



# WIND ENERGY RESEARCH & DEVELOPMENT

## Environmental Science

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# Environmental Science



## Environmental Processes and Impact Assessment

Advance technologies (e.g., thermal video cameras) and analytical tools (e.g., modeling Golden Eagle flight behavior) to better understand the interactions between wildlife and wind turbines



## Species-Specific Scientific Investigations

Research physiological and behavioral mechanisms associated with wind turbine and wildlife interactions to understand conditions and drivers of risk and make informed decisions about wind energy facility siting and operation



## Cost-Effective Mitigation

Conduct collaborative research to develop cost-effective mitigation solutions that enable wind energy facilities to operate efficiently in a competitive energy market



# Environmental Processes and Impact Assessment

- NREL supports efforts to reduce wildlife impacts at land-based and offshore wind energy facilities with monitoring and minimization technology solutions.
- We combine decades of field research experience, computational capabilities and infrastructure to advance technologies (e.g., thermal video cameras and multicomponent systems), and develop models that integrate biological, weather and wind turbine data to inform siting and operational decisions.

## Areas of Expertise

- Utility-scale research studies
- Computational modeling and statistical analyses
- Wind turbine instrumentation, measurements, and data collection
- Spatial analyses.

# Current Projects

Develop a computational framework for modeling golden eagle flight behavior near wind power plants



ENVIRONMENTAL PROCESSES  
AND IMPACT ASSESSMENT



## **CHALLENGE**

Develop models to predict interactions between golden eagles and wind energy to proactively reduce or avoid risk.

## **APPROACH**

An NREL-led project team combines knowledge of golden eagle behavior, high-fidelity atmospheric wind flow models, and behavior- modeling techniques to develop predictive golden eagle risk estimations.

## **IMPACTS**

Models help to:

- Identify locations for wind energy facilities with low likelihood of negative golden eagle interactions
- Make siting decisions for individual wind turbines within a facility to avoid negative interactions with golden eagles
- Identify conditions associated with high likelihood of golden eagle risk
- Optimize investments in impact-minimization technologies by targeting their use where they will have greatest impact.



# Species-Specific Scientific Investigations

- NREL investigates behavioral and physiological drivers of risk (e.g., attraction or displacement) to assess interactions with land-based and offshore wind turbines.
- Our research-based approach optimizes monitoring and minimization strategies, providing a suite of technologies to meet the various needs of the wind energy and wildlife community.

## Areas of Expertise

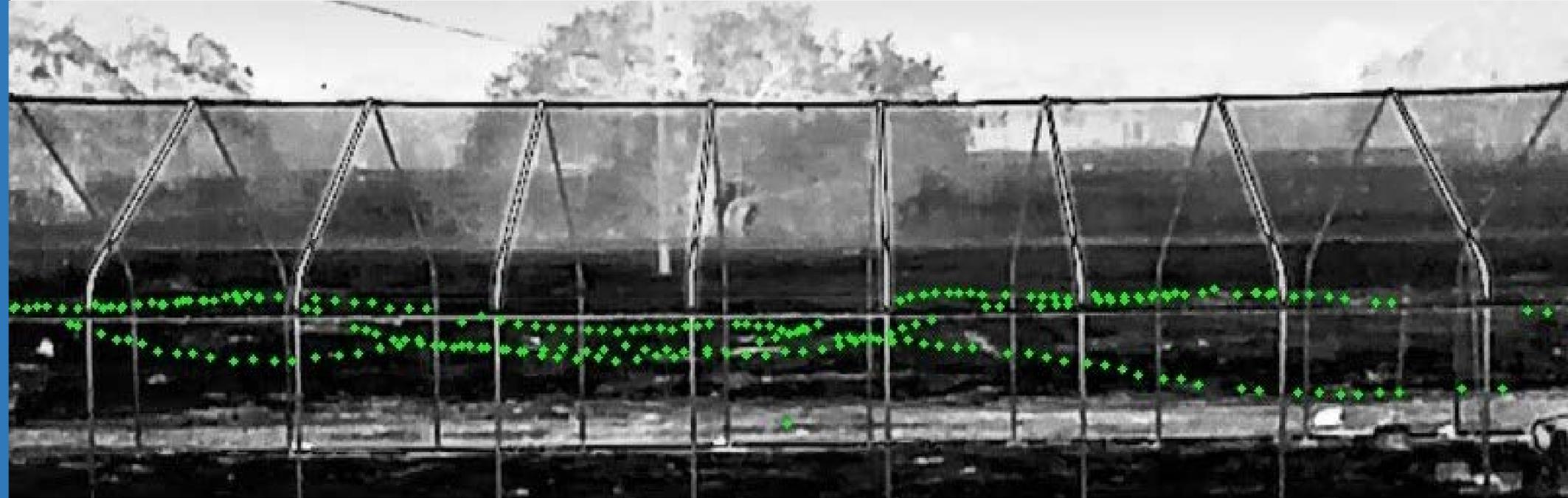
- Wildlife biology and behavior
- Partnership networks
- Environmental reviews and modeling.

