Environmental Management (2014) 54:744–755
DOI 10.1007/s00267-014-0333-8

PROFILE

Cautious but Committed: Moving Toward Adaptive Planning and Operation Strategies for Renewable Energy's Wildlife Implications

Johann Köppel · Marie Dahmen · Jennifer Helfrich · Eva Schuster · Lea Bulling

Received: 30 September 2013 / Accepted: 7 July 2014 / Published online: 7 August 2014

Abstract Wildlife planning for renewable energy must cope with the uncertainties of potential wildlife impacts. Unfortunately, the environmental policies which instigate renewable energy and those which protect wildlife are not coherently aligned—creating a green versus green dilemma. Thus, climate mitigation efforts trigger renewable energy development, but then face substantial barriers from biodiversity protection instruments and practices. This article briefly reviews wind energy and wildlife interactions, highlighting the lively debated effects on bats. Today, planning and siting of renewable energy are guided by the precautionary principle in an attempt to carefully address wildlife challenges. However, this planning attitude creates limitations as it struggles to negotiate the aforementioned green versus green dilemma. More adaptive planning and management strategies and practices hold the potential to reconcile these discrepancies to some degree. This adaptive approach is discussed using facets of case studies from policy, planning, siting, and operational stages of wind energy in Germany and the United States, with one case showing adaptive planning in action for solar energy as well. This article attempts to highlight the benefits of more adaptive approaches as well as the possible shortcomings, such as reduced planning security for renewable energy developers. In conclusion, these studies show that adaptive planning and operation strategies can be designed to supplement and enhance the precautionary principle in wildlife planning for green energy.

J. Köppel (✉) · M. Dahmen · J. Helfrich · E. Schuster (✉) · L. Bulling
Environmental Assessment and Planning Research Group, Technische Universität Berlin (Berlin Institute of Technology), Secr. EB 5, Straße des 17. Juni 145, 10623 Berlin, Germany
e-mail: johann.koeppel@tu-berlin.de

E. Schuster
e-mail: eva.schuster@tu-berlin.de

Keywords Wildlife planning · Renewable energy · Adaptive management · Precautionary principle · Wind energy and wildlife impacts

Introduction

Our energy supply is steadily transitioning from a mostly centralized power plant and transmission grid structure to a more decentralized supply based on an increasing share of renewable energies. The siting of renewables entails a different set of planning approaches, and decentralized power supply—by its very nature—requires more spatial planning. This is especially the case for wind energy, as it can be sourced not only from rural terrestrial landscapes, but also from off-shore seascapes. Germany and the USA are forerunners in wind (Geißler et al. 2013) and solar energy deployment, and have ambitious plans for continued development.

This has also triggered innovations in spatial planning, local zoning, marine spatial planning, and grid interlinkages along with the associated environmental planning challenges. These policies and implementation processes have been accompanied by a steady stream of uncertainties. Sound decision-making for renewable energy sites remains an ongoing dilemma, even more so given that wildlife impacts are not fully understood (e.g., Cryan 2011 and Voigt et al. 2012 for migratory bats). Yet, environmental planning and impact assessments have always been faced by uncertainties—the challenge is to adjust methodology and adapt planning and operation processes while allowing growth to continue to meet ambitious goals of renewable energy deployment.

In the following, we explore current and upcoming strategies for coping with the uncertainties of renewable energy siting and operation on wildlife. The first section sets the groundwork by identifying relevant planning theories and the challenges of effectively making relevant environmental policies coherent. This is followed by the question of does our current knowledge on wind energýs wildlife implications allow for a move toward more adaptive planning and management strategies? A brief review of research on wind energýs impacts on bats addresses this, as one of the most affected species groups. Third, we ask which strengths and weaknesses set the predominant precautionary principle's implications for the planning and siting of renewable energy. Recognizing that some aspects will always remain uncertain (e.g., Jalava et al. 2013), we then turn to the question of which more adaptive planning and management approaches might be available? We scrutinize this alongside facets of cases from the United States and Germany on policy, planning, siting, and operation levels of wind energy and focus on adaptive planning for solar energy in one case as well. We not only conclude with the merits of more adaptive approaches but also discuss possible downsides, thus addressing areas for further research.

Planning Theory and Environmental Policy Coherence

The predominant rational planning theory is primarily a pursuit of comprehensive, research and technology-based approaches to reduce the uncertainties involved in decision-making processes. However, our capacity to predict impacts of renewable energy on wildlife remains limited no matter the planning route. This restricts the potential of both comprehensive decision-making processes and environmental assessments. Rational planning is also, and inevitably, influenced by social attitudes and political pressure (Nie 2011). In contrast, in collaborative planning approaches (CEQ 2007), the planning process itself is the focus, rather than the pursuit of rational-technical outcomes. In a way, adaptive planning theory combines many of these strengths by relying on predictions and modeling, recognizing environmental dynamics, incorporating monitoring-based adaptations, and being grounded in the creation of trust among stakeholders (Dahmen 2012; Kato and Ahern 2008).

Another important consideration in wildlife-conscious renewable energy planning is the appropriate coherence and integration of environmental policies. This is especially the case where mitigation of climate change typically triggers renewable energy deployment which can impact ecosystems and wildlife. Coherent environmental policies, instruments, and implementation practices would help avoid problematic outcomes (Nilsson and Persson 2012; Nilsson et al. 2012). The deployment of renewable wind energy should not create unintended impacts on biodiversity objectives. Likewise, wildlife protection policies are not intended to counteract the achievement of climate protection goals via renewable energy deployment. Moreover, climate protection is actually in support of nature conservation and biodiversity efforts (ibid.; Ledec et al. 2011). Furthermore, this can require the coordination of not only intersectoral, intergovernmental, and public–private governance, but also include both spatial and temporal concerns (Portman and Fishhendler 2011). Integration and coordination of disparate governing and planning facets are discussed in more detail later.

Knowledge Integration: A Brief Review of Wind Energy's Effects on Bats

The last decade has seen the launch of numerous and varied research programs for understanding and mitigating wind energy's impacts on wildlife (e.g., Köller et al. 2006). In Europe, the Conference on Wind Energy and Wildlife (CWW 2011, Trondheim, Norway) and the Conference on Wind Power and Environmental Impacts (CWE 2013, Stockholm, Sweden) have been showcases of lessons learned from academic, professional, and agency initiatives. Current wildlife-conscious wind energy planning guidelines (e.g., Strickland et al. 2011; U.S. Fish and Wildlife Service 2012, Washington Department of Fish and Wildlife 2009) underpin and translate the state of research on the ongoing decision-making processes behind wind farm development and siting. Wildlife planning and impact assessment needs to be informed correspondingly; what do we know so far, which topics are still controversial, which predominant uncertainties remain? In the following, we provide an example in a brief overview of the potential effects of wind energy on bats which had long been underestimated (cf. Table 1).

Studies around the world have revealed concerning bat mortality rates (Arnett et al. 2008; Brinkmann et al. 2006; Doty and Martin 2013; Kerns and Kerlinger 2004; Kunz et al. 2007). Bat fatalities outnumber those of birds in most studies (Barclay et al. 2007; Doty and Martin 2013; Ledec et al. 2011; Piorkowski and O'Connell 2010). However, the number of observed and estimated fatality rates varies widely (Arnett et al. 2008; Barclay et al. 2007; Rydell et al. 2012), indicating that bat activity and fatality are species, season, site (Arnett et al. 2008; Kunz et al. 2007; Rydell et al. 2010b), and population specific (Voigt et al. 2012). Additionally, some authors stated that even though reported fatalities were high, the actual number of bats being killed may be even higher due to, among other things, limited search efficiency, carcass removals, seasonal duration of the studies (Arnett et al. 2008), and sublethal collision resulting in off-site deaths (Grodsky et al. 2011).

Rydell et al. (2012) showed an overview of corrected fatality rates per turbine and year reviewing studies from Europe and North America ranging from 0 to 70 dead bats.

