transmission (66 kV, 132 kV), distribution (11 kV, 22 kV), and supply of electricity in Cyprus. The length of all transmission lines is 1,150 km of which 212 km of cables are underground.

Czech Republic: The split of competencies of power companies is geographic. TSO ČEPS, a.s. operates 400 kV, 220 kV, partly 110 kV on the whole territory of the country. Three companies are responsible for the electricity distribution. ČEZ Distribuce, E.ON Distribuce and PREdistribuce manage 73,268 km medium-voltage electrical lines (50,881 km – ČEZ Distribuce 2018, 18,506 km – E.ON Distribuce 2018 and 3,881 km – PREdistribuce 2019). DSO ČEZ Distribuce, a. s. – operates power lines of 110 kV and less in regions: Plzeňský, Karlovarský, Ústecký, Středočeský, Liberecký, Královéhradecký, Pardubický, Olomoucký[2] and Moravskoslezský region, partly region Zlínský – only the district Vsetín town and region Vysočina – only the district Havlíčkův Brod town. DSO E.ON Distribuce, a. s. - operates 110 kV and less voltage lines in regions: Jihočeský, Vysočina[3] , Jihomoravský, Zlínský[4] . DSO PRE distribuce, a. s. operates 110 kV and less voltage lines in the capital Prague and the town Roztoky nad Vltavou.

2: with the exception of the district Prostějov town

3: with the exception of the district Havlíčkův Brod town

4: with the exception of the district Vsetín town

Denmark: The Danish transmission system is owned and operated by Energinet. This TSO is only responsible for voltage 132 kV, 220 kV, and 400 kV. Energinet operates nationwide. For medium (50 and 10 kV) and low voltage lines (0.4 kV), there is geographic division.

Estonia: The split of competencies is geographical, as well as by the type of power line. The biggest DSO is Elektrilevi OÜ covering ca 90% of Estonian customers. TSO Elering AS is a national transmission system operator for electricity and natural gas with headquarters in Tallinn, Estonia. This TSO manages 110 kV and 330 kV power lines.

Finland: The split of competencies is geographical, as well as by the type of power line. The power system in Finland consists of power plants, a nationwide transmission grid, regional networks, and distribution networks. TSO Fingrid operates power lines of 110 kV, 220 kV, and 400 kV on a nationwide level and across national boundaries. The distribution networks operate at a voltage level of 10 and 20 kV. The total length of high voltage networks is approximately 22,500 km, the medium voltage network consists of 140,000 km and the low voltage network consists of 240,000 km. The high voltage networks consist entirely of overhead lines. Of the medium voltage networks, 80% are overhead lines, 7% are aerial cables, and 13% are underground or underwater cables. (www.energia.fi).

France: The split of competencies is geographical, as well as by the type of power line. TSO Réseau de Transport d'Électricité (RTE) operates high and very-high voltage of 63 kV, 90 kV, 150 kV, 225 kV and 400 kV. DSO Enedis manages the electricity distribution network across 95% of mainland France. Local DSOs manage the remaining 5% in their exclusive service zones. DSO ERDF is the EDF subsidiary that operates 95% of the distribution system in terms of length of networks. TSO RTE owns and operates the public electricity transmission network, which runs for a total length of around 100,000 km . The total length of cables and infrastructures is well in excess of 1.3 million km. Between the medium and low voltage networks are some 700,000 distribution substations (www.cre.fr).

Germany: The split of competencies is due to the former service area of the big power provision companies, as well as by the type of power line – there are over 900 small and larger distribution system operators and 4 transmission system operators (50Hertz, Amprion, TenneT, TransnetBW). The German grid comprises four voltage levels: the extra high voltage level (380 and 220 kV), the high voltage level (110 kV), the medium voltage level (6 to 60 kV) and the low voltage level (230 and 400 V). The extra high voltage grid is over 35,000 km long. The high, medium and low voltage level grids have a length of about 77,000, 480,000 and 1.7m km respectively (www.cms.law).

Greece: The split of competencies is geographical, as well as by the type of power line. The network in Greece is covered by 2 state-owned companies. TSO Independent Power Transmission Operator (IPTO) is responsible for the high voltage (150 & 400 kV) network and Hellenic Electricity Distribution Network Operator (HEDNO) for the medium & low voltage (22 kV and 230 V) network.

Hungary: The split of competencies of power companies is geographic. North East – company ELMŰ-ÉMÁSZ manages power lines of 120 kV, 22 kV and 230/400 V; West and East – company E.ON Hungária manages power lines of 120 kV, 22 kV and 230 / 400 V; South-East – company NKM is managing power lines of 120 kV, 22 kV and 230/400 V; Countrywide – company MAVIR (Hungarian Transmission System Operator Company Ltd.) manages 120 kV (several sections), but mostly 220 kV and 400 kV power lines, with one section of 750 kV power line in eastern Hungary.

Ireland: TSO EirGrid plc is the state-owned electric power transmission system operator covers the whole of Ireland. The transmission system comprises 6,800 km of overhead power lines operating at 400 kV, 220 kV, and 110 kV. It comprises networks operating at 110 kV in the Dublin area, and the nationwide networks operating at 38 kV, 20 kV, and 10 kV and low voltage (LV) operated by DSO, ESB Networks (www.esbnetworks.ie).

Italy: The transmission of electricity is carried out by TSO Terna, which owns 94% of the national grid and operates 380 kV, 220 kV, and 132/150 kV lines. Distribution activities are carried out by a few operators on the basis of government concessions. Enel Distribuzione is the main DSO, with 86% of the distributed electricity volumes. Other DSOs are: A2A, Acea Distribuzione and Aem Torino Distribuzione. The remaining distributors hold units lower than 1% (www.cms.law).

Latvia: DSO joint-stock company "Sadales tikls" manages power lines of 230 and 400 V and 6–20 kV in Latvia, which covers 99% of the country’s territory. The total length of electricity distribution networks in 2020 reached 92,958 km (www.sadalestikls.lv). TSO ALS „Augstspriegumu tikls“ manages power lines of 330 kV and

110 kV with a total length 5 612,91 km within the territory of Latvia (www.ast.lv).

Lithuania: Power lines are divided into high voltage transmission network and a distribution network. The main function of these networks is to supply electricity to users while most of them are 400 V and 10 kV voltage power lines. Distribution networks in the country are managed by the state enterprise AB ESO. These networks are made up of 121,698 km power lines with 79% of them being overhead and 21% are underground. Meanwhile, the Lithuanian high voltage electricity transmission network consists of 400 kV, 330 kV, and 110 kV power lines, the majority of which run overhead[5] . The high voltage network is operated by the state enterprise AB LITGRID. The company is responsible for the management and development of this network. Currently, it covers 7,029 km of power lines and 236 transformer substations and distribution units.

5: underground power lines constitute a relatively small part

Luxembourg: The split of competencies is geographical. Company "Creos" operates the grid for the whole country. The total length of the Luxembourg electricity network managed by Creos is 10,023 km, including 587 km of high voltage lines, 3,653 kilometres of medium voltage lines and 5,783 kilometers of low voltage lines. The electricity is transmitted to six transformer stations (Flebour, Roost, Itzig/Blooren, Heisdorf, Bertange and Schifflange) where the voltage is reduced from 220 kV to 65 kV before being distributed to industries and large municipal distribution networks. The voltage is then reduced further from 65 kV to 20 kV in more than 60 transformer stations distributed across the whole country. The electrical energy obtained is distributed to SMEs, towns and villages where the transformers reduce the current voltage to 400 V before distributing it to the end consumer. A control center, known as Electricity Dispatching, remotely controls and manages these high and medium voltage networks.

Malta: DSO Enemalta is the leading energy services provider in the Maltese Islands, entrusted with the distribution of electricity, and the development of the national electricity distribution network. The distribution of electricity from the Delimara Power Station, from the Maghtab Terminal Station of the Malta-Italy Interconnector and from several grid-connected renewable energy sources located in different parts of the country, is achieved through a four-level network, comprising four different voltage levels, 132 kV[6] , 33 kV[7] , 11 kV (1,134 km underground) and 400/230 V. Another few kilometres of overhead high voltage lines are mostly in rural areas. Where possible, the company is phasing out overhead high voltage lines and replacing them with underground cables (www.enemalta.com).

6: 87 km are underground

7: 260 kilometres as underground cables

Netherlands: All transmission networks (i.e. electricity networks with a voltage level of 110 kV and higher) with around 23,500 km are owned and managed by the TSO TenneT, which is entirely owned by the state (www.tennet.eu). The country's distribution network operates on different regional levels. DSO Liander, operates in the Amsterdam area, DSO Stedin is active in cities as Rotterdam and Utrecht and most of the South Holland and Utrecht provinces.

DSO Enexis operates in five of the 12 Dutch provinces: Groningen, Drenthe, Overijssel, Noord-Brabant[8] and Limburg. Together, these three DSOs supply electricity to the majority of inhabitants in the Netherlands (www.statista.com).

8: except for the city of Eindhoven

Poland: The split of competencies of power companies is geographic. TSO Polskie Sieci Elektroenergetyczne S.A. (PSE) is a transmission system operator. The transmission grid is 110 kV, 220 kV and 400 kV and consists of 269 lines with a total length of 13,445 km, including: 104 lines of 400 kV voltage with a total length of 7,008 km and 164 lines of 220 kV voltage with a total length of 7,570 km (www.pse.pl).[9] In 2016, there were five big DSOs operating on the electricity market. DSO Energa Company is Poland's third largest distribution network operator (191,000 km of power lines) serving North and Central Poland, with the other major distributors being: PGE Polska Grupa Energetyczna S.A. (PGE SA or PGE Group), a state-owned public power company and the largest power producing company in Poland; and DSO, Enea SA, a power industry company based in Poznán and the fourth largest energy group in Poland.

9: as at 31 December 2019

Portugal: The split of competencies is geographical, as well as by the type of power line. DSO EDP – Distribuição manages low, medium and high voltage powerlines. The transmission of extra-high voltage electricity (150 kV, 220 kV and 400 kV) is done on the national transmission grid (RNT - Rede Nacional de Transport de Electricidade), under a concession granted by the Portuguese state in the form of a public service provided exclusively by TSO REN - Redes Energéticas Nacionais. The low voltage distribution grids are operated under concession contracts between municipalities and distributors. The Portuguese electricity grid is connected with Spain's and consists of 71,000 km of high/medium voltage transmission lines and 112,000 km of low voltage lines (www.geni.org).

Romania: The split of competencies of power companies is geographic. TSO Transelectrica is a state-owned company and manages very-high and high voltage power line grids in Romania. The high, medium and low voltage lines are geographically split in 8 areas among different companies: CEZ Distribute SA; ENEL Distributie Banat SA; ENEL Distributie Dobrogea SA; E.ON Moldova Distributie SA; ENEL Distributie Muntenia SUD SA; FDEE Electrica Distributie Muntenia Nord SA; FDEE Electrica Distributie Transilvania Sud SA; and FDEE Electrica Distributie Transilvania Nord SA (www.cms.law).

Slovakia: The split of competencies of electric companies is geographic. Western Slovakia - company ZSD manages power lines of 110 kV, 22 kV, 230/400 V; Central Slovakia - company SSD manges power lines of 110 kV, 22 kV and 230 / 400 V; Eastern Slovakia - company VSD manages power lines of 110 kV, 22 kV and 230 / 400 V. Countrywide - company SEPs, a.s. manages power lines of 110 kV (several sections) but mostly 220 kV and 400 kV. The total length of transmission and distribution power lines is about 35,000 km.

Slovenia: TSO ELES, a 100% state-owned company is responsible for 500 km of transmission lines in the 400 kV transmission network, 260 km of transmission lines in the 220 kV transmission network and 1,800 km of transmission lines in the 110 kV transmission network (www.eles.si). A distribution network consists of transformers and lines of different voltage levels (110 kV, 1–35 kV and 0.4 kV). Electricity DSO, company SODO d.o.o., carries out the tasks of general economic interest – an obligatory state service of electricity distribution in the territory of the Republic of Slovenia. Based on a concluded contract on leasing of the distribution network and carrying out the tasks of the electricity DSO on behalf of SODO, the electricity distribution activities are carried out by: Elektro Celje, d.d.; Elektro Gorenjska, d.d.; Elektro Ljubljana, d.d.; Elektro Maribor, d.d.; and Elektro Primorska, d.d. (www.agen-rs.si).

Spain: The split of competencies is geographical, as well as by the type of power line. TSO Red Eléctrica Española (REE) is the manager of the transmission network and the single carrier function under the exclusivity regime. The company operates around 20,000 km each of 400 kV and 220 kV power lines. Distribution company e-distribución supplies electricity in 27 Spanish provinces of 10 autonomous communities (Andalusia, Aragon, Balearic Islands, Extremadura, Catalonia, Castile and Leon, Valencian Community, Galicia and Navarra). Electricity distribution in Spain is regulated by the government by geography: Galicia - Gas Natural - Fenosa; Madrid - Gas Natural Fenosa and Iberdrola; Asturias - EDP; Cantabria - E.ON; Aragon - Endesa; Catalonia - Endesa; Balearic Islands - Endesa; Andalusia - Endesa; Basque Country - Iberdrola; Navarra - Iberdrola; La Rioaja - Iberdrola; Castile and Leon - Iberdrola; Extremadura - Endesa and Iberdrola; Castile La Mancha - Gas Natural Fenosa; Murcia - Iberdrola; Valencian Community - Iberdrola; Canary Islands - Endesa.

Sweden: The split is geographical, as well as by the type of power line. The Swedish electricity grid is divided into a 15,000 km national grid (400 kV and 220 kV), 31,000 km regional grid (40 kV to 130 kV), 160 backbone grid transformers and 2,330 regional grid transformers. There is one state-owned company, TSO Svenska kraftnät that is responsible for 220–400 kV in the whole country. A few DSOs such as E.ON, Vattenfall, Ellevio, Skellefteå kraft, Jämtkraft and a few others run 30 - 150 kV power lines in specific larger regions. The local grid of 400 V - 20 kV is owned by a large number of companies. Many of these small companies are very local in specific cities and municipalities. There are about 170 different grid owners and distributors of electricity in Sweden.

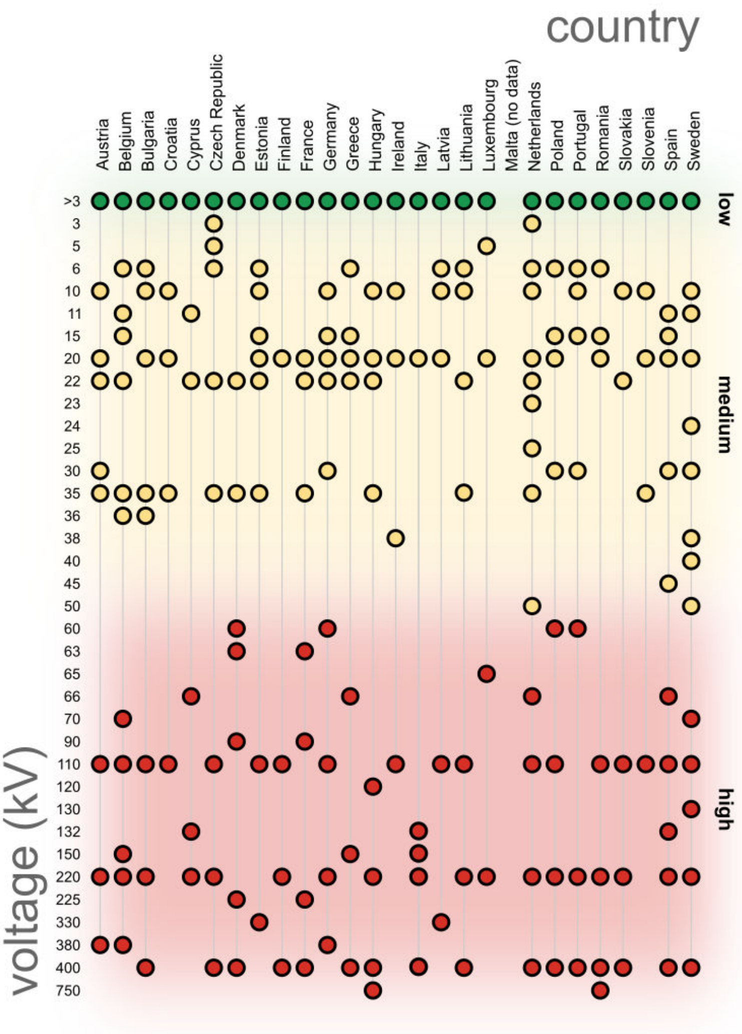

Figure 2.6: Voltage level used in a given country.

Birds vs. Powerlines | 3

Collisions and electrocutions on power lines are known to kill large numbers of birds annually across the world. For example, 700 dead birds per year, per km of power line a Dutch wetland; 250,000–300,000 birds die each year in Denmark by collision or electrocution; 1,000,000 birds die each year in France and 2,000 dead birds are found each year on a 100 km span of power lines within the Coto Doñana National Park in Spain[1] . Depending on the type of construction, power lines may cause fatal injuries and death to birds due to electrocution and collision. The unexpected effect of the development of power lines on birds – both transmission and distribution lines – was probably first noticed in the United States of America. Several publications began to warn of what was to become one of the most serious conservation problems resulting from human activity for many threatened species of birds. Since then, the number of publications on the interaction between birds and power lines elsewhere has increased rapidly, including in Europe [2, 4, 9–12] .

1: Carcasses get removed quickly by predators. Therefore findings are made less more often than they happen. Removal rates by predators and scavengers may vary widely between sites and seasons.

[4]: Ferrer (2012), 'Aves y tendidos eléctricos'
[9]: Karyakin et al. (2009), 'Raptor Electrocution in the Altai Region; Results of Surveys in 2009, Russia'
[10]: Raab et al. (2012), 'Underground Cabling and Marking of Power Lines: Conservation Measures Rapidly Reduced Mortality of West-Pannonian Great Bustards Otis tarda'
[2]: Derouaux et al. (2012), 'Reducing Bird Mortality Caused by a High-and Very-high-voltage Power Lines in Belgium'
[11]: Demeter et al. (2018), 'Documenting and Reducing Avian Electrocutions in Hungary: a Conservation Contribution from Citizen Scientists'
[12]: Gális et al. (2019), 'Comprehensive Analysis of Bird Mortality along Power Distribution Lines in Slovakia'

Above-ground power lines pose three main risks or perils to birds:

Risk of electrocution: birds sitting on power poles and/or conducting cables are killed if they cause short circuits (short circuit between phases, or short-to-ground). In particular, "bad engineering" practised on medium voltage power pole constructions has resulted in an enormous risk for numerous medium-sized and large birds, which use power poles as perching, roosting, and even nesting sites. Many species of large birds suffer heavy losses and have their populations decimated by electrocution. Some species are even threatened by extinction.

Risk of collision: in flight, birds can collide with cables of power lines, because the cables are difficult to perceive as obstacles. In most cases, the impact of collision leads to immediate death or to fatal injuries and mutilations, which cannot be survived.

Risk degradation, fragmentation and loss of habitat quality in staging and wintering areas: presence of above-ground power lines cutting across open landscapes and habitats can lead to sensitive bird species avoiding these important feeding, breeding or hibernating places (wetlands, steppe, etc.).

Overhead power lines are an important factor which significantly influences the life of birds. The level of collision risk does not correlate with constructions of the power line. More important is the composition of present avifauna, weather, and visibility factors, location of the power line sections, whether they cross important bird habitats/breeding areas or main migration routes, etc. The specific design of the power lines themselves plays a decisive role especially in the case of electrocution. Morphology is also one of the main factors [13] . Species that are long-lived, have low reproductive rates, and/or that are rare or are already in a vulnerable conservation state (such as many eagles, vultures and storks) may be particularly endangered.

