Solar Power and Wildlife/Natural Resources SYMPOSIUM

PROCEEDINGS

PRESENTED BY REWI (FORMERLY AWWI)

Meeting Proceedings

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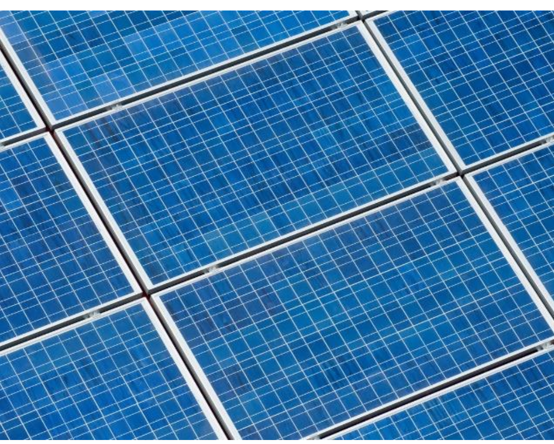

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- Theresa Carroll, AES Clean Energy
- Madeleine Ray, Apex Clean Energy
- Ray Kelly, Clearway Energy Group
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About REWI (formerly AWWI)

The Renewable Energy Wildlife Institute (REWI, formerly the American Wind Wildlife Institute) is an independent nonprofit 501(c)3 organization that advances scientific research and collaboration to better understand renewable energy's risks to wildlife and related natural resources and develop solutions. Built on a strong partnership of leaders, REWI works collaboratively with the wind and solar power industries, conservation and science organizations, and wildlife management agencies to facilitate timely and responsible development of renewable energy while protecting wildlife and wildlife habitat.

REWI plans to continue hosting biennial Wind Wildlife Research Meetings and Solar Symposia.

Abstract

It is estimated that solar power will grow up to eight-fold in the next decade. Solar developers and others working to advance renewable energy recognize that along with successful commercialization, sustainable development requires investment into understanding and minimizing risk from the interactions between solar energy facilities, wildlife, and natural resources. The Solar Symposium convened stakeholders from academia, industry, the conservation sector, and public agencies to review the state of the science and identify key concepts around balancing conservation and a rapidly growing solar market, and highlight what we know and emerging topics/questions related to:

- Evaluating and Mitigating Impacts on Wildlife and Their Habitats
- Land Management and Wildlife Compatibility
- Water Resource Management
- Solar Life-Cycle and Natural Resource Considerations

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Ordering Information

These Proceedings are available in PDF format with accompanying presentations available via links. Proceedings may be downloaded from the REWI website: rewi.org.

Disclaimer

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Abbreviations

AFWA	Association of Fish and Wildlife Agencies
AWWI	American Wind and Wildlife Institute (now Renewable Energy Wildlife Institute)
BFPP	Bona Fide Prospective Purchaser
COP26	2021 United Nations Climate Change Conference
CSP	Concentrating solar power
DOE	United States Department of Energy
EERE	Office of Energy Efficiency and Renewable Energy at the US Department of Energy
EPA	United States Environmental Protection Agency
ESA	Endangered Species Act
ESG	Environmental, Social and Governance
GW	Gigawatt
IPaC	US Fish and Wildlife Service Information for Planning and Consultation
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IRP	Integrated Resource Plan
kW	Kilowatt
LCOE	Levelized cost of electricity
MSGP	Multi-Sector General Permit
MW	Megawatt
MWh	Megawatt/hour
NERC	North American Electric Reliability Corporation
PV	Photovoltaic modules
RCRA	Resource Conservation and Recovery Act
REWI	Renewable Energy Wildlife Institute
RPS	Renewable Portfolio Standard
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WEGs	Land-Based Wind Energy Guidelines

Welcome

Abby Arnold

Executive Director, American Wind Wildlife Institute[1]

Welcome to this inaugural state of the science symposium on solar energy. What does our future look like; what human creativity and innovation is possible? What is the role of technology, and how can we as individuals, in our collective actions, ensure sustainability for future generations? We are committed to a sustainable energy transition, and we're committed to conservation. We can improve our world if we continue to learn together, apply all our tools, and collaborate to address the challenges we face.

Designing and planning this symposium is a model for how we all can work together, across the United States and with other countries. Thank you to the AWWI Board for supporting us in hosting this inaugural event; to our champions, top sponsors and others who underwrote the planning for this symposium; and to the over 50 members of our Planning Committee and the subcommittees for your time and commitment to this undertaking. Over three days, we're going to learn about the state of the science and the research needs. These proceedings will provide a starting point for developing a national wildlife-solar research plan modeled after AWWI's wind wildlife research plan.

Today AWWI is excited to announce that we are expanding our program to encompass solar and changing our name to the Renewable Energy Wildlife Institute: REWI. Our Board and staff are committed to forming new partnerships, working with researchers and stakeholders to build a solar-wildlife research program, and raising funding to support this program.

At the COP26 this past November, we all were reminded of the urgency of this transition to clean technology. We all know that renewables have a huge role to play. After three decades of studying wind-wildlife risk, developing solutions, and applying them on the ground, we know that the key to understanding and addressing the challenges associated with solar and wildlife is to bring all of our areas of expertise – biology, ecology, statistics, technology, engineering and policy – to bear. We hope this symposium will serve as a forum and a catalyst for the over 600 registered participants to engage with each other now and going forward.

[1] The American Wind Wildlife Institute became the Renewable Energy Wildlife Institute (REWI) in January 2022.

Solar Power in the U.S.

Moderator: Nathanael Greene

Senior Renewable Energy Advocate, National Resources Defense Council

Speakers:

- **Aimee Delach** – Senior Policy Analyst, Defenders of Wildlife
- **Dr. Robert Margolis** – Senior Energy Analyst, National Renewable Energy Lab
- **Dr. Xiaojing Sun** – Global Head of Solar Research, Wood Mackenzie

This panel set the stage for the Symposium by providing context for a joint approach to accelerating the development of solar energy while addressing wildlife conservation needs. It featured a review of the impacts of climate change on wildlife, an overview of projected buildout of solar power required to achieve net-zero emissions across the electricity grid by 2035 and across the entire economy by 2050, and a look at key drivers in terms of policy, economics, technology and land use.

Moderator Nathanael Greene underscored the ground-breaking nature of this work by citing a statement from Hans-Otto Pörtner, Co-Chair of the Scientific Steering Committee for the first joint workshop between the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and the Intergovernmental Panel on Climate Change (IPCC):

> "The evidence is clear: a sustainable global future for people and nature is still achievable, but it requires transformative change with rapid and far-reaching actions of a type never before attempted, building on ambitious emissions reductions. Solving some of the strong and apparently unavoidable trade-offs between climate and biodiversity will entail a profound collective shift of individual and shared values concerning nature…" – June 10, 2021[2]

Given the sheer scale and distribution of large-scale solar deployment necessary to avoid the worst impacts of climate change, discussion focused on land use requirements, and also touched on policy drivers, and the potential wildlife impacts of photovoltaic (PV) installations. The panel also discussed emerging technologies such as concentrating and floating solar power; however, the focus (this day and for the symposium as a whole) was on large-scale applications of PV solar technology, including novel applications for deployment in conjunction with agricultural uses.

Aimee Delach - Uncharted Waters (and Lands): Biodiversity Beyond 2°C [slide deck]

Why is it so important for both people and nature that we limit climate change to no more than 2°C, and preferably no more than 1.5°C, above the long-term global average temperatures? For context, global temperatures have fluctuated within a 1°C band over most of human civilization. However, due to greenhouse gas emissions, temperatures have been rising in recent decades, and the years 2016 and 2020 both exceeded 1°C in warming; in 2021, global average temperature was .84°C above the 145-year average.

[2] https://ipbes.net/sites/default/files/2021-06/20210606%20Media%20Release%20EMBARGO%203pm%20CEST%2010%20June.pdf

At least 85% of the world's population and 80% of the land area have already been affected by at least one type of extreme human-induced climate change event; just this year in the U.S., examples include an unprecedented and deadly heatwave in the Pacific Northwest, extreme precipitation and flooding in New York City, and historic drought and wildfires in the West and Southwest.

With an increase of 1.5^{o} or 2^{o}C in the long-term average temperature, we can expect to see much higher temperature increases in certain places, because warming is not uniform across the globe. Even with a 1^{o}C increase that we have already experienced, temperatures have increased $2\text{-}3^{o}$C in parts of the western U.S. Two of most important river systems (Colorado and Rio Grande) in the West have their headwaters in this "hot spot," where heat, drought and snowmelt change are reducing flow to these critical river systems. The Colorado River system has lost almost 20% of its water in recent decades.

Likewise, the human and ecological impacts of warming are not linear. A half-degree increase (from 1.5^{o} to 2^{o}C) can be expected to more than double the proportion of the earth's population exposed to extreme heat, from 14% to 37%. The number of species at risk of extinction also doubles with that same half-degree increase. Species dependent on sea ice are already severely affected, because the Arctic is warming so much more quickly than the rest of the globe. Coastal species and human communities are affected by rising sea levels as well as more frequent and more severe storms.

Even if all parties kept the commitments they made at Glasgow in 2021, we are on a path that would just barely keep us at 1.8^{o}C, well above the 1.5^{o} threshold. It is very clear that we need to do more. At the same time, climate change is not only threat wildlife faces. According to the IPBES report that came out in May 2019,[3] our natural ecosystems have declined by 47%, and about a quarter of our species are at risk of extinction, with climate change being only one of the drivers.

The 2021 IPBES-IPCC co-sponsored workshop was a ground-breaking attempt to bridge the gap between scientists and policymakers working on the two most pressing issues of the Anthropocene: climate change and biodiversity loss. We cannot ignore the biodiversity crisis, even as we work to solve the climate crisis. AWWI's work on wind-wildlife interactions is a model for the ever more time-critical work that lies ahead to enable us to solve both crises simultaneously.

Robert Margolis – The Role of Solar in Decarbonizing the U.S. Electricity Grid [slide deck]

In September 2021, the U.S. Department of Energy (USDOE) published the Solar Futures Study report, a comprehensive review of the potential role for solar energy in decarbonizing the U.S. electricity grid by 2035, and achieving a zero-carbon energy system by 2050.[4] Currently, the U.S. electric grid derives 60% of generation from fossil fuels and 3% from solar, mostly for buildings. The study posits a scenario in which:

- Deployment doubles – from 15 GW installed in the U.S. in 2020 to an average of 30 GW installed per year between now and 2025 – and doubles again to 60 GW per year from 2025-2030.

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[3] https://ipbes.net/sites/default/files/inline/files/ipbes_global_assessment_report_summary_for_policymakers.pdf

[4] DOE Website: https://www.energy.gov/eere/solar/solar-futures-study – includes Summary of Key Findings, Data Visualizations, Frequently Asked Questions.

- At 1,000 GW, solar meets 40% of electric demand in 2035, and 45% of total (not just residential and commercial buildings) electricity demand by 2050 with 1,600 GW.
- Major growth in wind also is required.
- Achieving and maintaining this level of deployment requires: reshaping the workforce, supply chains, siting and permitting, and regulation and policy, including limits on carbon emissions and/or clean energy incentives. Storage, transmission, and flexibility in load and generation are key to a reliable and resilient electrical grid.
- With continued technological advances, electricity prices do not increase through 2035.
- Expanding clean electricity supply to cover the building, transportation and industry sectors yields deeper decarbonization.
- Power sector water withdrawals would decline by 90% by 2050 in the decarbonization scenarios.

Annual solar installations grew by a factor of 20 from 2010 to 2020, and cumulative capacity increased by a factor of four. Utility-scale (i.e., ground-mounted projects >5 MW) accounted for 73% of new solar in 2020, and 61% of cumulative installed solar in the U.S. The dominant technology is and continues to be photovoltaic (PV) installations.

The Solar Futures Study sets a target of $20/MWh levelized cost of electricity (LCOE) by 2030, less than half the 2020 LCOE of $46.5/MWh. Cost-effectiveness gains will come from a combination of decreased costs – primarily for the PV modules but also from balance-of-system (BoS) components – and gains in reliability and yield. Advances in module architecture will include larger, more efficient utility-scale projects as well as modules tailored to specific applications, such as weight-constrained roofs, shingle-integrated products that can be integrated into the construction supply chain, and modules designed to capture wavelengths for electricity production while passing through sunlight that can be used by crops underneath.

Most of solar energy's contributions will come from PV installations, but as grid decarbonization approaches 100% (2035), Concentrating Solar Power (CSP) provides a key service to the grid as firm capacity, reaching 39 GWh by 2050. The best CSP resources are found in the Southwest, which could require additional transmission. Indeed, expanding the transmission system may be one of the biggest challenges we face, which means distributed solar may be part of the solution.

So where is solar going to go? Global horizontal radians (GHI) measures are good across the country, so the Futures Study showed significant growth of solar in all regions, particularly in the eastern U.S. Another study (Net Zero America, 2020) found that the top solar states in 2050 are likely to be: Texas, California, Florida, Pennsylvania, Georgia, South Carolina, Alabama and Virginia. Solar and wind very different in terms of deployment and how they impact land. Solar is more compact but more land intensive, directly impacting ~90% of the total site area. Wind requires significantly more area per MW, but directly impacts only 1% of the total site area.