Table 1 A survey of hypotheses on bat collision and barotrauma-induced mortality risk at wind turbines

Hypothesis	Supported	Not supported
Conditions/times of high activity/fatality		
An increase in temperature enhances bat activity (up to min. >21 °C)	Arnett et al. 2006, 2007; Brinkmann et al. 2011; Grodsky et al. 2012; Hein et al. 2011; Kerns et al. 2005: Meyersdale; Redell et al. 2006	Horn et al. 2008: but in combination with wind speed; Kerns et al. 2005: Mountaineer
A decrease in wind speed leads to a higher bat activity	Arnett et al. 2006, 2008; Baerwald et al. 2009; Brinkmann et al. 2011; Hein et al. 2011; Horn et al. 2008; Kerns et al. 2005; Redell et al. 2006	Arnett et al. 2007: highest at moderate wind (~8 m/s) and high temperature; Grodsky et al. 2012; Hein et al. 2011: low frequency bats
High air pressure before and after storms increases bat activity	Arnett et al. 2008; Kerns et al. 2005	Horn et al. 2008
During late summer/autumn	Amorim et al. 2012; Arnett et al. 2006, 2008; Brinkmann et al. 2006, 2011: July/August; Cryan and Brown 2007; Doty and Martin 2012: southern hemisphere; Grodsky et al. 2012; Hein et al. 2011; Jain 2005; Johnson et al. 2003, 2004; Redell et al. 2006; Rydell et al. 2010b	
Flight behavior		
Migratory species particularly at risk	Arnett et al. 2008; Baerwald et al. 2009; Cryan and Brown 2007; Cryan and Barclay 2009; Grodsky et al. 2012; Johnson et al. 2003, 2004; Kunz et al. 2007	Ahlén 2003; Brinkmann et al. 2006; Hull and Cawthen 2013; Rydell et al. 2010b; Voigt et al. 2012
Use of echolocation during flight, reaction time insufficient	Grodsky et al. 2011; Kunz et al. 2007; Long et al. 2009; Rydell et al. 2010b	
High risk flight behavior like mating, feeding or swarming leading to multiple approaches	Arnett et al. 2008; Cryan and Brown 2007; Cryan 2008; Doty and Martin 2012: insectivorous bats; Grodsky et al. 2011; Horn et al. 2008; Hull and Cawthen 2013; Redell et al. 2006; Rydell et al. 2010b	
Open-air foragers with narrow wings more exposed to collision risk	Ahlén 2003; Albrecht and Grünfelder 2011; Doty and Martin 2012; Hull and Cawthen 2013; Rydell et al. 2010a, b	
Increased mortality due to attraction		
Turbines as possible tree-roosts	Ahlén 2003; Cryan and Brown 2007; Cryan 2008; Cryan and Barclay 2009; Hull and Cawthen 2013; Kunz et al. 2007	
Attraction due to increased prey availability	Ahlén 2003; Ahlén et al. 2009; Arnett et al. 2011; Grodsky et al. 2012; Horn et al. 2008; Kunz et al. 2007; Rydell et al. 2010a	Hull and Cawthen 2013: collision victims had empty stomachs
Attraction to light	Johnson et al. 2004: higher activity but no difference in mortality rate	Arnett et al. 2008; Horn et al. 2008; Johnson et al. 2003; Kerns et al. 2005
Increased mortality risk caused by indirect interaction with operating turbines		
Rapid change in air pressure by moving blades can lead to internal injuries and accounts for the main cause of fatality (barotrauma)	Baerwald et al. 2008	Grodsky et al. 2011: combination of direct collision and barotrauma; Houck 2012; Rollins et al. 2012
Bats caught in vortices can be contorted, which may result in injury	Grodsky et al. 2011	

Hayes (2013) estimated that in 2012, over 600,000 bats might have been killed by wind turbines in the United States. In another study, only 50 % of bats found dead under turbines, showed external injury caused by direct collision, whereas up to 90 % had internal hemorrhage, indicating barotrauma (Baerwald et al. 2008). In contrast, Rollins et al. (2012) and Grodsky et al. (2011) argue that other factors like post mortem time, environmental temperature, and freezing of carcasses cause tissue damage, mimicking the diagnostic criteria of pulmonary barotrauma, implying direct collision as the primary fatality cause (Rollins et al. 2012).

Studies showed that most fatalities were tree-roosting (Hull and Cawthen 2013; Kunz et al. 2007), high-flying, open-air foraging (e.g., Doty and Martin 2013; Hull and Cawthen 2013), and insectivorous bats (e.g., Doty and Martin 2013; Horn et al. 2008) with long and narrow wings (Hull and Cawthen 2013). Surveys from Hull and Cawthen (2013) and Arnett et al. (2008) reported mostly adults among the fatalities, whereas Rydell et al. (2010b) found fatalities to be indifferent to age as well as sex. Many authors stated that migratory bats were at greater risk than local species (e.g., Arnett et al. 2008; Kunz et al. 2007), but resident species have also been reported (Brinkmann et al. 2006; Rydell et al. 2010b).

The reasons behind wind turbine-related bat deaths are not yet fully understood. It has been observed that bats seem to be attracted to moving turbines (Arnett et al. 2008; Horn et al. 2008; Kunz et al. 2007), bringing into question the relation between pre-construction bat activity and post-construction fatality (Ahlén and Baagøe 2013; Arnett et al. 2011; Hull and Cawthen 2013). Nevertheless, high temperature, low wind speed (Arnett et al. 2006), and insect abundance were significant predictors for bat activity (Ahlén et al. 2009; Horn et al. 2008). Other hypotheses explaining bat activity as due to an attraction for ultrasonic sounds, installed lighting, or roosting and mating behavior around turbines have not been fully tested yet (Arnett et al. 2008; Kunz et al. 2007).

Today, many bat species are threatened, and hence protected by the national and international laws e.g., the Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora. Only little is known about actual population sizes and mortality rates of bats, which makes it a challenge to assess the impacts of wind energy development (Willis et al. 2009). Given that only few bat species seem to be affected (Willis et al. 2009) and also the low reproduction rates of bats (Barclay and Harder 2003), it becomes likely that wind energy might effect some populations. With further development and increasing turbine height, bat mortality is likely to increase (Barclay et al. 2007).

However, impacts on wildlife from other anthropogenic structures and activities, such as vehicles, buildings, fossil fuel exploitation, and also cat predation need to be considered too (Erickson et al. 2005; Sovacool 2013 on birds). While some attempts have been made to estimate mortality rates for birds from anthropogenic causes, studies on bats are still scarce. Willis et al. (2009) stated that negative effects from fossil fuels on bats are likely, whereas Rydell et al. (2012) summarized the findings of the few existing studies from Poland and the Czech Republic on bat mortality from traffic. It is possible that the number of bat fatalities from traffic is notably higher than from wind energy stating a range of 0.3–6.8 bats (Lesinkski 2007) and an average of 15 bats per kilometer and year, respectively (Gaisler et al. 2009).

Studies on cumulative effects from wind energy on bats are also rare. Johnson et al. (2011) estimated a total bat mortality of 7,638 individuals annually for the Columbia Plateau, addressing a mean bat mortality estimate of 1.14 fatalities/MW/year. The authors conclude that with this relatively low rate, the impact is likely not significant in this region, but cannot be excluded. However, cumulative effects most likely vary among regions due to different vegetation types resulting in higher mean annual mortality rates (Johnson and Erickson 2011).

While the state of knowledge about wildlife interactions with onshore and off-shore wind farms is constantly improving, there are still many gaps. Yet, uncertainties will always remain—a fact which challenges the precautionary principle as an environmental planning paradigm when it comes to potentially competing environmental priorities like climate mitigation and wildlife protection.

Precautionary Principle: A Mandate for Vigilance and its Limitations

Given these myriad challenges, most actors have favored a cautious roadmap for decision-making on wind energy sites, using a well-established and long struggled for environmental policy approach: The precautionary principle (Harremoës et al. 2001; Kriebel et al. 2001). The inherent uncertainties of wind farm siting make cross-cutting implementation of the precautionary principle a rational approach. The precautionary principle is based on preventative action, exploring alternatives, shifting the burden of proof to proponents, and increasing public participation (Kriebel et al. 2001). The principle combines research with a mandate for vigilance. (ÓRiordan and Cameron 1994) defined the precautionary principle as a culturally framed concept grounded on social conceptions about the appropriate roles of science, economics, ethics, politics, and law in pro-active environmental protection and management. It is based on the German socio-legal tradition and implies a willingness to take action up front of scientific proof of evidence (ibid.). The term is said to have made its way into English in the early 1980s translating the German term "Vorsorgeprinzp" (Boehmer-Christiansen 1994). Harremoës et al. (2001) provided a comprehensive overview of its evolution in the 20th century, highlighting important milestones in the fields of fishery, radiation, PCBs, sulfur dioxide, hormones, the chemical contamination of the Great Lakes, and others.

