Concurrent challenges for Switzerland: interfaces in climate action, biodiversity conservation, energy security and landscape preservation

White paper

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Summary

Climate change measures pose various challenges: how can we simultaneously preserve biodiversity, maintain the landscape, and secure the energy supply? One example of such tradeoffs can be illustrated by the upcoming vote on the Federal Act on a Secure Electricity Supply from Renewable Energy Sources. In order to scientifically assess the issues in question, a group of scientists with diverse backgrounds in an interdisciplinary project across six institutions of the ETH domain, named SPEED2ZERO, have analysed the challenges, opportunities and conflicting goals between climate protection, biodiversity conservation, energy security and landscape preservation. These key messages are a summary of the insights to support decision-making:

Key messages:

- Switzerland must decarbonise its energy sector more rapidly to meet its climate targets and protect biodiversity.
- The state of biodiversity is concerning. In Switzerland, the drivers of biodiversity loss so far are mainly not energy-related. However, if climate change remains unaddressed, it is expected to become a main driver of biodiversity loss. Climate change is also increasingly putting landscapes under threat. Thus, a major motivation to mitigate climate change is to address the resulting biodiversity loss and impacts on the landscape.
- Switzerland plans to move away from fossil fuels mainly through electrification, e.g., of heating and mobility. Switzerland aims to meet this increased electricity demand by expanding renewable electricity production by investing primarily in solar photovoltaic and expanding hydropower capacity. These dominant sources will be complemented with other technologies like wind, waste-to-energy (with carbon capture and storage) and power plants that run on biomass, synthetic gases, and green hydrogen.
- All new infrastructure, including renewable energy infrastructure, is not without negative impacts, and tradeoffs are inevitable. The choice of renewable technologies and–perhaps more importantly–their location have direct consequences on biodiversity and landscape, but these can be minimised.
- Change is inevitable: doing nothing does not mean that nothing will change. Rather, doing nothing means inevitable changes will be less predictable and probably less desirable. Therefore, Switzerland needs to make conscious changes today, while it still has some levers to steer change in a desirable direction.
- Negative impacts on biodiversity can be minimised by following four guiding principles: The minimum extent principle, connectivity, complementarity, and sustainability.
- The current discussions about the impact of new energy infrastructure on biodiversity are important. However, it should be emphasised that such installations are not, and most likely never will be, the main cause of biodiversity loss. To address biodiversity loss in general, Switzerland should also discuss and address its other drivers.

Introduction

Over the next few years, the Swiss population will have to make various important decisions to tackle the multifaceted challenge of mitigating climate change: how to simultaneously conserve biodiversity, preserve the landscape, and secure the energy supply. In this short white paper, we discuss some of the implicit and necessary tradeoffs that Switzerland must deal with and how this urgent energy transition to address climate change can be approached to minimise impacts on biodiversity and the landscape.

Inadequate speed for the targets set

Whilst the democratically set domestic targets in Switzerland are within range to meet the ratified international climate goals, Switzerland's measures to reduce its greenhouse gas emissions so far are insufficient (*1*). Amongst others, an important way of reducing these greenhouse gas emissions is to move away from fossil fuels through electrification, e.g., of transport or space heating, combined with electricity from low-emissions sources (e.g., *2*). Domestic electricity generation in Switzerland has already been almost completely decarbonised for many decades. However, the rest of the energy system remains heavily dependent on fossil fuels (e.g., heating and transport).

The switch from fossil fuels to electricity, coupled with a growing population, will increase the demand for electricity in Switzerland by approximately one-third from 58.5 TWh/yr today to 70-90 TWh/yr in 2050, depending on the plan of action (*3*, *4*). Switzerland wants to meet this rise in demand using sources of renewable energy, such as solar photovoltaic (PV), hydropower, and wind power. These sources will need to be paired with more dispatchable technologies like power plants powered with waste (with carbon capture), biomass, synthetic gases, or green hydrogen. Owing to the current legal and financial situation, and the time required for construction, new nuclear power plants are not expected to be relevant through 2050 (*5*).