In the Futures Study decarbonization scenario, solar installations require use of 10 million acres (4 million hectares). This represents 0.5% of contiguous U.S. land area, or less than 10% of potentially suitable disturbed lands. For context, agriculture currently utilizes 43% of contiguous U.S. surface area, disturbed areas suitable for solar make up about 8%, while urban areas and paved roadways constitute 5%.

Proposed utility-scale solar energy projects have begun to generate land use conflicts in different parts of the country, but there are a number of factors that could help reduce that tension. Increased efficiency of solar technologies would reduce land requirements. Dual-use installations on grazing and cropland as well as land planted in pollinator-friendly vegetation could make large-scale solar more acceptable in agricultural landscapes. Siting solar on degraded lands – brownfields, landfills, Superfund sites – is another possibility. Such strategies come with their own challenges, which others will discuss during the next two days. Rooftop solar will certainly contribute to the solar future, but we will need to go significantly beyond rooftops to achieve 1-3 TW of power required to decarbonize our economy.

Additional reading/resources
Downloads: full; Solar Futures Study fact sheet; images and multimedia

Dr. Xiaojing Sun – A bright future: U.S. Solar Market Overview [slide deck]

Solar is an amazingly resilient industry. The US electric utility market has more than tripled its annual solar capacity additions in the past five years, from 6 GW in 2017 to 20 GW in 2021, and it is expected to add 35 GW in 2025 and 2026. (A forecast dip in deployment in 2022 is due to supply chain constraints resulting from the global pandemic.)

Of the 72.6 GW of current utility solar operating capacity in the U.S., with another 106 GW of utility solar is in development. California and Texas dominate with 40% of current utility-scale operating capacity; 17-24 states expected to have 500 MW or more in operation by 2022. Policy and market incentives as well as strong solar resources continue to favor California, Texas, and Florida – but high growth also is expected in the Midwestern states and some traditional wind energy states like Iowa and Pennsylvania.

Drivers of solar deployment
The main drivers of utility-scale solar development are policy and economics; coal retirement, utility procurement plans as well as voluntary and corporate procurement goals also play an important part.

Policy. The federal investment tax credit, currently being debated to extend another 10 years, has made a great difference, but state-level renewable portfolio standards (RPS) play a very important role as well. A total of 28 states have established a minimum amount of electricity that has to come from renewable or clean energy resources, and three more have set non-binding goals. RPS requirements have expired in seven states, but the minimum standards have been increasing in many states. For example, California's RPS originally called for 30% from renewables, which rose to 50%, and is now set at 100% by 2045.

Economic. Solar modules and system costs have decreased significantly over the past 10 years as the technology has matured. Solar already is one of the cheapest resources in 16 of the 50 states, and economic drivers will play a greater role as solar becomes the most economical energy source. Utility-scale PV is likely to remain the most economically competitive electricity source in most U.S. states. (There is a mismatch between when solar generation peaks and when demand peaks, however, so it will be important to develop storage technologies.)

Coal retirement. Of the 114 GW of power generating capacity expected to retire by 2026, 72% is coal-fired generation from plants that no longer make economic sense to maintain. Solar installations are likely fill the gap – even in a state like Texas which does not have a strict RPS requirement. Utilities across the Southeast and Midwest are committing to replace coal by adding solar.

Utility Integrated Resource Plans (IRPs). Solar procurement requirements outlined in utility IRPs reach 74 GW by 2031, with 72 utilities planning to procure over 1 GW of solar within the next ten years.

Corporate procurement. Environmental, societal and governance (ESG) strategies in the private sector are driving large corporations to procure electricity directly from solar providers rather than from the utility grid. About 29% of solar operating capacity has a "corporate off taker," and pressure from investors and other stakeholders is likely to mean that corporate procurement will be a stronger driver for solar in future.

Emerging solar technologies and applications

Concentrating Solar Power (CSP). There are 16 operational CSP plants in US. CSP requires high levels of solar radiation with limited cloud cover, so is likely to be confined largely to the U.S. Southwest. (California has about 50% of current CSP.) A CSP plant operates most efficiently and cost-effectively at sizes of 100 MW or larger, and typically requires 5-10 acres per MW of capacity. Power is concentrated to turn a steam turbine, so CSPs also require access to water – and a nearby connection point to the grid to get power to customers. These projects are difficult to pull off both financially and in terms of the engineering; nevertheless, 100% decarbonization will require CSP.

Floating Solar**.** Orlando, FL has utilized floating solar installations on retention ponds and lakes being used. The U.S. is a small player in terms of floating solar; China will continue to be the largest floating solar market.

Agrivoltaics. Combining solar development with agricultural uses has the potential to resolve land use concerns in the U.S. Benefits include generating revenues for farmers, increase farm yields, and make solar an integral part of conventional land uses. (Likewise, "aquavoltaics" where solar over fishery ponds helps mitigate algae growth by shading ponds?)

Audience Questions & Panelist Response/Discussion

The panel responded to questions about:

- Land use projections
- The impact of RPS as a policy driver
- Potential environmental impacts of CSP

What constitutes "disturbed" land and "suitable" land in the Futures Study analysis?

"Disturbed" land includes developed (but not built) lands, invasive-species impacted, quarries and gravel pits. This analysis draws heavily on EPA's land-screening tools and land types, environmentally sensitive land. There is more research to be done to avoid wildlife conflicts. "Suitable" land was established building on a set of screens developed in similar NREL research: excluding land with slope >5%, different cover types, urban development, etc. [See also: supplemental technical reports.]

The amount of land required is significant, but if we're smart about it we can find the sweet spot in terms of identifying the policies and incentives that will encourage people to use the disturbed land that doesn't present us with wildlife conservation conflicts. 43% of our land is used for agriculture. Using a small fraction of that for some of the dual use applications offers the potential for synergies that could reduce some of the conflicts. There are real challenges that we have to face – and this symposium is where it starts.

Uncertainty around policy drivers can hinder development; have RPS or expiring tax credits held back solar development in any way?

Dr. Sun: Renewable Portfolio Standards (RPS) are beneficial, and were very impactful at a time before solar was economically "bankable." They helped the industry to move up the learning curve, creating economies of scale and driving down the cost of the technology. As a result, market forces can now play a driving role in solar development in Southeastern states that do not have RPS.

Dr. Margolis: RPS have been a substantive incentive, but if we're serious about decarbonization they are not a substitute for a national-level policy.

What is known about avian interactions with CSP installations?

There were evaluations of avian deaths at a CSP installation in California in 2014. About a third of the fatalities around that power plant related to solar flux (an intense flare which can disorient birds, different from heat flux). We will need to do more research to understand this impact; at the same time, compared to other mature solar technologies, CSP is more costly and challenging – and so not as likely to have wide deployment as PV installations. DOE is taking an "all of the above" approach – not writing off any technology or application at this point – which includes evaluating new applications of CSP technologies for certain niche markets. It is always important to work with a community to come up with a joint plan for any major energy development.

Keynote Address: President Biden's DOE clean energy initiative and how it relates to wildlife

Kelly Speakes-Backman

Principal Deputy Assistant Secretary for the Office of Energy Efficiency and Renewable Energy (EERE) at the U.S. Department of Energy

Kelly Speakes-Backman leads and directs EERE, a U.S. Department of Energy (U.S. DOE) office focused on creating and sustaining American leadership in the transition to a global clean energy economy. She oversees the planning and execution of EERE's $2.8B portfolio in energy efficiency, renewable energy, and sustainable transportation. Speakes-Backman most recently served as the first CEO of the Energy Storage Association, the national trade organization for the energy storage industry. She has spent over two decades working in energy and environmental issues across sectors. In 2019, Speakes-Backman was honored by The Cleanie Awards as Woman of the Year.

Keynote Summary

The mission of EERE is to transition the economy to 100% clean energy no later than 2050. Research and development efforts are focused on cost parity and ensuring the reliability of a renewable-powered grid. The cost of solar has fallen tremendously over recent years, and there is now a strong economic case for deploying solar rapidly. Realizing the aggressive solar deployment outlined in DOE's Solar Futures Study would have major impacts across sectors:

- Solar could provide 40% of electricity produced in the U.S. by 2035
- Up to 1.5 million jobs could be created
- $1 trillion in climate impacts could be avoided

To do this given current efficiencies could require as much as 10 million acres of solar in 2050, or roughly 0.5% of land in the continental United States. However, decarbonization of the American economy would be possible by using just 6% of existing disturbed lands for solar deployment. Such a large change in land use highlights the importance of wildlife conservation considerations in the planning, deployment, and operational phases of solar development.

With the intersection of solar growth and wildlife conservation front of mind, EERE efforts include:

- Incorporating machine learning into solar and conservation monitoring
- Using advanced drones to monitor birds and other wildlife nesting and activity near solar facilities
- Understanding the role of agrivoltaics in the future of solar deployment
- Co-location of solar with other land uses

Agrivoltaics, and more specifically the co-location of solar on working farms, is a key interest of EERE. EERE has funded projects investigating the potential of solar development being made compatible with working farms, with the interests of both farmers and solar stakeholders in focus.

EERE has been actively involved in work to identify the best stormwater runoff practices on solar sites. Collaborations with the Environmental Protection Agency have resulted in a guide to best practices for developing solar on former landfills. Similarly, the recent bipartisan infrastructure bill includes $500 million dedicated to deploying clean energy on active and abandoned mine lands. PV recycling and waste management are also being investigated by DOE.

The continued research and work of DOE is supported by the continued involvement of stakeholders. The administration is focused on addressing environmental justice and equity. The Justice 40 Executive Order signed by President Biden on January 27, 2021 created a government-wide initiative that aims to deliver 40 percent of the overall benefits of relevant federal investments to disadvantaged communities. The legacy of pollution runs long and deep in communities of color. Our current energy system's design has disproportionately affected them. The clean energy transition requires a recalibration of how impacts and benefits are distributed with regards to all, especially disadvantaged communities. The Energy Justice Dashboard (beta) tracks DOE's initiatives to address environmental justice nationwide.

DOE Working groups involved in an equitable solar growth include the Equity Working Group, Metrics Working Group, Procurement Group and Stakeholder Engagement Group. Stakeholders matter; the DOE understands that it cannot make these changes alone. Decarbonizing the economy must include all efforts to mitigate effects on natural resources while addressing historical injustices.

Solar Site Selection & Development Process

Moderator: Jason Hight

Director of the Office of Conservation Planning Services,
Florida Fish and Wildlife Conservation Commission

Speakers:

- **Alyssa Edwards** – Vice President of Environmental Affairs and Government Relations, Lightsource BP
- **Jodie Eldridge** – Senior Manager of Environmental Services, NextEra Energy Resources
- **Stephen Czapka** – Biologist, U.S. Fish and Wildlife Service
- **Karen Voltura** – Energy Liaison, Colorado Parks and Wildlife

This panel focused on the dynamic factors at play during the site selection process for utility-scale solar development. Panelists presented perspectives on how developers avoid, minimize and mitigate conflicts in terms of both non-wildlife and wildlife/natural resource-related considerations, including the use of both desktop analyses and on-site investigations. They also discussed the role of state and federal agencies during the siting and due diligence processes.

Alyssa Edwards – Low Conflict Solar: Non-Wildlife Siting [Link to Slides]

From a solar siting perspective, community acceptance is an important aspect of the development process. To gain an understanding of public perceptions towards solar development, developers consider many factors, including population density, the location of major transportation corridors and stakeholder acceptance. Lightsource BP has found that higher population density is a predictor of community resistance to solar development. On-ground reconnaissance helps to gather stakeholder assessments and get a clear perspective of community acceptance. Viewshed concerns can impede community acceptance. Developers identify these kinds of concerns through dialog with the community.

Land designations can make or break a solar site. The first step towards assessing land designations is to identify if a parcel has any federal designation. Bureau of Land Management and U.S. Forest Service lands require a more intensive permitting process, and that is often a non-starter. State designations may be less well-known, but they're equally important to identify. Additional challenges caused by federal and state designations may prevent a project from being viable. Local zoning matters too, especially in proximity to an urban area.

Some states are restricting solar development on designated 'prime farmland.' This is most commonly encountered in the Midwest. There are also aviation considerations. The Federal Aviation Administration (FAA) notice of criteria tool helps developers to understand if PV arrays may create risk of glare to aircraft.

Projects need to be sited near transmission lines with available capacity that can bring energy to population centers. Furthermore, offtake drives project interest. In certain regions, energy pricing and political interests may affect development.

Environmental characteristics such as topography, tree cover, water resources and soil types can all influence solar siting. Flat land with few trees is preferred. Previously operating infrastructure, such as the presence of oil and gas wells, can complicate permitting and cause safety concerns. Areas prone to extreme weather and fire behavior create risk, which impacts the ability to obtain insurance for the project.

Jodie Eldridge – Siting: Solar Considerations [Link to Slides]

The first steps of solar siting involve desktop analyses to look for site suitability and any possible fatal flaws. Developers employ tools such as USGS-based site suitability layers, U.S. Fish and Wildlife Service Information for Planning and Consultation (IPaC), historical nesting data and bat hibernacula data. If desktop analyses fail to find any fatal flaws, the process moves forward into due diligence. This is a boots-on-the-ground investigation of site suitability as it relates to environmental characteristics. If this checks out, the process moves on to wildlife pre-construction surveys. These surveys are conducted by ecologists and involve surveys of birds, reptiles, amphibians, vegetation and more.

