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

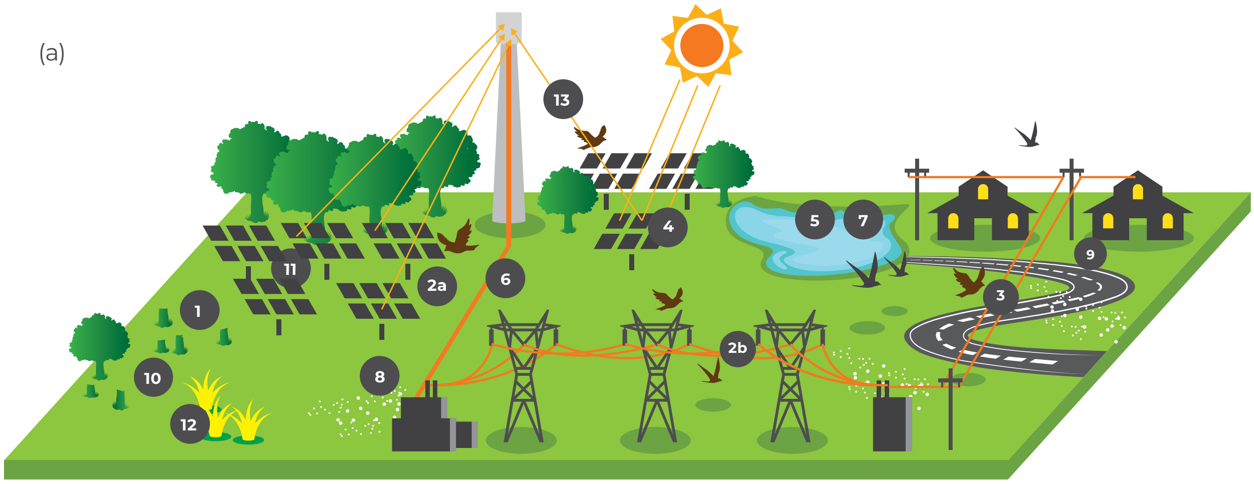
Biodiversity impacts associated to solar power projects

Compared to wind energy developments, there is currently limited scientific evidence of the impacts from solar developments on biodiversity and ecosystem service. From the available literature on biodiversity impacts, the potential biodiversity impacts of PV and CSP are similar but not identical and many are inferred. These impacts are illustrated in Figure 4.2, and summarised in Table 4-1.

Solar plants have been shown to create positive biodiversity impacts when compared to other types of intensive land use. For example, solar plants in the UK previously used for agriculture were found to have a greater diversity of flora and birds when managed through grazing. For more detailed information, read the IUCN ***Mitigating biodiversity impacts associated with solar and wind energy development Guidelines for project developers***.

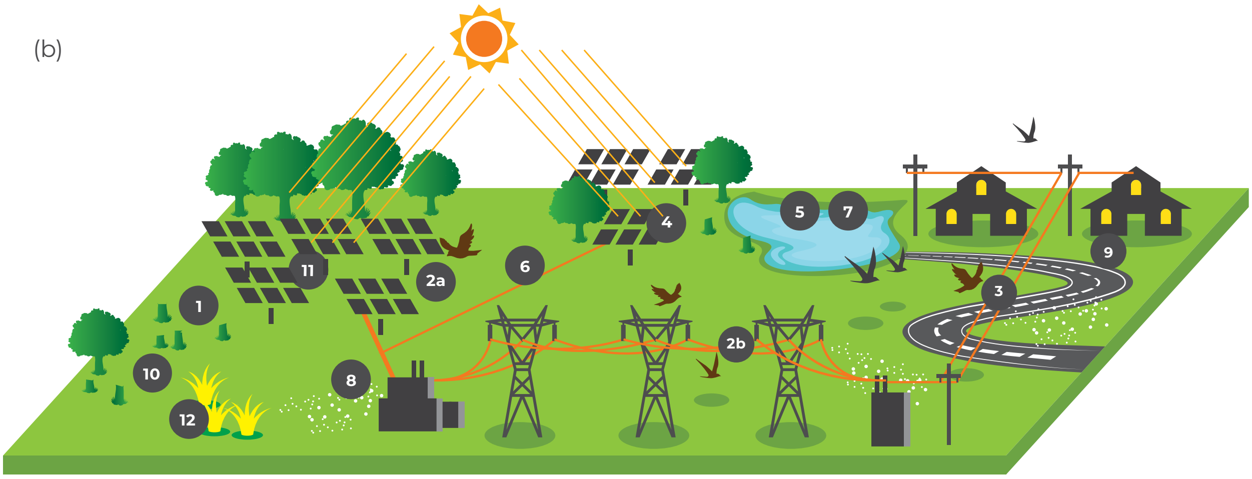
Figure 4.2 Impacts on biodiversity and the associated ecosystem services due to (a) CSP and (b) PV. Please see Table 4-1 for details on each impact type