Creating a new energy system based on renewables requires continuous and large investments that will take decades. In other words, in order to decarbonise by 2050, Switzerland needs to be proactive now. Until 2022, the annual increase in renewables capacity was too slow, at times substantially too slow, to reach overall decarbonisation targets. However, last year–for the first time–Switzerland installed solar PV at a rate (*6*) exceeding the rate required (i.e., 1100 MWp/year, including replacement) to achieve the Energy Strategy-targeted 34 TWh by 2050 (*7*). This rapid development was partly driven by high natural gas and electricity prices and uncertainties resulting from the international geopolitical situation as well as the ever-declining costs for PV. Gas and electricity prices have now relaxed (e.g., *8*), and it is unclear whether the pace from 2023 can be maintained. There are various reasons for the observed reluctance to adopt renewables, including the current system's momentum, high upfront costs, a lack of incentives, and complex social acceptance (e.g., *9*). Another part of this reluctance arises from concerns about expanding energy production at the expense of biodiversity and the landscape (e.g., *10*, *11*).

Worldwide, as well as in Switzerland, biodiversity losses are occurring at alarming rates. Switzerland needs to act more to prevent biodiversity losses. Efforts often go hand-in-hand with climate change mitigation. Recent assessments find that half of the habitats and a third of the species in Switzerland are threatened (*12*). With the decline in populations of species, genetic diversity is also being lost. The losses are continuing at other levels of biodiversity (species, ecosystem) (*12*). One of the most effective conservation measures is to leave more space for biodiversity (e.g., *13*). So far only 13.4% of Switzerland is protected with plans aiming for 17%, which is short of the 30% goal by 2030 agreed upon at COP15 and recommended by scientists[1]. Non-energy sector developments, such as urbanisation (*16*) and agriculture (*17*), are the biggest drivers of biodiversity loss. Within the energy-sector, the main–but not only–negative influence lies in the rapid warming induced by greenhouse gas emissions (*18*–*20*).

Inaction comes at a cost

With a warming of 2.8°C, Switzerland has warmed more than twice as much as the global average since the period 1871-1900 (*21*). The current and future rapid warming, and the altering of other key climate variables such as precipitation, will damage natural ecosystems and directly reduce biodiversity. While native species will disappear, non-native species will take their place, and some of them can become invasive, impacting ecosystems even further. The temperature increase has, and will, also change the landscape, for example through disappearing glaciers, destabilised slopes as a result of thawing permafrost, or dead, dried-up forests (*22*, *23*).

One of the main justifications for limiting global warming to 1.5°C is to avoid irreversible damage to global biodiversity (e.g., coral reefs, plant and animal species on land). With 2°C warming, global warming would become the largest driver of biodiversity loss (*24*). Therefore, any of the feasible net-zero strategies (different technology configurations are possible) will contribute to the protection of biodiversity by mitigating climate change. Even if the biodiversity loss is difficult to quantify and is rarely factored into decision-making (*25*), it is often irreversible damage that will continue to increase the costs of our inaction.

On the other hand, climate action measures, even if they preserve biodiversity and the landscape on a large scale, are not free of negative impacts at local or regional levels. In most cases, the best way to minimise the impact of new renewable infrastructure on biodiversity is when it is placed on existing infrastructure like buildings, roads, avalanche protection, or where biodiversity is already strongly affected, such as on managed land; these areas also enjoy greater social acceptance (*26*). But this is not possible–or necessarily optimal–in every case. A study by Salak et al. (*26*) found siting new renewable energy infrastructure to maximise ecosystem protection requires more total area for energy production compared with optimising placement for energy production alone. According to Salak et al., the increase in required area arises because ideal locations from a social acceptance and ecological standpoint are not necessarily the best locations to produce energy. Thus, a tension arises between minimising overall dedicated space and avoiding sensitive areas (*26*). Complex tradeoffs like this illustrate the costs of our urgently needed actions.

The costs of action and inaction are much more than just financial. But without a market or monetary equivalent it’s hard to choose between competing options or make fully informed policies. Ultimately, assigning options with a single cost value is highly uncertain[2]. For this reason, all-encompassing cost and benefit estimates cannot be credibly quantified (*27*). Still, there is a growing body of literature trying to quantify specific damages associated with climate change (e.g., *28*), including indirect damages such as the slow-down of economic growth (e.g., *29*, *30*). Despite having imperfect and incomplete estimates of these damages, when compared with the costs of mitigating climate change, a compelling case can be made that on a global level, the benefits from mitigating climate change are

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[1] Current protection status of Switzerland is 13.4%, and the current goal aimed for is 17% (14). The CBD (Convention on Biological Diversity) is asking for 30% by 2030, as agreed upon in 2022 in Montreal (*15*). Switzerland’s shortfall is at least 13%, therefore, as much as the entire area protected today.