For wind energy, Cryan (2011) and Voigt et al. (2012) called for a planning mentality which is vigilant about new insights into the effects on migratory bats. Carrete et al. (2009) presented how early even low reductions in bird survival associated with wind farms can impact the population viability of long-lived raptor species. Carrete and Sánchez-Zapata (2010) explicitly addressed the precautionary principle's importance for wind farm planning as data scarcity does not necessarily imply an absence of effects. In Germany, protected sites and no-go buffer zones protecting breeding sites of certain bird species ("Tierökologische Abstandskriterien" LAG-VSW 2007, MUGV 2012) have strongly influenced regional planning and local permitting processes for wind farm siting (Piela 2010).

While applying the precautionary principle to wind energy siting is prudent, the method also has a corresponding downside. Limited spatial resources, as in Germany, when combined with the precautionary principle and its extensive wind energy exclusion areas can detract from climate change mitigation objectives. The root cause of this type of difficulty is an overarching challenge in environmental policy making; the still-not-fully-paved road to feasible approaches for making environmental policies coherent. Unfortunately, this green versus green dilemma (Woody 2010) is clearly visible in the case of renewable energy versus biodiversity protection goals (Jackson 2011), or its equivalent in the environmental groups versus green energy phenomenon (Yonk et al. 2013). Jackson (2011) even raised the question of whether provisions for biodiversity protection are sacrosanct, even if they impede the progress of policies aimed at addressing climate change. Instruments for dealing with this delicate challenge, such as strategic environmental assessments, still often fail to avert conflicts on early planning levels (Geißler 2013). This brings overreliance on the precautionary approach into question, making the case for a supplemental evidence-based and site-specific planning approach for wind energy—a shift which, at its best, would allow for a better balance of environmental policies.

Uncertainty Will Always Remain: Adaptive Planning and Management

As there will always be uncertainties about wind energýs wildlife impacts, adaptive planning (Kato and Ahern 2008) and management (Williams et al. 2009, Williams 2011)—iterative decision-making processes based on interim results and stakeholder participation—might more actively facilitate the development of renewable energy as part of efforts to meet climate policy goals. However, feasible adaptive planning approaches cannot be established through trial and error. In contrast, it needs a clearly defined outcome, an investigative approach alongside possible pathways and respective management consequences, long-term measurement as well as the commitment of all stakeholders involved (CEQ 2003; Kato and Ahern 2008). With adaptive planning and management approaches, the established mitigation hierarchy of avoidance of impacts on wildlife (e.g., different locations), minimization (e.g., micro-siting of wind turbines, repowering), reduction (e.g., temporary curtailments), and compensation becomes supplemented with mandatory monitoring and reflexive adaption measures. Monitoring is the key element making the planning an iterative process where a development is regularly proofed, new data are acquired, and the effectiveness of the original or previously updated approach is regularly assessed (Morrison-Saunders et al. 2007).

Once constructed, wind turbines are not substantially modifiable but with adaptive measures, they can be operated with reduced risk for birds and bats. These measures can include temporary curtailments for times with high fatality risk (Brinkmann et al. 2009) as well as repowering approaches—a replacement of many smaller turbines with few larger ones (Smallwood et al. 2013). The knowledge gained at a project level can help decode causal interactions, as well as determine the accuracy of impact predictions (CEQ 2003). However, planning for wind energy projects is usually integrated into an overall energy policy addressing the spatial distribution of energy supply and demand. Thus, adaptive planning approaches for wind energy can be categorized into different levels: policy, planning, siting, and operation (cf. Fig. 1).

On the policy level, the adaptation of guidelines and laws can be accomplished according to new research and the meta-findings of ongoing monitoring, reviewed and implemented by stakeholder boards established for that purpose. In Germany, a joint federal-state working group, chaired by the Federal Ministry of the Environment (BLWE 2013), has been discussing adaptive adjustments with special attention to spatial planning. The efforts of this group have also been triggered by a recent Supreme Administrative Court decision requiring state and municipal planning agencies to identify substantial siting opportunities for wind energy.

The nuclear phase-out triggered southern German states as well to shift siting policies to allowing for more wind energy growth. For example, in Baden-Wuerttemberg state, wind energy development had been restricted to designated areas with other sites categorically excluded. With this 'black-and-white-planning' there was little scope left once the regional plans were set up. A more recent guidance calls for less exclusion and allocates more power to the local municipalities (UM 2012). Regulated by federal law, specific land use plans on wind energy deployment have been designed to avoid time-consuming full amendments of comprehensive regional and local land use plans (the latter so-called "Teilflächennutzungspläne," §5 Abs. 2b Federal Building Code). The revised statutory basis ensures accelerated procedures to meet the substantial siting requirements earlier and supports the repowering of wind farms (Söfker 2012).

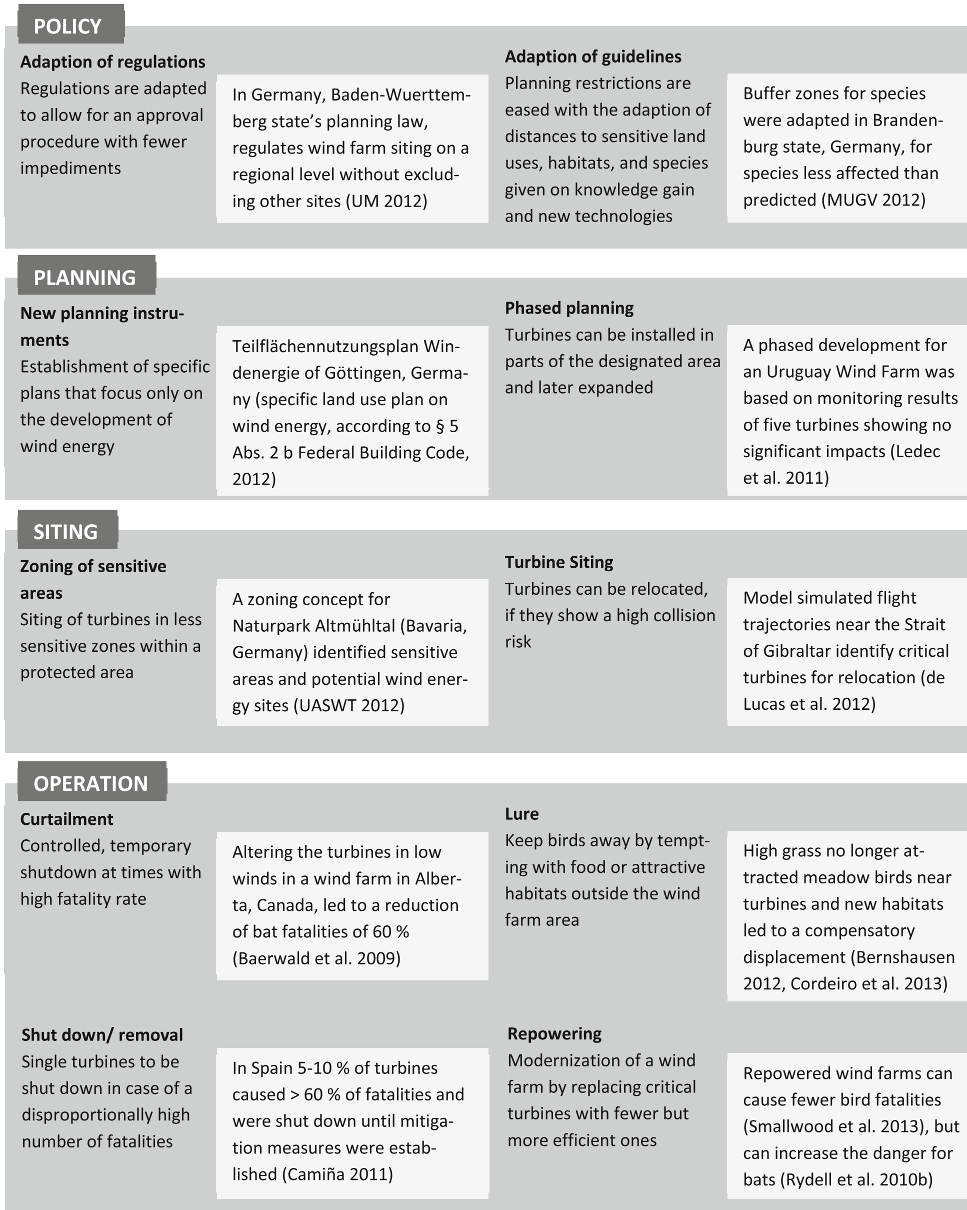

Fig. 1 Adaptive planning and management approaches and examples for wind energy on policy, planning, siting, and operation levels (allowing for iterative, i.e., pre- and post-construction practice)