[13]: Bevanger (1998), 'Biological and Conservation Aspects of Bird Mortality Caused by Electricity Power Lines: a Review'

The distances between the cross-arms or other energised parts of high voltage power lines and medium voltage distribution lines is an important factor from a nature conservation point of view as the risk of electrocution only exists for medium voltage distribution power lines whereas the risk of collision exists for both transmission and distribution lines. Bird accidents on the medium voltage and high voltage network can lead to interruptions (power outages), associated economic damages, and inconveniences for the local public and business customers. Mitigation measures have proven to be effective in reducing the level of mortality from both electrocution and collisions. Placing power lines underground - as the most effective solution - is now being carried out to differing extents in Netherlands, Belgium, Denmark, Germany, Luxembourg, Norway, and the United Kingdom. Otherwise, it has been only implemented in chosen regions, e. g. in Austria or Hungary due to the protection of the Great Bustard populations [10, 14] . More often, efforts by responsible authorities, bird protection organisations and electricity utilities concentrate on the improvement of used lines and pylon types.

[10]: Raab et al. (2012), 'Underground Cabling and Marking of Power Lines: Conservation Measures Rapidly Reduced Mortality of West-Pannonian Great Bustards Otis tarda'
[14]: Prinsen et al. (2011), 'Review of the Conflict Between Migratory Birds and Electricity Power Grids in the African-Eurasian Region'

Bird Electrocution 4

Electrocution is a worldwide problem identified especially on the medium voltage type of power lines (1–52 kV) and railway infrastructure. It can have a major impact on several bird species and cause the death of thousands of birds annually. It has been documented in a number of earlier and more recent reports from the USA. The problem has also been described in various countries in Asia, e.g. Mongolia, Saudi Arabia, India, Dagestan, and Europe [9, 11, 15–25] . Several of the available studies include quantified avian electrocution rates. Primarily, the greatest risk is associated with medium voltage power lines, which represent very attractive perches to many birds in open rural areas without tree growth [15]. An elevated seating place attracts birds from the surrounding areas and in particular provides predators with a suitable spot for observing prey and - if necessary - defending the territory.

[15]: APIC (2006), *Suggested Practices for Avian Protection on Power Lines: the State of the Art in 2006*
[16]: Lehman et al. (2010), 'Raptor Electrocution Rates for a Utility in the Intermountain Western United States'
[17]: Dwyer et al. (2015), 'Critical Dimensions of Raptors on Electric Utility Poles'
[18]: Gombobaatar et al. (2004), 'Saker Falcon (Falco cherrug milvipes Jerdon) Mortality in Central Mongolia and Population Threats'
[19]: Harness et al. (2008), 'Mongolian Distribution Power Lines and Raptor Electrocutions'
[9]: Karyakin et al. (2009), 'Raptor Electrocution in the Altai Region; Results of Surveys in 2009, Russia'
[20]: Shobrak (2012), 'Electrocution and Collision of Birds with Power Lines in Saudi Arabia: (Aves)'
[21]: Harness et al. (2013), 'Avian Electrocutions in Western Rajasthan, India'
[22]: Gadzhiev (2013), 'Death of Birds of Prey on Power Lines in Daghestan'
[23]: Demerdzhiev et al. (2009), 'Impact of Power Lines on Bird Mortality in Southern Bulgaria'
[24]: Samusenko et al. (2012), 'The Problem of Bird Mortality on Power Lines in Belarus: Preliminary Results of Studies'
[25]: Demerdzhiev (2014), 'Factors Influencing Bird Mortality Caused by Power Lines within Special Protected Areas and Undertaken Conservation Efforts'
[11]: Demeter et al. (2018), 'Documenting and Reducing Avian Electrocutions in Hungary: a Conservation Contribution from Citizen Scientists'

Avian death can occur either by **(1) short – circuits** (bird touches the two phase conductors and electricity flows through its body causing severe and often fatal burns and injuries) or by **(2) earthed-faults** that link the bird's body itself and an earthed part of the metal structure (Figure 4.1). Death can also occur after the bird falls from the pole and crashes to the ground immediately after electrocution.

The electrocution of large birds such as raptors, owls and corvids can also cause damage and sometimes result in interruption of power distribution. Large electrocuted birds (eagles, storks) very often remain in place, resulting in failure of the circuit as the operating system tries to re-energise the grid. Burning carcasses can also set fire to surrounding dry vegetation.

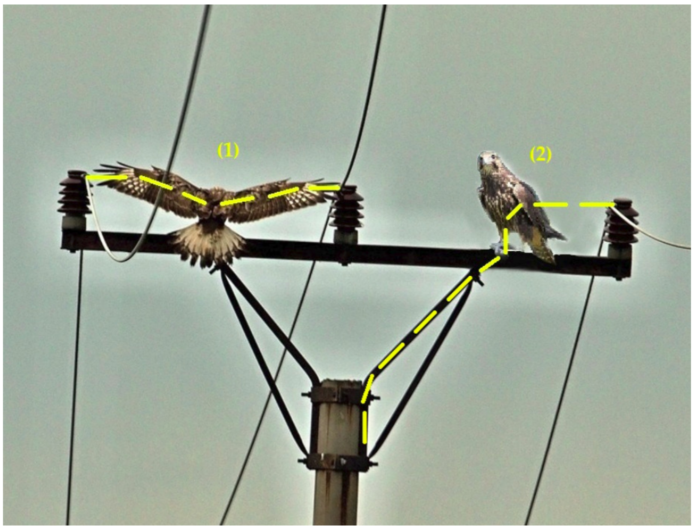

Figure 4.1: Typical pattern of electrocution on medium voltage poles: (1) short-circuit; (2) earthed-fault.
Source: Raptor Protection of Slovakia

4.1 National Overview of Electrocution Issue

Electrocution is not much of a problem in Luxembourg, the Netherlands, and Sweden, where most of the dangerous low and medium voltage lines have been placed underground. In some countries, such as Germany, the problem has mainly been reduced not by undergrounding cables, but by retrofitting dangerous poles, according to the requirements of national law. There are still many countries in Europe where low and medium voltage lines have not been placed underground or equipped with effective mitigation measures. In some countries, there is a general lack of data on bird fatalities from electrocution or it has never been the subject of systematic and long-lasting monitoring, e.g., in Austria, Belgium, Estonia, Finland, Greece and Latvia. However, the problem of electrocution has been known about for a long time, and victims of electrocution have been located sporadically and local monitoring realised, in order to identify the risk of electrocution on bird species. Several studies carried out have revealed bird interaction with power lines as one of the main threats for a number bird species (e.g., in Bulgaria, Czech Republic, Italy, Romania, Slovakia, Spain and Sweden).

In many countries, the problem was identified and cooperation started following incidents where large numbers of birds were found dead. Meetings were organised with the power line companies and the first steps took place to develop a cross-arm cover insulator and other devices. For many countries, no systematic monitoring in the sense of scientific investigations was realised, but they have a database where random findings are registered (e.g. Austria & Belgium). In other countries, the problem was identified after several repeated findings, and these data were later published and mutual communication with representatives of electric utility companies started, because apart from the environmental aspect, the companies also don't have relevant data which could showcase the amount of damage caused in the network and the subsequent costs that derive from bird electrocution incidents. These data initiated activities to study the loss of birds on power lines and their protection (e.g. Germany, Hungary & Slovakia). Data often come from observations reported by birders or citizen scientists who find a dead bird near a power line, which they can directly register into data portals or via a mobile application (Austria, Belgium, Slovakia). Another source of data is when electrocution causes power breaks, which also gives power companies a picture of the problem (e.g. Slovakia & Sweden).

Since the second half of the 20th century, attention has been paid to this problem in many countries. In some countries, first regular monitoring activities started mainly in the 60s, 70s, 80s and 90s (Figure 4.2), where victims of electrocution were located sporadically, but the first more extensive results were found after the year 2000. Often the surveys were/are realised under LIFE+ projects, national and international funds, within Natura 2000 sites and conflict areas outside SPAs, as well as all priority territories of rare and/or endangered bird species and those most vulnerable to electrocution, such as eagles, hawks, vultures, kites and falcons.

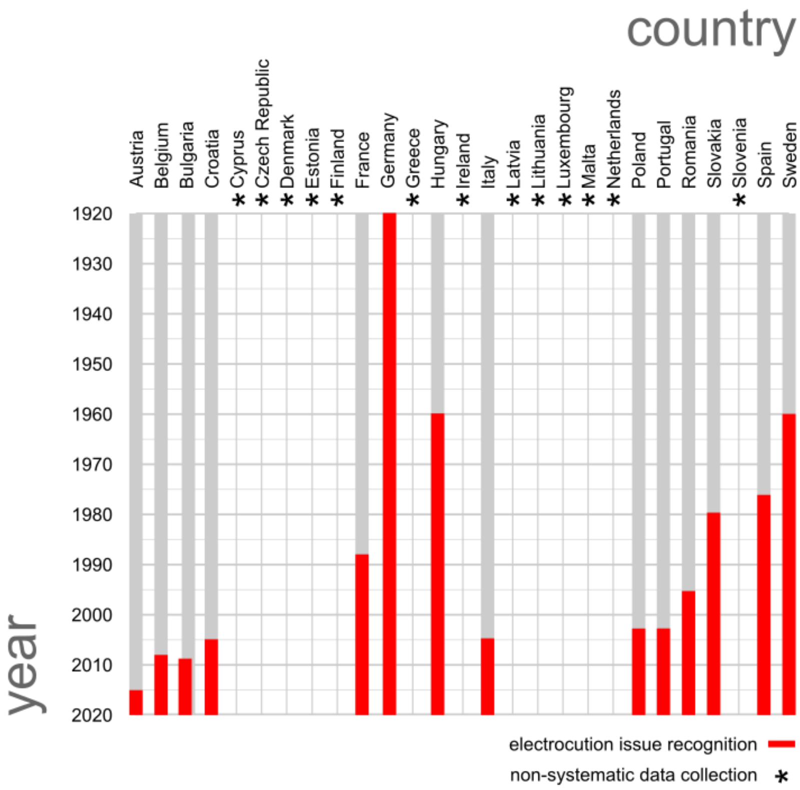

Figure 4.2: Historic overview of electrocution monitoring. The problem of bird electrocutions was first addressed around the 60s and 90s. Since then, extensive research has been conducted on the problem of bird electrocutions.

In **Czech Republic**, the public attention to the problem of bird mortality on power lines was first widely attracted by an exhibition „The Light for Prague" in 2001. But up to now, no system of regular monitoring has been developed. Data on electrocutions have been collected from various sources – rescue stations, results of particular projects, studies or assessments focused entirely or partially on this topic, as well as public databases (www.birds.cz/avif). Nevertheless, thanks to the general pressure of nature protection organisations and especially to an adoption of the EU legislation, distributors are now only allowed to use bird-friendly types of pylons and devices during the construction or reconstruction of medium voltage power lines and they have to retrofit all dangerous pylons with approved measures until 2024 [26] .

[26]: Hlaváč et al. (2013), 'Ochrana ptáků na linkách vysokého napětí - Blýská se na lepší časy?'

In **Germany** there have been some kinds of agreements for bird protection around power lines since the 1920s. In 1958, these were integrated into a VDE guideline norm, but this was removed in 1969. Major activities by nature conservationists from 1974 to 1985 led to a reintroduction of the paragraph in the guideline. High losses of white stork and eagle owl were well documented and severe back then. A VDEW measure catalogue with new technical solutions was introduced in 1986, and updated in 2011.

In **Hungary** the problem was identified in the late 1970s and early 1980s, in the region of Hortobágy, when many of storks and some raptors were found electrocuted. Meetings were organised with the power line companies and first steps took place to develop a cross-arm cover insulator. The first type of such an insulator was designed by MME in 1991 (plastic cover to hinder electrocution while birds are sitting on poles) and was installed in large numbers (50,000 pylons covered) countrywide. Regular national surveys were started by MME in 2004.

In **Slovakia** the problem of electrocution was identified in 1980, and since then a number of meetings have taken place with power line companies. The first bird protective device was designed by Raptor Protection of Slovakia (RPS) around 1990 (plastic "combs" to keep birds away from perching on poles) and was installed in 1993 in Mala Fatra mountains (Párnica – Zázrivá). Regular monitoring also started around this time.

In **Spain**, the first data come from the work of the naturalist Jesús Garzón, after he found several bodies of Iberian Imperial Eagles (*Aquila adalberti*) in the Donana National Park and communicated this at an international conference in Vienna (1977). Since then and until now, the interaction with power lines has been revealed as one of the main causes of mortality of Spanish birds. Several studies have been carried out, which have revealed the interaction with power lines as one of the main causes of the threat to numerous bird species.

There has never been any systematic monitoring in **Sweden**, despite the problem of electrocution being known about for a long time. Sometime around 1990, it led to actions when cooperation's between power companies and ornithologists took place. The protection device Huven-Uven was developed between grid owners and ornithologists and is now standard in the local grid used on pole-mounted transformers. When electrocution occurs, there is usually a power break, giving power companies a picture of the problem. All kinds of power breaks are monitored and investigated. All birds that are ring marked and found dead on or under power lines are sent to the Department of Environmental Research and Monitoring, Swedish Museum of Natural History in Stockholm. The museum published a report on this 2019. These data are unique in Europe and also a way of monitoring the problem.

There is no regular monitoring of electrocution in many other countries (Belgium, Croatia, Finland, etc.), the problem itself is low, or only sporadic victims are identified and recorded. Data come from observations mentioned by birders and field workers of utility companies.

4.2 Bird Species at Risk

The group most threatened with electrocution are defined as the diurnal bird species, specifically eagles, hawks, vultures, kites, falcons, storks and corvids [27] . The highest mortality rate due to electrocution is registered mainly for medium-sized and large birds whose body and wingspan are big enough to bridge electrified components. In certain cases, it can have a significant negative effect on the species, either on the local scale or even at the population level, such as has been documented for the saker falcon or imperial eagle [9, 11, 19, 28, 29] .

The negative impact of electrocution on endangered raptors, alongside many other direct, and indirect mortality factors, can lead to great reduction in population strength and density. This is especially the case for species where the loss of a few or even one individual may impact a local population or the overall population viability.

Main factors influencing the risk of bird electrocution can be divided into three main categories generally based on factors of origin, namely from the

[27]: Fransson et al. (2019), 'Collisions with Power Lines and Electrocution in Birds: an Analyses Based on Swedish Ringing Recoveries 1990-2017'

[19]: Harness et al. (2008), 'Mongolian Distribution Power Lines and Raptor Electrocutions'
[28]: Kovács et al. (2014), 'Saker Falcon Falco Cherrug Global Action Plan (SakerGAP)'
[29]: Bagyura et al. (2002), 'Population Increase of Imperial Eagle (Aquila heliaca) in Hungary between 1980 and 2000'
[9]: Karyakin et al. (2009), 'Raptor Electrocution in the Altai Region; Results of Surveys in 2009, Russia'
[11]: Demeter et al. (2018), 'Documenting and Reducing Avian Electrocutions in Hungary: a Conservation Contribution from Citizen Scientists'

biological (morphology, behaviour, age), **topographical/environmental** (habitats, season) and **technical perspective** (pole configuration, presence of jumper wire and other energised elements).

Energised hardware, such as transformers, can be especially hazardous, even to small birds, as they contain numerous, closely-spaced energised elements. The risk of the individual touching the components significantly increases with an increase in body proportions, mainly for medium-sized and large birds. Species susceptible to electrocution are particularly medium to large bird species such as the saker falcon (*Falco cherrug*), imperial eagle (*Aquila heliaca*). These are among the most frequent victims of electrocution, especially in areas with a lot of farmland and grassland, where places to perch are rare. [16]. They offer increased concentrations of field hamsters, small rodents and other main dietary sources of predators [28]. More species, such as storks, herones and owls, perch or roost on electric poles. Birds that use power poles to nest on are also more vulnerable [13] .

[13]: Bevanger (1998), 'Biological and Conservation Aspects of Bird Mortality Caused by Electricity Power Lines: a Review'

Young individuals are often reported as victims of electrocution (in Germany young white storks represent many victims). Juveniles of imperial eagle and saker falcon are especially common victims of electrocution in Slovakia, corresponding to results from other countries [28, 30–32] . Proximity of nests to non-insulated medium voltage poles poses a fatal risk for many young and inexperienced birds with lower ability to fly (Figure 4.3), as they try to take off or land on poles.

[30]: Nemček et al. (2016), 'Habitat Structure of Temporary Settlement Areas of Young Saker Falcon Falco Cherrug Females during Movements in Europe'
[31]: Veselovský et al. (2018), 'Telemetria orlov Kráľovských (Aquila Heliaca) na Slovensku. [Telemetry of Imperial Eagles in Slovakia]'
[28]: Kovács et al. (2014), 'Saker Falcon Falco Cherrug Global Action Plan (SakerGAP)'
[32]: Stoychev et al. (2014), 'Survival Rate and Mortality of Juvenile and Immature Eastern Imperial Eagles (Aquila Heliaca) from Bulgaria Studied by Satellite Telemetry'

Figure 4.3: Proximity of nesting imperial eagle to medium voltage power line can increase the mortality risk of young individuals from electrocution.
Source: Raptor Protection of Slovakia

Many of the nesting pairs of saker falcon and imperial eagle have gradually resettled from the foothills to the neighbouring agrocenoses, with higher risk of possible electrocution and/or collisions [33, 34] .

[33]: Danko et al. (2002), 'Orol Kráľovský (Aquila heliaca) [Imperial Eagle]'
[34]: Chavko (2002), 'Sokol Rároh (Falco cherrug). [Saker falcon]'

Species protection and population increase successes are contradicted as soon as these species expand their distribution areas to nonsecure places. This shows that measures must be undertaken in all suitable habitats, and not only in nature reserves or current breeding / resting areas.

Also man-made habitats can be of great attraction for birds susceptible to electrocution. Many bird species are observed in increasing numbers around gargabe dumps. Presence of poles of 22 kV with exposed jumper wires above the central phase close to the dumb have led to many victims in Slovakia. More than 110 individuals of corvids, magpies, storks and buzzards and many other species were identified under only 10 "killer poles" in only 14 field studies carried out between 2015-2022 (Figure 4.4).

Figure 4.4: Poles and bird victims: medium-voltage lines near garbage dumps (*up*) and carcasses of buzzards, storks and corvids founds (*down*).
Source: Raptor Protection of Slovakia

The frequency of bird mortality from electrocution has often two main peaks. Most casualties are reported from early Spring (March) and late Summer (September) due to the higher number of unexperienced juvenline birds. Such seasonal trends depend on migratory activity, density of bird populations and prey availability in the area around the power lines. During winter (December–January) and early summer (May–June), incidents are less common [12, 16, 35] .

[35]: Manville (2005), 'Bird Strike and Electrocutions at Power Lines, Communication Towers, and Wind Turbines: State of the Art and State of the Science—next Steps Toward Mitigation'
[16]: Lehman et al. (2010), 'Raptor Electrocution Rates for a Utility in the Intermountain Western United States'
[12]: Gális et al. (2019), 'Comprehensive Analysis of Bird Mortality along Power Distribution Lines in Slovakia'

Typical signs of electrocution on deceased individuals are burns to the feathers and legs, claws held in a convulsive pose, large necrotic areas on the limbs and skull fractures (Figure 4.5).

Figure 4.5: Typical signs visible on carcasses after electrocution. Arrows indicate places through which an electric current has entered the body.
Source: Raptor Protection of Slovakia

Report from various parts of Europe have identified the groups of birds most threatened by electrocution as noctural birds (owls) and diurnal birds of prey / raptors, specifally eagles, hawks, vultures, kites, falcons, storks and corvids (Corvidae) [1, 11, 14, 15, 22, 37] included in reports from various parts of Europe. A detailed list of the three bird species most affected by electrocution in individual countries is provided in Figure 4.6 and the most reported are visualised in Figure 4.7.