(a)



1. Loss of habitat through clearance or displacement of land
2. Bird collision with (a) solar panels, and (b) transmission lines
3. Bird and bat mortality through electrocution on distribution lines
4. Displacement due to attraction to reflective surface of solar panels
5. Wildlife mortality due to attraction to evaporation ponds
6. Barrier effects to terrestrial biodiversity movement
7. Habitat degradation due to changes in hydrology and water availability and quality
8. Pollution (e.g. dust, light, noise and vibration, solid/liquid waste)
9. Indirect impacts from displaced land-uses, induced access or increased economic activity
10. Associated ecosystem service impacts
11. Habitat alteration due to changes in microclimatic effect of solar panels
12. Introduction of invasive alien species
13. Singeing of birds that fly into path of concentrated light energy

(b)



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10. Associated ecosystem service impacts
11. Habitat alteration due to changes in microclimatic effect of solar panels
12. Introduction of alien species

Table 4-1 Summary of the key biodiversity and associated ecosystem service impacts of PV and CSP solar plants. The significance of particular potential impacts will be context-specific

No.*	Type of impact	Project stage	Description and examples
1	**Habitat loss through clearance or displacement**	Construction/ operation	Construction of PV and CSP plants and their associated facilities typically requires removal of vegetation and surface grading across large areas of land. This may cause habitat loss, degradation and fragmentation, leading to a reduction in species richness and density as demonstrated by a study on birds.[1] The significance of biodiversity impacts will vary depending on the level of degradation of the previous habitat and the geographic location, and in some circumstances may be positive. For example, in the UK solar plants have been found to support a greater diversity of vegetation, invertebrates and birds than surrounding agricultural or other brownfield land where they are often sited.[2] During operation, vegetation is significantly lost or altered. Solar plants typically require some form of vegetation management under, and in the gaps between solar panel arrays. Unwanted vegetation is sometimes discouraged using herbicides, or by covering the ground with gravel to facilitate facility operations. In other cases, some form of vegetation cover is grown but mowed frequently to keep it short. For example, in western North America, solar developments were estimated to have the largest impacts on shrublands compared to other ecosystem types, resulting in the conversion of between 0.60 to 19.9 million ha of the ecosystem.[3]
2	**Bird collisions with solar panels and/or transmission lines**	Operation	Like glass or reflective surfaces on buildings, PV panels and concentrating solar collectors, such as heliostats, could present a collision risk to bird and bat species, especially if the surfaces are vertically oriented and/or reflecting light. The extent and significance of these impacts are largely unknown and limited to a small number of studies. Results from fatality monitoring studies across c.13 years at 10 PV plants in California and Nevada, USA, estimated an average annual fatality of 2.49 birds per MmW per year.[4] Collisions with a PV plant with large continuous arrays (that water birds might mistake for water bodies) in Southern California, USA, resulted in a relatively high number of water bird fatalities.[5] Collisions with the (thin and hard to see) earth wire of transmission lines may lead to significant fatalities for some species such as bustards.[6]

1 Visser et al. (2019).
2 Montag et al. (2016).
3 Pocewicz et al. (2011).
4 Kosciuch et al. (2020).
5 Kagan et al. (2014). Other key references: Huso et al. (2016); Visser et al. (2019); Walston et al. (2016).
6 Mahood et al. (2017).