Furthermore, ca. 30 % of Germany is covered by "Landschaftsschutzgebiete" and "Naturparke," both categories designed to protect cultural landscapes. Recent state guidelines (e.g., in Bavaria) allow for zoning of these major protected sites, identifying some potential siting opportunities while still setting aside no-go areas. First attempts at this new zoning can be seen in "Naturparks" in Bavaria (UASWT 2012) and a methodological study for selected "Landschaftsschutzgebiete" in Brandenburg state (Erdmann 2013) where both have identified 10–20 % of the land as feasible sites which would not detract from the overarching protection objectives. Moreover, there are instances where German guidelines have been adapted based on monitoring, such as adjustments made to TAK ("Tierökologische Abstandskriterien") buffer zones for endangered birds' breeding sites in Brandenburg state based on more recent research results. Nadaï and Labussière (2010) address the relevance of micro-siting as well, based on the observed bird behavior.

In terms of operation, temporary curtailment of turbines during peak wildlife fatality times does not necessarily require the up front creation of permanent obligations, but can be adjusted based on monitoring. Besides curtailment, the collision risk can be reduced through adapted management methods for tempting birds away. An example of this practice is "vulture restaurants," which were successful in Northern Spain, where 5–10 % of the turbines caused 60 % of the fatalities. One year after offering carcasses at vulture restaurants, the vultureś mortality was reduced by 80 % (Camiña 2011). Another approach is the management of the turbine's close vicinity; higher grass, for instance, no longer attracts threatened meadow birds and newly designed habitats outside the wind farm area compensate for the loss and lead to a displacement effect (Bernshausen 2012, Cordeiro et al. 2013).

In the following, we examine three case studies which showcase ambitious adaptive management approaches.

Shaffer Mountain wind farm in Pennsylvania, USA (FWS 2011)

An adaptive management plan providing thresholds and operation standards for bats

Shaffer Mountain is a major flyway for migrating hawks, eagles, and especially for the endangered Indiana bat. A biological assessment under the EPA (Endangered Species Act) was required to address potential impacts and mitigation measures. Gamesa Inc. applied in 2006 for a 30 turbine, 60 MW wind power project. Due to the significant harms the turbines could cause and the uncertainty about actual effects, an Adaptive Management Plan (AMP) was drafted in 2011 by the local Fish and Wildlife Service as an Annex of the Biological Opinion. It allowed the turbine siting near a maternity colony of Indiana bats, as long as thresholds and operation standards were in compliance. The "AMP-compliant fatality rate" was not to exceed 2 % of the Indiana bat maternity colony annually (assuming the maternity colony consisted of 50 adult females). Minimization and habitat conservation measures should reduce bat fatalities and avoid colony extirpation in combination with post-construction monitoring and an adaptive management strategy that includes turbine curtailment.

For year one, a curtailment was set from April 1st to October 15th at a wind speed of below 5.5 m/s and turbines close to the primary roost trees under limited operation. If the fatality rate was not AMP compliant in year one, then the maximum wind speed for curtailment would be 6.5 m/s. As a 3rd level, the turbine cut-in speeds could be increased to above 6.5 m/s, and additional turbines should be under limited operation. The farm's management and approval would be under the surveillance of the Fish and Wildlife Service. However, Gamesa halted the project because of a combination of factors such as uncertain federal wind power subsidy policies and lingering concerns about the level to which the wind turbines might harm the endangered Indiana bat (Hopey 2012, Siwy 2012).

Ellern wind farm in Rhineland-Palatinate, Germany

An Agreement on Adaptive wind farm Operation Reducing Impacts on Bats

The case of Ellern illustrates that measurable objectives (in this case thresholds) are fundamental for adaptive management approaches. The wind farm Ellern is located in a forested mountain range as many sites for wind energy development, and consists of eight wind turbines (3–7.5 MW). Impacts on wildlife focus on bats, with 15 bat species at hand. As the knowledge on effects of wind farms in forestscapes remains poor (Rydell et al. 2012), uncertainties on the actual impacts on bats were likely to occur. The permit for the wind farm comprised adaptive management measures, not only including monitoring and curtailment schemes but also possible adjustments of the curtailment algorithms as well. However, the responsible authority (Kreisverwaltung Rhein-Hunsrück-Kreis, Simmern) did not fix specific thresholds triggering necessary adjustments. Environmental groups (NABU and BUND) then filed a suit against the permit heading for a more efficient bat protection. In a settlement out of court with the project developer (juwi Wind GmbH), the plaintiffs agreed on retaining the basic curtailment algorithm from April 1st to August 31st (1 h before sunset till sunrise) and September 1st to October 31st (3 h before sunset till sunrise) at a wind speed below 6 m/s and temperatures above 10 °C. In order to adapt this algorithm based on bat activities and fatalities, the developer set up monitoring surveys (carcass search and nacelle monitoring). After the first year of operation, the developer evaluated the results based on the out of court agreement thresholds. An adaption of curtailment algorithms was necessary until the thresholds of 0.5 bats/turbine/year for Nyctalus leisleri, 1.0 bats/turbine/year for Nyctalus noctula, and 2.0 bats/turbine/year for all bats were no longer exceeded (Juwi 2012, Kreisverwaltung 2012, NABU 2013).

Desert Renewable Energy Conservation Plan (DRECP), California, USA

Adaptive planning through collaboration at all planning stages

The Desert Renewable Energy Conservation Plan (DRECP) planning framework was launched to balance the goals of and increase the planning efficiency for renewable energy siting and conservation in the California desert (Geißler and Köppel 2012), predominantly focusing on solar energy siting. This approach involves an unprecedented level of intergovernmental coordination and integration of federal, state, and local land and environmental governance processes. The DRECP addresses (DRECP 2013a):

- intersectoral governance cooperation (California Energy Commission, California Department of Fish and Game)
- multi-level governmental cooperation (local governments, Californian agencies, US Bureau of Land Management, and U.S. Fish and Wildlife Service)

- cooperation between public (agencies, county governments), private (utilities, proponents from renewables industries), and community (citizens, non-profits)
- different spatial scales (conservation banking on a landscape level versus site-specific mitigation measures)
- different temporal scales, for example as an interim mitigation strategy when the availability of unprecedented funds (ARRA bailout budgets to overcome the economic crisis) called for accelerated decision-making processes.