When siting a solar project, developers adhere to the 'big three' strategies to reduce disturbances and conflicts with the natural environment and human populations: 1) avoidance, 2) minimization, and 3) mitigation. If land is not a limitation, site design can be adjusted to avoid disturbances. If mitigation is necessary, developers work with agencies to determine how to direct mitigation funds for maximum impact. NextEra, FPL and Gulf Power have 134 solar projects, and experience has found that no two are the same.

From the solar development perspective, there are questions surrounding wildlife interactions and mitigation strategies. Where do pollinator-friendly plantings make sense? What plant species are most effective at quickly establishing pollinator-friendly plantings, and are they compatible with solar operations? Another consideration is the lake effect hypothesis. Developers want to know if birds are mistaking solar panels for water, so that we can work together with biologists to find ways of avoiding and minimizing these impacts on birds. Of particular concern is any possible impacts on threatened or endangered species and the habitats they rely on.

Stephen Czapka – Environmental Review for Solar Energy Projects [Link to Slides]

The U.S. Fish and Wildlife Service (Service) strives to work with others to conserve, protect, and enhance wildlife populations and their habitats for the continued benefit of the American people. Codified natural resource statutes to protect wildlife include the Endangered Species Act (ESA), Migratory Bird Treaty Act (MBTA), Bald and Golden Eagle Protection Act (Eagle Act), and National Environmental Policy Act.

The ESA makes it unlawful to 'take' a listed endangered or threatened animal without a permit. A 'take' can involve hunting, collecting, killing and trapping. Incidental take is not intended, but ESA protections still apply to unintended take. The ESA also protects designated critical habitat if such habitat has been designated for a listed species.

The MBTA protects 1,093 bird species native to the United States. Under the previous administration, incidental take was not illegal. However, effective December 3, 2021, the Service returned to implementing the MBTA as prohibiting incidental take. Enforcement discretion, consistent with judicial precedent and long-standing agency practice prior to 2017, applies. The Service is currently developing regulations to authorize incidental take of migratory birds. The Eagle Act prohibits the take of bald and golden eagles. Disturbances that disrupt nesting and breeding fall within the protections of this law.

The Service is primarily concerned with federally listed species, recreationally and economically important species, migratory corridors, and habitat fragmentation. The goal of environmental reviews is to ensure a win-win for economic development and conservation. Reviews are typically handled by regional office staff. Developers are encouraged to consult their local Service office for information about the due diligence that applies to a given project.

Before contacting the Service, the IPaC system is useful for identifying and mapping a number of possible conflicts for development, such as documented incidences of threatened and endangered species, critical habitat, birds of conservation concern, federal lands, and wetlands. Google Earth is a good place to start desktop preliminary site assessments before advancing to other tools, such as USGS and Service databases.

Dr. Karen Voltura – State Permitting for Solar Energy Projects [Link to Slides]

State wildlife managers are guided by the public trust doctrine, which holds that wildlife resources are in the public trust. Beyond this central concept is the statutory responsibility that state wildlife agencies have to protect wildlife. However, state agencies cannot do this alone. There are overlapping responsibilities with state, federal, tribal and international interests. Nationally, there are State Wildlife Action Plans that outline how to prioritize protected species within each state. Wildlife don't abide by state boundaries, so these action plans also facilitate coordination with the federal level.

State agency permitting varies across the nation. State agencies are generally consulting agencies for land use, not approval. If public land or a federal nexus is involved, federal agencies are more involved in permitting, with state agencies in a support role.

No state wildlife agencies have direct authority over permitting, but they do have indirect roles to support other state agencies or permitting boards. Public utility commissions may or may not consider wildlife resources in their infrastructure planning. State energy or industrial siting boards sometimes have approval authority for solar projects.

The Association of Fish and Wildlife Agencies (AFWA)'s Energy and Wildlife Policy Committee now has a solar energy work group intended to serve as a forum that will help bring information to all stakeholders. Resources are posted on the AFWA website. A survey of state agencies is underway to better understand how AFWA can become a better resource for research and due diligence needs surrounding the intersection of wildlife biology and solar development.

Audience Questions & Panelist Discussion

The panel discussion revolved around responses to questions within the following broad categories:

- Reflections from recent years of solar growth
- Brownfield development considerations
- Ways of strengthening relationships between developers and agencies

Over the course of the past five years, what have you learned as the solar industry has grown? ***Panelists commented on this question with respect to: climate change considerations; regulatory flexibility; and geographic considerations.***

Climate change. The weather is changing as the climate warms, and this is causing unprecedented impacts on energy generation and insurance. This was not as big a topic of discussion as little as five years ago. Sometimes, issues become priorities quicker than expected. Cumulative impacts need to be better understood, and that's apparent now as we increasingly confront these challenges on the landscape.

Regulatory flexibility. Sometimes our greatest challenge is from within, not necessarily from a permitting or regulatory standpoint. From the perspective of the Florida Fish and Wildlife Conservation Commission, the Commission wishes it had foreseen the ways that rules and regulations could be designed to be more flexible while still ensuring the protection of wildlife.

Geographic considerations. From a sustainability perspective, the forested Eastern U.S. and arid desert Southwest are very different in terms of conservation concerns and wildlife. Fragmentation issues look different from one habitat to another. The scale and scope of projects also varies from one region to another, although we are starting to see larger projects nationwide. Regional partnerships are very important to ensure comprehensive planning processes.

Are solar developers considering brownfield or grayfield sites for future PV deployment? ***Panelists commented on this question with respect to: c*****lean energy consolidation near traditional generation; concerns with developing near oil and gas.**

Consolidation. There have been some consolidations of solar development near coal-fired power plants that are scheduled to close soon, although those examples are technically greenfield developments. Military installations have been home to solar facilities as the Department of Defense implements sustainability and cost-cutting energy measures. Land re-use opportunities are important but complex. Suitable brownfield sites are harder to find than most developers would hope for.

Concerns. Areas with historical or active oil and gas wells are generally avoided because of risks associated with hydrocarbon extraction infrastructure. The risks of creating a spill or leak are typically greater than developers are willing to take on. Developers are not interested in unnecessary risks if they can be avoided during site selection.

Where are there information gaps and research needs, and how can agencies and developers work together to achieve better working relationships?

USFWS is actively investigating best management practices and mitigation measures that can reduce impacts and wildlife conflicts, but many proposed mitigation strategies are not yet proven effective, so official guidance is limited for the time being. The more information that we have from a wildlife perspective, the more certainty we are able to bring to the industry as development progresses.

Understanding how developers and conservation interests can support each other's goals promotes strong relationships. If developers know that they can call an agency and communicate on the same level with similar goals, it goes a long way towards building trust and collaboration as solar continues to see unprecedented growth.

Public Acceptance

Moderator: Jaclyn Friedley

Director of Public Engagement, Apex Clean Energy

Panelists:

- **Dr. Sarah Mills** – Senior Project Manager, University of Michigan
- **Sarah Moser** – Development Director, Savion Energy
- **Dr. Sharlissa Moore** – Associate Professor, James Madison College – University of Michigan
- **Amy Berg Pickett** – Permitting and Stakeholder Engagement Specialist, Sunstone Energy
- **Steve Kalland** – Executive Director, North Carolina Clean Energy Technology Center

This panel focused on what solar developers have learned about the dynamics of public acceptance, and how developers and other stakeholders can improve perceptions of utility-scale solar installations. Panelists presented on the current state of knowledge, effective outreach strategies and possible solutions to the myriad challenges that developers face on the public acceptance front.

Discussion focused on:

- What are we learning about public perceptions of solar and how these influence solar energy development?
- The role of local governments, business organizations and institutions in acceptance
- Strategies for challenging misinformation
- Ways of building meaningful relationships with communities early in the planning phase

What are we learning about public acceptance and how it informs and influences solar development?

Communities have a strong sense of place. People have roots where they live, and that's worthy of consideration and should inspire collaboration with the community. Resistance should not be generalized as merely not-in-my-backyard (NIMBY) pushback. People have an emotional bond with where they live and the places they have a deep connection to. Understanding these intangible values requires public engagement on a local level. For example, viewshed concerns, historical significance and local identities are all most effectively understood by immersion in the local community. Experienced developers have found that it's important to understand intangible values early on. Sometimes, there are certain areas that may be best avoided.

Some communities draw parallels to prior energy development proposals. In some regions, wind energy is widely accepted following decades of growth. Wind and solar concerns are more similar than we would have previously thought. Solar is still a young industry in most areas, and there's still a learning curve and associated acceptance struggle to work through. This process of acceptance and change often elicits emotional responses, with larger developments provoking larger pushback. In Ohio, for example, concerns over large-scale solar have gained momentum and even shut down projects.

North Carolina saw early growth over the past decade, but smaller-scale developments didn't face the magnitude of pushback that more recent large-scale projects have had.

Approach acceptance on a case-by-case basis. Listen to community concerns and needs, which differ from one community to another. Some communities may have had interactions with other energy developers in the past, while others may be facing something totally new. Some concerns are rooted in viewshed issues or perceived threats to local heritage, while many others are economically based. Allocating funds early to support partnerships with communities is a way of keeping in mind the humanity of the communities we enter. When developers get out into the communities, they are reminded of the lives they may affect and the need for cooperation to reach outcomes that are mutually beneficial.

We can expect to learn more in the near term. Few public acceptance studies focus specifically on utility-scale solar larger than 50 megawatts. With recent growth, the industry is just now reaching the point where large installations are becoming numerous enough to gain a better understanding of public perceptions. In 2022-2023, a nationwide survey led by the Lawrence Berkeley National Laboratory will begin collecting much-needed data about national and regional perceptions of solar growth.

How do local governments play a role in public acceptance and solar development?

Local governments give constituents a voice. In Michigan, there are over 1,700 townships that have local jurisdiction. Zoning rules vary from one to the next. Involving the community and local leadership in the process early on provides opportunities for opinions and concerns to be heard while there's still ample opportunity to incorporate those concerns into project design. Local governments have echoed that they want to be consulted earlier in the planning phase to ensure that concerns are heard and addressed. In regions with indigenous peoples or other historically marginalized communities, ensure they are engaged in discussions early in planning and often.

Provide local governments with factual information. Help local, county and regional governments see the role of solar in the local economy and community. Don't expect them to self-educate, especially if there's the likelihood of spreading misinformation. Public perception relies heavily on local leadership: local governments and local politics. Will a local government consider solar as a new tax revenue, or as a facet of the so-called culture wars?

Partner with trusted local institutions to educate early and often. Partnerships with regional universities and institutions builds trust and a reputation for locally minded development interests. By teaming up with local and regional centers of higher learning, developers can become well-known as a reputable source of information for a community's questions. Support the community's ambitions for economic growth by empowering the community see itself as becoming more tech-savvy and forward-thinking.

What are some strategies for challenging misinformation? How can developers interact with those who have genuine questions and concerns as opposed to those who are getting involved to intentionally set up roadblocks to development?

Examples can be more powerful than broad statements. Experience has found that in many communities, generalized factsheets are less convincing than specific empirical evidence. People want to see examples from real communities rather than broad statements. Understanding the local economic context also has real value. For example, how will solar impact the local agricultural supply chain and economy?

Be transparent, informative and respectful. Informational workshops followed by Q&A sessions show the community that your proposed development is not trying to be secretive or exclusive. Be willing to provide as much information as you can give yet know that there's misinformation out there that will be repeated by honest and sincere citizens. Of critical importance is that developers and solar advocates are open and honest when there are unknowns. Honesty matters, especially in small communities unaccustomed to outsiders. It hurts the cause and public acceptance when voices of solar make claims they can't back up or elaborate with real-world examples.

Don't burn bridges. Challenging misinformation is a difficult fight. Still, it's important to believe in progress and the possibility of a positive outcome for both the community and developer. Maintain mutual respect, no matter the public sentiment.

What advice do you have for solar developers on how to build meaningful relationships with the public early on?

Interact with local leaders and the public early on. Get to know the community early and reach out often. Every community has a unique set of local economic, social and cultural characteristics. Developers should get out from behind the desk and interact with local leaders and public forums early in the planning process. Doing this early makes it possible to think about how the solar development can be designed to match local character and values. For example, agricultural impacts and coexistence, fencing types, viewshed perceptions and more are best understood early in planning.

Share best practices within the industry. Developers should keep the bigger picture in mind. There's a lot of value in collaboration among solar developers. If one developer creates bad perceptions due to inconsiderate development or major project flaws that affect the community, it could ruin development prospects for all solar interests moving forward. When developers share experiences and best practices, the entire renewable energy movement benefits, and development gains momentum.

Highlight the value of the energy generated. When building public trust and support, sometimes it helps to remind communities what the solar development will provide: electricity to supply the needs of our society. We all use energy, and there's value to knowing where it comes from.

Be active in local business communities. Developers should consider joining organizations like the local Chamber of Commerce, Better Business Bureau or local sustainability organizations to show local stakeholders their sincere commitment to becoming a contributing part of the community.