3	**Bird and bat mortality through electrocution on distribution lines**	Operation	Electrocution rates on pylons (or poles) of low- or medium-voltage lines can be high and disproportionately affect some species that use pylons of low-voltage lines as perches when hunting or for nesting. An annual mortality rate of c. 0.7 birds per pole was estimated as a result of electrocution on a distribution line in southern Morocco.[7] Electrocutions may also be partially responsible for the decline of some long-lived species.[8] For example, electrocution of Egyptian Vultures (*Neophron percnopterus*) over a 31-km stretch of powerline in Sudan is thought to have resulted in sufficient deaths to partially explain their population declines.[9] Electrocutions are rarely significant on high-voltage transmission lines. There is limited evidence of risks to bats, although electrocution of large bat species, particularly fruit bats, has been identified as an issue associated with distribution lines.[10]
4	**Displacement due to attraction to reflective surface of solar panels**	Operation	There is anecdotal evidence that birds can mistake the flat surfaces of PV panels for water bodies and attempt to land on them – termed the 'lake-effect' hypothesis.[11] This can risk injury and be detrimental to certain birds that cannot take off without a water body. Aquatic insects can also be attracted to the polarised light reflected by PV panels, and display maladaptive behaviour mistaking the panels for water surfaces.[12]
5	**Wildlife mortality due to attraction to evaporation ponds**	Operation	The wastewater from CSP towers is stored in evaporation ponds to facilitate concentration of chemicals before disposal. These ponds may attract wild animals and pose a risk in terms of poisoning (for example by selenium) and drowning.[13] A four-month study of a 50 MW CSP plan in South Africa identified 37 carcasses in evaporation ponds, of which 21 individuals were assessed to have likely drowned. This included birds (four species), reptiles (one species) and mammals (seven species), including the aardvark (*Orycteropus afer*).[14]
6	**Barrier effects**	Construction/ operation	Large areas of PV panels and their associated facilities can disrupt wildlife movement and/or migrations by acting as a barrier. For example, important stopover sites for migratory birds may be lost due to cumulative impacts from several large PV plants along their flyway.[15] Solar plants typically have security perimeter fencing installed. In some cases, existing ground clearance under fences, gaps in the fence weave, and gates allow small to medium sized mammals to pass. However, such fencing could still pose a barrier to large mammal movement and/or migrations. Although direct evidence of the barrier effect of solar facilities is largely unquantified, the barrier effects related to large scale developments and infrastructure components, such as fencing, has been demonstrated to impact species movement, and reduction of range size.[16]

7 Godino et al. (2016).
8 Angelov et al. (2013); Sarasola et al. (2020).
9 Angelov et al. (2013).
10 Kundu et al. (2019); O'Shea et al. (2016); Tella et al. (2020).
11 Horváth et al. (2009); Huso et al. (2016).
12 Horváth et al. (2010). Other key references: Harrison et al. (2016); Huso et al. (2016); Taylor et al. (2019).
13 Jeal et al. (2019); Smit (2012).
14 Jeal et al. (2019).
15 BirdLife International (n.d.).
16 Numerous studies have documented the barrier effects of infrastructure developments. For example, see Wingard et al. (2014); Wyckoff et al. (2018).

