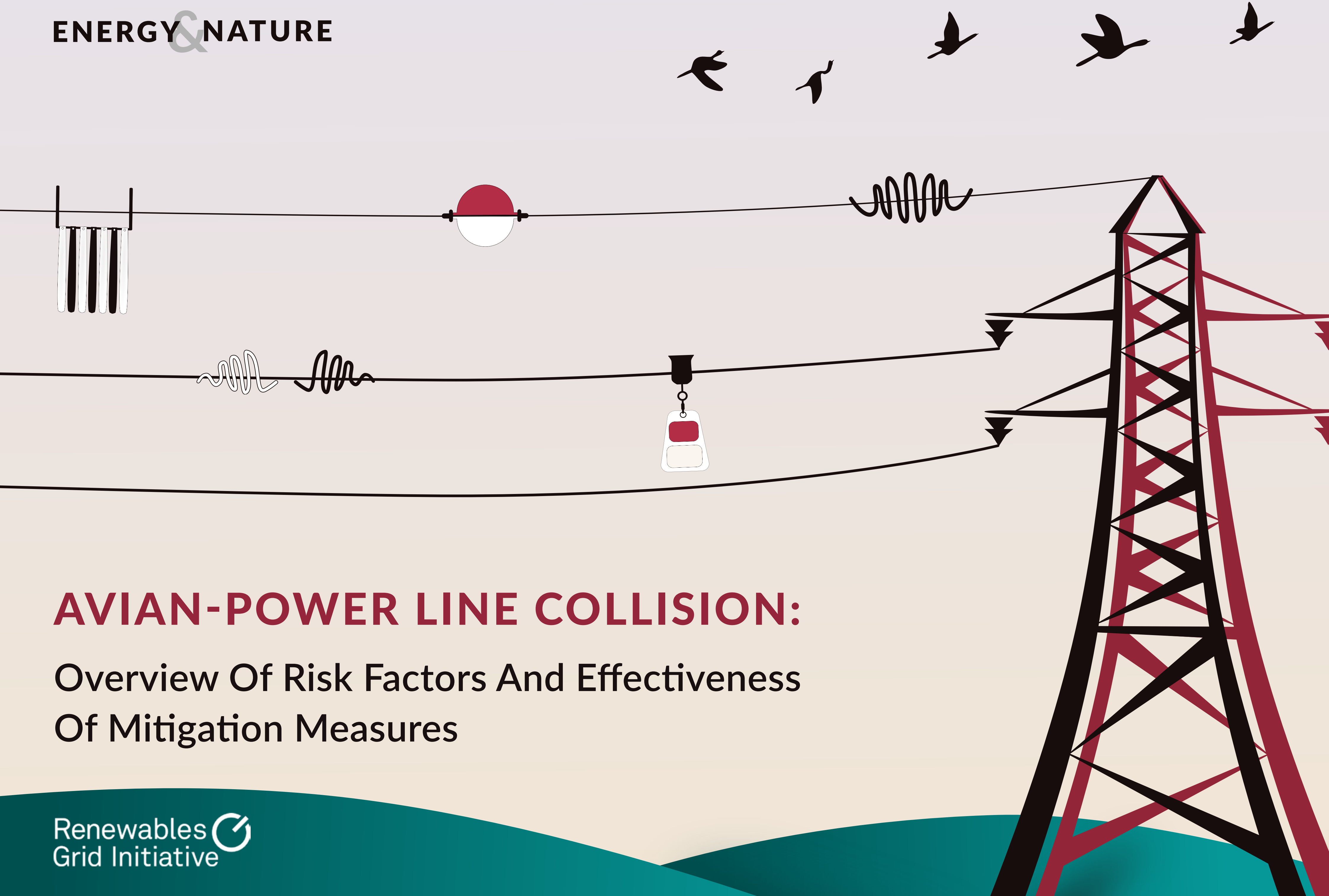
ENERGY & NATURE



AVIAN-POWER LINE COLLISION:

Overview Of Risk Factors And Effectiveness Of Mitigation Measures

Renewables Grid Initiative

STRATEGIES TO MITIGATE BIRD MORTALITY WITH POWER LINES

Bird Collision: *The Problem*

Power lines are crucial for decarbonising our societies and addressing climate change, yet they can pose significant mortality risks to some animal species through collision, electrocution, or disturbance. Birds are impacted by all three factors.