The DRECP was instigated by California's renewable energy goal of 33 % by 2020, but now serves as the framework for balancing 2050 GHG (Greenhouse Gas) goals against traditional conservation planning tools. To improve processes for approving renewable energy projects, the California Energy Commission and the Department of Fish and Game (DFG) created the Renewable Energy Action Team (REAT) to reduce the time and costs of renewable energy projects, signing a memorandum of understanding to coordinate with their federal counterparts, the U.S. Fish and Wildlife Service (FWS), and the U.S. Bureau of Land Management (BLM). REAT's goal was to streamline the application process for renewable energy by identifying areas for renewable energy development and developing best practices manual. The framework for the DRECP was initiated as a Natural Communities Conservation Plan (NCCP) for the Mojave and Colorado Desert regions, and other priority areas, to help make permitting and environmental review processes more effective, as well as provide developers with regulatory certainty. Approval will come later and will be defined by the outcomes of the DRECP. Over a period of 25–40 years, the DRECP will provide inter-alia (DRECP 2013a):

- Conservation and management of species covered in the Plan by developing more effective mitigation measures and protecting and restoring habitat and natural communities
- Increased certainty and efficiency in environmental review and permitting
- Reduced conflicts between species conservation and renewable energy development

The DRECP will allow for incidental "take" permits which extend over the full 25–40 year period, dependent on "science-based monitoring and adaptive management"—i.e., altering or refining actions based on ongoing information. The model for the planning process itself is incorporating a variety of governing agencies and stakeholders from multiple levels and fields, while primary agencies and DRECP leaders strive to be responsive to stakeholder and public input. In fact, in October of 2012, REAT responded to stakeholder requests for more involvement by releasing an informal "Description and Comparative Evaluation of Draft DRECP Alternatives," a draft to allow for another round of stakeholder review and comment period before issuing the official Draft EIR/EIS (Harlow 2012).

In recognition of the value of peer review, an Independent Science Advisory Panel was convened at the behest of government agencies working on the DRECP. The panel gave REAT recommendations for creating a science-based plan in October 2010, followed two years later by the DRECP's Independent Science Panel (DISP) report in November 2012. The DISP explicitly rebuked DRECP planners for their failure to add the technical expertise necessary for scientifically justified decision-making in multiple areas of draft DRECP work, including the lack of effort toward developing the DRECP's Adaptive Management Plan (DISP 2012). The panel recommended adding scientific expertise from government agencies and independent institutions, a significant lack which was neglected despite the collaborative design of the planning process. These recommendations are endorsed and echoed in the comments of "green" institutional stakeholders, such as the Defenders of Wildlife, Audubon California, The Nature Conservancy, and the Desert Tortoise Preserve Committee (DRECP 2013b, 2013c). Cross-jurisdictional coordination is also proving difficult. The Quechan Indian Tribes submitted comments noting that the DRECP does not consider the historical or cultural value of lands, a comment echoed by the Colorado River Indian Tribes (DRECP 2013d, Jozwiak et al. 2009).

However, the DRECP still holds great promise as an adaptive, collaborative planning method, not least as current renewable energy planning processes often suffer under piece-meal conservation efforts of project-by-project permitting. The DRECP Director responded to the panel acknowledging the interim lack of scientific expertise and the need to increase coordinating efforts (DRECP 2013e). In a recent interview, the California Audubon's Renewable Energy Director pointed to the DRECP as a promising route for wildlife and conservation conscious renewable energy siting, saying: "Large-scale planning for conservation of birds and other wildlife at the same time as planning for renewable energy by state, federal, and local agencies is another strategy being developed in California in the Desert Renewable Energy Conservation Plan." (Nunez 2013, in press).

Conclusions

In conclusion, adaptive planning and management approaches might be an appropriate supplement to the precautionary vigilance mandate, helping overcome its unintended limitations, and thus supporting a speedier integration of potentially conflicting, environmental policies. Manifold strategies to tackle uncertainties in terms of wind energy and wildlife interactions have been growing remarkably, and the increasing knowledge based on wind–wildlife interactions provides capacities to create adaptive approaches for policy, planning, operational, and institutional settings. Thus, more commitment to adaptive strategies would require the current focus on up front decision-making processes to shift toward a planning paradigm governed by a more post-project follow-up.

Both the precautionary principle as well as adaptive planning approaches have been used to tackle and overcome the inevitable uncertainties of wind farm impacts. Methods like the precautionary principle have served as useful planning guidelines. Yet, renewable siting does not face the same uncertainties as it did when it began, or even 10 years ago. Wind energýs impacts on wildlife are far more understood, with a multitude of precedents, both methodological and in planning processes, for addressing wildlife concerns. A myriad of interim research results is not only available but also combine for some remarkable patterns of insight. Moreover, no other project types potentially causing bird collision mortality, for example, as power lines, roads, and antennae, have been controlled this strictly (Janss et al. 2010).

However, still there are substantial challenges that need to be overcome in order to further develop adaptive planning and management approaches. An often voiced concern addresses a reduced up front planning security for wind farm proponents, developers, and their financial backers. Furthermore, the wind energy industry still tends to hesitate disclosing and sharing data on wildlife impacts. Also, the coverage of increasing monitoring costs will play a role, at least as long as those facts would not be fully balanced by benefits and incentives vice versa. As for the costs, the tradeoffs between better siting (to less favorable wind sites as well), sensitive operating for wildlife, and how much energy is lost remains to be seen.

Yet it is possible that this approach would allow smart growth too, for example, wind turbines to be added stepwise as an incentive for investors, in case monitoring results, are encouraging and thus confirm the feasibility of a site. Combining phased development with collaborative planning approaches could provide the trust and social capital necessary for developers to overcome the potential insecurities of adaptive planning. However, doing so requires safeguarding the accountability of all the involved stakeholders (CEQ 2003, Peck 1998 in Kato and Ahern 2008).

Although adaptive approaches have its benefits, this is not common practice in many countries yet, and even monitoring has often been neglected or incomplete. Providing guidance for a responsible development of renewable energy remains crucial. Last but not least, decision-making is based on balancing various issues of relevance for the development of renewable energy (i.e., technological, economic, societal, and environmental ones). This further constitutes an important aspect for planning, and there exist various methodologies for balancing tradeoffs, likewise multi-criteria assessments and least-cost-siting approaches. Finally, we cannot take an imperative for the expansion of renewable energy for granted without exploring other low-carbon energy strategies like demand management.

Acknowledgments We would like to thank California Secretary of Natural Resources John Laird and Deputy Secretary of Climate Change Ann Chan, for providing comments regarding the DRECP. The review section on bats was compiled as part of research supported by the German Federal Ministry for Economic Affairs and Energy on the basis of a decision by the German Bundestag. Roel May and two anonymous referees provided valuable comments that helped to improve this article.

References

Ahlén I (2003) Wind turbines and bats—a pilot study. Final report 11 December 2003. Uppsala, Sweden. http://publicationer.slu.se/Filer/08WindBatFinalReport.pdf. Accessed 11 June 2013

Ahlén I, Baagøe HJ (2013) Bats and wind power—investigations required for risk assessment in Denmark and Sweden. In: Naturvårdsverket (ed) Book of Abstracts. Conference on Wind Power and Environmental Impacts Stockholm 5–7 February, Stockholm, Sweden, p 30

Ahlén I, Baagøe HJ, Bach L (2009) Behavior of scandinavian bats during migration and foraging at sea. J Mammal 90(6):1318–1323

Albrecht K, Grünfelder C (2011) Fledermäuse für die Standortplanung von Windenergieanlagen erfassen. Erhebungen in kollisionsrelevanten Hoehen mit einem Heliumballon. Nat schutz Landsch plan 43 (1):5–14

Amorim F, Rebelo H, Rodrigues L (2012) Factors influencing bat activity and mortality at a wind farm in the mediterranean region. Acta Chiropterologica 14(2):439–457

Arnett EB, Hayes JP, Huso MMP (2006) An evaluation of the use of acoustic monitoring to predict bat fatality at a proposed wind facility in southcentral Pennsylvania. An annual report submitted to the Bats and Wind Energy Cooperative. Bat Conservation International. Austin, Texas, USA

Arnett EB, Huso MMP, Reynolds SD, Schirmacher MR (2007) Patterns of pre-construction bat activity at a proposed wind facility in northwest Massachusetts. An annual report submitted to the Bats and Wind Energy Cooperative, Austin, Texas, USA. http://www.batsandwind.org/pdf/ar2006.pdf. Accessed 16 Sept 2013

Arnett EB, Brown WK, Erickson WP, Fiedler JK, Hamilton BL, Henry TH, Jain A, Johnson GD, Kerns J, Koford RR, Nicholson CP, O'Connell TJ, Piorkowski MD, Tankersley RD (2008) Patterns of bat fatalities at wind energy facilities in North America. J Wildl Manag 72(1):61–78