[2] While investment costs or costs of adaptation can be estimated to some degree, the costs of biodiversity, ecosystem services, and changes in quality of life are difficult or impossible to quantify or compare reliably. These costs also must be treated differently due to their high uncertainty and potentially catastrophic and irreversible consequences. These costs also vary depending on time (e.g., deaths in 1,000 years vs. today) and location (e.g., somewhere on the globe vs. in a Swiss city).

likely to be larger than the cost of decarbonisation. This case is further strengthened if the co-benefits from decarbonisation are considered, for example, better health outcomes due to reduced air pollution, reduced impacts on biodiversity, and enhanced soil and water quality (e.g., *31*).

It may sound paradoxical, but doing nothing does not mean that nothing will change. Rather, doing nothing means inevitable changes will be less predictable and probably less desirable. Therefore, Switzerland needs to make conscious changes today, while it still has some levers to steer change in a desirable direction.

Maximising benefits, minimising impacts

A climate-neutral Switzerland by 2050 is technically and economically possible. The knowledge, technologies, and financial mechanisms are available (e.g., *32*). Studies have shown that the Swiss financial centre can cover investment requirements needed for a net-zero goal (*33*). However, Switzerland's political will is fluctuating. Yet–and perhaps luckily–there are many possible pathways to reach our climate goals. Ideally, Switzerland's task is to choose an energy pathway that also protects its biodiversity and landscape.

Biodiversity is not evenly distributed across the landscape, and therefore, a sound pathway avoiding the greatest negative impacts on biodiversity–and the services biodiversity or functioning ecosystems offer society–does not simply avoid constructing renewables in the most biodiverse locations. Rather, such a pathway requires careful optimisation procedures based on a few principles that can support decision-making.

1. The minimum extent principle: Successful biodiversity protection requires a minimal extent. The "30 by 30" rule, asking for protection of 30% of the national territory by 2030, is a sound compromise to reach sufficient area to protect the highly complex biodiversity in Switzerland (*34*).

The abundant species of Switzerland inhabit many different habitats from wet to dry, warm to cold, grasslands to forests. Furthermore, similar habitats in two different regions differ in species composition. Therefore, one cannot only protect a small area, as it will not give sufficient room for many species to survive, and it will not contain many different habitats (*35*). Moreover, it is not advisable to protect a larger area just in one region, even if it contains many habitats. This approach will leave many species from other regions unprotected.

2. Complementarity principle: Areas that are inhabited by species that are not otherwise well-protected by existing protected areas should be avoided for new constructions.

Switzerland needs to avoid new constructions in areas that are optimal for complementing biodiversity protection. In other words, one must assess to what degree Switzerland's biodiversity is preserved with existing protected areas, and then, additional areas to protect must be carefully selected in order to create a network maximising the number of protected species. Areas that primarily harbour species that are already well-protected are less harmful if lost to new constructions.

3. Connectivity principle: Areas that ideally connect existing protected areas within migration distance for the majority of species should be avoided for new construction.

Ongoing climate change requires many species to migrate in order to survive (*36*, *37*). The continued warming (and the often associated drying) requires species to find new locations that match their requirements regarding temperature and humidity. As a consequence, species are moving, often to higher elevations or to sites that were too humid or too cold before (*38*). Both migration as a natural part of a species life and migration stemming from climatic changes requires sufficient space. Most species cannot simply migrate across the landscape. Instead, species tend to migrate along patches of their preferred habitat (*39*). While this sounds complex, the national "ecological infrastructure" (*40*) approach, which is currently in the planning phase in the Cantons of Switzerland, is an excellent tool to support the connectivity principle.

4. Sustainability principle: Successful protection of biodiversity and maintenance of functioning ecosystems strongly contribute to climate change mitigation.