[1]: Haas (2005), *Protecting Birds from Powerlines: Convention on the Conservation of European Wildlife and Habitats (Bern Convention)*
[37]: Bahat (2008), 'Wintering Black Storks (Ciconia nigra) Cause Severe Damage to Transmission Lines in Israel: a Study on the Risk and Mitigation Possibilities'
[22]: Gadzhiev (2013), 'Death of Birds of Prey on Power Lines in Daghestan'
[14]: Prinsen et al. (2011), 'Review of the Conflict Between Migratory Birds and Electricity Power Grids in the African-Eurasian Region'
[15]: APIC (2006), *Suggested Practices for Avian Protection on Power Lines: the State of the Art in 2006*
[11]: Demeter et al. (2018), 'Documenting and Reducing Avian Electrocutions in Hungary: a Conservation Contribution from Citizen Scientists'

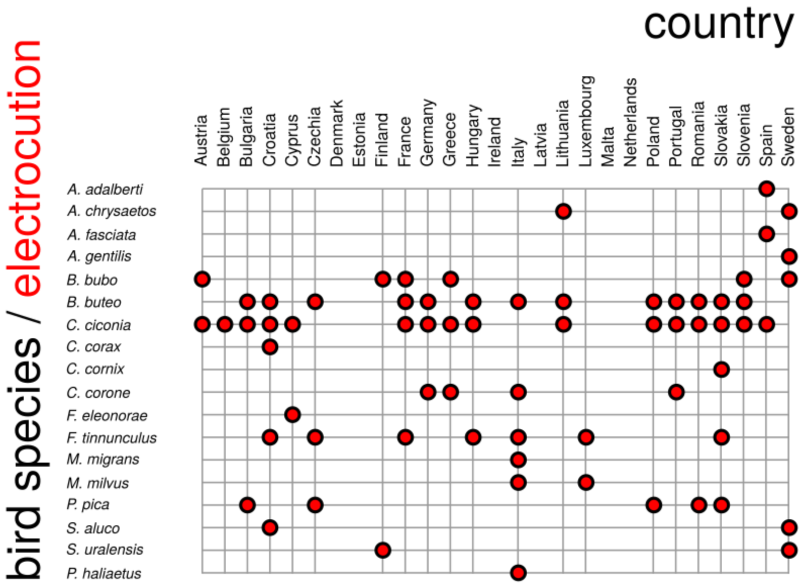

Figure 4.6: Most frequent victims of electrocution (as reported by countries). Storks, raptors and owls seem to dominate. *Source: Raptor Protection of Slovakia*

There is a large difference in the amount of quantitative information available between countries. Data about the victims of electrocution are often composed from the mixture of many sources: e.g. from results of several previous survey of avian mortality carried out within Interreg and LIFE+ projects (e.g. Bulgaria, Croatia, Czech Republic, Hungary, Italy, Lithuania, Slovakia etc.), as well as from bird ringing data (e.g. Finland, Sweden, Spain Slovakia), from publication by nature conservation agencies (e.g. Cyprus, Germany), museums and universities (Sweden). Typical sources of data are small-scale monitoring realised by ornithologists, members of NGOs and their long term knowledge from the field, plus reports from rehabilitation centres and electricity utilities (all countries, we regard here e.g. Austria, Belgium, France, Greece, Hungary, Luxembourg, Poland, Romania, Spain etc.). For the remaining 5 countries (Denmark, Latvia, Malta, Netherlands and Slovenia) data were missing.

Figure 4.7: Individuals of buzzards, storks, corvids and owls, are reported as the main victims of electrocution on power lines. *Source: Raptor Protection of Slovakia*

Altogether 18 bird species are the most reported victims of electrocution within all EU countries, owls and raptors are the most reported in Finland, Denmark and Sweden. Corvids, storks and raptors seem to be largely affected by electrocutions in some countries (e.g., Bulgaria, Czech Republic...), as they frequently use poles - often the tallest structures in grassland and open agricultural land - for roosting or hunting [11] . Corvids and birds of prey represented 85% of all identified electrocutions in a study from Slovakia [12]. Raptors were associated with 40% of all identified victims of electrocution. In Bulgaria, crows and birds of prey represented more than 53% of detected electrocutions, while in the Czech Republic this percentage is even higher, up to 88%. Larger dominance of corvids and birds of prey have been recorded in France - 85% of all electrocution records, and from Spain, corvids and birds of prey represented more than 80% of all identified electrocuted birds [23, 38–40] .

[11]: Demeter et al. (2018), 'Documenting and Reducing Avian Electrocutions in Hungary: a Conservation Contribution from Citizen Scientists'

[23]: Demerdzhiev et al. (2009), 'Impact of Power Lines on Bird Mortality in Southern Bulgaria'
[38]: Škorpíková et al. (2019), 'Bird Mortality on Medium-voltage Power Lines in the Czech Republic'
[39]: Bayle (1999), 'Preventing Birds of Prey Problems at Transmission Lines in Western Europe'
[40]: Janss et al. (2001), 'Avian Electrocution Mortality in Relation to Pole Design and Adjacent Habitat in Spain'

4.3 Dangerous Types of Power Lines

The following subchapter describes the most widely used types of poles in the 27 EU countries and their potential risk to birds. The risk of electrocution on poles depends primarily on the technical construction and detailed design of power facilities, i.e. how pin insulators are attached to the cross-arms and the space/distance between e.g. the exposed jumper wires and/or other energised and/or grounded elements.

The construction types of above-ground power lines used in different countries have many similarities (e.g. poles used in Slovakia and in Czech Republic), but many different types exist, even differing from company to company within one country. Some commonly used constructions of medium voltage power poles are also known as "killer poles".

A questionnaire answered by experts, revealed that the medium voltage poles and their mortality risk can be classified in three main groups:

A) Low risk: Many type of poles and pylons with suspended insulators; poles with conductors arranged to one black cable design mounted to concrete/wooden[1] pole without metal cross-arms and insulators. These poles are designed to minimise bird electrocution risk by providing sufficient separation of energised elements and conductors to prevent electrocution for all sizes of birds (Figure 4.8). Also metal and concrete poles with suspended insulators seem to pose a low risk.

1: wooden poles are not 100% safe, especially when they are wet

Figure 4.8: Completely insulated medium tension cable in Slovakia hanging from concrete pole without need for insulators.
Source: Raptor Protection of Slovakia

B) Medium risk: Utility poles with pin-insulators in upright position. These are the most common poles of medium voltage power lines and are also known as "killer poles" due to higher and repeated bird losses. The gap between the wires and the cross-arm is small, especially for larger bird (Figure 4.9). These are more numerous but are responsible for lower number of electrocuted birds than the poles listed under high risk category.

Figure 4.9: Concrete poles with pin-type insulators mounted upward.
Source: BirdLife Bulgaria

C) High risk: Poles with complex construction (Figure 4.10), such as corner, tensioning or branch types with several levels of cross-arms, pin insulators (Czech Republic, Greece, Portugal) and with combination of jumper wires and closely spaced conductors (Czech Republic, Slovakia, Spain); transformer stations and switch towers (Bulgaria, Hungary, Finland, Poland, Portugal). The gap between the wires and the cross-arms and all energised elements is small, even for medium and small bird species.

Figure 4.10: Strain poles with exposed jumper wires passing over the pin-insulators above the cross-arms are the most dangerous configuration responsible for many recorded electrocution fatalities. *Source: Raptor Protection of Slovakia*

Corner, strain and branch poles are significantly more dangerous for birds than utility poles in straight lines [12] . Bird mortality is lower for power line switch disconnectors and pole transformers, which are often situated at the edges of human settlements or are part of urban/industrial areas, with lower presence of birds and thus lower incidence of mortality. Corner and branch poles on medium voltage lines were also identified as the most dangerous in a survey done in the Czech Republic [38] . Similar results are reported also from Bulgaria: metal branch poles featuring jumper wires accounted for 54.3% of total detected electrocution mortality. Anchor poles in particular have been shown to pose a significant electrocution risk to birds, particularly due to the configuration of the jumper wires [23, 38, 41, 42] .

[12]: Gális et al. (2019), 'Comprehensive Analysis of Bird Mortality along Power Distribution Lines in Slovakia'

[38]: Škorpíková et al. (2019), 'Bird Mortality on Medium-voltage Power Lines in the Czech Republic'

[41]: Dixon et al. (2013), 'The Problem of Raptor Electrocution in Asia: Case Studies from Mongolia and China'
[42]: Dixon et al. (2017), 'Avian Electrocution Rates Associated with Density of Active Small Mammal Holes and Power-pole Mitigation: Implications for the Conservation of Threatened Raptors in Mongolia'
[38]: Škorpíková et al. (2019), 'Bird Mortality on Medium-voltage Power Lines in the Czech Republic'
[23]: Demerdzhiev et al. (2009), 'Impact of Power Lines on Bird Mortality in Southern Bulgaria'

For more pictures of safe and dangerous constructions of poles, please see the Annex B.

4.4 Mitigation Measures & Prevention of Electrocution

This chapter summarises the latest technical standards on electrocution mitigation and presents know-how on how to mitigate electrocution risk for birds. According to current knowledge and experience, it is possible to reduce the risk of electrocution significantly, within the realms of 'acceptable' costs for the electric utility companies.

Many types of mitigation measures and solutions have been tested in some EU countries. In some cases, electricity utility companies with in-house experts tried to solve the electrocution problem and thus started to use exclusion devices, or perch discouragers. Many of these turned out to be ineffective and indeed some of the devices applied increased the possible risk, as birds will still try to perch on constructions where space is limited, they have a higher chance of coming into contact with energised wires and elements. Products used to mitigate electrocution risk should be made from durable, long-lasting materials and should be installed properly to ensure the protection of birds. If they are damaged or incorrectly installed, they are useless or even more dangerous than non-insulated poles.

Many of the installed devices were tested and proved to be not effective in preventing electrocution. In Bulgaria, the use of "anti-bird spikes" solution is not efficient[2] in preventing electrocution (Figure 4.11 *up*). Another solution, the "wing spacers" are also not entirely effective as bird protection devices (Figure 4.11 *down*).

2: Recent reports show that storks even use these spikes as a good basis for nest building

Figure 4.11: Anti bird protection: (*up*) anti bird spikes - an inefficient retrofitting used in Bulgaria; (*down*) wing spacers attached on metal pylon in Bulgaria are also not entirely effective.
Source: BirdLife Bulgaria

Artificial bird perches and perch deterrents have proven to be unsafe for small birds in some cases in Croatia. In Czech Republic, none of the following measures were thoroughly tested, however their short use on power lines revealed their inappropriateness. Similar *combs* also used in Slovakia have many negative aspects, including short lifetime and that damaged combs become even more dangerous than missing protection. The *bench* takes up space on the console, but the birds still sit on the console and, worse, are pushed further towards the powered conductors than in the case without a bench.

Plastic belt covers on insulators have very short lifespan. Damaged, these are more dangerous than missing protection (Figure 4.12).

Figure 4.12: Inappropriate anti-bird protection measures: bench (*up*); plastic belt (unrolled) (*middle*); plastic covers on insulators (*down*).
Source: AOPK ČR

In Hungary, a number of different experiences have been had. Regarding new data, a range of products and retrofitting mitigation measures have been fitted, including cross-arm cover insulators (green and orange) and plastic phase covers which allow birds to perch safely on the console. Ignoring recommendations, such plastic products could be attached the wrong way to cross-arms and insulators, and these also have a short lifetime. Often, after retrofitting mitigation measures, power line comanies do not pay enough attention to regular maintenance or replacement of missing elements/kit.

In Portugal, insulating tape around the conductors has been used. The distribution company, Energias de Portugal (EDP) tested these and continued to observe mortality of raptors and corvids on retrofitted lines. It turned out that the birds tear at the tape with their claws and sometimes bills, thus opening holes in the tape and becoming electrocuting in the process.

In Slovakia, plastic "combs" in different colours (Figure 4.13), as well as other products installed wrongly (Figure 4.13 (*up*)) or without respect for recommendations, often turned out to be inefficient and cause a higher chance of birds coming into contact with energised wires and elements, because the "safe" space is even more limited (Figure 4.13 (*down*)).

Figure 4.13: Because the birds will still try to perch on the constructions, plastic combs are wrong solutions. Many birds were electrocuted on damaged combs, especially if the remains of the product were located in the middle of two insulators, forcing birds to perch closer to the phase conductors or other energised elements. *Source: Raptor Protection of Slovakia*

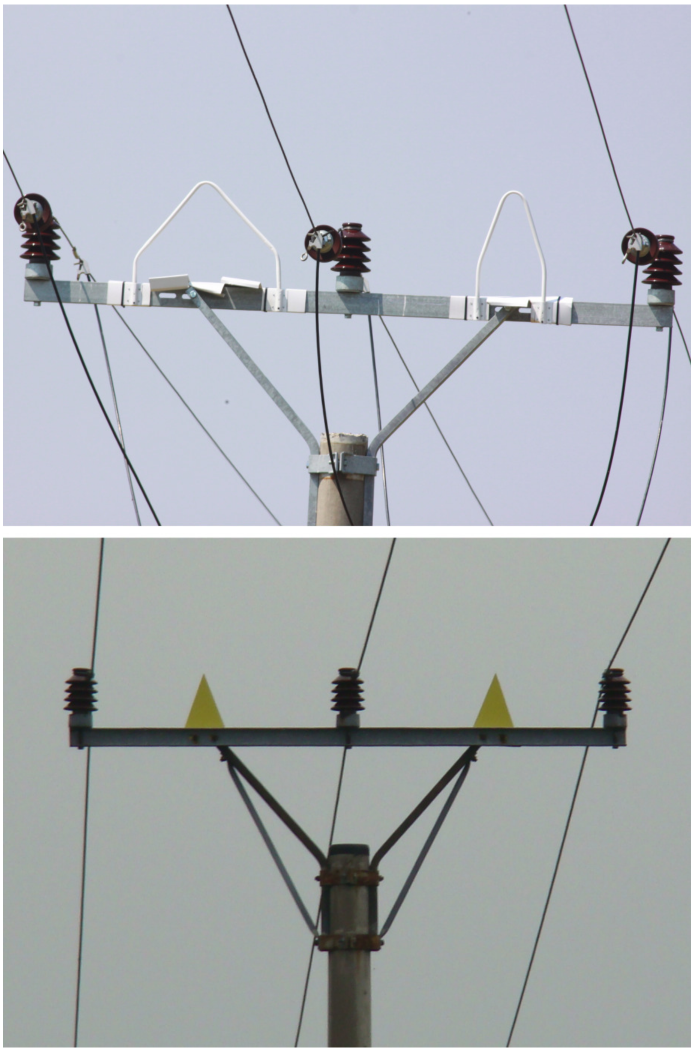

Figure 4.14: Wrong installation can increase the risk of electrocution rapidly. Due the installation (even if correct) of protective devices in the middle of the cross-arm, the space could be more limited, thus forcing birds to perch even closer to energised parts.
Source: Raptor Protection of Slovakia

In Spain, the main problem related with the mitigation measures for electrocution is the degradation over time of the insulating material. The devices are ineffective because they deteriorate very quickly in inclement weather. Some devices that birds cannot rest on have also proved ineffective.

In several countries, "killer poles" only stated to disappear or to be retrofitted after legislative action, which also made the construction of new such poles became generally prohibited. Also catalogues of suitable designs and solutions were set up by the electric utility companies, in close co-operation with government and conservation groups [1] .

[1]: Haas (2005), *Protecting Birds from Powerlines: Convention on the Conservation of European Wildlife and Habitats (Bern Convention)*

There are many types of **effective measures and solutions** (please see the Annex 3) to mitigate electrocution on medium voltage power lines such as: plastic hoods, silicon tubes, long rod insulators, plastic insulators covering the metal console etc. **The best solutions how to prevent electrocution are those which allow the birds to perch safely on poles.**[3]

3: Of course, the ultimate solution is still to replace overhead conductors with underground cables.

Cross-arms, insulators and other parts of the power lines should be constructed so that there is no space for birds to perch close to energised wires, or so that the shape of the console discourages birds from perching at all.

It is necessary to mention, that almost no insulation measure is 100% safe for birds, especially in long-term. It depends mostly on how well the equipment gets installed, local weather conditions (salty air, strong winds, temperature), landscape and which bird species we are trying to save from getting electrocuted. Some pole designs, such as disconnectors and substations, can't be entirely insulated because of moving parts. In these cases, the only effective mitigation method is to change their construction.

Where underground cabling is impossible (for whatever reasons) like in Austria, bird protection hoods in particular have proved to be very valuable services. Correspondingly adapted systems have been used at junctions and transformer stations (Figure 4.15).

Figure 4.15: Bird protection hoods installed on branch poles are proven to be a very valuable measure.
Source: BirdLife Austria

Insulation caps for pin-type pylons turned out to be 100% effective in protecting birds from electrocution in Bulgaria (Figure 4.16).

Figure 4.16: Insulator cap on 20 kV pole pin-type in Bulgaria.
Source: BirdLife Bulgaria

The exchange of bare conductors for insulated phase conductors has proved to be the safest solution (Figure 4.17) for preventing avian electrocution adopted in Croatia and Sweden. In Croatia, insulated overhead lines are used in a few short stretches, representing a very small portion of the total overhead grid. It also represents a long-term solution and its effectiveness does not decrease with use, as opposed to the installation of insulation equipment. In the long term, the installation of insulated lines (where possible) represents the most cost-effective solution, and it brings the additional advantage of enabling easier detection of breakdowns and regular network maintenance.

Figure 4.17: Replacement of the bare conductors of overhead power lines with covered conductors is a long lasting solution which doesn't cause difficulties with maintenance, compared with the installation of insulation equipment. Full Covered Conductor Solutions provide an even more complete protection for the line and bird species.
Source: HEP Croatia, BirdLife Sweden

The practice of installing insulated conductors in Croatia is currently mostly installed in forest areas by HEP DSO. The installation of insulation equipment onto pole transformer stations, disconnectors and individual dangerous poles is the most appropriate and cost-effective solution for "dotted" protection of birds from electrocution (Figure 4.18).

Figure 4.18: Using insulated conductors is the most appropriate and cost-effective solution for preventing bird electrocution. *Source: HEP Croatia*

The most effective measure in Czech Republic is „Pařát console type" with a perch or „Delta Variant console type" with a perch. The shape of the console discourages birds from sitting down and, at the same time, the perch offers a place to sit. A study realised between 2011-2012 evaluated the results of this solution [43] . The new technical solution consisted of a bar with a perch below the console, allowing safe landing for the birds (Fig. 4.19). The monitoring of this solution at 4 selected power lines in different parts of the Czech Republic has shown that perches were frequently used by common buzzards and showed a high protection value, and results indiciate that this will also be the case for other raptors which typically use poles as perches, e.g. black kite, red kite, rough-legged buzzard. Despite that, species such as magpie and common crow used the perches less often. In the case of two last species, the perches were evaluated as entirely ineffective. For the common kestrel, no positive effect of the perch could be proved. Overall, the evaluation of the perch was positive and only 10% of tested common buzzards performed risky behaviour; the rest of birds were protected against electrocution due to using the perch.

[43]: Škorpíková et al. (2012), *Monitoring Účinnosti Bidel na Konzolách Typu "PAŘÁT"*

Figure 4.19: The shape of console discourages birds from sitting down and at the same time, the perch offers a place to sit. *Source: AOPK ČR*

Different type of solutions have been tested and are applied (mainly plastic-insulated covers on the central wire, "sheathed bridges", anti-landing tools and the installation of a perch structure above switch poles) in France.

As reported in many countries, including Germany, underground cables, pylons with suspended insulators (cross-arm to constructor > 60cm), insulating hoods for pin-type insulators and switches attached below the cross-arms seem to be a especially effective measures for decreasing mortality through electrocution. The long-term and high effectiveness of underground cables has been reported in the Netherlands.