Capstone: Current and Future Opportunities to Collaborate for Sustainable Development

Moderator: Abby Arnold

Executive Director, American Wind and Wildlife Institute

Panelists:

- **Tom Starrs** – Vice President of Government Affairs, EDP Renewables
- **Renee Stone** – Senior Vice President for Conservation Programs and General Counsel, Defenders of Wildlife

This panel explored ways of furthering the collaborative relationships between environmental protection advocacy organizations and solar industry developers. Despite some differences at the local project level, solar developers and conservationists share common goals of decarbonization and biodiversity preservation. The moderator and panelists discussed how both sides can come together to chart a more collaborative path forward.

Discussion focused on:

- Developer and conservationist perspectives on sustainable solar growth
- What is needed to better address development conflicts at the local level
- Next steps to continue constructive dialog

Looking ahead, what are your perspectives about opportunities related to building out solar to achieve net-zero and accomplish the biodiversity and climate goals that the 30 by 30 initiative is meant to move forward? What will we need to do to get there?

Environmental advocacy perspective*:* Large-scale electrification powered by clean energy is the way forward in our critical and time-sensitive efforts to address climate change. We need to decarbonize all sectors of the global economy, from power generation to transportation and more. We now need to take clean energy technologies to larger scale and transition away from fossil fuels. With a common goal, strong alliances have formed between clean energy developers and climate action advocates. The deployment of large-scale clean energies must be done responsibly and quickly. There are opportunities to work together to ensure that this happens as an effective and lasting solution to the climate crisis.

Industry perspective*:* We're likely to reach a new equilibrium in the clean energy transition that will involve a mix of solar, wind and other technologies. Research suggests that the U.S. will need 22,000 square miles of solar to meet our clean energy needs. This totals 0.7% of our total land area. We must take the technologies we have and make it work. When we talk about 30 by 30 as a goal for protecting habitat and biodiversity, the idea that there might be conflicts between conservation efforts and clean energy deployment is of low concern considering the monumental tasks before us all.

It's an important part of the conversation to share tangible information that puts into perspective the ways that we can transition to clean energy quickly while managing the impacts responsibly.

Coming from your industry and environmental advocacy backgrounds, what is your advice for how to address some of the challenges and conflicts we're seeing at the local level?

***Industry perspective**:* In the past, we've struggled to communicate the connection between shared higher-level goals and what we're doing at the project level. We've had projects that were far along, only to face opposition from the environmental community and others that have resulted in tensions, delays and sometimes even cancellation. When this happens, the goals that we share aren't reached. At the very least, better collaboration and communication at the project-level would be a meaningful step in the right direction. Industry needs to be more proactive about this.

***Environmental advocacy perspective**:* Getting to know the needs and concerns of the community is important, as is ensuring that the community has the opportunity to participate in the decision-making process. It's important to remember that there are many voices and perspectives from within the environmental community. Nationally operating organizations are often different than local environmental advocacy groups. There's no substitute for community-based involvement.

What is one thing that you want to do as a next step to continue this dialog?

***Environmental advocacy perspective**:* It's important to understand that we have overlapping interests, and that there are some issues where we are unlikely to disagree. Industry and environmental advocates should strengthen broad coalitions that will further our shared goals.

***Industry perspective**:* Many participants in the meeting have a long history working with wind. However, there are differences between wind and solar that affect how we approach build-out challenges and considerations. There's no hiding the fact that solar occupies more land than wind. Furthermore, the impacts of utility-scale solar are less well-studied than wind. There's a real need for a science-based approach to better understand the impacts of solar development on wildlife. The solar industry should commit to supporting independent science-based research to investigate these issues, and we stand ready to make that commitment.

Risks of PV Solar Development to Avian Species (Direct, Habitat, and Cumulative Impacts)

Moderator: Dr. Taber Allison

Director of Research, American Wind Wildlife Institute

Panelists:

- **Dr. Ryan Harrigan** – Associate Adjunct Professor, Institute of the Environment and Sustainability at University of California, Los Angeles
- **Dr. Todd Katzner** – Supervisory Research Wildlife Biologist, U.S. Geological Survey
- **Dr. Karl Kosciuch** – Research Biologist, Western EcoSystems Technology, Inc.
- **Leroy Walston** – Landscape Ecologist, Argonne National Laboratory

This panel discussion explored the current state of avian research in relation to the emerging utility-scale solar industry, focusing on photo-voltaic (PV) solar. Research methodologies, accomplishments and challenges were discussed, with an emphasis on future research priorities. Understanding mechanisms of bird mortality within solar PV facilities is key to interpreting limited data sets. Researchers shared novel data collection and analysis methods they have developed to better understand the population-level impacts of solar PV facilities.

Panelist Discussion

The panel discussion revolved around responses to questions within the following broad categories:

- The current state of knowledge about the risks to avian species from solar facilities
- The state of the science in terms of methods and tools being used to study avian-solar facility interactions
- Key knowledge gaps and future research priorities

What is the current state of knowledge about the risks to avian species from solar facilities? Panelists provided historic context and outlined what we know so far about patterns of mortality, fatality mechanisms, habitat impacts, and the limits of inferences we can make currently about solar impacts to avian species.

Historic context. When utility-scale solar was new, there were surprising observations of greater than expected bird deaths. Working groups were formed to get ahead of this issue by sharing information and identifying research needs. In 2017, a symposium was held to review progress and to establish a path forward. Questions about the magnitude of avian impacts remain, especially regarding PV lake effects, population effects, the geographic extent of avian impacts and more.

Patterns of mortality. Recently published research investigating patterns of bird mortality in the Southwest found that common ground-dwelling bird species, such as horned lark, mourning dove and western meadowlark seemed to be most affected. Also noted was the considerable variability in the composition of avian mortality related to proximity to water, and among birds that are associated with water versus land.

Fatality mechanisms. The causal mechanism for a collision may be attraction, including birds mistaking an array of PV panels for a lake or other body of water, escaping from predation, collisions with powerlines or other mechanisms that may have several factors at play. For example, the time of day, angle of the panels and other factors may play a role in bird mortality in solar facilities. Fatalities are often inferred by the observation of 'feather spots', which are multiple feathers found in a small, localized area. Some feather spots could be the result of predation or other sources of background mortality; however, mortality source is hard to determine without a carcass, and background mortality is often not accounted for simply because of the high cost of monitoring for it. Computer simulations of bird collisions have been useful in exploring causal mechanisms.

Habitat impacts. Wind and solar energy facilities adversely affect avian habitat in very different ways. A PV facility changes the landscape by increasing shading. Vegetation management is much more common with solar, and that can produce unexpected outcomes for wildlife. For instance, studies with greater sage grouse in Wyoming have found 56 observations of the species in a solar facility that had been reseeded with native forbs and grasses.

Some impacts are obvious in hindsight, but many interactions have not been well-studied. Argonne National Laboratory has developed a camera-based edge-computing continuous monitoring methodology (akin to a very smart game camera) intended to detect collisions and bird presence.

Restoration and site management too often ignore bird populations. Better pre-construction baseline data, including bird community composition studies, are needed to better understand the community-level responses to solar-related land use changes.

Limits of our inferences. The Southwest U.S. is the only region for which we have substantial data. One study in this region found 2.49 fatalities per megawatt per year across all avian taxa. While this study showed low fatality rates, additional studies are needed to evaluate the generality of this result.

What's the state of the science for studying avian impacts at solar facilities? Panelists discussed methods and tools used to estimate mortality as well as to extrapolate from individual fatalities to population-level impacts and cumulative ecological consequences.

Fatality monitoring and mortality estimation. Avian fatalities at solar facilities are determined by monitoring a portion of PV array and power line or fence line, and then extrapolating the findings to the rest of the facility. Detection bias is a concern that researchers are working to address, because we cannot draw firm biological conclusions unless we understand potential errors in detection, which includes impacts of scavenger removal rates. For example, there may be a bias towards waterbirds due to higher detection rates for bigger birds.

It is also hard to draw biological conclusions without measuring background mortality, but because this is expensive, we have limited information. In one USGS study in the Mojave Desert, large differences were observed between the background fatality rate and avian fatalities at solar facilities. Another study found a high rate of mourning dove feather spots in a both the solar facility and a reference area; this was not surprising given that mourning doves are a common prey item for predators in this ecosystem.

Much of what we think we know about solar impacts to avian species is coming from one region: the American Southwest. Data from other solar facilities in other landscapes of the U.S. are lacking.

Extrapolating from individual fatalities to population-level impacts. Methods developed to genetically identify feather spots can help us better understand all fatalities at solar sites. Species-specific and even individual-level identification is now possible through genetic work being done at UCLA. (See Ryan Harrigan's Presentation-on-Demand.) We're finding that even certain populations of otherwise common species are in decline. Researchers can't just focus on listed endangered species. It's important to assess the relative risk of solar operations on bird populations while considering other threats. For example, challenges in their wintering grounds thousands of miles away may be much more detrimental than a solar development. These data have also introduced unexpected insights. Preliminary data shows that nearly all feather spots on solar sites represent individual fatalities. What is less clear is the cause of mortality for each individual bird that dies onsite.

Cumulative impacts. Building models of populations is crucial to understanding the scale and magnitude of effects on local and overall populations. USGS has built population models for 25 different species adversely affected by solar and has found that sometimes it is not the local population that experiences impacts, but a migratory species that is passing through. We must understand the population of interest, in the context of its full life cycle, to get the full picture of demographic impacts. For example, in the U.S. Southwest, desert obligates are around solar facilities year-round, but migrants pass through and have other unknown challenges throughout the rest of their annual range. Novel genetic methods of feather spot identification indicate that the science is ready for tackling these challenges.

What are the research priorities that we want to address in the next five years? Panelists highlighted the importance of gathering baseline data, understanding population-level effects, and standardizing protocols as well as creating a publicly accessible database.

Baseline data. Collecting data and establishing pre-construction baseline estimates is a high priority. Wind energy is just getting there after decades of data collection. We need to collect data now so that time series data sets grow as solar deploys. Baseline data makes it possible to see what's changing over the years. Are birds only affected by construction? Do birds adjust to the changes over time? These types of questions can only be answered with long-term data sets – including data from across the nation.

Bird community composition studies are needed as well. Biodiversity responses to solar development are absent from our datasets so far.

Emphasis on population-level effects. Land managers need a better understanding of the population-level effects. Being able to identify that a certain population is at risk from a solar facility would allow us to target compensation activities for a specific population of birds. Similarly, understanding that the population at risk is a migratory species might indicate that blanket year-round monitoring is not an efficient use of resources. This may be an option to explore to reduce soft costs for development while still gathering valuable data.

We need documentation (carcasses, feather spots) to better understand population-level analysis. For example, if there were 100 yellow warbler fatalities at a solar facility, we would interpret the impact differently if we knew that these individuals all came from a single local population rather than from completely different places and populations. [Stakeholders are encouraged to reach out to Dr. Todd Katzner or Dr. Ryan Harrigan if they can provide bird carcasses or feathers from solar sites.]

Standardized protocols & accessible database. Inconsistencies in data collection methods make it difficult to draw conclusions. Standardizing protocols would make future research more valuable for management decisions on solar development sites. The U.S. Fish & Wildlife Service's Wind Energy Guidelines could be a model for standardizing wildlife studies and decision-making in the context of solar energy development. Likewise, the American Wind Wildlife Information Center (AWWIC) could be a model for a publicly accessible database for solar-related wildlife data. Computer simulations of bird collisions have even been useful in exploring causal mechanisms.

Risks of PV Solar Development to Other Wildlife Species (Direct, Habitat, and Cumulative Impacts)

Moderator: Dr. Taber Allison

Director of Research, American Wind Wildlife Institute

Panelists:

- **David Bender** – Ecologist, Stantec
- **Matthew Ihnken** – Certified Wildlife Biologist and Practice Leader in Species Conservation, Environmental Consulting & Technology, Inc.
- **Dr. Todd Katzner** – Supervisory Research Wildlife Biologist, U.S. Geological Survey
- **Dr. Karl Kosciuch** – Research Biologist, Western EcoSystems Technology, Inc.

This panel focused on the risks associated with solar development to non-avian wildlife. Panelists shared their perspectives on how to best investigate the impacts and the best mitigation strategies for big game, ground dwellers, and other non-avian wildlife. Research priorities were explored with the goal of establishing a path forward for data collection and modeling. As solar deployment expands beyond the core growth areas in the South and Southwest, future investigations will pair existing modeling methods with novel data collection techniques and a greater geographic focus.

Panelist Discussion

The panel discussion revolved around responses to questions within the following categories:

- What are the main impacts of interest or concern for non-avian species?
- How do we study non-avian species?
- What is the state of the science in terms of predicting impacts?
- What are our research priorities and where do we hope to be in five years?

What are the main impacts of interest or concern for non-avian species? Panelists spoke to the question of direct mortality vs. displacement impacts, whether habitat conservation should be a broad concern (vs. focusing on species of habitat concern), and on potential impacts to big game species.