The vegetation cover of Switzerland binds large amounts of carbon; dry mass of vegetation consists of roughly 50% of carbon (e.g., *41*). Plants constantly die and regenerate. When dying, they emit carbon to the atmosphere. When growing, they extract carbon from the atmosphere. Worldwide, vegetation has absorbed around 30% of human CO_2 emissions through the CO_2-fertilisation effect and thus contributed to climate change mitigation (*42*). Ongoing climate change is causing ecosystems to show clear stress symptoms. Pine forests in the Valais and beech forests in the lowlands of the Swiss Plateau show increasing diebacks of dominant tree species in response to increasingly severe drought events (*43*). Massive diebacks, and the slower growth potential under drier conditions, will have a negative effect on the potential to extract carbon from the atmosphere (*44*). More biodiverse plant communities are more resilient to such negative influences from ongoing climate change than less biodiverse communities (*45*, *46*) and can for instance also help to stabilise steep slopes, and thus, to mitigate natural hazards.

With these guidelines in mind, Switzerland must choose which technologies and resources it will use for its electricity supply, and importantly, where to locate them. Most researchers agree that Switzerland will primarily rely on hydropower, photovoltaics, and to a lesser extent, on imports in order to achieve the democratically agreed upon energy transition. Switzerland will also rely on some combination of wind power and thermal generators (i.e., that run on wood, waste, biogas, or green hydrogen); however, these technologies' shares will be small compared to hydro or PV (*4*): Most scenario results suggest that by 2050, Switzerland will generate around 50% of its electricity with hydropower (including the expansion planned by the Swiss government), while the share of solar energy in future electricity demand will be around 40% (*4*).[3]

Typically, hydropower produces the most electricity in the spring and summer from the melting snowpack and glaciers. Solar produces the most electricity in summer when the days are long. While all these electricity sources also produce in winter, especially those in mountain regions, electricity demand in Europe is also higher in winter. Therefore, this electricity supply will need to be complemented by electricity trade, technologies producing more in winter (e.g., wind, high altitude solar) and/or with dispatchable generation (e.g., existing or upgraded hydro storage or thermal power plants using natural gas with carbon capture and storage, biogas or hydrogen) (*47*). The physical configuration of these technologies will have an impact on biodiversity and landscape. Nevertheless, there are options to reduce this impact while still achieving our energy targets, especially in high mountain regions, where biodiversity is particularly vulnerable to climate change, extremes, and other disturbances.

Scientific acceptance surveys on new renewable energy infrastructure conclude the following two main points: Renewable energy plants in Switzerland are rated more favourably in already built-up areas, e.g., in the densely populated Central Plateau or in regions with existing tourist infrastructure (e.g., *48*). In addition, a landscape scenario is rated more favourably if the landscape and energy installations are perceived as compatible with the natural landscape. Secondly, if the energy plants are built in a condensed way instead of distributed across landscapes, socio-political acceptance is higher

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[3] In this respect, Switzerland is an outlier in Europe: across the rest of the continent, wind energy currently produces the most renewable electricity, and according to national development plans, will continue to be expanded (*5*).

(*49*). These two points are also in line with the guiding principles for biodiversity protection. Furthermore, stakeholder workshops assessed a set of relevant criteria for planning new renewable energies in a biodiversity and landscape-friendly way (*50*).

Renewable energies and their effects

Given the various options for renewable energy sources, it makes sense to analyse them for their energy potential, effects on the landscape, and the biodiversity in Switzerland.

Hydropower provides about two-thirds of the current Swiss electricity mix but has a significant impact on biodiversity and landscape, and there is not as much flexibility in choosing where to place this infrastructure. These impacts vary according to the type of hydropower facility: run-of-river, storage, or pumped storage. For example, the Swiss Water Protection Act (*51*) requires restoring the free passage of fish along rivers, which would in turn be negatively impacted by new run-of-river power plants. In general, run-of-river hydropower plants are detrimental to spawning fish and greatly impact the movement of nutrient-rich sediment. Storage lakes and pumped storage facilities damage biodiversity mainly by flooding or draining/washing away habitats where species are breeding (or growing in the case of plant life). Hydropower is also a contributor to erosion and shoreline instability, which can equally contribute to biodiversity loss, and potentially trigger landslides or rock falls.