In Hungary the most effective solution appears to be a complete change of the pylon head construction for the new, bird-friendly scaled type with well geometry. Switch poles could be changed to closed types filled with gas. Branch poles can be fitted with a new perching frame, which offers a safe landing and sitting surface for birds.

There is a lack of data from Poland on most effective protective measures, as no general evaluation has been carried out. Removal of dangerous parts of installation can help in most cases, but regularly gathered data is missing.

In Portugal, "Derancourt insulators" - insulating silicon sleeves around the wires near the pylon and protection around the conductors have shown very good efficiency in reduce overall mortality on pylons (>85% and sometimes >90%) in Portugal. However, some problems have been reported due to debris entering the empty space between the wire and the sleeve. The "Combined solution", a new device currently being tested by EDP Distribuição which combines insulating tape with conductor protectors (Figure 4.20) seems to be effective, but more date is necessary.

Figure 4.20: Insulating tape with conductor protectors on a medium voltage pole. *Source: SPEA - Portuguese Society for the Study of Birds*

In Romania, underwater cables and cable insulations have been recommended as effective solutions.

In Slovakia the most effective solution appears to be a complete change of the construction for the new type so called Antibird and Ecobird models (Figure 4.21). Aside from this, phase covers and various types of plastic insulators which allow birds to perch safely on the console or do not allow birds to perch on the construction at all have also been recorded as effective. Antibird is effective thanks to the shape of the console (45° angle of the arms). Between 2006-2007, three new elements were tested that proved to be the most appropriate type; they are still used today and are called “Tooth" - insulators, which allow birds to safely perch. A new type of insulation with telescopic parts has been developed for 22 kV power lines, to eliminate the distance between the insulation and support insulators (Figure 4.22).

Figure 4.21: Antibird (*up*) and Ecobird (*down*) cross-arms solution is effective thanks to the shape of the console (45° angle of the arms).
Source: Raptor Protection of Slovakia

Figure 4.22: Telescopic construction of device eliminates the dangerous "free" space between the protection and pin- insulators and allow the birds to perch safely on poles at the same time.
Source: Raptor Protection of Slovakia

Furthermore, changes in the pole construction and position of jumper wires have proven to be quite an effective mitigation measure against electrocution (Figure 4.23).

Figure 4.23: A medium voltage pole in Slovakia, unsafe for perching raptors due to position of conductors above pin insulators, on top of cross-arm (*left*). The same pole voltage after mitigation measures. Fully covered jumper wire is suspended below cross-arm and the pole is now safe for perching of saker falcon (*right*).
Source: Raptor Protection of Slovakia

In Sweden larger parts of the power grid (0.4–20 kV) have been rebuilt since the 1990s, and especially since 2005, following a large storm. Many kilometers of this grid have been laid down as underground cables and most of the remaining grid has been have been fitted with plastic isolated wires (please see Figure 4.17). The dangerous pole mounted transformers have been built with isolator protection called "Huven-Uven" (Figure 4.24) since around the mid 1990s. On certain power lines of 10–20 kV that have not been retrofitted, plastic protection has been mounted on isolators in important areas e.g. for eagles. On 40-50 kV power lines with upright pin insulators, the distance between phases has been increased from 1,350 mm to 1,600 mm to reduce the risk of electrocution of large birds. Statistics from the electricity company show that bird-caused problems on the lines were thus reduced.

Figure 4.24: Insulator protection called "Huven-Uven" used on a pole transformer in Sweden.
Source: Swedish Ornithological Society

Retrofitting of poles is an effective way of decreasing mortality of birds. In a study by Gális et al. [12] the highest percentage (78%) of bird carcasses were found under non-retrofitted poles. A further 5% were found under poles with a damaged component and 3% under poles where the product/device had been incorrecetly installed.

[12]: Gális et al. (2019), 'Comprehensive Analysis of Bird Mortality along Power Distribution Lines in Slovakia'

Bird Collisions | 5

Bird casualties due to collision with overground power lines can happen on distribution or transmission electricity grids. Larger, heavy-bodied birds with short wing spans (e.g. swans, bustards) and poorer vision are more susceptible to collisions than smaller, lightweight birds with relatively large wing spans, agility and good vision [37] . Moreover, species with narrow visual fields (e.g. swans, ducks, herons, storks) are at higher collision risk as they cannot see the wires from a certain angle [54, 61] .

[37]: Bahat (2008), 'Wintering Black Storks (Ciconia nigra) Cause Severe Damage to Transmission Lines in Israel: a Study on the Risk and Mitigation Possibilities'
[61]: Martin et al. (2010), 'Bird Collisions with Power Lines: Failing to See the Way Ahead?'
[54]: Martin (2011), 'Understanding Bird Collisions with Man-made Objects: a Sensory Ecology Approach'

The main cause of collisions is a bird being unable to register the obstacle ahead. Power lines crossing the birds' daily movement corridors can be particularly problematic. Research suggests that on grasslands, there are 113 collisions / km / year on agricultural land 58 collisions/km/year and near river crossings 489 collisions/km/year. Collision risks also are exacerbated during low light, fog, or inclement weather conditions [3, 45–48] .

[45]: Savereno et al. (1996), 'Avian Behavior and Mortality at Power Lines in Coastal South Carolina'
[3]: APIC (2012), *Reducing Avian Collisions with Power Lines: the State of the Art in 2012*
[46]: Frost (2008), 'The use of 'Flight Diverters' Reduces Mute Swan Cygnus olor Collision with Power Lines at Abberton Reservoir, Essex, England'
[47]: Stehn et al. (2008), 'Whooping Crane Collisions with Power Lines: an Issue Paper'
[48]: Erickson et al. (2001), *Avian Collisions with Wind Turbines: a Summary of Existing Studies and Comparisons to Other Sources of Avian Collision Mortality in the United States*

Understanding the nature of bird collisions is essential for minimising them. Problems of collisions with power lines can be generally divided into four main categories: **biological, topographical, meteorological** and **technical** factors [3]. The biological parameters include the physiology of the bird's vision, as well as type and speed of flight behaviour. Meteorological factors such as gusts of wind and poor visibility are a significant contributing factor to collisions. Technical factors include the height of pylons and power lines, horizontal and vertical division of aerial space and the presence of one/two earth (ground) wires on the top of the transmission voltage pylons, which is almost invisible for the birds. Data from many studies indicate that up to 80% of collisions occur with the earth wire [3] .

[3]: APIC (2012), *Reducing Avian Collisions with Power Lines: the State of the Art in 2012*

5.1 National Overview of Collision Issue

In some countries, there is a general lack of data on bird fatalities from collisions in and no regular, long-term monitoring has been carried out [1] . In many cases, collisions have only been located sporadically and only recently has the problem received more serious attention. More recently, local monitoring has been carried out in order to identify the risk of collisions on bird species in hot spots. Several studies have been carried out, which have revealed the interaction with power lines as one of the important causes of the threat of numerous bird species (Austria, Belgium, Bulgaria, Hungary, Italy, Latvia, Lithuania, Romania & Slovakia, etc.). In particular, the problem was identified following repeated location of high numbers of dead birds under dangerous sections of power lines, and cooperation on the matter has since started.

1: Mainly due to a specific focus given to the issue of electrocution

In other countries, the problem was identified after several repeated findings. This data was later published and mutual communication with representatives of electric utility companies started. The results proved the need for use of proper mitigation measures in important habitats, in order to increase wire visibility for most susceptible bird species (e.g. Hungary & Slovakia). The data often comes also from observations by birdwatchers or citizens scientists, as well as data registered in data portals (Austria, Belgium & Slovakia). When collision occurs on low or medium voltage line, there is usually a power outage, meaning that the power company also provides a report with GPS coordinates of the span where the incident was identified (e.g. Slovakia, in case of collisions of mute swans).

While victims of collisions had previously only been located sporadically, first regular monitoring started mainly in the 90s, later than monitoring for electrocution. Since the end of the 20th century, an increased attention has been given to this problem in many countries, but more intensive focus was given after the year 2000 and in the past 4-5 years (Croatia, Denmark, Estonia, Netherlands, Latvia & Lithuania). Often, surveys were and are realised under LIFE+ projects; with national and international funds within Natura 2000 sites; conflict areas outside of SPAs and priority territories of rare/endangered birds; as well as close to important bird habitats and migration routes.´

The collision topic has not been worked on so intensively so far by BirdLife in Austria. However, there have been numerous projects in this direction, such as the efforts to save the great bustard.

In Slovakia deaths from collisions had been located sporadically, but first more extensive results were found out in the year 2010 in the SPA, Ondavská rovina. The results proved the need for a systematic approach, and collisions have thus been monitored regularly since 2014. One 5-year project, LIFE Energy (2014-2019) focussed on collisions of birds with 22 kV and 110 kV power lines. In general, there is first a need to identify the most dangerous types of power lines for collisions (e.g. in Slovakia, 22 kV and 110 kV power lines) as well as to identify those dangerous sites with high collision rates. Between 2016-2019, the Slovakian project LIFE13 NAT/SK/001272 identified a complex methodology for the monitoring of these power lines and results were evaluated in the study Gális et al. [6] .

[6]: Gális et al. (2019), 'Monitoring of Effectiveness of Bird Flight Diverters in Preventing Bird Mortality from Powerline Collisions in Slovakia'

In Hungary, deaths from collisions had been located sporadically. First extensive survey and results were found out in the frame of the LIFE project entitled „Conservation of Otis tarda in Hungary" between 2004-2008, mainly in Kiskunság National Park Directorate. The results proved the need to use bird diverters on the wires in bustard habitats, thus increasing visibility, as well as focussing on placing existing power lines underground.

In Lithuania, during the implementation of the EU LIFE+ funded project "Installation of the bird protection measures on the high voltage electricity transmission", most frequently recorded were deaths of night-migrating passerines, sandpipers in dense flocks and large waterbirds. Some electrocuted predatory birds were also found under the electricity transmission lines. For example, 72 sections of high voltage electricity transmission lines in various locations of North and Middle Lithuania were inspected between October 2017 - April 2018. During this period, 51 dead birds (18 species) were found under the power lines in the mentioned sections. Most frequent among them were plovers and lapwings.

In Sweden, ringmarked dead birds found under power lines are sent to the Swedish Museum of Natural History. In many cases, it is hard to determine if a bird has been electrocuted or if it died from collision. It is very difficult to monitor collisions, for example because it takes a lot of time to train and work with a specialised-dog.

5.2 Bird Species at Risk

Collisions of birds with electrical infrastructure represent a significant mortality factor for several species. Fatal high-speed clashes can be frequently observed in open areas where the power line crosses feeding, foraging and nesting habitats used by birds and can occur equally with transmission and distribution lines [12, 49] . A particular problem arises when there are frequent movements of large flocks between their feeding and nesting biotopes, or if the power lines pass perpendicularly across the birds' main migration routes [20, 33]. At such locations, bird losses can exceed hundreds of casualties per kilometer of powerline every year.

[49]: Jenkins et al. (2010), 'Avian Collisions with Power Lines: a Global Review of Causes and Mitigation with a South African Perspective'
[12]: Gális et al. (2019), 'Comprehensive Analysis of Bird Mortality along Power Distribution Lines in Slovakia'

Bird casualties due to collision with overhead power lines can happen to any flying bird species. Some bird species which are active in the vicinity of power lines are more susceptible to collision risk than others. Usually it depends on the bird size, weight, character of flying, field of vision, time of the day and the special features of habitats near the power lines. Morphology plays a decisive role [50, 51] . Birds with low maneuverability, i.e. those with high wing load and low aspect ratio, such as bustards, pelicans, waterfowl, cranes, storks and grouse, are among the species most likely to collide with power lines.

[50]: Brown (1993), 'Avian Collisions with Utility Structures: Biological Perspectives'
[51]: Crowder et al. (2002), 'Relationships between Wing Morphology and Behavioral Responses to Unmarked Power Transmission Lines'

Species with narrow visual fields (e.g. swans, ducks, egrets) are at higher collision risk as they cannot see the wires from a certain angle [52-54].

From the biological point of view, the group most susceptible to collisions and therefore at greatest risk are the large, heavy bird species [55] and certain specific orders of birds, e.g. Anseriformes, Ciconiiformes, Gaviiformes, Pelecaniformes, Otidiformes, Gruiformes, defined according to their morphological parameters (e.g. weight, wing size/area, manner/type of flight). Species which tend to group together in large flocks (Figure 5.1) are also associated with higher probability of collision [56] .

[55]: Rubolini et al. (2001), 'Eagle Owl Bubo Bubo and Power Line Interactions in the Italian Alps'

[56]: Drewitt et al. (2008), 'Collision Effects of Wind-power Generators and Other Obstacles on Birds'

Figure 5.1: An important factor is the habit of some bird species such as ducks, swans, geese and waders, to fly in (large) flocks, which increases the chance to collide with obstacles especially for the birds in the back of the group.
Source: Raptor Protection of Slovakia

Power line features can also influence the risk of bird collision based on different power line voltage and thus configuration, especially including the number of vertical levels, wire height and presence of shield wire [49, 57, 58] . Technical installations of power lines can also become damaged by bird accidents - collisions can cause conductor cables to sever or to strike together. Short circuits to ground can damage insulators and switches. Bird accidents can lead to outages (Figure 5.2) and subsequent economic damages [1].

[57]: Murphy et al. (2009), 'Effectiveness of Avian Collision Averters in Preventing Migratory Bird Mortality from Powerline Strikes in the Central Platte River, Nebraska'
[58]: Shaw et al. (2018), 'High Power Line Collision Mortality of Threatened Bustards at a Regional Scale in the Karoo, South Africa'
[49]: Jenkins et al. (2010), 'Avian Collisions with Power Lines: a Global Review of Causes and Mitigation with a South African Perspective'

Figure 5.2: Collisions of large bird species, such as swans, can results in a short circuit, with current flowing through the bird's body, and electrocution, often accompanied by an outage of the electricity supply.
Source: Raptor Protection of Slovakia

In case of collision accidents, birds crash at high flight speed into cables or wires. The resulting injuries such as broken bones, wings, legs and shoulder bones, wounds (Figure 5.3) vary widely and can be comparable to types of traumas caused by collisions with cars.

Figure 5.3: A broken neck is a typical reason for dead after collision,, especially for large and long necked bird species, such as mute swan and purple heron.
Source: Raptor Protection of Slovakia

Collision susceptibility may be influenced by flight behaviour. Gregarious species are generally thought to be more vulnerable than species with solitary habits [3] . On the basis of published data, the groups of birds most often and most seriously threatened by collisions in various parts of the world include pelicans, storks, cranes, grouses (Tertaonidae), rails, gallinules, coots (Rallidae), bustards, waders (Charadriidae + Scolopacidae) [1] . Examples of most collision-susceptible groups of birds from reports from across Europe are the orders Anseriformes, Ciconiiformes, Gaviiformes and Pelicaniformes. A detailed list of the three bird species most affected by collisions in individual countries is provided in Figure 5.4.

[3]: APIC (2012), *Reducing Avian Collisions with Power Lines: the State of the Art in 2012*

[1]: Haas (2005), *Protecting Birds from Powerlines: Convention on the Conservation of European Wildlife and Habitats (Bern Convention)*

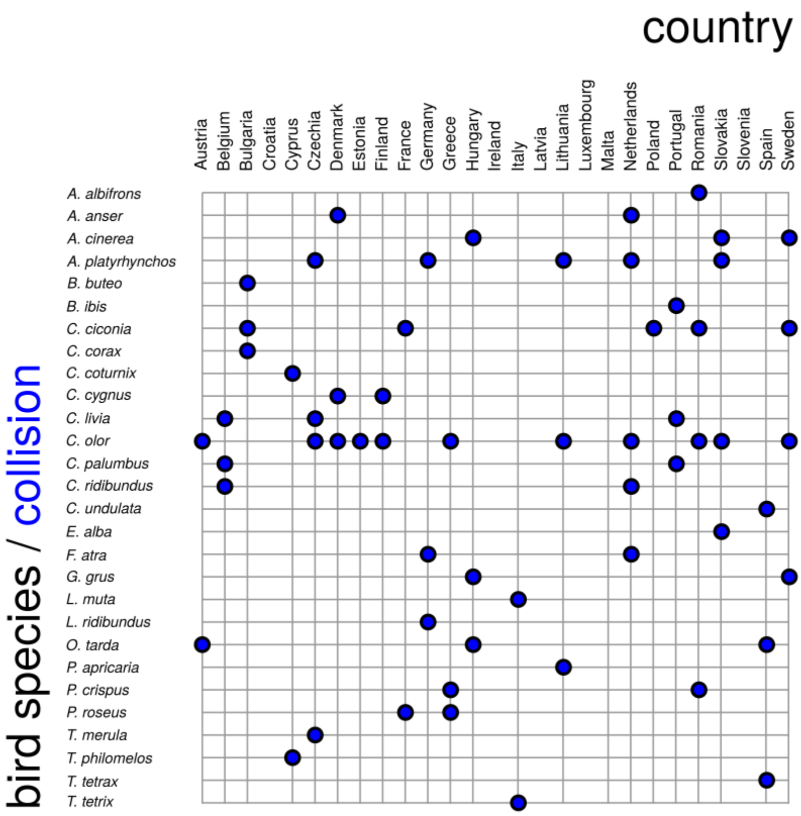

Figure 5.4: Most frequent victims of collision (as reported by countries). Swans, ducks, herons seems to dominate

Data on victims of collisions are often composed from the mixture of many sources: e.g. from results of several previous surveys of the avian mortality carried out within Interreg and LIFE + projects (e.g. Bulgaria, Croatia, Czech Republic, Hungary, Italy, Lithuania, Slovakia etc.), from bird ringing data (e.g. Finland, Sweden, Spain, Slovakia), as well as from publications from nature conservation agencies (e.g. Cyprus, Germany), museums and universities (Sweden). Typical sources are small-scale monitoring realised by ornithologists, members of NGOs and their long term knowledge from the field, reports from rehabilitation centres and electricity companies (main share of all 27 EU countries, e.g. Austria, Belgium, France, Greece, Hungary, Poland, Portugal, Romania, Slovakia, Spain, etc.). For the remaining four countries (Latvia, Luxembourg, Malta and Slovenia), data were missing or insufficient.

Altogether, 29 bird species have been reported as victims of collisions within the EU countries. The percentage of raptors and corvids colliding with power lines was very small, compared to electrocuted individuals. The highest mortality has been recorded for the mute swan.[35, 51] .

[51]: Crowder et al. (2002), 'Relationships between Wing Morphology and Behavioral Responses to Unmarked Power Transmission Lines'
[35]: Manville (2005), 'Bird Strike and Electrocutions at Power Lines, Communication Towers, and Wind Turbines: State of the Art and State of the Science—next Steps Toward Mitigation'

Swans are often among the commonly recorded victims [50, 59, 60] . The dominance of mute swans is probably a result of their behaviour, as swans fly mainly in flocks. They also require long stretches for takeoff and landing. Spring growth of winter wheat and oilseed crops on surrounding arable land provides a timely alternative food supply for the swans and geese, resulting in large numbers flying out of the wetlands several times a day to feed in these fields and then returning to the wetlands for a safe refuge when they cease feeding (Figure 5.5). Moreover, species with narrow visual fields (e.g. swans, ducks, herons, storks. . .) are at higher collision risk as they cannot see the wires from a certain angle [54, 61] .

[59]: Perrins et al. (1991), 'Collisions with Overhead Wires as a Cause of Mortality in Mute Swans Cygnus Olor'
[50]: Brown (1993), 'Avian Collisions with Utility Structures: Biological Perspectives'
[60]: Mathiasson (1993), 'Mute Swans, Cygnus olor, Killed from Collision with Electrical Wires, a Study of Two Situations in Sweden'

[61]: Martin et al. (2010), 'Bird Collisions with Power Lines: Failing to See the Way Ahead?'
[54]: Martin (2011), 'Understanding Bird Collisions with Man-made Objects: a Sensory Ecology Approach'

Figure 5.5: Mute swans are more susceptible to collision if they regularly cross and fly close to power lines that are situated between the resting and main feeding field with oilseed rape. Often, tens of killed individuals can be found on these locations. *Source: Raptor Protection of Slovakia*

5.3 Dangerous Types of Powerlines

More important than the voltage level is the location of the construction relative to bird habitats or main migration routes. Although different bird species fly at differing heights above the ground, there is a prevailing consensus that the lower power line cables are to the ground, the better they are for preventing bird collision. There is also a consensus that reduced vertical separation of cables is preferred, as it poses less of an "obstacle" for birds to collide with. Horizontal separation of conductors is therefore preferred [14] .