7	**Habitat degradation due to changes in hydrology and water availability and quality**	Construction/ operation	CSP plants use high amounts of water for cooling the system and washing the mirrors, although the use of manual dry brushing methods can help reduce water usage. CSP and PV may also require large amounts of water for cleaning of dust from panels. This water use could alter the availability of surface and groundwater sources to sustain habitats, such as riparian vegetation, particularly in arid regions. Excessive groundwater withdrawal in the Southwestern United States, unrelated to solar developments, reduced riparian plant density and composition,[17] and contributed to the decline of endangered species such as the Devils Hole pupfish (*Cyprinodon diabolis*).[18] Solar plant construction and operation can also lead to water pollution impacts. For example, operational CSP plants can result in thermal pollution from releasing cooling water into freshwater systems, leading to algal blooms and fish mortality, while employing wet-cooling technologies can lead to a risk of contaminating water bodies with hazardous chemicals, such as cooling system toxicants, antifreeze agents, dust suppressors, rust inhibitors, herbicides and heavy metals.[19]
8	**Pollution (dust, light, noise and vibration, solid/liquid waste)**	Construction/ operation	In general, limited process emissions is generated from operational solar plants other than increased polarised light levels and wastewater as already mentioned. Construction, decommissioning and repowering can lead to dust, waste, noise and light pollution impacts. Examples specific to solar developments are limited, but are widely available for other types of infrastructure development.[20]
9	**Indirect impacts**	Construction/ operation	In some cases, land take for solar developments and their associated facilities may displace other land uses such as agriculture). For example, c.150 km^2 of agriculture land was converted into land use for solar developments in California, USA.[21] This could result in land use activities previously taking place on site to occur in new areas, resulting in impacts being created away from the site. Induced access through construction of roads into previously remote areas could lead to increased pollution or contamination, as well as natural resource collection, including of vulnerable species.
10	**Associated ecosystem service impacts**	Construction/ operation	Land take for solar developments and their associated facilities could lead to reduced access to, and the loss of important provisioning services such as areas important for agriculture or provision of natural resources. However, some developments are underway to combine these activities and preserve agricultural yields[22] and grazing areas.[23] Local communities may also feel a loss of cultural values, including a sense of place and belonging. Concerns relating to the visual impact of solar development are common. Ecosystem service impacts in relation to solar developments are not well understood[24] and require particular attention in early planning.

17 Webb & Leake (2006).
18 Riggs & Deacon (2002).
19 The Joint Institute for Strategic Energy Analysis (2015).
20 For some examples, see Farmer (1993); McClure et al. (2013); Rahul & Jain (2014).
21 Hernandez et al. (2015).
22 Hoffacker et al. (2017).
23 Montag et al. (2016).
24 De Marco et al. (2014); Terrapon-Pfaff et al. (2019).

11	**Habitat alteration due to changes in microclimatic effects of solar panels**	Operation	Shadow effects caused by solar panels can alter the species composition and diversity of underlying habitats as a result of air and soil microclimate variation. A study of a UK solar plant revegetated with grassland showed that species diversity was lower under PV panels as a result of differences in soil and air temperature.[25] Differences in microclimate beneath panels have also preliminarily indicated that they can also help preserve vegetation such as crops during heatwaves and periods of drought.[26]
12	**Introduction of invasive alien species**	Construction	Movement of equipment, people or components may facilitate the introduction of invasive alien species (IAS) by various pathways, for example, by being transported in soil on machinery or attached to clothing. The creation of new habitats, for instance by land disturbance during construction or creating open spaces, may also facilitate the spread of IAS already present on the site.[27]
13	**Bird mortality due to being burned or singed by CSP infrastructure**	Operation	Birds that fly into the path of the concentrated light energy risk being burned or singed. Mortalities have been documented from several CSP farms in Israel, Spain and the USA.[28]

25 Armstrong et al. (2016).

26 Barron-Gafford et al. (2019).

27 Pathways for the spread of IAS are generally applicable to all types of construction projects. For some examples, see IPIECA & OGP (2010).

28 Ho (2016); Kagan et al. (2014). Other key references: Huso et al. (2016); McCrary et al. (1986).