According to the Swiss Federal Office of Energy, Switzerland has already exploited the majority of its hydropower potential with its almost 700 hydropower plants with capacities of greater than 300 MW nationwide. These plants can produce around 37 TWh per year or 60% of total electricity demand (*3*). Still, in the Energy Strategy, Switzerland committed to producing more electricity from hydropower. Ultimately, the Swiss government, together with relevant stakeholders, selected 15 hydropower investments based on the projected biodiversity and landscape impacts as well as how much additional capacity the projects would provide. The selected projects will increase winter production by 2 TWh (*52*). The majority of these projects are upgrades at existing facilities (i.e., heightening of existing dams to increase storage capacity); however, two new facilities are also being planned at the Gorner and Trift glaciers (*53*). These new facilities will also be important in managing the excess water from melting glaciers.

In terms of social acceptance, existing hydropower plants are largely uncontroversial, partly because people have gotten accustomed to them, and municipalities often benefit financially. In fact, some Swiss dams are even considered iconic and important to tourism. However, new plants do not have the same level of acceptance (*54*). Some studies suggest that ecological compensation, such as the renaturation of local streams in the region, has a favourable influence on acceptance (*55*), which would also support local biodiversity preservation. In addition, multi-purpose uses of hydropower plants can increase acceptance regionally and nationally (*56*): In addition to electricity production, plants can also be used for agricultural irrigation or drinking water supply, to protect against flooding, or to create tourist attractions.

Switzerland's significant **solar PV** potential is just beginning to be exploited. In 2023, Switzerland installed 1500 MW of new solar PV capacity and the total installed capacity reached 6200 MW, producing 6.4 TWh (*6*). Last year's rate would be sufficient to meet the scenario targets of up to 34 TWh (*57*). Still, there is a long way to go. Especially since it is likely that last year's installation rate, partly motivated by the natural gas shortage in Europe and the uncertainties around France's capacity to export electricity, may not be sustained without additional measures. Almost all current scenarios assume that the majority of this new capacity will come from solar installations on roofs and facades, as the investment risk is low, social acceptance is high (*58*), and individuals can benefit from self-consumption (*54*). Indeed, the vast majority of existing solar PV is on buildings (*59*). Yet, the PV potential on a roof is often only partially exploited, reflecting private financial benefits rather than societal needs. But if all private investors only exploit part of the solar potential on their roofs, the installed capacity on roofs will not be adequate to meet the Swiss targets and other locations/types of PV will need to be pursued to a greater extent.

There is also a high level of acceptance for PV on other installations such as noise barriers along motorways or other functional structures such as avalanche barriers. Synergies through multifunctional land use are also conceivable, for example, if agricultural or pasture land remains usable despite PV panels. Switzerland is very restrictive regarding ground-mounted solar PV, while in the European Union, three-quarters of the solar power generated comes from ground-mounted systems. Ground-mounted solar can be built faster, and is typically less expensive, while the land in many cases can still be used for its original purpose (e.g., animal grazing). Recent studies suggest ground-mounted systems will be important to meeting national targets (*26*). Other proposed locations include industrial and farming locations, and most controversially, in alpine locations.

PV panels located on roofs or in already built-up areas are in line with the guiding principles for biodiversity protection, as they have minimal to no adverse effect on biodiversity (*60*). There is currently only a small body of literature, but so far there is no evidence that solar infrastructure, when built on land that had (or continues to be) devoted to agriculture, has negative effects on biodiversity (e.g., *61–63*). Alpine PV has the advantage that it produces more electricity in winter, when future electricity generation in Switzerland will likely have a higher value (e.g., *47*). However, the alpine location is sensitive both regarding biodiversity and landscape. From an energy perspective, solar PV panels would most likely be located on south-facing slopes, where the solar potential is highest. Positioned there, the panels would block sunlight from the ground and change the plant abundance and/or species composition. Depending on the size and placement of the panels, animal migration or grazing space could also be reduced (*60*). While PV may affect species' distribution, it is important to note that many planned alpine PV locations are not in pristine natural habitats but on managed land, where biodiversity is already strongly affected, e.g., by grazing livestock or tourism.

From a landscape perspective, social acceptance for PV panels in the mountains is considered lower than on buildings, but a recent survey suggests this is changing with about 60% of the Swiss population and 56% of the local population in favour (*64*). About two-thirds of the proposed alpine PV projects passed a local vote. One proposal is to co-locate PV panels on avalanche guards to reduce the visual impacts of these infrastructures (*65*). However, the latter is also associated with technical issues (and related high financial costs for construction and maintenance) and potential reduction of the primary protection function of the avalanche guards (*66*). Regardless, most researchers do not expect alpine PV investments without significant government support (*67*).