This brochure addresses the issue of **bird collision with power lines.**

Birds can collide with poorly sited overhead lines of any voltage level or type. Collision risk is higher on taller structures, longer spans, ground wires and conductors with smaller diameters. Due to unique physiological and behavioural traits, some species face a higher collision risk. Furthermore, geographical and weather factors can also increase this risk. For some species, mortality by collision can have substantial impacts on population viability. Thus, action to mitigate this impact is crucial.

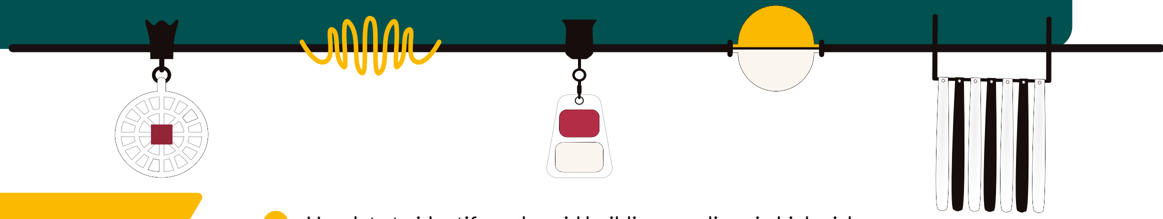
Wire Markers: *A Solution*

Visual markers can help to attract flying birds' attention earlier and thus to avoid collision. Thus, grid operators apply **"wire markers" (or bird flight diverters - BFDs)** to lines in high-risk areas.

There are many products on the market, provided by different developers. Quantifying their effectiveness is no easy task: it is influenced by many contextual factors. However, scientists generally agree that wire markers can indeed reduce collision risk. Furthermore, factors like **durability, cost, and technical implications** are important considerations for grid operators.

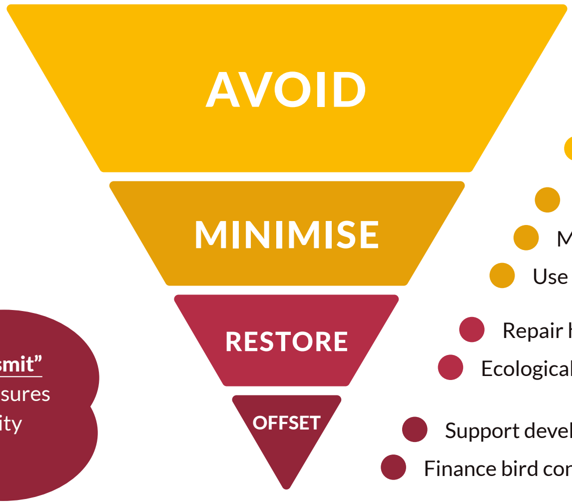
All things considered, it can be difficult for grid operators to decide which wire marker is best suited to their specific case.

This brochure provides a visual summary of available research on collision risk factors and available research on wire marker effectiveness, to help inform the decision basis for mitigation measures. Read more in the **Methodology Report.**



The Mitigation Hierarchy

Incorporating the mitigation hierarchy right from the early stages of planning grid infrastructure is crucial for effectively reducing bird mortality linked to collision with power lines



- Use data to identify and avoid building new lines in high-risk areas
- Avoid building new overhead lines, upgrade existing ones and bury lines where possible
- Avoid introducing new collision risks by building new lines parallel to existing lines
- Avoid designing taller structures with vertically arranged circuits
- Minimise the spacing between towers to reduce the length of dangerous spans
- Minimise the use of ground wires when possible, and use alternative lightning mitigation
- Use wire markers to increase line visibility
- Repair habitat damage after construction
- Ecologically manage vegetation around the grid to enhance habitats for affected species
- Support development of intact habitats elsewhere which benefit negatively impacted species
- Finance bird conservation efforts through monitoring, research, and partnerships

BirdLife International's tool **"Transmit"** gives an overview of a range of measures available to reduce avian mortality around overhead lines

WHICH BIRDS ARE MAINLY SUSCEPTIBLE TO COLLISION?