Direct mortality vs. displacement. Whether the focus of interest or concern is direct mortality or displacement due to habitat changes depends on the site and the species of concern. For some species, something as simple as a roadway can be detrimental. For others, the impacts occur more at the landscape level. Solar facility infrastructure isn't usually built in a way that would cause direct mortality to non-avian wildlife, so the significant impacts are likely to be habitat-related, especially as solar energy development ramps up.

Broad vs. species-specific habitat conservation – what are the drivers? Solar is unique: there's an initial construction phase that is dramatic, but it's followed by opportunities to manage habitat immediately surrounding the solar panels. At the end of the day, habitat questions get narrowed down to siting issues. For example, we wouldn't want to put solar on the 0.01% of native prairie remaining in Iowa; on the other hand, placing solar in previously disturbed landscapes probably has minimal impacts. Because solar does have the potential for biodiversity enhancement or retention, revegetation methods are important. We've seen sage grouse inhabiting revegetated solar sites. Exploring effects of revegetation and/or restoration further is going to be of interest.

Effects on big game species. Pronghorn, mule deer and elk are excluded from solar facilities by fencing. A snake can go through, maybe even tortoises, but big game rarely can, e.g., as a study of Pronghorn showed in a study at a Wyoming solar facility. Movement corridors through a solar project are likely needed for large facilities to allow big game to pass through. In other cases, wildlife-friendly fencing should be explored as an economically viable mitigation strategy.

Conversations about wildlife-friendly fencing at solar facilities are ongoing, and not only for big game – kit fox, badger, and other medium-sized predators are also affected. This is a great area for research, as there are likely to be economically viable options for mitigation. Developing solar guidelines (like the WEGS for the wind industry) would encourage development and implementation of mitigation options.

What is involved in studying non-avian impacts? Panelists were asked to describe approaches to studying specific species, such as snakes, and to studying community dynamics with regards to ecosystem services beyond individual species.

Species-specific impacts. While we cannot yet draw species-specific conclusions, it seems that long-term habitat management will be important for the continued coexistence of reptiles and amphibians on solar sites. Roadway construction impacts will need to be studied, as this is a major impact of solar development. Some herpetofauna have high site fidelity for burrowing, so if construction results in the collapse of burrows, it may change how those species use the habitat in ways that we do not yet understand. Detection is a major challenge with reptiles, and it requires a lot of field hours to monitor what is happening with species like Northern racers, indigo snakes, or gopher tortoises.

There is also the potential for concurrent positive and negative effects. Construction of utility lines brings in some species while potentially extirpating others. It's not necessarily a tradeoff, but there is a bigger picture to investigate. For example, if we relocate tortoises and instead establish pollinator habitat on a site, how complex are the changes going to be? If we relocate burrowing habitat, what considerations go into the design of facilities and mitigation measures?

Community dynamics with regards to ecosystem services. Biodiversity is unlikely to be lost, but biodiversity will change with a solar installation. Generalist species are more likely to adapt to habitat changes. There are going to be changes in flora that will affect how wildlife use the site. We need information that includes but goes far beyond individual species to understand how this plays out. It's not unreasonable to think that impacts on species particularly vulnerable to changes brought on by solar development would then cause cascading effects within the ecosystem.

It also makes sense to move beyond studying individual facilities. As we start to study cumulative effects across multiple facilities, we'll acquire more knowledge about solar and wildlife interactions. Keep in mind that, although a "solar future" requires less than 1 percent of land area in the U.S., these facilities cannot go just anywhere. This means there are likely to be substantial effects on certain species as build-out ramps up, with major differences between regions. For example, building utility lines in the Desert Southwest can have cascading effects due to a potential increase in predator numbers. Given that utility-scale solar is still relatively new, we should expect the unexpected, especially as solar expands to new areas.

What is the state of the science in terms of predicting impacts? Panelists were asked about the role of forecasts and predictions in our current knowledge, and about our capacity to predict how build-out will impact wildlife at an ecoregional scale.

How well can we forecast fatalities? Studies of wildlife mortality at solar facilities have produced widely varying estimates. For example, WEST Inc.'s 2020 study of facilities across the Southwest found 2.49 bird deaths per megawatt, whereas a previous study had estimated 9.9 bird deaths per megawatt. This suggests we have more work to do to figure out which mortality rate is closer to the mark. We do know that facility siting in minimal impact areas makes a difference, along with thoughtful design of the facility and vegetation management.

Comparing impacts. The big picture question – whether the impacts of unmitigated climate change on wildlife species are worse than the habitat impacts associated with renewable energy development – is hard to predict, particularly if we try to compare the immediate impacts of a solar facility on wildlife with the multi-generational impacts of climate change. This is where population modeling comes in; comparing simple counts of fatalities or displacement from different causes doesn't account for how those events adversely affect populations or species. Part of our response to climate change impacts involves predicting habitat change and making sure that wildlife can relocate as changes occur.

Can we predict cumulative impacts? So much of solar build-out depends on the regulatory environment and grid infrastructure. Rarely do these considerations line up with ecosystem boundaries. Shifting to eco-regional data and understandings would be far more relevant and useful than following state boundaries. We do have tools to model where critical habitats are at a landscape scale. We just need the willpower to put these existing maps to use.

USGS maintains a wind turbine database, which has been helpful for analysis of impacts at the eco-region level. There is no such a database for solar facilities, but with funding such a project would be feasible and helpful.

From a research priority perspective, where do we want to be in five years? Panelists articulated the need to better understand cumulative effects, account for positive as well as negative impacts, and leveraging research resources.

Cumulative effects. A better understanding of cumulative effects is a priority for research. We have the tools and technology to investigate the questions and the modeling frameworks for how to study these issues; we just need to modify and adapt our tools and get to work. We have the technology now, and it's within reach.

One requirement for improved assessment of cumulative impacts is rethinking our expectations; if, for example, our expectation is to figure out exactly how many bats we can afford to lose, we're at a disadvantage from day one due to how little we know about bat populations. But if our goal is to improve our understanding of effects and to identify vulnerable species, we can gather an abundance of modeling data to better address these types of questions.

Positive impacts. In addition to understanding potential negative impacts, we should also measure tangible positive impacts. For example, how might Monarch butterflies benefit from the acres of pollinator habitat that has replaced row crops at some solar facilities? How has biodiversity improved at solar facilities reclaimed from brownfield sites and other uses?

Standardization and leveraging resources. Standardization of studies and data collection would benefit the solar industry by allowing us to approach these questions at a landscape scale. We need to quantify the impacts, to be able to evaluate how impacts differ among regions. Identifying the questions most important to wildlife managers and then leveraging individual project monitoring to help us answer larger questions would be a more cost-efficient way to help us close our data gaps than trying to undertake large-scale studies. Low cost, accurate methods of data collection, such as camera technologies, can be used to reduce the uncertainty in biodiversity responses for developers and biologists for specific impacts, such as the effect of fencing on big game.

Siting Panel: Science, Tools, and Solutions

Moderator: Nicole Hughes

Executive Director of Renewable Northwest

Speakers:

- **Dr. Shilo Felton** – Field Manager, Clean Energy Initiative - National Audubon Society
- **Dr. Yuki Hamada** – Biophysical Remote Sensing Scientist, Argonne National Laboratory
- **Andrew Pinger** – Senior Regional Environmental Manager, EDP Renewables North America
- **Sarah Reif** – Natural Resources Specialist, Oregon Department of Fish and Wildlife

Siting solar energy facilities can be controversial. Biophysical scientist Dr. Yuki Hamada reviewed current and emerging siting tools and strategies available to avoid and minimize impacts to wildlife and habitat. A panel of stakeholders representing solar development, natural resources conservation and state-level wildlife agencies discussed challenges and opportunities associated with existing tools and strategies. Panelists identified how planning and mitigation protocols could continue to improve with the best interests of both wildlife and renewable energy growth in mind.

Dr. Yuki Hamada – Solar Energy Siting: Science, Tools, and Other Solutions – Wildlife and Natural Resources Considerations [link to slides]

Dr. Hamada introduced several site assessment tools currently employed by the solar industry to minimize development conflicts with wildlife and natural resources considerations.

Solar Energy Development Mapper. Developed by Argonne/DOE for the Bureau of Land Management (BLM), this tool enables site screening across a region with an emphasis on public lands. It provides access to a screening-level data set composed of 18 themes and 67 data layers, including spatial distribution of flora and fauna critical habitat. This tool covers the six southwestern states: California, Nevada, Arizona, Utah, Colorado and New Mexico.

California Energy Infrastructure Planning Analyst. Developed by the Conservation Biology Institute for the California Energy Commission, this tool is designed to improve planning efficiency while minimizing environmental risks. It enables multi-purpose screening for energy infrastructure, such as solar, grids and substations, while also assessing site exposure to risks associated with climate change. The 8 categories and 56 data layers include detailed metadata and data documentation with a focus on biodiversity considerations for initial screenings. Data includes species counts, habitats by category and critical habitat designations. This tool covers all of California with resolution varying by the data layer of focus.

Maine Audubon Renewable Energy Siting Tool (MAREST). Developed by Maine Audubon, this tool encourages solar development on degraded lands by providing developers and decision-makers with resources needed to locate solar and wind projects while minimizing impacts on wildlife habitat. MAREST provides vector layers for high levels of detail across all of Maine. It applies potential siting compatibility using a 'stoplight' model. Summary statistics are offered as *.csv files, or as PDFs for datasets selected by the user. At an ecological scale, this map features 10 layers including habitat focus areas, conserved lands, high-value plant and animal habitats, and forest blocks.

Murray County Mapping Tool was created as a collaboration between the University of Minnesota and regional sustainable development partnerships. This map features data that considers impacts on pollinators for solar siting in Murray County, MN. The 25 layers in this county-specific map help developers to co-locate solar with agriculture. Layers such as crop type and crop productivity index provide vector-level mapping for renewable energy planning.

Compass. Oregon's Department of Fish and Wildlife has created Compass, a mapping tool to support early planning for large-scale land-use, development, or conservation projects in Oregon. Compass contains 157 layers of wildlife habitats and many individual species accounts.

These tools are not for regulatory purposes, they are built with decision-making in mind. As we can see from the differences in developmental approaches, there is no standard approach among these tools, despite their similar goals. Taxa are not equally considered. For example, there are limited considerations for insects, which are largely missing from the layers in these tools. Future conditions due to climate change and land use are not known. This uncertainty highlights the importance of regular updates to these resources.

Avoidance is best achieved during the exploratory stage of solar development. These tools are central to avoidance by helping users visualize the complexity of wildlife considerations. From a project development standpoint, these kinds of tools can help make the case to investors that the developer has done due diligence in terms of high-level screening for wildlife conservation criteria. Decision-making informed using these tools and similar resources is critical for building out solar in a way that not only preserves biodiversity, but also builds relationships and grows public support for renewables development.

Panelist Discussion

The panel discussion revolved around responses to questions within the following categories:

- What scale should we be looking at for these avoidance and mitigation discussions?
- From a wildlife management perspective, what does the successful application of these tools look like?
- With the research you've done so far, what are the top three areas you'd like to focus on moving forward?

What scale should we be looking at for these avoidance and mitigation discussions? Panelists made the point that wildlife impacts may need to be considered on multiple scales, while developers need guidance that allows them to focus their resources on the project site level.

Biodiversity impacts should be considered at an ecological scale. Species and habitats don't abide by political and regulatory boundaries, a reality that is especially important in regions of high habitat diversity. While many of these tools have sharp boundaries that coincide with state or even county lines (indicative of artificial not natural differences), users have access to the data used to build the tools. New tools with larger scales could be created using the existing datasets.

The National Audubon Society looks predominantly at the flyway scale: whooping cranes, for example, are facing extinction because of habitat loss due to land use change and now climate change. Whooping cranes require farmland or grassland as primary stopover habitat, so conserving this species requires considering the implications of using grassland or farmland habitat for solar development in these sensitive areas, particularly where the habitat type is already in short supply.

The Association of Fish & Wildlife Agencies (AFWA)'s Energy and Wildlife Policy Committee and Solar Wildlife Working Group seeks to support as-yet untapped opportunities to address these questions at multiple scales, from local populations to flyways and other regional scales or even at a national level. The key issues vary considerably from one part of the country to another (e.g., the Pacific Northwest compared to the Southeast). Apart from the fact that wildlife are not bounded by political jurisdictions, given that we have national energy goals that rely on regional transmission systems, it makes sense to address siting questions at least at a regional rather than strictly at the state level.

In terms of wildlife distribution, the mapping tools provide only a limited level of detail. Wildlife presence does not necessarily tell us whether species are adversely affected or not. At the same time, solar developers need tools that diminish the amount of time needed to get a project into the ground; detailed wildlife information on too broad a scale is not helpful. Audubon is working with the Avian Solar Working Group and AWWI (now REWI) to get information that can inform these planning processes with the goal of making it more efficient to build in lowest-impact sites.

From a wildlife management perspective, will these tools help us get at the issues that you want to see addressed? What does the successful application of all these tools look like to you?

Avoidance is the starting point. It's useful to think in terms of mitigation hierarchy. Avoidance is always the starting point, and it is best achieved in the exploratory phase of siting for any development, including solar. Tools like these are very helpful at this early stage, particularly by helping planners visualize the complexity of the situation. However, the resolution provided by most tools is not that granular, so it doesn't replace site-specific consultation. Oregon will be launching a new tool that overlays wildlife habitat, agricultural interests, soil classes, cultural data, military infrastructure and much more. This next generation of siting tools will further assist decision-makers.