Arnett EB, Hein CD, Patterson R (2011) Synthesis of activities (2004–2011). Key findings and next steps. The Bats and Wind Energy Cooperative. Bat Conservation International. http://

www.batsandwind.org/pdf/BWEC_Synthesis_2004-2011.pdf. Accessed 05 Aug 2013

Baerwald EF, D'Amours GH, Klug BJ, Barclay R, Barclay (2008) Barotrauma is a significant cause of bat fatalities at wind turbines. Curr Biol 18(16):R695

Baerwald EF, Edworthy J, Holder M, Barclay RMR (2009) A large-scale mitigation experiment to reduce bat fatalities at wind energy facilities. J Wildl Manag 73(7):1077–1081

Barclay R, Harder LM (2003) Life histories of bats: life in the slow lane. In Kunz TH, Brock Fenton M (eds) Bat ecology. Chicago, Illinois, USA: Univ. of Chicago Press:209–253

Barclay R, Baerwald EF, Gruver JC (2007) Variation in bat and bird fatalities at wind energy facilities: assessing the effects of rotor size and tower height. Can J Zool 85(3):381–387

Bernshausen F (2012) Windenergienutzung und Rotmilanschutz—ein unüberwindbarer Konflikt? Presentation Naturschutzakademie Hessen, 28 March, Wetzlar, Germany. http://www.na-hessen.de/downloads/12n35rotmilanwindenergie.pdf. Accessed 05 Aug 2013

BLWE (2013) Bund-Länder-Initiative Windenergie. http://www.erneuerbare-energien.de/die-themen/windenergie/bund-laender-initiative-windenergie/. Accessed 05 Aug 2013

Boehmer-Christiansen S (1994) The precautionary principle in Germany—enabling government. In: ÓRiordan T, Cameron J (eds) Interpreting the precautionary principle. Earthscan, London

Brinkmann R, Schauer-Weisshahn H, Bontadina F (2006) Survey of possible operational impacts on bats by wind facilities in Southern Germany. Brinkmann Ecological Consultancy, Freiburg

Brinkmann R, Niermann I, Behr O, Mages J, Korner-Nievergelt F, Reich M (2009) Zusammenfassung der Ergebnisse für die Planungspraxis und Ausblick. In: Fachtagung Methoden zur Untersuchung und Reduktion des Kollisionsrisikos von Fled-ermäu-sen an Onshore-Windenergieanlagen. Kurzfassung der Vorträge 9. Juni 2009, Hannover, Germany, p 23 et seq

Brinkmann R, Behr O, Niermann I, Reich M (eds) (2011) Entwicklung von Methoden zur Untersuchung und Reduktion des Kollisionsrisikos von Fledermäusen an Onshore-Windenergieanlagen. Ergebnisse eines Forschungsvorhabens. Göttingen: Cuvillier (Umwelt und Raum, 4)

Camiña A (2011) The effect of wind farms on vultures in northern Spain—fatalities behaviour and correction measures. In: May R, Bevanger K (eds) Proceedings. Conference on Wind energy and Wildlife impacts 2–5 May, Trondheim, Norway NINA Report 693, p 17

Carrete M, Sánchez-Zapata JA (2010) The precautionary principle and wind-farm planning: data scarcity does not imply absence of effects. Biol Conserv 143:829–830

Carrete M, Sánchez-Zapata JA, Benítez JR, Lobón M, Donázar JA (2009) Large-scale risk-assessment of wind-farms on population viability of a globally endangered long-lived raptor. Biol Conserv 142:2954–2961

City of Göttingen (2012) Abstandsanalyse/Potentielle Windenergiestandorte—Teil-Flächennutzungsplan Windenergie. http://www.goettingen.de/pics/medien/1_1359387632/WKE_PotentielleRestflaeche_A3_2012_10_04.pdf Accessed 05 Aug 2013

Cordeiro A, Mascarenhas M, Costa H (2013) Long term survey of wind farms impacts on Common Kestrel's populations and definition of an appropriate mitigation plan. In: Naturvårdsverket (ed) Book of Abstracts. Conference on Wind Power and Environmental Impacts Stockholm 5–7 February, Stockholm, Sweden, p 47

CEQ, Council on Environmental Quality (2003) The NEPA Task Force Report to the Council on Environmental Quality, Modernizing NEPA Implementation, p 44–56. http://ceq.hss.doe.gov/ntf/report/finalreport.pdf. Accessed 05 Aug 2013

CEQ, Council on Environmental Quality (2007) Collaboration in NEPA a handbook for NEPA practitioners. https://www.ecr.gov/pdf/Collaboration_in_NEPA_Oct_2007.pdf. Accessed 13 Sept 2013

Cryan PM (2008) Mating behavior as a possible cause of bat fatalities at wind turbines. J Wildl Manag 72(3):845–849

Cryan PM (2011) Wind turbines as landscape impediments to the migratory connectivity of bats. Environ law 41:355

Cryan PM, Barclay RMR (2009) Causes of bat fatalities at wind turbines: hypotheses and predictions. J Mammal 90(6):1330–1340

Cryan PM, Brown AC (2007) Migration of bats past a remote island offers clues toward the problem of bat fatalities at wind turbines. Biol Conserv 139(1–2):1–11

Dahmen M (2012) Adaptive Management in der Umweltplanung—neue Ansätze für die Windenergie. Bachelor Thesis, TU Berlin, Environmental Assessment and Planning Research Group

De Lucas M, Ferrer M, Janss GFE (2012) Using wind tunnels to predict bird mortality in wind farms: the case of griffon vultures. PLoS One 7(11):e48092

DISP, The DRECP Independent Science Panel (2012) Final Report: Independent Science Review For The California Desert Renewable Energy Conservation Plan (DRECP) http://drecp.org/documents/docs/independent_science_2012/Independent_Science_Panel_2012_Final_Report.pdf. Accessed 2 Feb 2013

Doty AC, Martin AP (2012) Assessment of bat and avian mortality at a pilot wind turbine at Coega, Port Elizabeth, Eastern Cape South Africa. N Z J Zool 40(1):75–80

DRECP (2013a). http://www.drecp.org/. Accessed 1 Feb 2013

DRECP (2013b). http://www.drecp.org/documents/docs/baseline_biology_report/comments/. Accessed 2 Feb 2013

DRECP (2013c) Retrieved February 2, 2013. http://drecp.org/documents/docs/independent_science_2012/comments/. Accessed 2 Feb 2013

DRECP (2013d) Retrieved February 2, 2013. http://www.drecp.org/documents/docs/comments-evals/Colorado_River_Indian_Tribes_comments.pdf. Accessed 2 Feb 2013

DRECP (2013e). http://drecp.org/documents/docs/independent_science_2012/Response_to_Draft_Report_ISP_2012.pdf . Accessed 2 Feb 2013

Erdmann J (2013) Zonierung von Landschaftsschutzgebieten für die Windenergie. Master Thesis, TU Berlin, Environmental Assessment and Planning Working Group

Erickson WP, Johnson GD, Young Jr. DP (2005) A Summary and Comparison of Bird Mortality from Anthropogenic Causes with an Emphasis on Collisions. In: Ralph CJ, Rich TD (eds) (2005) Bird Conservation Implementation and Integration in the Americas: Proceedings of the Third International Partners in Flight Conference. 2002 March 20–24; Asilomar, California, Volume 2 Gen. Tech. Rep. PSW-GTR-191. Albany, CA: U.S. Dept. of Agriculture, Forest Service, Pacific Southwest Research Station: p 1029–1042

FWS; U.S. Fish and Wildlife Service, Pennsylvania Field Office (2011) Biological Opinion. Effects of the Shaffer Mountain Wind Farm on the Indiana Bat (Myotis sodalist). Appendix A. Shaffer Mountain Wind Farm. Adaptive management plan. www.fws.gov/midwest/Endangered/mammals/inba/bos/11_PA_ShafferMtWindFarm.pdf http://www.fws.gov/midwest/endangered/mammals/inba/bos/11_PA_ShafferMtWindFarm.pdf. Accessed 8 Aug 2013

Gaisler J, Rehák Z, Bartonicka T (2009) Bat casualties by road traffic (Brno-Vienna). Acta Theriol 54:147–155

Geißler G (2013) Strategic environmental assessments for renewable energy development—comparing the United States and energy. J Environ Assess Policy Manag 15:1340003 [31 p.]