While in all scenarios within the Swiss research community solar PV and hydropower will provide the majority of electricity, Switzerland will also rely on technologies like wind, synthetic gases, and waste combustion. **Wind power** currently produces approximately 0.14 TWh/year from 40 wind power sites (*68*). According to the most recent study by the Swiss Federal Office of Energy, the total technical potential of wind is 29.5 TWh/year in Switzerland (*69*). Wind produces the majority of its annual electricity during the wintertime; therefore, it is a favoured technology to help compensate for reduced production by solar and hydropower during these months.

From a biodiversity perspective, wind power overall has limited impacts. However, there is a pronounced effect on certain species–in Switzerland, mainly birds and bats. This impact can be reduced by careful planning of wind power plant locations at safe distances to bird breeding sites or migration routes of endangered species and by active measures, such as automatic detection of approaching birds to temporarily switch-off the wind power plant to avoid collisions (*70*). The acceptance of wind power plants is limited–especially due to their high visibility (*71*)–particularly in the lowlands close to population centres. Financial benefits, distributed in proportion to the amount of electricity produced, can also increase the acceptance of wind turbines and create incentives for the local population, as seen with the successful approaches of Bürgerwindparks in Germany. Synergies through multifunctional land use are also conceivable, for example, if agricultural land remains usable despite wind turbines. Some studies also find that when wind power is combined with PV, its acceptance is increased to a certain extent (*54*).

Waste-to-energy and synthetic gas power plants, including biogas or hydrogen, can be so-called ‘dispatchable’ energy. That is, electricity can be produced whenever it is demanded, independent of the weather or season. There is disagreement about the roles synthetic fuels and hydrogen will play or where these fuels will be sourced. Not only can electricity imports substitute for synthetic gas combustion domestically, but imports of the synthetic fuels themselves can let Switzerland consume rather than produce. Much of the disagreement stems from uncertainties in future costs of hydrogen and synthetic fuels, which are strongly determined by decisions and investments abroad.

Switzerland has been using its waste incineration to produce both heat and electricity. In 2019, these plants produced approximately 4 TWh of heating and 1.8 TWh of electricity (*72*). These plants also contributed 5% to Switzerland’s greenhouse gas emissions in 2022 (*73*). However, according to plans of the Federal Council, carbon capture and storage technologies will be deployed at the 29 waste incineration sites around Switzerland (*74*). If the experience of these plants to date holds, energy production with waste may increase over the century due to increased consumption patterns (*75*), though efficiency and circularity measures could moderate that increase.

If their CO_2 emissions are abated, these infrastructures are unlikely to have a large impact on biodiversity and landscape. These thermal plants are large and centralised, and typically close to where the demand for their energy (human populations) is located. Thus, one can anticipate that locations that can host large facilities close to population centres are likely already densely populated and or already hosting a generation facility.

Existing waste-to-energy plants are widely accepted in Switzerland, yet the use of biogas power plants has so far not been widespread. Studies by WSL have shown that farmers would be more willing to invest in biogas plants if they received higher remuneration for the energy carrier produced. They also prefer to own their own plants instead of building larger plants together with other farms (*54*). From an energy policy perspective, however, centralised plants make sense as they can operate more efficiently and simplify the feeding in of biogas, as most farms do not have a gas pipeline nearby. Accordingly, agricultural biogas production could be expanded if municipalities, agricultural cooperatives and/or energy companies were to encourage and coordinate such an expansion. This would reduce the coordination effort for farmers and make community plants more attractive for them (*54*).

Regardless of discussions around energy, Switzerland needs to actively protect and preserve biodiversity

The current debate around the impact of new renewable energy installations on biodiversity and the landscape is important. However, it should be emphasised that such installations are not, and most likely, never will be, the main cause of biodiversity loss. Among many other essential ecosystem services, ecosystems with intact biodiversity offer resilience against the effects of a warming climate and therefore are an important aspect of climate change mitigation (*2*). The continuation of the biodiversity loss we have observed in recent decades poses a major threat to our society, locally and globally. To prevent further loss, we must broaden our policy discussions and also critically review the use of common practices (*76*) that currently put biodiversity under great pressure.

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