[14]: Prinsen et al. (2011), 'Review of the Conflict Between Migratory Birds and Electricity Power Grids in the African-Eurasian Region'

Collisions can be observed most frequently in areas where the power lines cross the feeding and nesting biotopes used by large bird populations. Even if the power lines are just in the vicinity of those areas, there is still high probability of numerous collisions [62, 63] , especially near places used for taking off and landing [57]. The environmental conditions of the site influencing the degree of collision risk are, above all, the character and composition of the landscape. Open, flat land with low vegetation enables birds to fly low and close to the terrain, seeking out sources of food and resting places. In such open habiats, no vertical obstacles or linear structures in the air would be naturally present and are thus not "learned" by relevant bird species. As a result, they may tend not to notice potential obstacles such as electric power lines. Furthermore, birds have a general tendency to look downwards, and thus for certain species, the space ahead of them becomes a so-called 'blind zone' [54, 61] .

[62]: Wallace et al. (2005), *A Summary and Comparison of Bird Mortality from Anthropogenic Causes with an Emphasis on Collisions*

[63]: Andriushchenko et al. (2012), 'Birds and Power Lines in Steppe Crimea: Positive and Negative Impacts, Ukraine.'

[61]: Martin et al. (2010), 'Bird Collisions with Power Lines: Failing to See the Way Ahead?'

[54]: Martin (2011), 'Understanding Bird Collisions with Man-made Objects: a Sensory Ecology Approach'

The principal technical parameters affecting the degree of risk represented by a power line are the thickness of the cables, the height of the line and the number of parallel lines. Higher lines probably increase the risk of collision. Not only do the birds have to overcome a higher barrier, but relatively often they then collide with the thinner earth wire, which is found at the very top of higher tension distribution and transmission lines to protect them from lightning strikes (Figure 5.6).

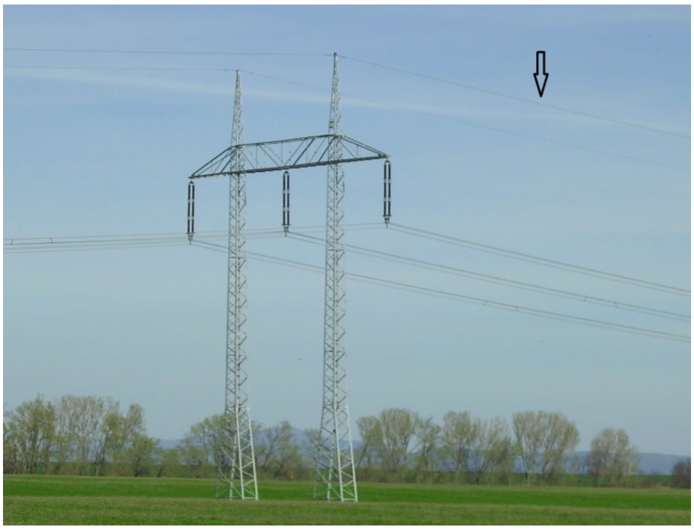

Figure 5.6: The single thin wire at the top of the power line is the earth wire (also called shield wire) that is mostly positioned above the phase conductors. Without any equipped diverters, is almost invisible for birds.
Source: Raptor Protection of Slovakia

Thus, in trying to avoid the visibly thicker live cables by flying over them [65] birds often fly into the practically invisible earth wire above them. Denser networks of parallel power lines are more visible to birds, so they manage to react to the obstacle earlier [56, 64] , and they can usually fly over sets of parallel lines with a single soar.

[64]: Bevanger (1995), 'Estimates and Population Consequences of Tetraonid Mortality Caused by Collisions with High Tension Power Lines in Norway'

[56]: Drewitt et al. (2008), 'Collision Effects of Wind-power Generators and Other Obstacles on Birds'

Data provides a strong correlation that proximity to bird habitats (e.g., rivers and water bodies, coasts, extensively used low lands) or main migration routes is a more important factor than voltage.

5.4 Mitigation Measures & Prevention of Collisions

When hazardous power lines cannot be put underground, marking the lines is one of the best solutions [65, 66] and has become the preferred mitigation option worldwide. A wide range of potential line marking devices has evolved over the years, including avian balls, swinging plates, spiral vibration dampers, strips, ribbons, tapes, plates, flags and crossed bands [3]. The effectiveness of marking lines has varied widely across studies, with primary factors being habitat, bird species, season as well as type and configuration of power lines [67, 68] .

[65]: Morkill et al. (1991), 'Effectiveness of Marking Powerlines to Reduce Sandhill Crane Collisions'
[66]: Brown et al. (1995), 'Evaluation of Two Power Line Markers to Reduce Crane and Waterfowl Collision Mortality'

[67]: Koops (1987), 'Collision Victims of High-tension Lines in the Netherlands and Effects of Marking'
[68]: Wright et al. (2009), 'Mortality of Cranes (Gruidae) Associated with Powerlines over a Major Roost on the Platte River, Nebraska'

Barrientos et al. [5] reviewed 21 wire marking devices and concluded that wire marking reduced bird mortality by 55–94%. Understanding the nature of bird collisions is essential for minimising them. To date, fewer studies have attempted to reduce avian collisions with distribution power lines, and more attention has been paid to transmission power lines [69–71] .

[69]: De La Zerda et al. (2002), 'Mitigating Collision of Birds Against Transmission Lines in Wetland Areas in Columbia by Marking the Ground Wire with Bird Flight Diverters (BFD)'
[70]: Sporer et al. (2013), 'Marking Power Lines to Reduce Avian Collisions near the Audubon National Wildlife Refuge, North Dakota'
[71]: Yee (2008), *Testing the Effectiveness of an Avian Flight Diverter for Reducing Avian Collisions with Distribution Power Lines in the Sacramento Valley, California: PIER Final Project Report*

In infrastructure planning, risk can be entirely removed by routing power lines to avoid sensitive bird areas in the first place. Once infrastructure exists, line modification is the other known approach. Line modification can take several forms, which can be broadly divided into three categories: those which make power lines less of an obstacle for birds to collide with; those which keep birds away from the power line; and those which make the power line more visible [14].

I.) Line design or configuration–less of an 'obstacle' to flying birds Birds are believed to collide most often with the earth or shield wire (the thinnest wire at the top of the power line structure (see Fig.39). At close range, birds recognise the relatively thick conductor cables and perform obstacle avoidance maneuvers that can lead them crashing into the thin shield wire. Removing this wire or designing power lines from the outset without this wire is therefore a potential collision mitigation measure. However, since these wires are used to protect the infrastructure from lightning, this is unlikely to be a widely used measure unless a viable alternative for lightning protection is developed [3] . Reducing the height and the number of pylon levels (and therefore number of vertical obstacles) lowers the collision risk. Often, low and medium voltage supply lines use well insulated cables, directly attached to support poles (see Fig.4), which is the second-best solution. Collision risk is minimised, because the highly-visible black cables replace a number of conductor wires.

[3]: APIC (2012), *Reducing Avian Collisions with Power Lines: the State of the Art in 2012*

II.) Line marking – making lines more visible to birds Line marking is the best solution for making the cables more visible to birds in flight. The presence of bird flight diverters is associated with a decrease in collision mortality [66, 70] . The placement of various designs of diverter devices on wires has shown to effectively reduce bird collisions by between 55-94% [12] and has become the preferred mitigation option worldwide. A wide range of potential line marking devices (see Annex D) has evolved over the years, including: spheres, swinging plates, spiral vibration dampers, strips, SWAN-FLIGHT Diverters, FireFly Bird diverters, bird flappers, aerial marker spheres, ribbons, tapes, flags, fishing floats, aviation balls, crossed bands (Figure 5.7).

[66]: Brown et al. (1995), 'Evaluation of Two Power Line Markers to Reduce Crane and Waterfowl Collision Mortality'
[70]: Sporer et al. (2013), 'Marking Power Lines to Reduce Avian Collisions near the Audubon National Wildlife Refuge, North Dakota'

Figure 5.7: The main used bird diverters (*from up to down*): SWAN-FLIGHT Diverter, RIBE Vogelschutzfahnen, FireFly Bird Diverter, Aviation balls.
Source: Raptor Protection of Slovakia

The various types of line marking devices require different installation techniques, including by ground bucket truck, boat, drone or other means. Some devices can be attached by hand and others need to be attached with a hot stick (Figure 5.8). Major factors impacting the cost of line marking include: line design, voltage, locations in the terrain, negotiation with landowners/users, type of selected diverter to be used, installation method, period of installation, weather, duration of installation, use of trained expert staff, use of special devices and machines and if the installation is carried out on energised or switched-off power line.

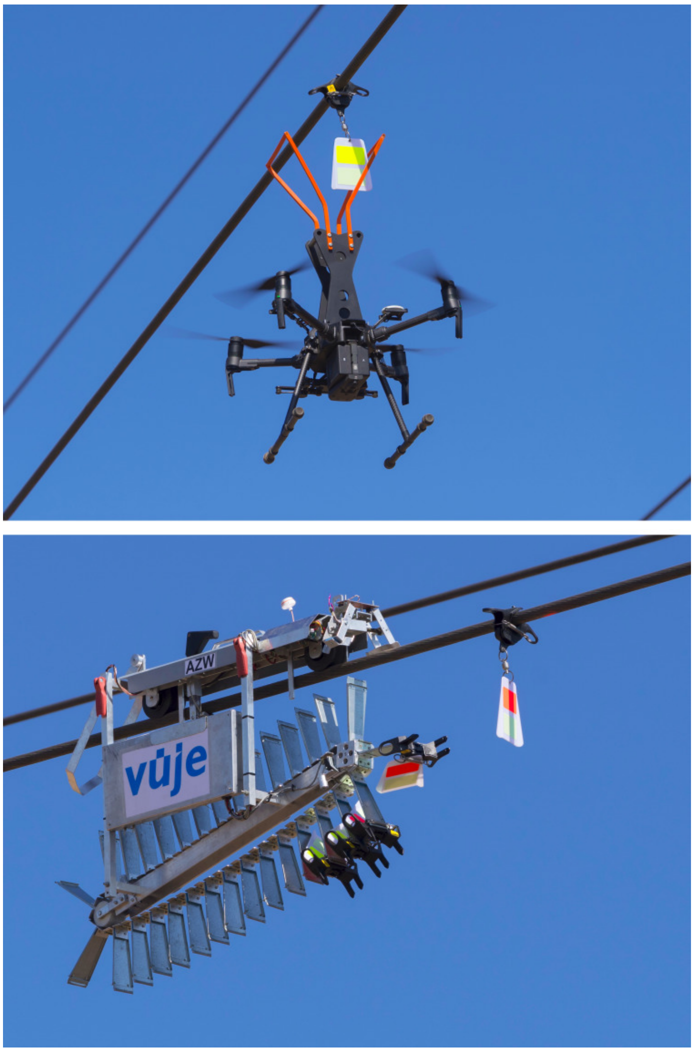

Figure 5.8: Drone and special self-movement device constructed and used for installation of FireFly Bird Diverter in Slovakia.
Source: Východoslovenská distribučná, a.s.

There is a large amount of literature available on efficiency of such marking devices in mitigating collision mortality. Some examples from the African-Eurasian Flyways region are presented in the AEWA/CMS International Review on Bird-Power Line Interactions [14] . Spacing recommendations vary depending on species considerations, environmental conditions, line location, and engineering specifications (e.g., pylon construction and statics, wind and ice loading, conductor size, and the presence or absence of the shield wire). In general, intervals of 5 to 30 m have been most commonly used and are recommended for all markers [3] .

[14]: Prinsen et al. (2011), 'Review of the Conflict Between Migratory Birds and Electricity Power Grids in the African-Eurasian Region'

[3]: APIC (2012), *Reducing Avian Collisions with Power Lines: the State of the Art in 2012*

Some of the installed devices tested have proved not to be effective in preventing collision. In Germany, orange, yellow and red diverters have been reported as non-effective, especially if they don't move (e.g. spirals) or if they are too small. Many bird species do not see colour the same as humans do, or their colour vision does not work in the dark.

In Portugal, simple spirals or pigtails diverters (Figure 5.9), either grey or alternated colors red and white, were observed as ineffective. These devices have shown to have low efficiency in reducing collision mortality (on average not more than 18%); even through the colours are better than the grey, they are not visible enough by the birds.

Figure 5.9: "Pigtail" diverter in grey colour can be ineffective in prevention of collision. Due the low level of contrast to the background, markers can be invisible for approaching birds at twilight or even at day time.
Source: Raptor Protection of Slovakia

Short life span of some wire markers (due to extreme weather or poor quality of materials used) has been one of many problems reported in Spain, as parts of or entire markers have fallen down. Another issue recorded is the maximum general effectiveness of 60%, and different effectiveness for each bird species, e.g. the great bustard.

Testing of markers has not been performed systematically and ersults from long term monitoring studies are not yet available. Bird diverters have often been installed on several sections of power lines, without their effectiveness being evaluated (e.g., in Croatia, Czech Republic, France, Latvia, Luxembourg, Poland).

Positive experiences and high effectiveness of marking devices in mitigating collision mortality have, however, prevailed. In Austria, several effective types of bird diverters were used in the past: e.g. double black and white aviation marker balls (Figure 5.10) and marker plates (alternating in contrast between black and white). Five years after underground cabling and marking of power lines within core areas of the West-Pannonian distribution range of the great bustard, the population was already subject to a significantly decreased mortality rate [10] . In recent years, the hard plastic black & white RIBE strip diverters have begun to be used on high voltage power lines.

[10]: Raab et al. (2012), 'Underground Cabling and Marking of Power Lines: Conservation Measures Rapidly Reduced Mortality of West-Pannonian Great Bustards Otis tarda'

Figure 5.10: Double black and white aviation marker balls used for 220 kV power lines (one marker per 30–35 m earth wire and conductor).
Source: Raptor Protection of Slovakia

Highest contrast bird diverters, black and white flapping diverters and FireFly markers have lead to the greatest reduction in mortality (up to 90%) in Germany. As of recently, testing of a drone-adjustable system for FireFly diverters has been underway in Hungary. Black & white RIBE strip diverters, BirdMark Afterglow, and different aerial balls are other effective products used in Hungary, showing different project results (see [10]).

[10]: Raab et al. (2012), 'Underground Cabling and Marking of Power Lines: Conservation Measures Rapidly Reduced Mortality of West-Pannonian Great Bustards Otis tarda'

Rotating FireFly Bird Diverters and rubber strap devices seem to be effective in Portugal. These devices have shown good to very good effectiveness in reducing collision mortality (on average more than 65%), even though the samples were not enough to have significant results. Rotating devices seem to be the best and they are the only satisfactory device for steppe land birds, especially great bustards.

In 2016, RPS carried out a first short monitoring scheme into the effectiveness of the BirdMark device in Slovakia. The diverter was tested by observing the reactions of swans and an effectiveness of 92% was confirmed by comparing the number of individuals flying above to the number of collisions. Within the project LIFE Energy (www.lifeenergia.sk), bird flight observations and carcass searches were carried out along distribution power lines in Slovakia. 77 km of 22 kV and 110 kV lines were marked on a total of 108 sections to evaluate the effectiveness of three types of bird flight diverters (FireFly Bird Diverter, RIBE Bird Flight Diverter and SWANFLIGHT Diverter). Numbers of carcasses were compared before and after installation of the devices and reaction distances on marked power lines were surveyed. A 94% reduction (93 vs. 6) was observed in the number of fatalities after line marking (June 2016 - June 2019), compared to before installation (December 2014 - February 2016). A 2,296 flight reactions were observed and an estimated total of 41,885 individuals (57 bird species belonging to 13 orders) were recorded with their reactions to marked lines in the period 06/2016–06/2019 [6] .

[6]: Gális et al. (2019), 'Monitoring of Effectiveness of Bird Flight Diverters in Preventing Bird Mortality from Powerline Collisions in Slovakia'

One positive and very important fact is that only some parts of potentially dangerous lines are responsible for the majority of killed birds. These sections need to be identified and treated with proper mitigation measures. RPS prepared a special methodology [72] aimed at classifying power lines according to the risk they present. The identification of those

[72]: Šmídt et al. (2019), 'Methodology of Risk Assessment for Electricity Distribution Lines in Slovakia with Regard to Potential Bird Mortality Due to Collisions with Power Lines'

power lines with the highest risk of possible bird collision requires easily accessed biological, technical, and landscape information of power line orientation relative to the important migration routes of birds, the effect of nearby tree growth (when higher than the evaluated power lines), as well as the complexity of the landscape relief.

Attaching bird flight diverters to the wire has proved to reduce, but not eliminate collisions in Spain. The best results have been had with luminous anti-collision devices, such as the Swedish FireFly Bird Diverters (as recommended by contacts in Belgium, Bulgaria, Lithuania, Romania and Sweden), as well as the black and white flapping RIBE diverter (recommended by contacts in Germany, Hungary and Slovakia). Due to the cost of marking devices, preliminary monitoring to identify hotspots where these markers are most needed should be realised. It is also important to highlight the fact, that every additionally fixed diverter causes high financial implications in case of any retrofitting mitigation, especially on an already working transmission power line system in comparison to marking of power lines during the process of construction. Furthermore, it would be worthwhile to investigate new flight diverters (including non-visual devices).

III.) Burying power lines If cases where power lines must be constructed - e.g., because no alternative routing is possible - then burying them underground offers the best solution against bird electrocution and collisions. For example, in Bulgaria, a 43 km stretch of overhead power line was replaced by an underground cable, as the most effective and long-lasting solution. Although this has relatively seldom been implemented for any significant length of line, mainly due to the technical and financial challenges (estimated at 3 to 20 times more expensive – [73] in at least certain parts of Europe, it does appear that burying power lines is more widely practised). The process of placing low voltage utility and medium voltage distribution lines underground has been completed in the Netherlands and is currently being carried out in Belgium, the United Kingdom, Norway, Denmark and Germany, and hence the severity of the electrocution problem is reducing in these regions [14] . In Hungary, for example, laying cables underground is estimated to be 20 times more expensive (approximately 48,000 €/km) than the use of the RIBE bird flappers (a type of line marker) to mitigate collisions. In Slovakia, for example, laying cables of 110 kV lines underground is estimated to be at least 650,000 €/km and for cables of 22 kV at least 50-60,000 €/km.

[73]: APIC (1994), 'Mitigating Bird Collisions with Power Lines: the State of the Art in 1994'

[14]: Prinsen et al. (2011), 'Review of the Conflict Between Migratory Birds and Electricity Power Grids in the African-Eurasian Region'

EU Legislation & Policy Framework 6

Three main international treaties address the conservation of birds of prey in Europe: the 1979 Convention on the Conservation of Migratory Species of Wild Animals (known as the 'Bonn Convention'), 1999 African-Eurasian Waterbird Agreement (AEWA) and the 1979 Convention on the Conservation of European Wildlife and Natural Habitats (known as the 'Bern Convention'). Within the EU, the Birds Directive (Directive 2009/147/EC of the European Parliament and of the Council on the conservation of wild birds) also establishes a general system of bird species protection [74] . The Birds and Habitats Directives are the cornerstones of the EU's biodiversity policy. They enable all EU Member States to work together, within a common legislative framework, to conserve Europe's most endangered and valuable species and habitats across their entire natural range within the EU, irrespective of political or administrative boundaries.