Particular sensitivity according to collision-susceptibility, conservation status, collision events and potential population impact. Read more in the [Methodology Report](#).

Bird groups with higher susceptibility to collision with power lines	Avian morphology factors		Avian behaviour factors					Examples of species most at risk according to 'Collision Sensitivity Indices' in *Bernotat et al. 2021b, D'Amico et al. 2019, Gauld et al. 2022, Silva et al.*
	Wing size, weight, speed & manoeuvrability	Vision	Flocking / gregarious	Long distance migration	Nocturnal birds & night migration	Foraging / roosting trips	Aerial hunters	
Pelicans, herons, egrets, bitterns, ibis, spoonbills	X	X	X	X	X	X		Black-crowned night heron, Purple heron, Little bittern, Eurasian spoonbill, Great white egret
Cranes, rails, gallinules	X	X	X	X	X	X		Eurasian crane, Corncrake, Spotted crake, Little crake, Baillon's crake, Western swamphen, Crested coot
Waterfowl (e.g. ducks, geese, swans)	X	X	X	X	X	X		Ferruginous duck, Greater scaup duck, Lesser white-fronted goose, Garganey, Northern pintail, Northern shoveler
Waders, gulls, and storks	X	X	X	X	X			White stork, Black stork, Stone curlew, Black-tailed godwit, Golden plover, Kentish plover, Little gull, Whiskered tern
Bustards	X	X	X	X		X		Great bustard, Little bustard
Divers, grebes, and cormorants	X	X	X	X				White-billed diver, Horned grebe, Red-throated diver, Red-necked grebe, Black-necked grebe, Great northern diver
Eagles, hawks, harriers, vultures, and falcons	X	X		X		X	X	Lesser spotted eagle, Golden eagle, Red kite, Spanish imperial eagle, Short-toed snake eagle, Osprey
Owls		X		X	X			Eurasian eagle owl, Ural owl, Little owl, Eurasian scops owl, Barn owl, Short-eared owl
Landfowl (e.g. grouse, pheasants)	X	X		X	X			Black grouse, Western capercaillie, Ptarmigan, Hazel grouse, Black-bellied sand grouse, European quail
Passerines (incl. corvids)	X		X	X	X			Ring ouzel, Common raven, Alpine chough, Common starling

Heavier birds with shorter, wider wings (high wing loading and low wing aspect ratio) are more susceptible to collision due to higher flight speed and lower manoeuvrability. Such species tend to be less skilled fliers, making them more collision-prone.

Birds often have blind areas straight ahead, for example when looking downwards during flight. Additionally, birds with widely-spaced eyes and lateral vision may have difficulty determining time to contact an object lying ahead.

Flocking in large groups can make birds more collision-prone due to limited manoeuvring space and potential for internal collisions. Furthermore, birds at the back of the flock may struggle to see obstacles ahead.

Migration brings risk as birds fly long distances through unfamiliar areas, often in large flocks. Juveniles are more vulnerable as they lack knowledge of landscape features. Risk is greater when birds fly low during stopovers, particularly amid low-light conditions.

Nighttime collisions are more common due to reduced wire visibility. Night-migrating species, like songbirds and herons, face increased collision risk when bad weather forces lower flight altitudes.

Collision risk for foraging birds arise when they must cross power lines while departing from and returning to breeding or nesting sites. Risk varies based on flight direction and crossing frequency.

High-speed pursuit of prey by birds can lead to power line collisions due to reduced perception. Extended periods in flight while hunting for prey can raise the likelihood of aerial bird predators encountering power lines or overlooking them.

EXTERNAL FACTORS INFLUENCING BIRD COLLISION

Topography

Any topographical feature that concentrates migratory flocks into a narrow channel (e.g. valleys, rivers) – presents higher risk scenario and should be given priority treatment either at planning stage or mitigation planning.

Weather & Light Conditions

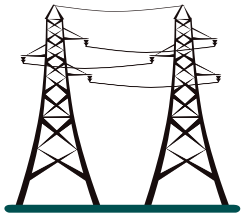
There is a higher risk of avian wildlife collision in lower light which impairs visibility, (i.e. dawn, dusk, night time and in overcast cloudy weather). Birds fly at lower altitudes in fog, and under cloud cover and when facing head winds increasing collision risk. Wind, gusts and cross winds can result in loss of control especially with juvenile birds.