There's a false dichotomy of either/or – either we address the climate problem with solar OR protect wildlife, but not both. We *can* do both, and these robust tools get us part of the way there. But there's also a human dimension, and a need for thoughtful collaboration and compromise to maximize the various values presented in multilayered datasets. These tools are just one piece of the puzzle, incentivizing developers to look at least-conflict areas for development.

From a developer's perspective, there are a lot of pressures including but not limited to wildlife concerns. Solar developers can benefit from these tools when looking at potential project areas to avoid; on the other hand, screening tools don't always align with observations on the ground. Sometimes ground surveys reveal that what looks like it might be an obstacle based on the screening tools is in fact not a problem at all.

Early stakeholder involvement is key. Audubon and agencies like ODFW want to enhance the toolkit available for solar development planners to adequately consider wildlife and human factors in due diligence and the permitting process.

Compensatory mitigation. Avoidance is the first and highest priority in the mitigation hierarchy. There are some examples of successful compensatory mitigation where developers work closely with agencies and stakeholders (such as Audubon) to compensate for impacts to threatened and endangered species.

Oregon's wildlife agency has found that there is not as much ecological or population-level benefit to generating "postage-stamp sized mitigation sites" for wind development. The state is focusing on how to design projects across the larger landscape in ways that maintain working lands (e.g., ranch, forest) while emphasizing the implementation of large-scale conservation easements to which individual projects contribute. Typically, a 3rd party like a land trust will determine who the long-term steward of mitigation sites will be. Sometimes, developers would rather simply write a check and hand it off to someone, but we need coordinated partnerships to make that possible.

With the research you've done so far, what are the top three areas you'd like to focus on moving forward? Panelists weighed in from both the conservation and solar development perspectives.

Conservation research needs

- How can we consider what to expect 10-20 years into the future, especially as climate change alters how lands are being used by flora and fauna?
- Today's tools consider large geographic areas to be homogeneous. Getting more granular details that may be important for avoidance and wildlife-friendly siting would be helpful.
- Developing models for scenario testing would enrich our insights further.

From the developer's perspective

- Project design impact-minimization tools that are still effective at informing users of the complexities of wildlife habitats and the infrastructure and human elements would greatly support solar developers.
- If use of a landscape-scale tool were to expedite permitting, rather than being just one more hurdle in the process, that would be an incentive.

Stormwater Management

Moderator: James McCall

Energy and Environment Analyst, National Renewable Energy Laboratory

Panelists:

- **Jay Johnstone** – Senior Engineer, Stantec
- **Deron Lawrence** – Senior Director of Natural Resources, Permitting, and Policy, Longroad Energy
- **Todd Smith** – Engineer, Minnesota Pollution Control Agency
- **Chris Stone** – Engineer, Connecticut Department of Energy and Environmental Protection
- **Jacob Thompson** – Senior Environmental Engineer, Barr Engineering

REWI (formerly AWWI) has identified water resource management as an important component of environmentally-sound planning when siting large-scale solar facilities. Developers navigate the plethora of regulations and expectations that differ from one jurisdiction and environment to another. Stormwater management falls under the multi-sector general permit (MSGP) for solar and other facilities, with permitting authority varying from state to state. Panelists outlined the permitting process for solar facilities with respect to stormwater management in three different states, including such solar development factors as how runoff volume is calculated, stormwater treatment options, soil compaction and panel orientation. Discussion following the presentations focused on best practices, key challenges, and research needs to improve stormwater management during solar facility construction and post-construction management.

Todd Smith – Stormwater Management for Solar Projects in Minnesota [link to slides]

The Minnesota Pollution Control Agency (MPCA)'s permit requires stormwater treatment on-site for all projects that create a net increase of impervious surfaces of more than one acre. In Minnesota, volume reduction (infiltration) is prioritized over basins and filtration.

For solar panels with established vegetation underneath, developers can opt for a reduction credit that is calculated based on stormwater modeling and a solar-specific MPCA formula. A key feature of the MPCA formula is the ratio of impervious to pervious surfaces on the solar site. Infiltration mechanisms are preferred, and include rain gardens, swales, natural depressions and shallow berms. In localities with high-clay soils and high sediment loads, basins and sediment ponds are constructed for filtration. Minnesota's stormwater management protocols were designed for relatively flat topography, and may not align with the needs of hilly regions.

Chris Stone – Construction Permitting for Solar in Connecticut [link to slides]

Connecticut's 2013 permit update did not account for solar development. The result was the permitting of solar arrays constructed and oriented in ways that increased runoff and lacked the proper controls to mitigate stormwater problems. Lack of runoff management has been a problem for some solar developments in Connecticut. Inadequate post-construction flow calculations led to ineffective stormwater management, such as berm failures and flash flooding.

Connecticut's 2021 permit reissue includes an appendix dedicated to solar design and construction measures. Setbacks and buffers are established for wetlands, and stabilization requirements increase with slope. Qualified professional engineers are now required for inspections, and the conservation district conducts multiple visits and consultations with the developer on-site. The registrant must provide a letter of credit to ensure money is available if additional stormwater management work is ever needed.

Also new with the 2021 permit reissue are post-construction design measures intended to mitigate stormwater problems:

- Panel orientation must consider drainage patterns
- Non-erosive water velocity and volume must be maintained at the property line
- Pre- and post-construction hydrologic analyses are required
- Site-specific soil mapping
- Hydrologic soil group down-grades depending on cut/fill and post-construction calculations

Panelist Discussion

The panel discussion revolved around responses to questions within the following broad categories:

- Best practices for addressing stormwater management during solar facility siting and installation
- Establishment and management of ground cover to reduce runoff and enhance habitat
- Compliance and jurisdictional challenges
- Key knowledge gaps and future research priorities

What are some best practices for stormwater management that stakeholders should take into consideration when planning and installing solar facilities? Panelists highlighted the need to consider the total drainage area, panel orientation, soil compaction, planning for extreme weather events, and the use of infiltration systems.

Account for drainage patterns beyond property boundaries. The total drainage area that affects the property needs to be considered during the planning phase. For example, if neighboring properties feature hills that slope into the solar site, there will be a higher volume of water moving through the site than expected based on the topography of the property alone.

Consider panel orientation. The orientation of panel rows with relation to topography plays a huge role in determining surface water velocities, and in turn the capacity of the surface to absorb water. The objective is to prevent water velocities from reaching the point where most water runs off without percolating into the soil, causing erosion in the process.

Address soil compaction during and after construction. Compaction turns porous surfaces into impervious surfaces, causing soils to act more like a parking lot when precipitation falls. It's important to minimize soil compaction and de-compact surfaces following the completion of construction. One of the easiest strategies for minimizing compaction is to limit construction crews to alternate rows during construction. Additionally, using cover crops during construction will reduce soil compaction and speed restoration at the end of the project.

Anticipate "worst case" weather events. Climate change is bringing more frequent severe precipitation events, and we're already seeing the impacts of this. Planning for severe weather is increasingly important for solar projects and other facilities. Solar developers and their engineers can work closely with ecologists and other stakeholders to foresee what could go wrong during both normal and extreme weather events, and implement preventative and mitigation measures to avoid and minimize stormwater problems.

Filtration versus infiltration. Infiltration is preferred over filtration management. Infiltration includes basins or raingardens, swales, natural depressions and shallow berms. Filtration systems are engineered with an underdrain system that functions according to the limits of maximum depth, drawdown time and other factors.

How can adequate groundcover be established in a manner that aligns with the best interests of the developer, regulatory agencies and the local environment? Panelists noted that importance of cover crops, and called for active oversight of re-seeding, factoring vegetation establishment into permitting timelines, and management plans to ensure long-term success.

Plant cover crops as needed, sometimes repeatedly. Cover crops stabilize soil and aid water percolation. Multiple plantings may be needed depending on the construction process, but the reduction in erosion and runoff is unmatched as a mitigation strategy.

Involve construction managers in the revegetation process. It's important that vendors contracted for seeding the site implement measures for proper vegetation establishment. Most notably, seeding under the panels is very important. Without that, a large portion of the property is without cover, and it presents an opportunity for weed establishment. When the management plan calls for native plant restoration, construction managers must ensure that seeding vendors are using seed drills, as many of the native seeds are wind-borne dispersers and will blow away if not drilled into the soil surface.

Factor vegetation establishment into permitting timelines. Native species that support pollinators are encouraged in some seeding guidance. With native seeds, it may take two years to get to the target ground coverage. Permitting timelines for ground stabilization should consider how long it may take for a seed mix to become established.

Management plans increase the likelihood of long-term success. When a solar development changes hands, it's important that a plan is already in place for stormwater and habitat management. Vegetation management plans guide stewardship so that establishment is more likely to succeed without the need for costly reseeding or weed and tree removal. A mixture of cover crops and slower-growing native species may be the best path forward, but it is important to consult with regional botanists in establishing the ground cover management plan.

What are some of the compliance and jurisdictional challenges for stormwater management at solar facilities?

Inadequate compliance monitoring. In some states, inspectors for stormwater management compliance can be hired by either the developer or the regulatory agency. In some instances, compliance monitoring has misrepresented the impacts onsite. Inadequate post-construction controls lead to runoff issues. Some states, such as Connecticut, are now mandating that compliance monitoring be conducted by a Certified Professional in Erosion and Sediment Control (CPESC).

A complex regulatory environment. In many states, local regulatory entities have implemented more rigorous stormwater management requirements and oversight than what exists at the state level. Developers have noted that site designs have changed based on SW requirements even though sites are relatively close in geography and site conditions. Installers navigate an increasingly complex regulatory environment with evolving standards as solar grows.

Cooperation with developers. In one notable case, Connecticut issued a cease and desist order against a solar developer after they failed to cooperate with regulatory agencies in efforts to ensure environmental compliance. Establishing open communication and fruitful collaboration between developers and stormwater managers is crucial.

What are today's research priorities for advancing stormwater management at solar facilities? Panelists highlighted the importance of understanding how agricultural interests can coexist with solar energy operations, as well as identifying best practices for the establishment of pollinator-friendly vegetation in a manner than mitigates stormwater impacts.

Collaborative management strategies. A better understanding of the utility of cover crop plant species and native plant species for solar site stabilization is needed. Restoration ecologists, botanists, engineers and construction managers should collaborate to identify site management protocols for vegetation management with sound stormwater management in mind.
Impact of panel orientation on runoff. Data on how panel orientation affects runoff is limited currently. A better understanding of how panel arrangement with respect to natural topography affects stormwater management could lead to better siting and installation practices and help builders ensure that non-erosive water volume and velocities are maintained at the property line.

Land Management Considerations for Native Vegetation, Pollinators, Wildlife, and Habitat

Moderator: Iris Caldwell

Program Manager of Sustainable Landscapes, Energy Resources Center at the University of Illinois, Chicago

Panelists:

- **Misti Sporer** – Environmental Scientist, Duke Energy
- **Dan Salas** – Senior Ecologist, Cardno
- **Brian Croft** – Division Supervisor, Mojave Desert Division, U.S. Fish and Wildlife Service
- **Magdalena Rodriguez** – Senior Environmental Scientist, California Department of Fish and Wildlife
- **Jenny Wong** – Fish and Wildlife Biologist, U.S. Fish and Wildlife Service
- **Thomas Swinford** – Program Coordinator, Indiana DNR Nature Preserves
- **Bryan Thompson** – Wildlife Biologist, U.S. Fish and Wildlife Service
- **Marylou Horan** – Wildlife Biologist, Georgia Department of Natural Resources

This panel focused on the diverse perspectives of land management as it relates to solar development in different regions of the U.S. In response to a series of (fictional) solar development scenarios in the Southwest, Midwest and Southeast, panelists explored the conservation and land management challenges unique to each region and discussed tradeoffs related to management for native vegetation, pollinator species habitat, and research needs, as well as other considerations such as project costs and worker safety.

Discussion touched on:

- Regional differences and tradeoffs related to vegetation management strategies
- Fencing considerations for wildlife and site security
- Management considerations for pollinator-friendly plantings
- Gopher tortoise coexistence and translocation
- Endangered Species Act liability concerns and safe harbor agreements
- Invasive species management at solar facilities
- Adapting to changes in project scale

Scenario #1: Southwestern U.S.

Panelists were asked to consider the pros and cons of alternative vegetation management and fencing proposals for the following scenario:

A 50 MW solar PV facility has been proposed in the Mojave Desert in an area that has not seen previous solar development. The area is not designated critical habitat for the desert tortoise, *but habitat modeling suggests the area would provide high quality habitat to the tortoise, and initial surveys identified tortoises within the area proposed for development."*

Wildlife conservation groups have been calling for minimal grading and soil during site preparation. Instead, they promote the use of mowing to keep vegetation at desirable heights. What are some of the costs, benefits, advantages and disadvantages of mowing versus other vegetation management strategies?