[74]: Stroud (2003), 'The Status and Legislative Protection of Birds of Prey and Their Habitats in Europe'

Guidelines on the conflict between birds and power lines have been published before. Most notable are the Convention on the Conservation of European Wildlife and Natural Habitats (the Bern Convention) published detailed guidelines to be implemented for the protection of birds on medium voltage power lines, based on Haas et al. [1] ; and the Bern Convention Standing Committee's 2004 adoption of Recommendation No. 110 on minimising adverse effects of above ground power lines. Furthermore, in 2002, CMS/COP 7 adopted a resolution (No. 7.4 "Electrocution of Migratory Birds"), which called on Parties and Non-parties to implement technical and legislative measures to mitigate the electrocution of birds on power lines, based on guidelines published in a brochure by NABU (German BirdLife partner), which is a precursor of Haas et al.. Moreover, for North America, extensive practical guidelines are available, published by APLIC [3, 15, 73] .

[1]: Haas (2005), *Protecting Birds from Powerlines: Convention on the Conservation of European Wildlife and Habitats (Bern Convention)*

[73]: APIC (1994), 'Mitigating Bird Collisions with Power Lines: the State of the Art in 1994'
[15]: APIC (2006), *Suggested Practices for Avian Protection on Power Lines: the State of the Art in 2006*
[3]: APIC (2012), *Reducing Avian Collisions with Power Lines: the State of the Art in 2012*

Guidelines for mitigating conflict between migratory birds and electricity power grids were prepared and adopted in 2011 by the AEWA and CMS (Bonn) Conventions (reported prepared by Prinsen et al. [14]. The report presents the available information (including references to other reviews) on the topic from the wider area of the African-Eurasian region. All of these documents summarise the latest technical standards on electrocution mitigation and review and present guidelines to mitigate collision risk for birds, a topic that received less attention in both the guidelines of the Bern Convention and the 2002 CMS Resolution 7.4.

The Position statement of BirdLife International „On the risks to birds from electricity transmission facilities" and how to minimise any such adverse effects has been prepared by Rybanič in 2007, derived from materials prepared by NABU, presented by [1]. The Position statement defines the main adverse impacts of power lines on birds and appeals for urgency in addressing and minimising the ongoing worldwide threat to birds from electrocution, collision and loss of habitat availability due to electricity transmission facilities.

After years of bilateral negotiations between stakeholders, all three utility companies in Hungary, the Ministry of Environment and Water (MEW), and MME/BirdLife Hungary signed the 'Accessible Sky' agreement in 2008. They pledged full cooperation in all aspects to efficiently reduce electrocution and collision problems. The Coordination Committee of the agreement has come to be the most important forum for problem solving. It convenes at least twice a year to discuss plans, implementation and monitoring. Both reactive and proactive actions are undertaken with the announced goal to retrofit all dangerous lines before 2020. Also in Hungary, the Budapest Declaration on bird protection and power lines has been adopted by the conference 'Power lines and bird mortality in Europe' (Budapest, 13 April 2011). The declaration called on all interested parties to jointly undertake a programme of follow up actions leading to effective minimisation of power line-induced bird mortality across the European continent and beyond.

Other national and international initiatives, such as the Renewables Grid Initiative (RGI) and The Energy & Biodiversity initiative take action by adopting technical standards; contributing to the development of safer power lines, better planning, anti-collision measures; minimising harm to biodiversity; as well as by supporting environmental and nature conservation projects (e.g., the LIFE+ programme).

In some cases, certain lines can be removed as the technology advances. For example, in some countries, overhead telephone and telegraph lines are being dismantled. In addition, favourable trends are reported from low and medium voltage networks of some utility companies, which are making the step to change from overhead to underground power lines [1] .

[1]: Haas (2005), *Protecting Birds from Powerlines: Convention on the Conservation of European Wildlife and Habitats (Bern Convention)*

6.1 National Legislation, Legal Obligation, Standards & Cooperation

All 27 EU countries are contracting parties of Bern Convention, Bonn Convention, CITES and AEWA and almost all countries have legislation that brings the construction of power lines under a regime of an Environmental Impact Assessment (EIA), which should take into account existing habitat and wildlife conservation legislation, including for birds [14] .

[14]: Prinsen et al. (2011), 'Review of the Conflict Between Migratory Birds and Electricity Power Grids in the African-Eurasian Region'

An important step in the legislative and organisational approach of the conflict between power lines and birds is cooperation between government agencies and/or NGOs with the electrical utility companies on a voluntary basis. The first step by conservationists dealing with this issue should therefore be to aim for a collaboration with the relevant utility companies, realising that energy supply is an overriding public interest. Examples of such successful cooperation between electricity companies, government agencies and/or NGOs exist in Czech Republic, Germany, France, Hungary, Portugal, Slovakia, Sweden etc. From the questionnaires returned, it is clear that a lot of countries over the years have developed national legislation and/or adopted also legislation that brings the building of power lines under a regime of an Environmental Impact Assessment (EIA) (see Annex E for overview).

Detailed responses to the questionnaire in this area have been provided by 23 countries. Responses given by NGOs, experts and electricity companies include: brief summaries of general and/or specific national legislation and/or national regulation and legal obligations of owner/provider of the power line; electricity company standards in the area of bird protection; cost coverage for bird protection methods; internal technical guidelines of electricity companies and memoranda and agreements of cooperation between companies and nature protection organisations, NGO, etc

For some countries, due the insufficient quality of provided data and/or missing replies and answers, this information was taken and combined with the results of questionnaire survey in study Prinsen et al. [14] .

[14]: Prinsen et al. (2011), 'Review of the Conflict Between Migratory Birds and Electricity Power Grids in the African-Eurasian Region'

Austria: It is important to note that in Austria, there is no legal obligation for bird protection measures on overhead lines (unless they are prescribed by the authorities in individual cases of a construction project) but EIA procedures are in place on high voltage power lines. A high percentage of medium voltage lines are already underground. Marking on wires has taken place for specific areas such as Natura 2000 sites and especially those areas important for the great bustard. Approval procedures for power lines may include the application of mitigation measures [14].

Grid operators must themselves cover actions such as consultations by BirdLife Austria, database management for projects, and implementation (i.e. buying and fitting). However, there are official approval processes, in the course of which mandatory regulations for the operator can be made. It is therefore important for BirdLife Austria to inform the authorities about the dangers of overhead lines and solutions for bird protection. In principle, the agreement with grid operators is good. However, projects that are too big cannot be carried out in this way, as they are simply too expensive.

Belgium: Once a permit is granted, no additional requests can be imposed - these must be imposed in the permit to construct the line. TSO Elia reacts to the reports of bird collisions under high voltage lines by contacting specialised NGOs to identify the "black lines" and to advise them on the best management in order to mitigate the number of collisions. Elia's internal policy is to take into consideration the results of the NGOs' studies and to place markers where proposed in the studies.

Bulgaria: There are no legal obligations for newly built or reconstructed power lines to be bird-safe. The authorities might request the owner to insulate a particular pylon if a legally protected bird specimen as been electrocuted on it, but there are no legal obligations. No internal guidelines on the part of the Bulgarian grid operator are publicly available. There is a good cooperation on specific issues in particular areas but large scale cooperation for change in the state policy and retrofitting of all hazardous power lines is lacking.

Croatia: The National Strategy and Action Plan on Biodiversity addresses this issue as well. Planning and construction of power lines is subject to detailed EIA procedures [14] . Following the Regulation on conservation objectives and basic measures for the

[14]: Prinsen et al. (2011), 'Review of the Conflict Between Migratory Birds and Electricity Power Grids in the African-Eurasian Region'

conservation of birds in the ecological network (OG 25/20 and OG 38/20), measures for conservation in the field of electricity include 23 bird species endangered by electrocution. Measures include planning and constructing new electricity infrastructure to prevent electrocution of birds on medium voltage lines and implementing measures for preventing bird fatalities on the existing transmission lines where an increased risk of electrocution is identified by monitoring.

TSO HOPS complies with the relevant national legislation regarding the design and construction of transmission lines by installing diverters on power lines to prevent collisions. In the case of the detection of high risk for bird collision with a certain transmission line, the owner/provider of the line has a legal obligation to install diverters to prevent collisions.

DSO HEP is committed to reducing its negative impacts on biodiversity and the environment, as electrocution has proved to be a significant threat to some protected bird species. The company is working on this and implementing their own solutions.

It is very important to establish good cooperation between different sectors in solving common problems. Joint innovative technical solutions against bird collision have become possible through cooperation between the energy sector and the conservation sector, with the latter's knowledge on species' biology and ecology. For example:

- **Special agreement for protection of White Stork** with Ministry of Environment and Energy since 2004 (revision 2016).
- **Implementation of bird protection measures** in Natura park Lonjsko polje (2018-2019)
- Associated Beneficiary in project **"Transnational conservation of birds along Danube River"** (LIFE DANUBE FREE SKY)
- **Memorandum of cooperation** with Birdlife partner in Croatia-Association BIOM since 2016.
- **Active stakeholder** in national action plans for protection of *Gyps fulvus*, *Coracius garrulus* and *Aquila chrysaetos*.

In 2019 PINPKR and HEP DSO signed Memorandum of Cooperation. This Memorandum of Cooperation intends to foster and further develop the cooperation among Public Institution Nature Park Kopački rit and HEP DSO to protect birds at power lines along the Danube. TSO HOPS has been taking appropriate actions to prevent bird mortality regarding collisions with power lines. The cooperation is based on joint participation in projects of nature and landscape conservation.

Cyprus: No memorandum, agreement or contracts are in place.

Czech Republic: Based on Act no. 114/1992 Coll., on nature and landscape protection, everybody who builds or reconstructs high voltage lines has to apply efficient protective measures to prevent birds from being killed by electrocutions.

According to Act no. 114/1992 Coll., on nature and landscape protection, natural and juridical persons must act in such a way to avoid excessive death and injuries to animals, which can be prevented by technically and economically available measures (the energy sector is explicitly mentioned). If this is not done, the implementation of such mitigation measures can be ordered (however, in practice, enforcement is very rare).

The law defines an obligation for distribution grid operators to ensure protection for birds on power lines before 2024. This fact motivates them to cooperate - but there is no penalty if they do not keep to the limit of 2024, hence the function of this time limit is weak. Obtaining and keeping a positive image in the eyes of the public is another motivation of companies. In 2016, the Ministry of the Environment issued binding Guidelines for bird protection against electrocutions. Distributors collaborated on these guidelines and they should comply with the rules they stipulate. The organisation ČSO cooperates with the company E.ON ČR, a. s., on the basis of fixed-term contracts.

In the above-mentioned methodological Guidelines and methodological Guidelines prepared by Ministry of the Environment of the Czech Republic, , grid operators endeavoured to only include bird-safe components in their technical requirements for component providers. Written assessments of components' safety carried out by the Czech Nature Conservation Agency are available to grid operators. Currently, E.ON Disitribuce, a.s. fulfills the commitments of the Guidelines, while ČEZ Distrubce, a.s. only partially fulfills them.

To date, cooperation with the E.ON Distribuce, a.s. is rather positive, whereas coooperation with ČEZ Distribuce, a.s. is not optimal. Given the negligible amount over overhead lines they manage, no coopeation is ongoing with the company PRE Distribuce, a.s. In general, the problem lies in slow rate of replacing dangerous poles or their refitting with protective measures. Timing and organisation of reconstructions is also an issue, as this seldom takes full account of birds' specific protection priorities. The costs are covered by the providers of the lines.

Denmark: A decision has been taken on a major project to underground all power lines, starting with the lower voltage ones and later, pending technical solutions, also higher voltage power lines. This decision is directly related to the considerable increase in the number of wind turbines and therefore a much denser power line network. Besides this long term and costly plan, EIAs must always be carried out and their outcome can influence a change in the routing and transects of power lines, or a decision to partially place them underground e.g., when crossing wetlands, larger streams, valleys etc. is unavoidable. Protected areas will, as much as possible, be avoided [14] . Environmental Assessments (Natura 2000-Assessments) are carried out to determine whether there is a need for mitigation methods, while legal obligation is linked to the Habitats and Birds Directives. Cooperation is based on joint participation in projects for nature and landscape conservation.

[14]: Prinsen et al. (2011), 'Review of the Conflict Between Migratory Birds and Electricity Power Grids in the African-Eurasian Region'

Estonia: There is no specific legislation on the topic of birds and power lines, but there are EIA procedures which must consider the issue. There are strong efforts to place power lines underground [14] .

[14]: Prinsen et al. (2011), 'Review of the Conflict Between Migratory Birds and Electricity Power Grids in the African-Eurasian Region'

Environmental assessments considering the need for mitigation measures and line markers on new power lines are carried out.

Finland: The problem is neither recognised in national legislation, nor environmental policy, and neither national standards nor mitgiation guidelines are available. Grid operators have their own guidelines on bird mitigation measures, for example they may choose to use ball markers and place short transects underground. Mitigation by the companies focuses on outage prevention and aircraft safety and there are some bird related recommendations [14]. Companies are reportedly interested in the issue and cooperative (i..e willing to receive information), but so far no discussions have been held on alrger scale projects or monitoring, and indeed NGOs have no allocated resources for particularly this. One small scale co-operation agreement exists between an NGO and the DSO, Elenia. The overall lack of data from Finland explains why this issue is currently very present, despite being a potentially major conservation problem.

France: Currently, there is no real legal obligation for new lines to be bird-safe, however it is increasingly common to see bird-friendly materials used for new constructions (e.g. different types of poles). There is an awareness that agreements help to encourage bird-friendly industrial practice and, generally, risk to birds is taken into consideration.

Cooperation between grid operators and NGOs is improving, and a ’common language’ has been found. A reported problem is the turnover of staff in the companies.

Grid operators do have some guidelines, but these are not shared openly. NGOs and experts currently help the process by providing training for teams, but this is not sufficient. However, it is encouraging to see that birds are considered in planning of works.

Germany: For new constructions of medium voltage power and railways lines, § 41 of the Bundesnaturschutzgesetz (Federal Nature Conservation Act) on bird protection on power lines applies. The law reads, "For the protection of bird species, newly erected masts and technical components of medium-voltage lines must be constructed in such a way that birds are protected against electric shock. On existing masts and technical components of medium voltage lines with high risk to birds, the necessary measures to protect against electric shock must be carried out by 31 December 2012. The retrofitting of dangerous pylons has been obligatory since 2009, but has still not been entirely fulfilled. Furthermore, the application guide VDE-AR-N 4210-11, which contains obligatory technical solutions for medium voltage power lines has been available since August 2011 (as an implementation guide for the Federal Nature Conservation Act), and this proceeds the VDEW Measurement catalogue.

One of the most important milestones for bird safety on medium-voltage power lines was the reinstatement of the article on bird protection in the technical standard DIN VDE 0210 (VDE 0210):1985-12, which states that "the crossarms, insulator supports and other elements of power lines shall be designed so that birds cannot perch in dangerous vicinity of energised conductors". When an electrocution occurs and is documented (although this is not centralised by the government), providers must either upgrade constructions to prevent electrocutions (as per the VDE guidelines), or install diverters on power lines to prevent collision. In rare cases, critical configurations are ignored and brought to court by the NGO, NABU or other organisations.

Transmission grid operators have to carry out an EIA for every new 380-kV-grid project and often have to fulfill official requirements for installing bird diverters. However, there is no legal requirement for the retrofitting of power lines.

4 TSOs and 2 DSOs cooperate under the Renewables Grid Initiative (RGI)/NABU project "Bird find & power line portal" (Portal Vogelfund & Stromleitung), by funding the project and carrying out some own research on bird collision (e.g., TSOs 50Hertz, TenneT) or even holding conferences on the topic (e.g., 50Hertz in October 2017, Amprion in April 2018). This also helps them to gain recognition for social and conservational acceptance.

Grid operators also have their own internal guidelines, for example the TSO 50Hertz's guidelines on bird protection (March 2018) and guidelines on ecological line management (TSOs 50Hertz and Amprion).

The TSO-NGO network of RGI is based on a memorandium of understanding, the European Grid Declaration. Under this, another project 'BESTGRID' ran in 2014 and 2015 in 3 European countries (with 2 grid projects in Germany). No such agreement has been made between with medium voltage grid operators. There is an ongoing struggle for more legal requirements since 2014 with the German railway, especially over a request by NABU to stop the use of pin type insulators.

The main resources to cover the cost of mitigation measures come from company budgets (electricity tax), and in the case of grid development projects, costs are partially or refunded by the Federal Grid Agency, BNetzA.

Greece: Providers' obligations are currently under investigation by the HOS policy team. In practical terms, until this day companies are not obliged to do something.

Cooperation with power utility companies is gradually developing during the last 5 years but it is still very weak. Project-specific memorandums. No national-scale implementation plan has ever been adopted.

Hungary: The general basis of legal responsibility in the field of environmental protection and nature conservation is laid down in Law for protection of the Environment (Act LIII. /1995/ on the Protection of the Environment) IX. Chapter 101-102. §. Power line companies are declared as environmental users. The environmental users' obligation to cover environmental measures includes measures to prevent damage to the environment and restore the damage that has already occurred.

Special rules for protected areas and species of nature conservation concern are laid down in Law for Nature Conservation (Act LIII /1996/ on Nature Conservation) 78/A §.

The Nature Conservation Law was changed in 2009, forcing grid operators that newly develop or rebuild power lines to do this in a bird-friendly manner.

Anyone building or planning an aerial (overhead) power line is requested to use a technical solution which prevents electrocution:

7 § (5) When installing aerial power lines, and when renovating / reconstructing a medium voltage aerial power line over a distance, technical solutions shall be applied that do not endanger wild birds.

43 § (1) It is forbidden to disrupt, damage, torture, destroy, proliferate and otherwise endanger individuals of protected species, or to destroy or damage their living, feeding, breeding, resting or hiding places.

78 / A. § The species and their habitats, feeding and rest areas, natural habitats, protected natural sites and protected natural values specified in each separate law, Section 10, point 10 and impairment of point 13, the criteria for determining the degree of damage and the order of prevention and restoration of the environment shall be determined by the Government. These Government Decrees are as follows:

- Decree 90/2007 on the Prevention and Remedy of Environmental Damage; (IV.26.) Government Decree,
- Decree 91/2007 on the Determination of the Damage in Nature and the Remedies Regulations. (IV.26.) Government decree.

Both laws cover the species, habitats, feeding and resting places as defined in the EU Birds and Habitats Directives. This especially applies to protected species, Natura 2000 sites and nationally-protected natural areas.

The law regulating the electricity sector and the work of grid operators (VET) (Act LXXXVI. /2007/ regulating electricity service and work of electric companies) complies with environmental and nature protection considerations as follows:

78 § When granting new production capacities in a transparent way, in compliance with the requirement of equal treatment, the following criteria shall be applied: (a) the security of the electricity system and its components; the protection of public health and public security.

96 § subsection (da) of section (1), the licensing office is obliged to withdraw the license if the licensee is unable to meet his obligations or the electricity company is responsible for security of supply, life, health, plant and property security, operating in a seriously endangered environment.

So far, the problems have always been solved after mutual communication, either by upgrading constructions to prevent electrocutions or installing diverters on power lines to prevent collisions. Since 2017, implementation of bird friendly retrofitting mitigation or reconstruction works, grid operators have begun considering the protection of birds at the very beginning of planning procedures to prevent collisions and electrocution. A good, cooperative relationship has been built between NGO - name - and grid operators, and is perceived to be more effective, useful and important than the legal obligations. However, in some cases (e.g. large scale mortality of protected species, or planning old scheme solutions on distribution power lines, the 91/2007 (IV.26.) Government Decree should be heeded in order to hinder further incidents.