# Current Projects

Behavioral response of bats to ultrasonic stimuli



SPECIES-SPECIFIC  
SCIENTIFIC INVESTIGATIONS



## CHALLENGE

Evaluate deterrent stimuli for increasing species-specific effectiveness of an advanced ultrasonic deterrent.

## APPROACH

NREL researchers and their partners created a 60-meter-long experimental flight cage to track bat responses to ultrasonic deterrents. Using new software that records a bat's movement in the open-air cage, the team gathers quantitative data on bat behavioral responses relative to various treatments.

## IMPACT

Ultrasonic deterrents may offer wind energy facilities a more cost-effective solution for impact reduction than curtailment. NREL's research is helping clarify variations in the technology's effectiveness related to ultrasound frequencies, weather effects, and behavioral differences among bat species.



# Cost-Effective Mitigation

- NREL leads multistakeholder collaborations to address complex issues related to wildlife interactions at land-based and offshore wind turbines, and to ensure all perspectives are represented
- NREL's engagement and outreach activities foster dialogue among partners and promotes decisions that meet both conservation and energy production goals.

## Areas of Expertise

- Environmental impacts of wind and marine energy
- Environmental monitoring programs and effective mitigation strategies.

# Current Projects

Working Together To Resolve Environmental Effects of Wind Energy (WREN)



COST-EFFECTIVE MITIGATION



## **CHALLENGE**

Supporting deployment of wind energy technology around the globe through a better understanding of environmental issues, particularly those related to wildlife, efficient monitoring programs, and effective mitigation strategies.

## **APPROACH**

NREL facilitates Task 34 (WREN), through the International Energy Agency's Wind Technical Collaborative program, that advances global understanding of the environmental effects of land-based and offshore wind energy development. The program creates a shared global knowledge base for recommended practices for monitoring, research, and mitigation.

## **IMPACT**

Leverages global perspectives and research to lower the levelized cost of energy, facilitate wind energy deployment through environmental compatibility, and fosters collaborative research and exchange of best practices and data.

# Accomplishments & Impacts



NREL's unparalleled expertise and reputation in the field of Environmental Science result in:

- Collaborations—environmental and industry stakeholders work together to identify and prioritize wildlife issues that face land-based and offshore wind energy facilities
- Impactful Research—at its Flatirons Campus, NREL technical experts partner with other National Laboratories, government agencies, academia, and industry to conduct research and learn about wildlife interactions with wind turbines, which creates monitoring, modeling, and minimization solutions that are effective in both land-based and offshore applications
- Cost-Effective Solutions—our experts work with stakeholders to promote decisions that meet both conservation goals and industry goals, including lowering financial risk while minimizing wildlife interactions
- Information Sharing—NREL experts support and work with national and world-based environmental organizations to synthesize and disseminate the most recent wind-power-related wildlife research.