Habitat

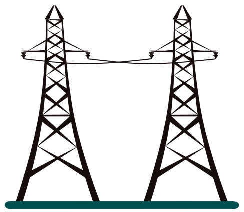
Collision risk is higher when power lines are located close to areas from which birds take off or land. Planning should avoid these sites or allow space for birds to take off and land safely. Vegetation significantly influences bird-power line interactions. Open areas like swamps and pastures lead to lower flying altitudes, elevating collision risks. In forests, birds fly near tree canopies, making tall power lines hazardous.

Human Factors

Studies show bird collisions with power lines can be linked to human disturbances like hunting, recreation, agriculture, and infrastructure maintenance. Transportation-related disturbances from roads, railways, and aircraft noise may also raise risks. Research varies: motorways could increase collisions, but birds may avoid human activity areas, reducing risk. Deeper investigation is needed here.



High collision risk
Higher, vertical configuration with 4 levels



Lowest collision risk
Lower, horizontal configuration with earth wire removed

Power Line Specific Factors

Power line design has a big impact on the visibility of wires to birds and thus collision risk. Lines in critical areas should be considered for undergrounding. If this is not possible, risks can be mitigated by designing lower height structures, shorter spans, using flight diverters on ground wires.

Risk maps are a key tool for planning infrastructure away from high-risk areas. BirdLife Internatinoal's **AVISTEP** is a good example. Read more in the **Methodology Report**!

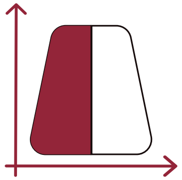
Based on current scientific understanding, the following *principles* contribute to a *marker being more effective and useable*.

While each characteristic is crucial on its own, their combination culminates in An "Optimal" Marker

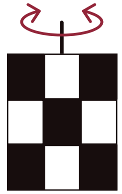
BASIC PRINCIPLES FOR EFFECTIVE WIRE MARKERS

Bigger Is Better

Larger surfaces perpendicular to the approaching bird are more visible, esp. at a distance and high speed



Provide High Internal Contrast For Visibility In All Conditions & Against All Backgrounds

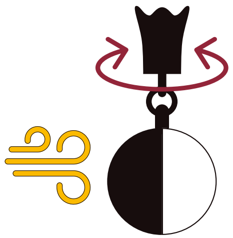


e.g. black & white

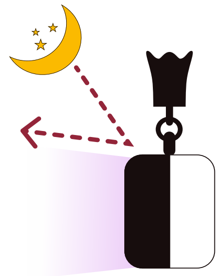
Mobile & Wind-Driven

e.g. rotating, flapping

Durable motions that enable flickering of reflective elements are advantageous



Visible In Low-Light For Flight In Twilight Hours & Nocturnal Migrants

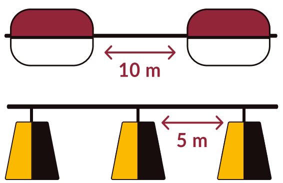


e.g. illumination, UV, fluorescence and phosphorescent element (afterglow)

Note: Research on effectiveness of UV light is ongoing

Mounted In Short Intervals Along Wires

Place markers as close together as engineering constraints allow. Consider staggering on parallel power lines to increase overall coverage.



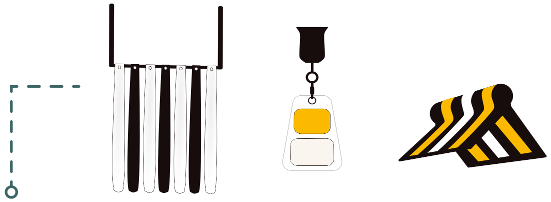
Durable Over Time & Under Different Weather Conditions

Economically Feasible

incl. cost per unit, mounting costs & lifetime expectation

AN INTRODUCTION TO AVAILABLE WIRE MARKERS

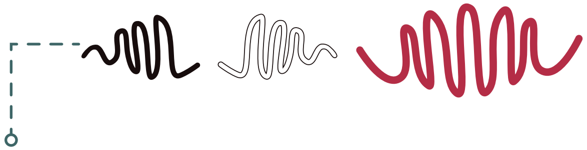
Several different models of wire markers are available. They can be **active (moving)** or **passive (non-moving)** and can be roughly divided into three groups:



Active

Suspended Devices or "Flapper"

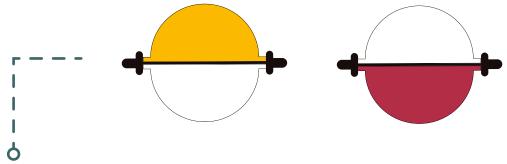
- **Movement:** Dynamic - swinging, rotating and fixed
- **Size (surface area):** Smaller flappers approx. 150 - 200cm^2, larger flappers approx. 1,500cm
- **Colours:** Available in a variety of colours
- **Note:** Several models available, polymeric shapes that hang from composite clamps



Passive

Spirals

- **Movement:** Static
- **Size (outer coil):** Small - approx. 12.7 x 38cm, large - approx. 20 x 116cm
- **Colours:** Available in a variety of colours
- **Note:** Two main models in circulation are larger symmetrical spiral and smaller "pigtial" spiral



Passive

Large Spheres

- **Movement:** Static
- **Size (diameter):** Approx. 130-140cm
- **Colours:** Yellow, red, orange, black & white. Some models have one half fluorescent
- **Note:** Akin to aviation warning balls

Scientias-Energy's **'Buyers Guide'** gives an overview of technical detail of available markers

EFFECTIVENESS OF WIRE MARKERS IN REDUCING COLLISION

Available research and recent meta-studies suggests that overall wire marking can reduce collision risk from on average 56-78% (Barrientos et al., 2011; Bernadino et al., 2019). However, results from individual studies vary widely: both in their results (from 14%-98%) and the study design and parameters.

This **Brochure** and the **Methodology Report** seek to build on available research and make the science more accessible to practitioners. To this end:

01 We conducted a review of 50 studies that evaluated the effectiveness of individual wire markers. The full table is available in the Methodology Report.

02 We identified wire markers for which at least **4 studies** were carried out according to the most scientifically rigorous approaches.

a We prioritised Before-After-Control-Impact (BACI) design, as it accounts for spatio-temporal variations in mortality rate between survey areas (as per Bernadino et al., 2019).

b Noting that too few BACI studies were available, we also considered peer-reviewed Before-After or Control-Impact studies which clearly presented their methodology.

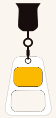
On the next page are the 20 BACI and peer-reviewed BA/CI studies for 4 markers commonly used by grid operators in Europe and beyond.

AN OVERVIEW OF PEER REVIEWED STUDIES

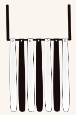
BACI Design — Peer-Reviewed BA or CI Design

Criteria

Bird Flappers



Rotating Flapper

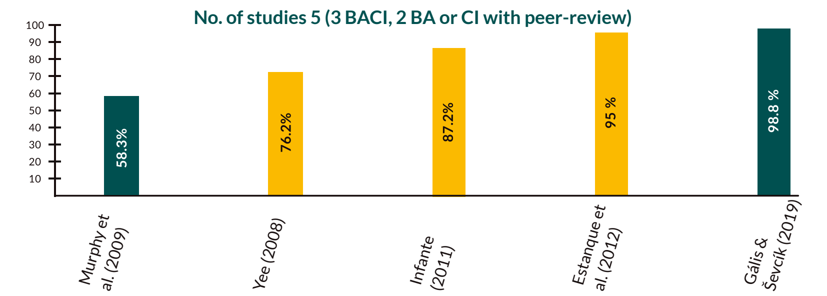


Zebra Flapper

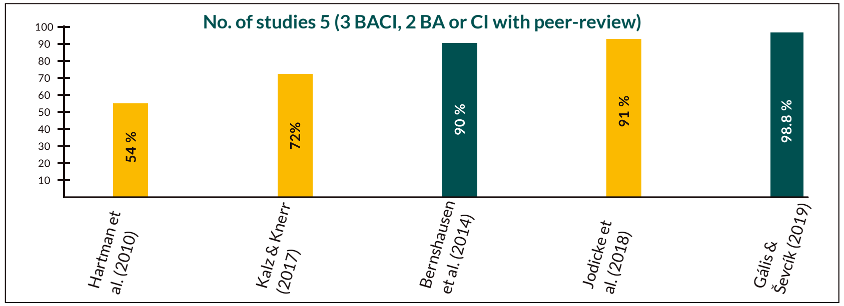
Effectiveness studies

Effectiveness (range & average) acc. research result sets

Rotating Flapper:



Zebra Flapper:



Species researched

Rotating Flapper: Cranes; Swans, Geese and Ducks; Egrets, Herons and Bitterns; Storks; Pheasants and Allies; Lapwings and Plovers; Rails, Gallinules, and Coots; Cormorants and Shags; Gulls, Terns, and Skimmers; Grebes; Passerines; Swallows and Martins

Zebra Flapper: Geese, Gucks and Swans: Egrets, Herons and Bitterns; Storks; Lapwings and Plovers; Thrushes; Finches; Larks; Warblers; Starlings; Snipes and woodcocks; Rails; Gallinules and Coots; Pheasants and Allies; Pigeons and Doves; Corvids; Passerines; Swallows and martins

Spirals

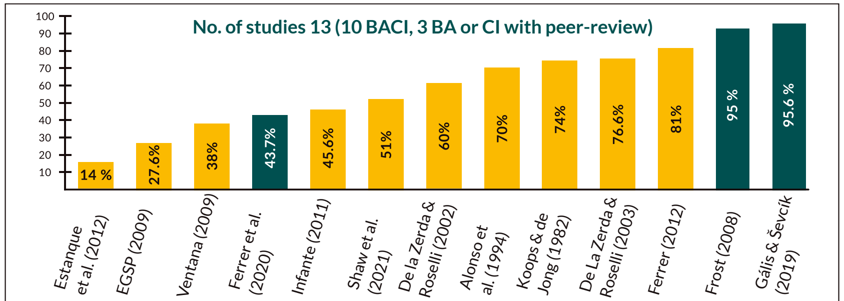
Large Spiral

Small Spiral

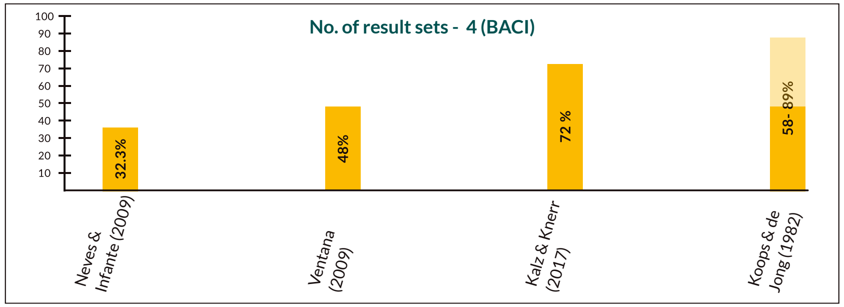
Effectiveness studies

Effectiveness (range & average) acc. research result sets

Large Spiral:



Small Spiral:



Species researched

Large Spiral: Cranes; Geese, Ducks and Swans; Herons, Egrets and Bitterns; Grebes; Flamingos; Plovers and Lapwings; Raptors; Pigeons and Doves; Gulls; Rails, Gallinules and Coots; Warblers; Thrushes; Starlings; Corvids; Owls; Bee-eaters; Cuckoos; Icterids; Ibises; Passerines; Swallows and Martins

Small Spiral: Cranes; Geese, Ducks and Swans; Herons and Egrets; Gulls; Pigeons and Doves; Plovers; Bustards; Storks; Falcons; Thick-knees; Corvids; Grebes; Cormorant; Ibises; Rails; new world Vultures; Raptors; Sandgrouse; Swifts; Rollers; Passerines; Swallows and Martins;

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12101 Berlin, Germany

This brochure is designed to be a visual overview on the effectiveness of wire markers in reducing bird collisions.

A full methodology report, including topical research, a summary of available studies and many further useful sources is available on **our website**.

If you have questions, don't hesitate to reach out at: **communication@renewables-grid.eu**

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