All companies have internal guidelines on procedures in case of electrocutions, and perhaps also clearly defined ways to handle certain types of constructions, or certain diverters which are used for specific occasions. These guidelines are updated regularly. BirdLife Hungary has also worked with partners on internal guidelines for nature conservation authorities and National Park Directorates based on results of the KFO survey and modelling of geometry and scaling of new bird-friendly pylon head structures for the distribution grid. The costs for protection of birds from power lines are covered mostly by the European Union under LIFE projects, "KEOP" and "KEHOP" projects, by grid operators themselves and also the Ministry of Environment of Hungary, perhaps with the support of other donors.

Cooperation is good and it is still working in term of electrocutions. Grid operators have a responsible approach to the matter, but in some cases it requires more firm action. Cooperation is good and, in the case of electrocutions, is ongoing. The TSO MAVIR is committed to the matter and regularly initiates joint project proposals. The cooperation is based on the Accesible Sky Agreement (2008), which brings together all grid operators, the Ministry of Environment and MME BirdLife Hungary. Partnerships have also been organised for several other projects, for example through LIFE projects, or subcontracts with NGOs, whereby grid operators cover the main costs of products used for retrofitting and mitigation measures.

Ireland: Unknown

Italy: At the national level, the legislative interest in issues related to the possible impacts caused by power lines dates back to 2001, when the official "Framework law on the protection from exposure to electric, magnetic and electromagnetic fields" (Legge quo sulla protezione dall' esposizione a campi elettrici, magnetici, e elettromagneticadri n°36 of 22.02.2001). Paragraph 2 of article 5 of this law emphasises the need, subject to the opinion of the Committee referred to in article 6, and following hearing the component parliamentary commissions, to adopt measures to reduce electrical risk (of power lines, mobile telephone and radio broadcasting systems), and in particular the risk of electrocution and bird collision. Furthermore, paragraph 1 of the same article 5 provides for the issue of a specific regulation, in which "specific measures are adopted relating to the technical characteristics of the infrastructure and the location of the routes for the design, construction and modification of power lines. The decree of 17 October 2007 of the Ministry of the Environment and Land and Sea Protection published in the Official

Gazette no. 258 of 6-11-2007 concerning “Minimum criteria for the definition of conservation measures relating to Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) "provides in Article 5 for all SPAs: in point 2. b) the obligation, by autonomous regions and provinces, to ensure the safety, with respect to the risk of electrocution and collision of birds, of high and medium voltage power lines and overheads lines of new constructions, or under specific maintenance or renovation. Furthermore, point 3. b) encourages the the removal of aerial cables from disused power lines. Some regions have also issued specific regulations on the prevention of collision with power lines [75] .

[75]: Pirovano et al. (2008), ‘Linee Guida per la Mitigazione Dell’impatto Delle Linee Elettriche Sull’avifauna’

Latvia: The legal obligations of power line owners/providers when (re)constructing lines are not strictly defined. Cooperation is perceived as fairly good, but insufficient. The costs for bird protection measures are covered by the European Union and the Latvian state under a project of ’grid building and reconstruction’.

Lithuania: In the Republic of Lithuania, installation of power lines is regulated by the Rules for the Installation of Electrical Lines and Wiring approved by the Ministry of Energy. These Rules set out the technical parameters for how overhead lines must be installed; specifies the distances, materials and layout of wires; and also gives specifications for the installation of power lines across forests and above water bodies. The Rules specify the necessary distances between overhead power lines and water bodies, trees and green spaces. The Rules do not provide for any specific requirements or recommendations regarding conservation of biodiversity, which is ensured while drafting technical projects. When building new overhead power lines or reconstructing the currently existing power lines in Lithuania, an Environmental Impact Assessment (EIA) needs to be carried out. During this assessment, especially in recent years, significant attention is paid to the protection of birds in sensitive ornithological areas. For these areas, EIAs provide various measures to reduce negative effects on birds and to ensure better protection in planning.

Luxembourg: It is also unknown if grid operators have internal guidelines. The majority of power lines in Luxembourg are planned as underground lines. Cooperation is perceived as good, and TSO Creos has been known to react quickly and take immediate measures of their own accord.

Malta: Unknown

Netherlands: All low and medium voltage distribution lines have been placed underground.

Poland: Bird species are protected by the Ramsar, Bonn and Bern Conventions, as well as by Polish nature protection law. Today, the fundamental legal measure concerning wildlife protection in Poland is the Wildlife Conservation Act of April 16, 2004 (Journal of Laws, No. 92, item 880), whereas the protective status of individual species is determined by the related order of the Ministry of the Environment of September 28, 2004, on wild animal species subject to protection (Journal of Laws, No. 220, item 2237) (Dolata 2006).

There are 2-3 general sentences on the topic in the main operator's policies, however there are no known specific internal guidelines for ecological power lines.

The legal obligation of power line owners/providers is to follow the EIA process and obey environmental decisions by regional nature conservation authorities. They usually require mitigations measures (e.g., bird diverters) for big investments, as well as pre- & post-construction monitoring. This is reported, but not made public (as the investors' finances are involved, it is classed as private data).However, lower voltage levels (less than 60 kV) are usually constructed and operated without an EIA, which means no monitoring and no mitigation is done. In theory, they act according to EU Directives, so that mitigation is required and they usually install bird diverters to power lines and carry out some monitoring. The cooperation with public utility companies is weak, as the problem of the collisions and electrocutions is not well enough studied, proven or understood.

Such measures at the stage of power line construction are usually funded by investors. Small actions are done by NGOs with their own funds from different small projects.

Portugal: DSO EDP Distribuição is the sole owner of the lines and is obliged, in the implementation and maintenance of lines, to keep the electricity supply in a good condition. Although there is a free market for electrical energy supplies, all suppliers use the national grid which is owned and maintained by EDP Distribuição. When the line crosses a private property, the owner can request payment for each pylon upon construction. An environmental license is required to build medium tension power lines. It stipulates that if power lines are situated inside protected areas, the national conservation authority requires a preliminary technical opinion and mitigation measures specific to this power line type, if needed.

All retrofitting done by EDP Distribuição to date on existing power lines has been voluntary. As mentioned above, for new lines in protected areas, national institutions can oblige the implementation of mitigation measures. For high-voltage power-lines, because they need to go through an EIA process, they are subject to obligatory mitigation devices against collision when they are placed in areas which are sensitive for avifauna.

Cooperation with the public utility companies is perceived as good and tends to improve with the possibility of LIFE projects to implement mitigation measures and identify dangerous power lines. This is especially the case with EDP Distribuição and a cooperation exists between with name of NGO. Cooperation is based on contracts for the identification and monitoring of dangerous power lines, as well as for the development of methods to better identify these power lines. In terms of implementation of mitigation measures, there are valid agreements for Birds and Power Lines Protocols and contracts for LIFE projects.

TSO REN has adopted guidelines which set the criteria by which a new line requires anti-collision devices. EDP Distribuição has an internal norm, developed within protocol Avifauna III, which defines criteria for planning and retrofitting new power lines, in ecologically sensitive areas. The Institute for Nature Conservation and Forestry (INCF) - a public institution - has public guidelines for the evaluatio of linear infrastructure (ICNB, 2008. Manual de apoio à análise de projectos relativos à Implementação de infra-estruturas lineares).

There are some LIFE funded projects which apply mitigation measures for the protection of birds. The Birds and Power Lines Protocol ´also implements mitigation measures on identified dangerous power lines and the costs are covered by EDP-Distribuição, the sponsor of the project.

Romania: Regarding the implementation of "Nature 2000" Network, Romanian legislation transposed the provisions of the two Directives through Government Emergency Ordinance No. 57/2007 on the regime of protected natural habitats, conservation of natural habitats of flora and fauna approved with amendments by Law No. 49/2011, the Minister Order No. 2387/2011 on the establishment of protected natural area regime for the sites of community importance and by Decision No. 971/2011 regarding the declaration of Special protection areas as integrant parts of the European ecological network „Nature 2000" in Romania (Ministry of Environment and Forests). The law is not very clear when a high risk for birds on a certain power line is detected. If the power line affects protected species, then the authorities should be notified. They will then start an investigation, which could result in companies being required to take action in order to mitigate this impact.

Grid operators do have internal protocol how to proceed in case of electrocutions. All incidents are internally reported and organised in a database. Grid operators also have their own prioritisation of problematic power lines. They tend to focus on locations with the most inicidents which caused power failures.

Some initial steps towards collaboration with grid operators have been taken. In some projects, on specific sites, there have been collaborations on these subjects (collisions and electrocution) but there is no extended action. Discussion with all companies from this sector already started, some years ago, but no memorandum, agreement or contract regarding this were signed. Mutual agreements are signed between DDBRA and grid operators.

Slovakia: The Law 543/2002 Coll. on the conservation of nature and landscape says: § 4 (4) Everyone building or planning an aerial power line, is requested to use a technical solution that prevents the electrocution of birds. (5) If a proven electrocution takes place on a power line or telecommunication devices, a nature conservation authority can decide that the administrator must undertake technical measures to prevent electrocution of birds. So far, the problems have always been solved after mutual communication, either by upgrading constructions to prevent electrocutions or installing diverters on power lines to prevent collisions. Since implementation of the LIFE Energy project, all grid operators in Slovakia have now consider the protection of birds even in the initial preparation and planning phases, in order to prevent collisions and electrocution.

The good relationship, cooperation and trust that was built with the grid operators is far more effective, useful and important than the obligations set by the law. Also very good cooperation has been strengthened with the State Nature Conservancy of the Slovak Republic. Some electric companies do have internal guidelines (the Eastern Slovakia Electricity Company issued an internal technical norm called: 'Construction and amendment of aerial 22kV power lines with respect to bird protection.') on how to proceed in case of electrocution, and have perhaps clearly defined ways to handle certain types of constructions, or which bird diverters to use for a specific occasion. These guidelines are updated regularly based on recent findings. The costs for protection of birds from power lines are covered mostly by the European Union under LIFE projects, from the grid operators' resources and by the Ministry of Environment of the Slovak Republic, perhaps with the support of other donors.

Slovenia: Unknown.

Spain: In accordance with Spanish legislation (REAL DECRETO 1432/2008, de 29 de agosto, por el que se establecen medidas para la protección de la avifauna contra la colisión y la electrocución en líneas eléctricas de alta tensión), it is only obligatory for owners of the power lines to mark the lines to avoid collisions and for new power lines within protected Natura 2000 areas to have a bird-safe design.

The costs of mitigation measures are covered mostly by the European Union under LIFE projects, from the Ministry of Environment of Spain and the regional administration, perhaps with the support of grid operators' resources.

Sweden: The national law of Sweden is rather weak in this aspect, although the law regulating electricity distribution has a paragraph saying that "concession should save common interests and civil rights and protect human health and the environment from damage and inconveniences". There is a very detailed permit process, especially on 30-400 kV, for building new powerlines. The owner carrying out the construction must show how the power line will affect the environment in different ways. The companies must also describe if measures are to be taken to reduce the risks for birds and other environmental aspects. In general, the company must carry out field studies to describe what species exist in the planned area. In environmental law there is nothing specific about birds. The legislation on EU-level is followed and incorporated in Swedish law, such as the Birds Directive. Some grid operators do have internal guidelines and work continually to reduce the company's environmental impact and to prevent bird mortality. Some adopted standards are: the 0.4-20 kV grid is always built with isolated lines or underground; pole mounted transformers are built with insulator protection and isolated slacks up to phaselines. The prescribed distance between phases on uninsulated power lines of between 40-50 kV has been increased from 1350 to 1600 mm. Electricity companies must cover the costs for the protection of birds from risks of power lines themselves. In the end, these costs are paid for by customers / power consumers.

In particular, EIA procedures are in place in most countries, guarantee that the interests of nature are generally taken into account. Almost all countries apply mitigation measures against both electrocution and collision from the very beginning of a power line construction. Many electricity companies / grid operators also have internal guidelines on procedures in case of electrocutions, and some may have clearly defined ways to handle certain types of constructions, or which bird diverters to use for which occasion etc. These guidelines are updated regularly based on recent findings. A high percentage of medium voltage lines are already underground in Austria, Netherlands, Germany, Luxembourg and Sweden. Policy of many TSOs is compliant with the relevant national legislation concerning the design and construction of transmission lines by installing diverters on power lines to prevent collisions. Cooperation between experts and public utility companies is a very good, positive step and the likelihood of this tends to increase with the possibility of LIFE projects to implement mitigation measures and identify dangerous power lines. It is also based especially on contracts for identifying and monitoring dangerous powerlines, as well for developing methods for better identify this powerlines. Cooperation with power utility companies is gradually developing and most companies retrofit power lines after incidents very quickly. In many cases, the good relationship, cooperation and trust built with electricity companies are far more effective, useful and important than the obligations set by the law. The costs for protection of birds from power lines are covered mostly by the European Union under LIFE projects, financed by the electricity companies / grid operators and also the relevant ministries, perhaps with the support of other donors.

6.2 Organisations Dealing with the Topic on National Level

Austria: Electrocution is mainly handled by BirdLife Austria. Above all (but not only) in the case of collisions, there are initiatives in (LIFE+) projects (e.g., on the great bustard) from the federal states, operators etc. There is no known list of activities which summarises all the measures taken and those responsible.

Belgium: Natuurpunt and Natagora are two NGOs working in nature conservation. They are specialised in bird monitoring and protection. Elia asked them to assist with the management of power lines to avoid and reduce bird collisions. Until 2017, Elia also lead a LIFE-Nature project to improve biodiversity under power lines (`https://www.life-elia.eu/`)

Bulgaria: Bulgarian Society for the Protection of Birds and the three private companies implement common EU funded projects aiming to protect endangered species that die from electrocution and collision. The priority species are the imperial eagle (*Aquila heliaca*), the egyptian vulture (*Neophron percnopterus*), the griffon vulture (*Gyps fulvus*) and the dalmatian pelican (*Pelecanus crispus*). Other NGOs and Nature Parks also work on local level for safeguarding power lines in specific areas.

Croatia: On a higher level, the Ministry of Economy and Sustainable Development has the authority on conservation objectives and measures for target bird species in ecologically important network areas. There are also several NGOs (such as the Association BIOM and the Croatian Society for Birds and Nature Protection) who deal with these problems, conduct monitoring for different protected areas in Croatiaa nd also suggest mitigation measures that can be incorporated into important documents. TSO HOPS cooperates with manufacturers of products for protection of birds from collisions and prepares plans for implementing the best solutions to eliminate the risks. Before implementation, these solutions are discussed with local experts. HEP DSO conducted a survey in cooperation with Association BIOMm (Birdlife partner in Croatia) to identify priority sites, i.e. possible hotspots for electrocution in selected Natura 2000 SPAs. HEP DSO also finds solutions and funds mitigation of electrocution on its own, as there aren't any guidelines on national level.

Czech Republic: The Nature Conservation Agency of the Czech Republic (an expert body of the Ministry of the Environment) issues expert opinions about the safety for birds of particular components of the transmission system (e.g. console), negotiates methdological approaches and new technical solutions with the Ministry of Industry and Trade and with the providers of the transmission grid. It also insists on the use of bird-safe components in the transmission grid, is an advisor for other nature conservation authorities and organises monitoring of power lines. The Czech Society for Ornithology (NGO) and its regional offices collect data, identify dangerous power lines, negotiate with grid operators and insist on the use of bird-safe components, as well as on the retrofitting of the most dangerous poles and power line sections. They also cooperate with NCA and the Ministry of Environment and participate in the evaluation of safety of grid components for birds and develop methodological and conceptual materials. The Czech Union for Nature Conservation (NGO), as the "umbrella organisation" of rescue states in the Czech Republic, ensures data collection and also insist on the use of bird-safe components.

Cyprus: The Game and Fauna Service is the competent authority for birds in Cyprus. Also partners involved in projects with relevant activities (e.g. Akrotiri Salt Lake Antennae Project, LIFE with Vultures, LIFE Oroklini, LIFE Bonelli East Med) have responsibilities laid out as part of project activities and project partnership agreements.

Denmark: Danish Ornithological Society (NGO); Environmental Agency (related to permits and Environmental assessment); Consultancies (related to concrete projects); Energinet (Grid operator - related to concrete projects and existing infrastructure).

Finland: More or less all power companies, such as Elenia and Finngrid are interested in receiving more infomration about sensitive sites.

France: The State (regional scale: DREAL & OFB)and NGO by means of agreements. There is at least 10 years of long cooperation to date, including 4 agreements with Enedis aiming to mitigate risk of electrocution of birds of prey (namely the Bonelli's eagle), collision and training Enedis teams in bird conservation. Another priority is the identification of dangerous grid portions for birds in high-stake areas.

Germany: NABU federal association and NABU expert group „BAG Stromtod" (communication and policy work on the issue on federal level, task force member with railway German railway and VDE working group member on collision mitigation means); Deutsche Umwelthilfe e. V. (DUH) (political guidelines on grid extension); EGE Eulen e.V. (local policy work on risks for owls and raptors through medium voltage, especially in Northrhine-Westfalia; Kommitee gegen den Vogelmord e. V. (mainly focussing on illegal shooting); Authorities: Brandenburg office for bird protection (collecting data); Federal association for nature conservation (BfN) (initiating and funding of research projects on bird protection); Deutsche Bahn (German railway company) and Federal railway office (bird protection on railway power lines and poles)

Greece: HOS (Birdlife Greece) and rehabilitation centres. There is no division of goals and responsibilities.

Hungary: BirdLife Hungary (MME) coordinates field surveys of KFO project (Monitoring of medium-voltage power lines) and cooperates with producers of products the protection of birds from electrocution and collisions. National Park Directorates deal with collisions, monitoring the victims and preparing a heat map of relevant sections of transmission power lines for MAVIR. MME is also preparing plans for implementation of various solutions to eliminate the risks.

Italy: Lipu has carried out a study with Terna (national transmission grid operator) on the impact of power lines on bird mortality. Lipu is currently involved in a LIFE project (Gestire 2020) and is cooperating with Enel and Terna to identify dangerous power lines and mitigate their effects on birds in the region of Lombardy.

Latvia: The only research into collision has been carried out by LOB on 3 sections of power line "Kurzemes loks" between 2015-2017. This research was commissioned and financed by private company "Augstspriegumu tīkls".

Luxembourg: In cases where a bird is found, natur&ëmwelt contacts the grid operator, Creos, and then specific measures are planned together.

Poland: There is no organisation dealing with the topic on a regular basis. In general, national and regional nature conservation authorities are responsible, especially when it comes to EIAs. NGOs are involved sporadically and act if there is a local problem (e.g., raptors in Lublin area - LTO, white storks in East & North East Poland - TP Bocian, PTOP, etc.) Grid operators only react from case to case and only if formally urged by national conservation authorities.

Portugal: SPEA, Quercus, LPN – Liga para a Protecção da Natureza, ICNF – Instituto para a Conservação da Natureza e Florestas and

EDP – Distribuição collaborate in Protocolos Avifauna, identifying the most dangerous areas for avian electrocution and implementing anti-electrocution measures on the dangerous power lines. SPEA, LPN and Quercus do field work to look for avian collision and electrocution evidence and identify power lines for retrofitting. EDP Distribuição is responsible for implementing mitigation measures. ICNF, the National Nature Conservation Authority, is responsible for providing information about sensible species, such as nesting areas and validating decisions.

Romania: Usually this is in the hands of the electric companies. The NGOs such as MILVUS GROUP, ROS (BirdLife Romania) or other institutions only have minor and quite localised monitoring, research or interests on the subject. On the other hand, this threat for birds and bats has been included in many Managements Plans for Natura 2000 sites. Accordingly, for those conservation measures, the isolation and marking of power lines is covered by the relevant projects / programmes / strategies.

Slovakia: Raptor Protection of Slovakia coordinates field survey and cooperates with producers of products for the protection of birds from electrocution and collisions. They also prepare plans for implementation of various solutions to eliminate the risks. Before the solutions are implemented, they are discussed with State Nature Conservancy of the Slovak Republic and Energy Supply Companies in Slovakia. Often there are mutual memoranda. However, grid operators do have a responsible approach, which makes cooperation easier, for example in joint participation on projects such as LIFE Energy. Furthermore, Act 543 / 2002 Coll. on the Conservation of Nature and Landscapes obliges those responsible for power lines to prevent bird mortality. In case it happens, they have to take actions to prevent it from happening again in the future.