Conservation and restoration perspective*:* Mowing makes it easier to restore the site if the facility is decommissioned at some point in the future. Other wildlife species besides the tortoise use these habitats, and mowing maintains some habitat for use. Vegetation efforts make the most sense when permeable fencing is on the table. Otherwise, there's little habitat value if the surface remains a bare moonscape.

Developer's perspective*:* One critical consideration for developers is how long it takes to establish some vegetation. Will erosion become an issue if plant species are slow to establish? Are cover crops needed? There are multiple nuances to vegetative cover under and around solar facilities. To some extent, localized grading and blading helps to ensure that panels will be installed securely. It can be minimized in lower impact areas, such as between rows. It's important to design solar facilities in ways that avoid and minimize habitat destruction as much as possible, but avoidance is not always possible. Therefore, any opportunity to maintain habitat connectivity is valued.

In the next phase of this fictional scenario, one member of the development team is proposing to keep the fence at ground level so that gopher tortoises can't access the array where they may be in danger. Another member of the team is promoting keeping the fence bottom 6-12 inches above the ground to allow for other wildlife to access the habitat. What are the advantages and disadvantages of these approaches?

Conservation and restoration perspective*:* Translocations of tortoises off the site will be needed. If fences are lifted for other wildlife, translocations will need to be a greater distance away so they don't return to the site. There are operational considerations, translocation considerations, and more. When we think about this species, we need to think about what the constraints are. There are limited places for establishing translocation areas. Adaptability is important. Over the life of a solar PV installation, changes will come and go in all aspects of development and management. It's important to be flexible and be willing to learn.

Developer's perspective*:* Operational measures may include a greater level of biological monitoring to identify fatalities, track progress and more. There is always the potential that a tortoise could enter the perimeter, but in general there are fewer concerns if fencing is maintained. There are things that developers can do to avoid conflicts and mitigate impacts, such as reducing speed limits, perimeter checks, etc. There's a lot developers can do to get staff up to speed with desert tortoise avoidance, minimization and mitigation practices. There are reasons that developers might push back against a lifted fence. As an energy-producing facility, there are components on site that present a risk to human safety, such as high voltage components. Grid access extends NERC critical infrastructure protections as a security issue. In the past, some jurisdictions have explicitly forbidden desert tortoises on solar PV sites. The lay of the land with regards to local, state and federal regulations is a big factor. Ongoing dialog is crucial; it's never "one and done."

***Regulatory agency (USFWS) perspective*:** Lifting a fence doesn't make sense if the development results in a large moonscape site. Site development methods matter. It's important that wildlife agencies work with the developer; adequate planning and consideration of all the options is important.

Scenario #2: Midwestern U.S.

Panelists were asked to consider the implications of a campaign to require pollinator-friendly vegetation management as a condition of permitting in the following scenario:

> *"A 50 MW solar PV facility has been proposed in Illinois in an area that has not seen previous solar development. The proposed facility site consists of a mix of about 50% active farmland (corn and soybeans), 25% fallow farmland, and 25% small woodlots. A local conservation group has mounted a campaign advocating that the entire site, both under and between panel rows, be planted with a native seed mix dominated by wildflowers to support pollinators. The group is also urging local officials to make this a condition of the county-level permitting process."*

How would you respond to this campaign, and what are your thoughts as to what could be accommodated, and what could be difficult to include?

***Conservation and restoration perspective*:** In Indiana, utility-scale solar is quite new, and the state is dealing with these challenges. Finding plants that stay under 30" in height is a challenge in the region. There's a need for best-management practices that include a pragmatic approach. Developers also must consider operational constraints. Pollinator habitat can be variable. There's a balance of weighing trade-offs among plant species height, benefit to pollinators, availability, cost, establishment time, and other factors. It's wise to maximize benefits for the given situation.

***Regulatory agency perspective*:** U.S. Fish and Wildlife Service recommends reseeding with native species for all development types, not just solar facilities. It may not always be the most economically feasible option, but it adds tremendous ecological and even agricultural benefits. Pollinator species can be a win-win for wildlife and local agriculture where crops rely on insect pollinators.

***Developer's perspective*:** It's important for developers and conservationists to get on the same page when discussing seed mixes. Are we talking strictly native, or also non-native but non-invasive plants? Many native species take 2-3 years to get established. What happens in the meantime? Will cover crops be the best option for erosion control? Developers navigate complex decision-making processes where it is often difficult to meet everyone's expectations. We work towards the best outcome by maintaining communication with stakeholders and being open to compromise.

How might design constraints affect vegetative height requirements for seed mixes that are under consideration for planting around panels?

***Developer's perspective*:** Leading edge height and system design (pivot, bifacial panels, mechanical components beneath the panels, etc.) determine vegetation compatibility. For example, an 18-24" leading edge height often precludes the use of native plants and limits selections to cool-season cover species. Panel height is a major determinant of the type of vegetation that can be used. Furthermore, seed availability is limited for not only native seeds, but also for traditional cover crops when planting at such a large scale.

Conservation and restoration perspective*:* Establishing native vegetation requires a long-term commitment. From the slow growth habits of some species to managing invasive species and woody invaders, there are several challenges that require monitoring, maintenance and patience. There are unrealistic expectations from those who may not be aware of the complexity of establishing a native prairie in the Midwest.

How should developers consider liability concerns with regards to the Endangered Species Act if their vegetation on site becomes home to a federally-listed species?

Regulatory agency perspective*:* Regardless of approach, there's likely to be a vegetation management component for most solar developments in the Midwest. From what we've seen in the Midwest so far, with due diligence, there are measures in place to help lower the regulatory burden of the Endangered Species Act when actions such as pollinator planting are included in development. For example, safe harbor agreements can be established for developments that meet the criteria and feature adequate habitat management plans. A relevant example is the monarch butterfly. Right now, it is not listed under the ESA, but there are agreements and protections that can ensure pollinator habitat established by the developer won't become a regulatory burden for them down the road if the habitat becomes home to a listed species.

Thinking about invasive species in our scenario, how would we deal with stands of invasive Johnson grass or kudzu in our example development?

Developer's perspective*:* Ideally, developers would get invasive species like these under control when breaking ground and keep them under control with vegetation management. Aside from the ecological reasons for eliminating these invasives, there's also an agricultural aspect. Developers want to be good neighbors and not harbor noxious weeds.

An important factor to consider is that often, solar developers are not the landowner. The land may be leased from the landowner. The landowner may retain rights to certain aspects of development, and that can be a factor in vegetation management considerations.

Conservation and restoration perspective: Right of ways can become excellent habitats for wildlife, and management of invasives becomes a shared interest for the property owner, developer and wildlife agencies. Invasive species prevention best management practices are great as a component of vegetation management plans.

Scenario #3: Southeastern U.S.

Panelists were asked to consider two alternative approaches to conserving gopher tortoises in the following development scenario:

> *"A 50 MW solar PV facility has been proposed in Georgia in an area that has not seen previous solar development. The proposed facility site consists of a mix of about ⅓ farmland, ⅓ slash pine grown for timber production, and ⅓ natural longleaf pine forest. The site is within range of the gopher tortoise, and initial surveys found gopher tortoises within the longleaf pine forest and agricultural and timber lands. The initial plan is to permanently relocate all gopher tortoises to a recipient site. However, a conservation organization is advocating for instead*

maintaining native vegetation on the site, minimizing disturbance and grading and returning the turtles to the site after construction is complete."

What are the advantages and disadvantages of these two proposals?

***Conservation and restoration perspective**:* Although gopher tortoise habitat has historically not been ideal for agriculture due to poor soils, solar development is more of a threat to their habitat. The plant communities that the gopher tortoise relies on are predominantly managed by fire, and fire isn't compatible with solar development. Revegetation is not an easy solution because many of the plants in these habitats are very difficult to establish once removed. Mowing may be a better compromise to investigate, but we're not sure how sufficient that would be for the plant and wildlife communities. It's important to consider not only what's under panels and between the rows. Solar sites have buffer areas that are important to plan for from a land management standpoint.

***Developer's perspective**:* It's important for developers to think adaptively. We're dealing with increasingly constrained landscapes. There are limited areas with the potential for large solar facilities. Safe harbor agreements are important aspects of how we can maintain solar facility sites so that they remain a possible habitat for listed species. There are unique construction measures to be taken when large burrowing animals exist on the property. For instance, inverters sit on a concrete pad. With burrowing wildlife, the concrete pad may need to be thicker to avoid attracting burrowers to such a high-traffic part of the solar facility. Worker awareness training is important to minimize conflicts. For example, speed limits can be implemented to avoid collisions, and perimeter checks may need to be routine.

***Regulatory agency perspective**:* Dialogue is important to advance towards the common goal of figuring out what works, especially for species with unique needs like the gopher tortoise. All stakeholders should come together, look at similar situations that have been navigated in other regions, and find the best path forward to meet the unique needs of the situation.

What comments can you share on the possibility of utilizing incentives to promote the coexistence of solar facilities with the gopher tortoise?

***Regulatory agency perspective**:* With the gopher tortoise, it's not officially listed as of now, so we are coming at it from a relatively weak standpoint with regards to incentives. Perhaps a better approach is to educate prospective developers about the economic tradeoffs of developing on tracts of land with this species versus on tracts where land may be more expensive but require less intensive and less expensive land management. Site-by-site assessment is crucial; over-generalization can lead to shortcomings not only for wildlife, but also for development goals. The speed of development far outpaces the ability for conservation agencies to gauge impacts. This highlights the need for cooperation between industry and wildlife conservation agencies as the science catches up to the changes we're seeing.

How does permeable fencing look in Southeastern habitats?

***Regulatory agency perspective**:* In the Southeast, we've worked with fencing that isn't raised above the ground like one might see in gopher tortoise habitat, but instead it has larger gaps to allow for other wildlife species to pass. Game cameras have been deployed to monitor effects, and several wildlife species have been seen using these permeable fences.

Developer's perspective: Wildlife-friendly fencing is often more visually appealing than traditional fencing. One aspect that has to be considered in this region is wild hogs. With wildlife-permeable fencing, how will wild hogs be managed on site?

Conservation and restoration perspective: When tortoises hit a barrier, they follow it until they can get around it. Instead of lifting fences, one solar facility in Georgia has intentionally left occasional gaps in the fence to allow tortoises to pass through.

How might a substantial increase in the size of solar developments affect some of these wildlife considerations? For example, let's consider challenges that may arise when additional developments are proposed in the vicinity of the original 50 MW scenario.

Conservation and restoration perspective: It's difficult to find suitable translocation sites for larger developments when wildlife needs to be removed. Maintaining habitat connectivity is more critical when developments occupy such a large footprint. Sometimes, adjacent solar installations are owned by different operators. That can complicate the landscape conservation context. Multiple adjacent large tracts of development make cumulative impacts more important to consider. Notably, biologists are still working to understand cumulative impacts from solar development. There's nuance to how we approach every situation.

Opportunities for Dual-Use of Land for Solar and Agriculture (Grazing Livestock, Crop Production)

Moderator: Dr. Stacie Peterson

Director of Energy Programs, National Center for Appropriate Technology

Panelists:

- **Kevin Campbell** – Senior Manager - Development, EDF Renewables
- **Lexie Hain** – Founder and Executive Director, American Solar Growing Association
- **Cody Smith** – Community Resilience Coordinator, Environmental Resilience Institute
- **Brittany Staie** – Farm Manager, Sprout City Farms

This panel focused on opportunities for the dual use of land for both agriculture and solar energy production. Agrivoltaics entails the co-location of solar and any agricultural operation, including but not limited to crop production, grazing and beekeeping. Currently, approximately 12,000 acres of land are occupied by dual use agrivoltaics in 32 states. Panelists explored the opportunities for added value that agrivoltaics provides for both farmers and solar developers. With thoughtful planning and flexibility, dual land use provides new opportunities for solar developments to enhance rural economies.

Panelist Discussion & Audience Questions

Discussion focused on:

- Lessons learned to date
- Financial and liability considerations for solar operators and farmers
- Scaling up agrivoltaics to larger solar facilities
- Wildlife management compatibility

What lessons are you learning in agrivoltaics, and what future modifications would be helpful for solar energy and agricultural coexistence to thrive?

Prior to the first partnerships between solar facility operators and farmers, not much was known about how agrivoltaics would play out. We've now learned about some unexpected benefits of co-locating solar PV with agriculture. For example, the partial shade provided by panels slows soil evaporation, lowers ground temperatures, and can even aid the germination of seedlings. Solar operators have benefited from the vegetation management provided by farmers and livestock.

It makes sense to start small and scale up. There are lots of lessons to be learned through firsthand experience, and pilot trials make positive outcomes more likely and tangible.

Plan ahead for compatibility. Several factors have to be taken into consideration when adapting agricultural activities to an established solar facility – or conversely, when designing a solar PV installation for compatibility with a given agricultural use. Fencing types limit livestock production, panel height limits crop compatibility, and row width excludes large tractors for crop production. Farmers benefit from access to information about livestock stocking levels, sourcing and pasture rotation options. Solar facility design determines which types of agricultural activities will be suitable for the site. Many of the challenges that farmers face could be addressed by design adjustments such as panel height, soil de-compaction and irrigation planning.