Geißler G, Köppel J (2012) Upside down—Weiterentwicklung von US-amerikanischen Konzepten zur naturhaushaltlichen Kompensation. Wetland Mitigation und Conservation Banking. Nat schutz Landsch plan 44 (12): 364–370

Geißler G, Köppel J, Gunter P (2013) Wind Energy and environmental assessments—a hard look at two forerunnerś approaches: Germany and the United States. Renew Energy 51:71–78

Grodsky SM, Behr MJ, Gendler A, Drake D, Dieterle BD, Rudd RJ, Walrath NL (2011) Investigating the causes of death for wind turbine-associated bat fatalities. J Mammal 92(5):917–925

Grodsky SM, Jennelle CS, Drake D, Virzi T (2012) Bat mortality at a wind-energy facility in southeastern Wisconsin. Wildl Soc Bull 36(4):773–783

Harlow DL (DRECP Director) (2012) Dear Stakeholders and Working Group Members. http://www.drecp.org/whatisdrecp/docs/2012-10-10_Email_from_D_Harlow_on_Schedule.pdf. Accessed 2 Feb 2013

Harremoës P, Gee D, Mac Garvin M, Stirling A, Wynne B, Vaz SG (eds) (2001) Late lessons from early warnings: the precautionary principle 1896–2000. European Environment Agency Copenhagen, Environmental Issue Report 22

Hayes MA (2013) Bats killed in large numbers at United States wind energy facilities. Bioscience 63(12):975–979

Hein CD, Arnett EB, Schirmacher MR, Huso MMP, Reynolds DS (2011) Patterns of preconstruction bat activity at the proposed Hoosac wind energy project, Massachusetts, 2006–2007. A final project report submitted to the Bats and Wind Energy Cooperative. Bat Conservation International. Austin, Texas, USA. http://www.batsandwind.org/pdf/Hoosac_Preconstruction_Final%20Report.pdf. Accessed 16 Sept 2013

Hopey D (2012) Company cancels Shaffer Mountain wind power project. Third Pa. turbine axed this month over tax credits. Pittsburgh Post-Gazette July 13, 2012. http://www.post-gazette.com/stories/local/region/company-cancels-shaffer-mountain-wind-power-project-640108/#ixzz2es5JNg5s. Accessed 13 Sept 2013

Horn JW, Arnett EB, Kunz TH (2008) Behavioral responses of bats to operating wind turbines. J Wildl Manag 72(1):123–132

Houck DR (2012) Computational fluid dynamics simulations of bats flying near operating wind turbines: Quantification of pressure-time histories of likely flight paths. Portland State University. Available through the U.S. DOE Office of Science, Office of Workforce Development for Teachers and Scientists Application Review System (WARS)

Hull CL, Cawthen L (2013) Bat fatalities at two wind farms in Tasmania, Australia: bat characteristics, and spatial and temporal patterns. N Z J Zool 40(1):5–15

Jackson ALR (2011) Renewable energy vs. biodiversity: policy conflicts and the future of nature conservation. Glob Environ Change 21:1195–1208

Jain A (2005) Bird and bat behavior and mortality at a northern Iowa windfarm. Master Thesis, Iowa State University, Arnes, Iowa, USA, Accessed 26 Aug 2013

Jalava K, Pölönen I, Hokkanen P, Kuitunen M (2013) The precautionary principle and management of uncertainties in EIAs—analysis of waste incineration cases in Finland. Impact Assess Proj Apprais 31(4):280–290

Janss G, Whitfield PD, Lazo A (2010) The precautionary principle and wind-farm planning in Andalucía. Biol Conserv 143:1827–1828

Johnson GD, Erickson WP (2011) Avian, bat and habitat cumulative impacts associated with wind energy development in the Columbia Plateau ecoregion of Eastern Washington and Oregon. Prepared for Klickitat County Planning Department, Goldendale, WA. http://www.fws.gov/southwest/es/documents/R2ES/LitCited/LPC_2012/Johnson_and_Erickson_2011.pdf. Accessed 23 May 2014

Johnson GD, Erickson WP, Strickland MD, Shepherd M, Shepherd D, Sarappo S (2003) Mortality of bats at a large-scale Wind Power Development at Buffalo Ridge, Minnesota. Am Midl Nat 150(2):332–342

Johnson GD, Perlik MK, Erickson WP, Strickland MD (2004) Bat activity, composition, and collision mortality at a large wind plant in Minnesota. Wildl Soc Bull 32(4):1278–1288

Johnson JS, Watrous KS, Giumarro GJ, Peterson TS, Boyden SA, Lacki MJ (2011) Seasonal and geographic trends in acoustic detection of tree-roosting bats. Acta Chiropterologica 13(1):157–168

Jozwiak RF, Morisset DM, Schlosser TP, Somerville DT (2009) Quechan Indian Tribe's Comments on Draft Planing Agreement, 09-Renew EO-O 1. http://www.energy.ca.gov/33by2020/documents/draft_planning_agreement_public_comments/Quechan_Indian_Tribes_Comments_on_Draft_Planning_Agreement_TN-54213.pdf. Accessed 2 Feb 2013

Juwi Wind GmbH (2012) Wind farm Ellern. http://www.juwi.com/fileadmin/user_upload/de/pdf/Steckbriefe/Wind_Farm_Ellern_Englisch_120724_jed.pdf. Accessed 22 May 2014

Kato S, Ahern J (2008) Learning by doing': adaptive planning as a strategy to address uncertainty in planning. J Environ Plan Manag 51(4):543–559

Kerns J, Kerlinger P (2004) A study of bird and bat collision mortalities at the Mountaineer Wind Energy Center, Tucker County, West Virginia. Annual Report for 2003, McLean, Virginia, USA

Kerns J, Erickson WP, Arnett EB (2005) Bat and bird mortality at wind energy facilities in Pennsylvania and West Virginia. In: Bat Conservation International (ed) Relationships between Bats and Wind Turbines in Pennsylvania and West Virginia. An assessment of fatality search protocols, patterns of fatality, and behavioral interactions with wind turbines. A final report submitted to the Bats and Wind Energy Cooperative, Austin, Texas, USA, pp 24–95

Köller J, Köppel J, Peters W (eds) (2006) Offshore Wind Energy. Research on environmental impacts. Springer, Berlin

Kriebel D, Tickner J, Epstein P, Lemons J, Levins R, Loechler EL, Quinn M, Rudel R, Schettler T, Stoto M (2001) The precautionary principle in environmental sciences. Environ Health Perspect 109(9):871–876

Kunz TH, Arnett EB, Erickson WP, Hoar AR, Johnson GD, Larkin RP, Strickland MD, Thresher RW, Tuttle MD (2007) Ecological impacts of wind energy development on bats: questions, research needs, and hypotheses. Front Ecol Environ 5(6):315–324

LAG-VSW, Länderarbeitsgemeinschaft der Vogelschutzwarten (2007) Abstandsregelungen für Windenergieanlagen zu bedeutsamen Vogellebensräumen sowie Brutplätzen ausgewählter Vogelarten. Ber Vogelschutz 44:151–153

Ledec G, Rapp KW, Aiello R (2011) Greening the wind. Environmental and social considerations for wind power development. World Bank, Washington, D.C, USA. https://openknowledge.worldbank.org/bitstream/handle/10986/2388/662330PUBEPI00e0wind09780821389263.pdf?sequence=1. Accessed 19 May 2014

Lesinkski G (2007) Bat road casualties and factors determining their number. Mammalia 71:138–142

Long CV, Flint JA, Lepper PA, Dible SA (2009) Wind turbines and bat mortality: interactions of bat echolocation pulses with moving turbine rotor blades. Proc Inst of Acoust 31(1):185–192

Morrison-Saunders A, Marshall R, Arts J (2007) EIA Follow-up. International Best Practice Principles. Special Publication Series 6, International Association for Impact Assessment, Fargo, USA