Spain: In Spain, there are several NGOs dealing with the issue of bird mortality around power lines. Currently, the SOS-Tendidos Platform brings together most of the organisations trying to address the issue.

Sweden: BirdLife Sweden deals with the topic, both nationally and through its regional societies, and Kungsörn Sverige ('Golden Eagle Sweden') as well as regional Eagle Owl projects (such as 'Berguv Nord') are engaged in the matter. Discussions occur with the Ministry of Environment, Swedish Environmental Protection Agency, Swedish Energy Markets Inspectorate (Ei). There are also local initiatives between NGOs and different electricity companies, such as Vattenfall, E.ON, Fortum and Skellefteå Kraft to discuss and find solutions to minimise both collision and electrocution. Permitting authorities always consider to what extent a power line will affect avifauna and what precautions are to be taken. In Sweden it is Energimarknadsinspektionen and Länsstyrelserna (County administrative board) that are responsible authorities.

Conclusions & Recommendations 7

This document provides a useful source of ideas on the different types of techniques and approaches that can be used for implementing best practice standards to reduce bird mortalities. It might also be useful for risk mitigation and retrofitting of power lines in regions with a large demand for effective practical measures.

The number of overhead transmission and distribution power lines worldwide is increasing, due to the continuous growth in the human population and the consequent increase in energy demand. Power lines cross different types of ecosystems and represent an important factor in the anthropisation of the landscape and mortality of many bird species. A certain percentage of power lines cross areas of primary conservation importance for wildlife and the environments associated with it. Interaction with power lines causes the deaths of millions of birds worldwide and, in some areas, has been identified as the leading cause for the decline of threatened species. The issue of electrocutions is already dealt with quite extensively, as this is a long-running problem and has received more attention in the past. In several countries, "killer poles" started to disappear or be retrofitted on a large scale after legislative action was taken and the construction of new "killer poles" was banned. Recognition of the importance of collision is relatively recent and this has lacked a systematic approach in the past. In reality, this problem is large enough to represent one of the greatest factors of unnatural bird mortality.

The good practice procedures and proposed recommendations described in this chapter aim to offer useful advice, ideas and suggestions based on feedback and input from competent authorities, energy business representatives, NGOs and other experts and stakeholders.

Electrocution. The risk of electrocution on poles depends primarily on the technical construction and detailed design of power facilities: how insulators are attached to the cross-arms and the space/distance between e.g. the exposed jumper wires and/or other energised and/or grounded elements.

The highest risk is associated with medium voltage power lines which are attractive perches to many birds. The highest mortality rate due to electrocution is registered among medium-sized and large birds, as they are more likely to make simultaneous contact with unprotected elements of the pole construction.

Electrocution can have significant negative effect on the species, either on the local scale or even at the population level, such as has been documented e.g. for the saker falcon or imperial eagle. Young individuals are common victims of electrocution. Proximity of non-insulated medium voltage poles to nests can pose a fatal risk for many young and inexperienced birds with a lower flying capabilities, as they try to take off or land land on poles.

Corner, strain and branch poles are significantly more dangerous for birds than utility poles in straight lines. Bird mortality is lower for power line switch disconnectors and poleborne transformers, which are often situated at the edges of human settlements or are part of urban/industrial areas, with lower presence of birds.

Mitigation of Electrocution. Electrocution is not much of a problem in Germany, Luxembourg, Netherlands, Sweden, where most of the dangerous low and medium voltage lines have been placed underground or have been retrofitted sufficiently, but there are still many countries in Europe, where low and medium voltage lines have not been equipped with effective mitigating measures.

Mitigation measures should focus especially on medium-sized birds and on corner, strain and branch pole types. The risk of possible electrocution is significantly higher on utility poles without insulation, especially for construction types with one pin-insulator per phase conductor. The most appropriate solution is to substitute them with insulators in suspended position. If they cannot be substituted as such, then they must be retrofitted, for example with plastic caps and/or insulations which allow birds to perch safely on the console.

The products used to mitigate the electrocution risk should be made from durable, long-lasting materials and should be installed properly to ensure that birds are properly protected. If they are damaged or incorrectly installed, they are useless and more dangerous than non-insulated poles.

Switches should be attached below the cross-arms with insulated jumper wires and upright insulators substituted for suspended insulators.

The position of jumper wires should be changed to be below the cross-arm and an insulated conductor should be used.

All dangerous cross-arm constructions should be replaced with cross-arms at a 45° angle, with a perch attached below. The shape of the console discourages birds from sitting down and, at the same time, the perch offers a place to sit.

The use of bare conductors for insulated phase conductors is the safest solution for preventing avian electrocution (besides placing cables underground). This also represents a long-term solution and its effectiveness does not decrease with use, as opposed to solutions which imply the installation of protective devices.

Collisions. Bird casualties due to collision with overhead power lines can happen on any electricity grid (distribution or transmission). Larger, heavy bodied birds with short wing spans and poorer vision are more susceptible to collisions than smaller, lightweight birds with relatively large wing spans, agility and good vision.

The level of collision risk does not correlate with constructions of the power line. More important factors are the composition of the avifauna present, weather and visibility, location of the power line sections, whether they cross important bird habitats/breeding areas or main migration routes etc.

For high and extra-high voltage power lines, the highest risk is associated with ground wires (the highest one, which is the thinnest).

Far fewer bird individuals (but a broader range of bird species) are killed by collision than by electrocution. Birds with low maneuverability, i.e. those with high wing loading and low aspect ratio, such as bustards, pelicans, waterfowl, cranes, storks and grouse, are among the species most likely to collide with power lines.

Species which tend to group together into large flocks are also included, as this habit makes them more likely to collide with power lines. A particular problem arises with frequent movements of large flocks between their feeding and nesting biotopes, or if the power lines pass perpendicularly across the birds' main migration routes. Habitats with oilseed rape fields have been found to correlate with high mortality of mute swans, especially where power lines run close by.

Mitigation of Collisions. Infrastructure planning and routing of power lines should avoid priority areas and sites (breeding and wintering areas, migration bottlenecks, breeding colonies, congregation sites, coast lines, wetlands) when possible.

In areas where an especially high risk of bird collision has been found, it is very important that no new power lines are built and existing ones are modified by burying them underground or installing visual markers (bird diverters/beacons) that are durable and effective.

Line marking - making the wires more visible to birds in flight - is one of the best solutions. The most effective markers are contrasting black and white flapping diverters and luminous anti-collision devices, able reflect sunlight during the daylight hours and emit luminescent light at twilight and at night. Bird species that regularly fly low at night or in twilight are more susceptible to collision than species that mostly fly during the day.

Placing power lines underground as the most effective solution has not been credibly studied, nor has the potential for worldwide impairment for other protected goods. More knowledge about the factors increasing collision mortality rates on the species level is necessary to produce essential guidelines for proper bird friendly measures in the case of existing and/or for the construction of new power lines.

General recommendations. Grid operators should assume the cost of adapting their facilities to make their business compatible with the conservation of birds.

The competent authorities responsible for the conservation of wild species must fully recognise the severity of this issue. Environmental managers must identify the most problematic points for mortality, demand their modification or isolation and be actively involved in solving the problem.

Furthermore, the European Commission should enact binding guidelines for member states on how to address and minimise bird mortality on power lines and provide national authorities with a catalogue of the most effective measures. Based on these binding guidelines, each TSO and DSO should produce guidelines for technical solutions to mitigate bird collisions or electrocution hazard at national level, as well as a implementation plan for mitigation measures.

For planned construction or reconstruction of power lines, it is strongly recommended that expert field surveys are realised, including at last one year of ornithological investigations in order to characterise local and regional avifauna, bird movements, key sites for breeding, feeding and resting areas as well as seasonal migration to ensure that new overhead power lines will be safe for birds. Such investigations should also include research on flight movements during the day and especially in dawn and dusk period, when the light conditions are insufficient and birds are also most active, hence the highest risk potential for collision.

Before-After Control-Impact (BACI) assessment and supporting monitoring should be planned for all developments.

It is also strongly recommended that national/international sensitivity maps are carried out in order to locate the most critical areas of bird / power line interaction. This will prioritise power line sections with the most risk for electrocutions and collisions and thus streamline and save time and money.

Special attention should also be paid to vulnerable and endangered species, as listed by national and international legislation.

A further important step is to increase and support systematic data monitoring, which would influence public opinion and persuade grid operators in countries with no current relevant data of the need to implement mitigation measures.

Long-term studies to assess local/regional population trends and to prioritise the most important areas for bird conservation - taking into account the cumulative impacts of existing or foreseen energy infrastructure - are also necessary.

Exchange of existing know-how among countries and experts is vital. This is true not only for technical possibilities, but also for legal guidance and information about implementation on national level.

An international database to collect information about bird collisions and electrocutions is recommended, in order to help with preventing future bird / power line incidents, and to standardise protocols to improve reliability and potential utility in meta-analyses.

Preventing birds from collisions and electrocution is even more important in order to compensate for other threats which endangered species are faced with. A systematic approach and standardised monitoring on transnational level will enable invest into the most effective measures and a focus on areas with the highest priority. It is important to rise awareness of stakeholders through education, volunteering and other activities. Transnational cooperation is of great advantage for knowledge transfer, sharing experience and should be seized upon immediately. An increase in sources of European Commission LIFE project funding and other national sources for conservation projects to more intensively support international exchange of experience is highly recommended. For example, the LIFE Danube Free Sky project (www.danubefreesky.eu) will define a standard for mitigation measures that could be replicated in countries through which important large rivers for bird migration flow.

This includes: marking of power lines crossing large rivers, international monitoring scheme standards, avian reporting system, international database, construction design standards, etc. The project represents a unique example of wide transnational cooperation along one of the most important migration corridors, stop-over sites, and wintering places for many bird species in Europe - the Danube river.Bird conservation and protection against potential risk around power lines should become the top priority in areas of important EU migration corridors.

The information provided by the countries in the scope of this report shows different policies to deal with and reduce the problems of bird / power line interactions. Some countries already apply mitigation measures against both electrocution and collision from the very beginning of a construction. In order to reduce electrocution/collision mortality, bird protection must be taken into account especially early in the planning stage of new distribution and/or transmission lines. Ornithological findings and the results of field survey and observations must be adopted in the planning and taking into consideration for the construction features of power lines. In many EU countries, a large amount of knowledge is available, because different methods for bird safety around power lines have been tested, and many of them have been found to be highly. effective and cost effective in the same time. This carries a strong international benefit, because the construction principles of power lines are almost the same across the globe. This is also a key reason why new national and international projects and cooperations continue to be so important. Only when the most dangerous lines are treated and highly effective methods are applied more broadly will large numbers of birds be protected from risk. More expert knowledge about the main inputs and factors increasing collision and electrocution mortality rates will produce essential guidelines and technical standards for proper bird friendly measures in the case of existing and/or for the construction of new power lines. All lines identified as being most lethal should be retrofitting as a priority and the practical, organisational and legal aspects should be addressed. Finally, it is necessary to raise awareness of the issue of electrocution and collision not only within the corporate culture of grid operators and their business associates, but also within nature protection institutions and the local population.

Annexes

Pylons/Poles of electrical grid A

Figure A.1: High voltage pylons of 400 kV transmission line in Slovakia.
Source: Raptor Protection of Slovakia

Figure A.2: High voltage pylons of 110 kV distribution line in Slovakia.
Source: Raptor Protection of Slovakia

Figure A.3: Medium voltage pole of 22 kV distribution line in Slovakia.
Source: Raptor Protection of Slovakia

Figure A.4: Low voltage lines bringing the electricity directly to consumption points.
Source: Raptor Protection of Slovakia

Dangerous & safe construction | B

Figure B.1: Branch pole of 22 kV line with many exposed jumper wires used in Slovakia.
Source: Raptor Protection of Slovakia

Figure B.2: Dangerous construction of a metal-framed tension pole in Bulgaria.
Source: BSPB

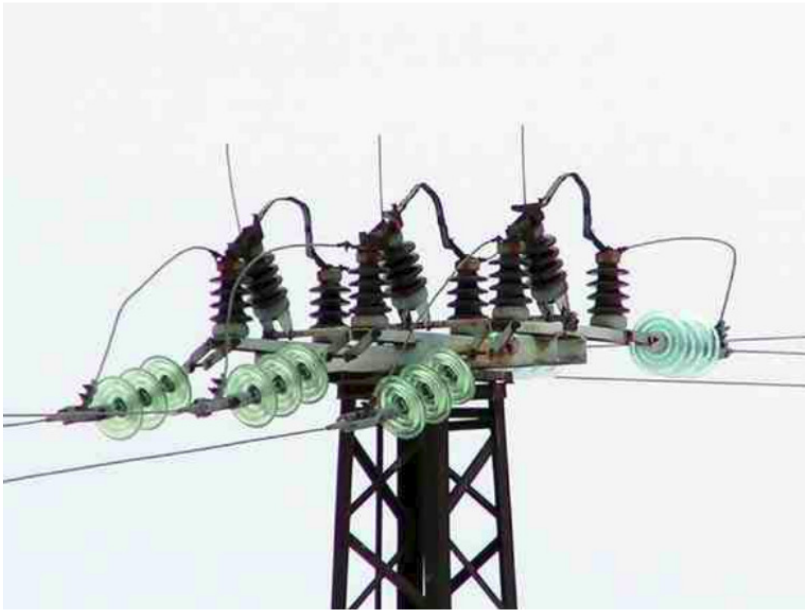

Figure B.3: Detail on elements of a switch tower in Bulgaria.
Source: BSPB

Figure B.4: Branch pole of 22 kV line in Czech Republic. Construction is very similar to poles used in Slovakia.
Source: AOPK ČR

Figure B.5: Unisolated jumper wires on 10 kV pole in Sweden.
Source: EON Sweden

Figure B.6: Pole transformer with many energised elements can also pose a great risk to small bird species.
Source: Raptor Protection of Slovakia

Figure B.7: Medium voltage pole with suspended insulators for single-circuit line.
Source: Raptor Protection of Slovakia

Figure B.8: Medium voltage pole with suspended insulators for double-circuit line.
Source: Raptor Protection of Slovakia

Effective solutions against electrocution

C

Figure C.1: Plastic cover of cross-arm allows bird to perch safely.
Source: Raptor Protection of Slovakia

Figure C.2: Insulation caps for pin-type pylons in Sweden.
Source: BirdLife Sweden

Figure C.3: Insulation caps for pin-type pylons in Czech Republic.
Source: AOPK ČR

Figure C.4: Insulation with telescopic parts eliminates the distance between the products and pin-insulators.
Source: Raptor Protection of Slovakia

Figure C.5: Effective solutions for bird protection in Slovakia. Dangerous jumper wires were placed under the cross-arm with fully insulated phase conductors.
Source: Raptor Protection of Slovakia

Figure C.6: Old types of switch disconnectors can be replaced with new one attached below the main cross-arm, as preferred in Slovakia.
Source: Raptor Protection of Slovakia

D Bird flight diverters

Figure D.1: Dangerous sections of 22 kV lines marked with FireFly Bird Diverters.
Source: Raptor Protection of Slovakia

Figure D.2: Fully protected medium voltage line in Slovakia. Orange spiral diverters increase the visibility for bird species in their feeding area.
Source: Raptor Protection of Slovakia

Figure D.3: FireFly Bird Diverters include an orange and a yellow part that reflect sunlight during the daylight hours and alert approaching birds to an obstruction in their flight path.
Source: Raptor Protection of Slovakia

Figure D.4: FireFly Bird Diverters are able emit luminescent light at twilight and at night.
Source: Raptor Protection of Slovakia

Figure D.5: For high voltage lines up to 110 kV is important to increase the visibility of all phase conductors and the earth (shield) wire on the top.
Source: Raptor Protection of Slovakia

Figure D.6: Avian marker balls provide visual warning for planes but are also effective for bird protection.
Source: Raptor Protection of Slovakia

Figure D.7: Flags to prevent bird collisions attached on trolley wires in Krakow.
Source: Raptor Protection of Slovakia

Figure D.8: Different combination of bird diverters (spiral and devices with movement parts) can be used to increase the visibility of line.
Source: Raptor Protection of Slovakia

E Legislation overview

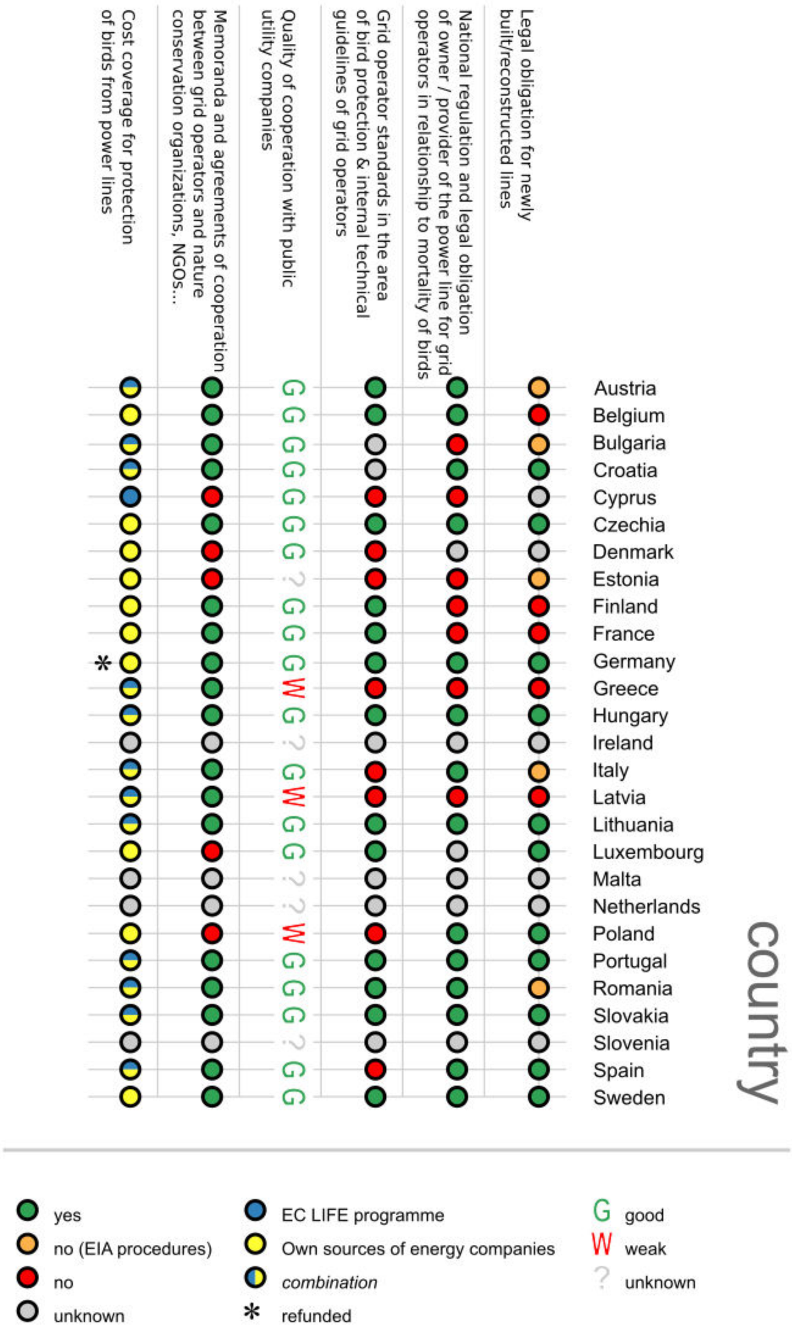

Figure E.1: Legislation overview.

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