MUGV (2012) Beachtung naturschutzfachlicher Belange bei der Ausweisung von Windeignungsgebieten und bei der Genehmigung von Windenergieanlagen. Erlass des Ministeriums für Umwelt, Gesundheit und Verbraucherschutz vom 01. Januar 2011. Anlage 1. Tierökologische Abstandskriterien für die Errichtung von Windenergieanlagen in Brandenburg (TAK). Stand 15. 10. 2012

Nadaï A, Labussière O (2010) Birds, wind and the making of wind power landscapes in Aude Southern France. Landsc Res 35(2):209–233

Nie M (2011) NEPA, Interest Groups and Federal Lands Management. UVP-Report 25(4):198–201

Nilsson M, Persson A (2012) Can Earth system be governed? Governance functions for linking climate change mitigation with land use, freshwater and biodiversity protection. Ecol Econ 75:61–71

Nilsson M, Zamparutti T, Petersen JE, Nykvist B, Rudberg P, McGuinn J (2012) Understanding policy coherence: analytical framework and examples of sector-environment policy interactions in the EU. Environ Policy Gov 22:394–423

Nunez C (2013) Wind farm faces fine over golden eagle's death. National Geographic. http://energyblog.nationalgeographic.com/2013/04/03/wind-farm-faces-fine-over-golden-eagles-death/. Accessed 3 Feb 2013

ÓRiordan T, Cameron J (1994) The history and contemporary significance of the precautionary principle. In: ÓRiordan T, Cameron J (eds) Interpreting the precautionary principle. Earthscan, London, pp 12–30

Piela A (2010) Tierökologische Abstandskriterien bei der Errichtung von Windenergieanlagen in Brandenburg (TAK). Ein Beitrag zur Konfliktbewältigung im Spannungsfeld Vogel-und Fledermausschutz—Windenergie. Nat Landschaft 85 (2): 51–60

Piorkowski MD, O'Connell TJ (2010) Spatial pattern of summer bat mortality from collisions with wind turbines in mixed-grass prairie. Am Midl Nat 164(2):260–269

Portman ME, Fishhendler I (2011) Towards integrated coastal zone management: a toolkit for practitioners. Hebrew University: Jerusalem. pp 35. http://www.rozinblog.com/michelle/wp-content/uploads/2011/08/Toolkit-for-ICZM_EU_FP7_SECOA.pdf. Accessed May 15, 2013

Redell D, Arnett EB, Hayes JP, Huso MMP (2006) Patterns of preconstruction bat activity determined using acoustic monitoring at a proposed wind facility in south-central Wisconsin. A final report submitted to the Bats and Wind Energy Cooperative. http://www.batsandwind.org/pdf/precon_wi.pdf. Accessed 16 Sept 2013

Rhein-Hunsrück-Kreis Kreisverwaltung (2012) Genehmigungsbescheid für den Betrieb von 8 Windkraftanlagen in den Gemarkungen Ellern und Rheinböllern. Simmern, Germany

NABU Rheinland-Pfalz (2013) juwi macht Zugeständnisse beim Fledermausschutz—Naturschutzverbände ziehen Klage gegen acht Windräder im Soonwald zurück. Press release March 18th 2013. http://rlp.nabu.de/presse/pressemitteilungen/index.php?popup=true&show=811&db=presseservice_rlp. Accessed 22 May 2014

Rollins KE, Meyerholz DK, Johnson GD, Capparella AP, Loew SS (2012) A forensic investigation into the etiology of bat mortality at a wind farm: barotrauma or traumatic injury? Vet Pathol 49(2):362–371

Rydell J, Bach L, Dubourg-Savage MJ, Green M, Rodrigues L, Hedenström A (2010a) Mortality of bats at wind turbines links to nocturnal insect migration? Eur J Wildl Res 56:823–827

Rydell J, Bach L, Dubourg-Savage M, Green M, Rodrigues L, Hedenström A (2010b) Bat mortality at wind turbines in Northwestern Europe. Acta Chiropterologica 12(2):261–274

Rydell J, Engström H, Hedenström A, Larsen JK, Pettersson J, Green M (2012) The effect of wind power on birds and bats. A synthesis. Swedish Environmental Protection Agency, Stockholm

Siwy B (2012) Gamesa halts Shaffer Mountain wind plans. Daily American Staff Writer June 12, 2012. http://articles.dailyamerican.com/2012-06-12/news/32200358_1_gamesa-jack-buchan-shaffer-mountain-wind-farm. Accessed 13 Sept 2013

Smallwood KS, Neher L, Bell DA (2013) Predicting Collision Hazard Zones to guide Repowering of the Altamont Pass Wind Resource Area. In: Naturvårdsverket (ed) Book of abstracts. Conference on Wind power and environmental impacts Stockholm 5–7 February, Stockholm, Sweden, p 98

Söfker W (2012) Der Teilflächennutzungsplan—ein Instrument zur Steuerung der Windenergie im Außenbereich. Hintergrundpapier Repowering InfoBörse. http://www.repowering-kommunal.de/uploads/tx_tcdownloadmngr/RIB_Teilflaechennutzungsplan_04.01.2012.pdf. Accessed 05 Aug 2013

Sovacool BK (2013) The avian benefits of wind energy. A 2009 update. Renew Energy 49:19–24

Strickland MD, Arnett EB, Erickson WP, Johnson DH, Johnson GD, Morrison ML, Shaffer JA, Warren-Hicks W (2011) Comprehensive guide to studying wind energy/wildlife interactions. Prepared for the National Wind Coordinating Collaborative, Washington, D.C, USA. http://www.nationalwind.org/assets/publications/Comprehensive_Guide_to_Studying_Wind_Energy_Wildlife_Interactions_2011_Updated.pdf. Accessed 05 Aug 2013

UASWT (University of Applied Sciences Weihenstephan-Triesdorf) (2012) Modellprojekt "Standortfindung für Windkraftanlagen im Naturpark Altmühltal—Zonierungskonzept". http://www.hswt.de/forschung/infodienst/2012/november/landschaftsarchitektur.html. Accessed 05 Aug 2013

UM (2012) Windenergieerlass Baden-Württemberg. Gemeinsame Verwaltungsvorschrift des Ministeriums für Umwelt, Klima und Energiewirtschaft, des Ministeriums für Ländlichen Raum und Verbraucherschutz, des Ministeriums für Verkehr und Infrastruktur und des Ministeriums für Finanzen und Wirtschaft. v. 09. Mai 2012—Az.: 64–4583/404

U.S. Fish and Wildlife Service (2012) Land-based wind energy guidelines. http://www.fws.gov/windenergy/docs/weg_final.pdf. Accessed 15 Sept 2013

Voigt CC, Popa-Lisseanu AG, Niermann I, Kramer-Schadt S (2012) The catchment area of wind farms for European bats: a plea for international regulations. Biol Conserv 153:80–86

Washington Department of fish and wildlife (2009) Wind Power Guidelines, Olympia, Washington, USA. http://wdfw.wa.gov/publications/00294/. Accessed 15 Sept 2013

Williams BK (2011) Adaptive management of natural resources—framework and issues. J Environ Manag 92:1346–1353

Williams BK, Szaro RC, Shapiro CP (2009) Adaptive management. The U.S. Department of the Interior Technical Guidance. Adaptive Management Working Group, U.S., Department of the Interior, Washington D.C. http://www.doi.gov/initiatives/AdaptiveManagement/TechGuide.pdf. Accessed 05 Aug 2013

Willis CKR, Barclay RMR, Boyles JG, Brigham RM, Brack V Jr, Waldien DL, Reichard J (2009) Bats are not birds and other problems with Sovacool's (2009) analysis of animal fatalities due to electricity generation. Energy Policy. doi:10.1016/j.enpol.2009.08.034

Woody T (2010) It's green against green in Mojave Desert solar battle. Yale Environment 360, Yale School of Forestry & Environmental Studies. http://e360.yale.edu/content/feature.msp?id=2236. Accessed 02 July 2012

Yonk EM, Simmons RT, Steed BC (2013) Green vs. Green: the political, legal, and administrative pitfalls facing green energy production. Routledge, New York