Local ordinances matter. Regulatory authorities need to plan for allowing dual-use with solar development. Most of these ordinances are implemented at the county level. Solar developers and agricultural interests should highlight the added value of agrivoltaic partnerships early in the local decision-making process.

What financial, insurance or liability considerations have you encountered with agrivoltaics?

Every partnership is unique, so the financial aspect of agrivoltaics should be considered on a case-by-case basis. Financial considerations are beneficial to both parties in some cases, but not in others.

Liability limits site modification. In general, panels and associated hardware can't be used for any kind of agricultural attachment, water collection device, or anything else. Safety, coexistence and mutual benefit are priorities for all parties involved and avoiding PV hardware disruptions is a key facet of reaching those shared goals.

Benefits for the solar operator. With agrivoltaic partnerships, farmers are typically on-site far more often than solar technicians are. As stewards of the land and extra eyes on the property, farmers may notice and report any issues with facility operations earlier than they would be detected otherwise.

What are the challenges for scaling up agrivoltaics to larger solar sites?

Both solar and agriculture need to be able to meet their financial goals and profitability. At larger scales, finances become more complex. For example, agricultural opportunities increase when panels are installed higher with wider rows. Yet these two modifications may raise costs of solar energy production by requiring more steel and more land. At large scale, these adjustments can lead to big differences in energy production and overhead expenditures.

What are the contractual arrangements between the solar facility operator and farmer?
The American Solar Growing Association (ASGA) offers a solar grazing contract template for anyone to use. Typically, farmers enter into a vegetation management transaction that is separate from the lease. Farmers prefer multi-year contracts. Longer-term agreements help farmers to plan ahead, and they justify farmer investments in the soil health and the general health of the land.

The demand question: Are there enough farmers and solar operators who are interested in such large collaborations? Will unforeseen changes in the economic equation lead to future changes in the dynamics of agrivoltaic relationships? A lot can change over the two to three decade lifespan of a solar facility. Furthermore, will agricultural supply chains accommodate this production model?

How do wildlife management practices at solar facilities coexist with the needs and operations of agrivoltaics?

There are some conflicting interests that impact design elements. Wildlife-friendly fencing is not compatible with small livestock grazing, for instance. Predation can interfere with agricultural operations, so exclusionary efforts for predators may be needed at the site. Farmers, wildlife biologists and solar facility operators should collaborate early and often to find the best design and management solutions to meet the needs of all stakeholders.

Re-Development of Degraded Sites

Moderator: Roger Clarke

Principal Environmental Scientist, Xcel Energy

Panelists:

- **Benjamin Cowan** – Environmental Lawyer, Locke Lord LLP
- **Eric Hansen** – Director of Environmental Services, Westwood Professional Services
- **Erich Miarka** – Director of Development, Savion
- **Lora Strine** – Team Leader for the US Environmental Protection agency's RE-Powering America's Land Initiative

This panel focused on the opportunities and challenges associated with developing utility-scale solar on degraded and contaminated lands. Offering their perspectives as developers and civil engineers, environmental lawyers, and the U.S. Environmental Protection Agency, panelists touched on:

- What characterizes a "degraded" site
- Challenges associated with the redevelopment of degraded sites
- Benefits of working with brownfield sites
- Best management practices
- Future research and resource needs

From your professional perspective, how would you define the term 'degraded site'?

***EPA perspective**:* Degraded sites need to be cleaned up before reuse is possible. In EPA parlance, 'contaminated land' is an umbrella term for all sites that may be contaminated from prior use.

***Civil engineering perspective**:* Any land that requires unusual construction methods to be prepared for use is a degraded site. Typically, degraded sites are under institutional control.

What are the challenges associated with the development of degraded sites?

***Civil engineering perspective**:* Due diligence and pre-development requires an in-depth understanding of the history of the site, and the different contaminants that may exist. Relevant information must be distilled down to understand how to make appropriate use of the site. Are there any developmental restrictions? How will these conditions and needs affect cost? Looking forward, what will third parties think about developing the degraded site? Developers must show third parties that risks, costs and challenges are understood and accounted for.

***Commercial development perspective**:* It's a challenge to get the costs down enough to compete with other solar developments. Degraded site landowners are often not the original landowner from when the site was contaminated. Current owners may not be fully aware of the history of the site, and the status of reclamation efforts. It's a tedious challenge to close out mining permits so that construction can begin. Historically, some coal companies who were the original miners on the site were unwilling to provide enough funds for land remediation. Liability can be insurmountable for solar developers, not just on mining sites, but any brownfield sites. Some states have liability protections in place for entities that are trying to redevelop degraded sites, others have lesser protections. Developers need to understand these at the outset of planning and financing.

Developers need to work in concert with whatever institutional controls are in place for the site. Consult regulators early in the process to understand how site development can work within the limits of applicable regulations and controls. Protection of human health and the environment is the priority of these institutional controls and brownfield development restrictions.

Projects with higher risk and more environmental challenges are more expensive to develop, and therefore the energy produced will be less affordable. Developers and solar operators need to be able to find an off-taker willing to pay a premium for the energy if the site requires costly remediation, insurance, or other preparations for development.

Environmental law perspective*:* A brownfield site lessee may be considered a potentially liable party simply by working on a contaminated site. If things go awry, the lessee is potentially responsible for cleanup, even if they were not the original developers. Current owners and operators of a site are potentially liable parties should contaminants become uncontained.

The EPA can issue what is commonly called a 'comfort letter', but the applications of the EPA letter are limited. In its current form, the comfort letter simply states the regulations and outlines how parties can remain in the clear. Bona Fide prospective purchaser (BFPP) defense is an affirmative defense, meaning that qualification for this defense is not confirmed until it is used as a defense in court. It would be helpful for prospective brownfield developers if the EPA provided clear indications for BFPPs so that they are not treated as a potentially responsible party under superfund site regulations.

What are the opportunities for the redevelopment for these sites in terms of land reuse and social and environmental benefit?

Developer perspective*:* In some regions, such as Appalachia, level ground is hard to come by. Reclaimed mining sites present a rare opportunity to develop solar in areas with a lot of topography. The demand for energy is there, and transmission infrastructure is often already in place due to the energy needs of mining operations. Moreover, redevelopment of degraded sites provides economic growth in areas that historically struggle to generate economic activity or may have recently lost employment and tax revenues when mining operations shut down.

What are the best management practices associated with the redevelopment of degraded sites for solar energy production?

Developer perspective*:* Have a very thorough understanding of the history of the site and conduct a robust environmental review. Work closely with the state agency that is responsible for administering the permits, including closing out mining permits and associated obligations. Understand what would have to be done to avoid disturbing contaminant controls.

EPA perspective*:* Investigate funding avenues at both the state and federal level. Funding often is available from programs that may not outwardly be targeting renewable development on reclaimed lands. Several states have financial incentives for this kind of development. EPA regional contacts for RE-Powering America's Land Initiative can help prospective developers find relevant funding.

Moving forward, what are the research needs and data deficiencies that should be addressed?

Developer perspective*:* Industry would benefit from a better grasp of the differences in cost between greenfield and brownfield sites. As of now, we have limited data points showing 10-15% higher costs of development on degraded sites, but more data is needed to gain a clearer picture.

Developers would benefit from a resource that outlines the development schedule that is to be expected when developing contaminated sites. The better informed developers are, the more confident they will be when pursuing projects on degraded lands.

Environmental law perspective*:* Meaningful liability protection would lower barriers to brownfield development. What kinds of policy changes could be enacted to address developer liability concerns?

Product End-of-Life Management

Moderator: Dr. Stephanie Shaw

Technical Executive, Electric Power Research Institute

Speakers:

- **Dr. Garvin Heath** – Senior Scientist, National Renewable Energy Laboratory
- **Chris Newman** – Environmental Scientist, U.S. Environmental Protection Agency
- **Dr. David Wagger** – Chief Scientist and Director of Environmental Management, Institute of Scrap Recycling Industries

This panel focused on the current state of solar photovoltaic (PV) module end-of-life management. Panelists provided background on product end-of-life management, discussed options for reuse of materials and which PV components may be classified as hazardous waste, and provided insights to the challenges recyclers face as solar PV facilities approach the end of their operational life.

Dr. Stephanie Shaw – Product End-of-Life Management [link to slides]

The recycling of solar materials provides opportunities for the industry to demonstrate environmental stewardship through responsible planning. Responsibility for managing potentially toxic materials and the potentially associated liability is important for the health of the environment and those around us and supports the positive image of renewable energy industries. Furthermore, stakeholders such as customers, financiers, and the public care about sustainability.

Recycling needs are not a distant reality. There's an immediate need for recycling today as individual modules fail and as existing solar operators seek to upgrade their facilities with more modern PV equipment to increase energy production. Beginning late this decade, large-scale recycling will be needed as older PV systems reach the end of their operational life.

Currently, end-of-life management options include reuse, recycling, landfilling and hazardous waste disposal. Cost per module varies widely, with hazardous waste disposal options costing $3.60 per module and above, and recycling from $10-$30 per module. The affordability and availability of recycling and reuse needs to improve rapidly before large volumes of modules reach end of life. However, there’s immense value in the recyclable materials within solar modules if they can be efficiently extracted. The International Renewable Energy Agency (IRENA) estimates that recyclable materials in older solar modules will be worth $15 billion by 2050.

With current state-of-the-art recycling capabilities, 78% of materials in a module are recovered and recycled. Emerging recycling methods targeted to PV modules as opposed to in mixed glass or e-waste lines have been shown to recover 92% of materials. Most current recycling is done in mixed-recycling facilities. Targeting recycling would likely increase recovery rates.

Recycling solar hardware will be crucial to a sustainable, circular economy in a clean energy future. The renewable energy transition represents a unique opportunity to get this right from the beginning by planning for future waste needs.

Dr. Garvin Heath – Why Focus on End-of-Life Management: A Focus on Materials Management [link to slides]

By 2050, PV panel waste could exceed 10 percent of global e-waste. By that same year, the U.S. is expected to be the second largest source of PV waste globally. Researchers forecast that decommissioned modules will catch up to new installations in the 2030s.

It is estimated that 20-40 percent of global silver, aluminum and silicon virgin material demand could come from recovered materials from decommissioned PV modules. Besides recovering materials, other motivations for recycling PV include reputation of the industry, legalities and liabilities, and the growth of the circular economy.

Chris Newman – Are Solar Panels Hazardous Waste? [link to slides]

A hazardous waste designation results from a series of classifications. One is whether the material in question will be reused or discarded. If it is a solid waste that is to be disposed of or discarded, it may be a hazardous waste. Solar panels are not listed hazardous wastes, but some PV models may be considered a characteristic hazardous waste due to how certain materials contained in the PV panel are released in specific situations. A toxicity characteristic leachate procedure (TCLP) estimates degradation of a waste in a landfill environment to determine if the leaching of hazardous contaminants exceeds regulatory thresholds. If the TCLP results of a waste panel exceeds the regulatory threshold for one or more Resource Conservation and Recovery Act (RCRA) contaminants, it is considered hazardous waste, and requires management as such. It's important to note that some solar panels may be determined to be hazardous waste, while others are not. This is sometimes true even within the same model and manufacturer.

David Wagger – Recycling Industry Perspectives

In the recycling industry, PV modules are considered an option for generating commodity-level raw materials. But recyclers don't want to handle hazardous waste. The biggest challenge with recycling solar PV modules is the cell material. How can cell materials be recycled profitably, especially when so many different chemistries are used in their manufacturing?

From a recycler's perspective, it's preferable to have a large quantity of a single model rather than an assortment of different models with differing chemistries and designs. Having such single model scale facilitates reuse opportunities. Aluminum, cable, wiring, circuit boards, and glass are all recyclable materials from PV modules if reuse is not an option.

Federal RCRA regulations are important for recyclers to consider, but state waste regulations can be more stringent than federal RCRA regulations. States may allow a recycler to remove easy-access materials from modules under RCRA exemption rules for recycled materials, such as metal, circuit boards, cable, and wiring. The cell material is what typically remains and is most often the component that has the potential to be hazardous waste due to cadmium, lead, selenium and silver, but that will depend on chemistry.

A key improvement would be if PV modules are designed with recycling in mind so that they are more easily recyclable. It's helpful for solar PV materials to be classified as 'universal waste', which allows recyclers to handle PV modules or components with fewer limitations when recycled. However, universal waste would not apply to reusable modules, which are products and not waste at all when reused, or to easy-access materials with an applicable RCRA recycling exemption that are removed for separate recycling.

Panelist Discussion

The panel discussion revolved around responses to questions within the following broad categories:

- Reuse options and challenges for solar PV modules
- Novel recycling methods
- Regulatory considerations

What reuse options are possible for solar PV modules? Are there any specific challenges to be resolved to make reuse more feasible?

In the U.S., modules have been sold on the secondary market for non-grid connected uses. Grid-tied reuse would require costly recertification of the panels, which is not cost-effective. Some panels are sent abroad to other markets.

Utilities have made efforts to support reuse of their solar modules but have often encountered uncertainty with how liability will transfer as the materials exchange hands globally. Lack of clarity on liability and cost of refurbishment are detriments to reuse. How much time and effort can be put into repairing modules without exhausting the value left in them? This is a challenge that needs to be explored. Limited data shows that reused modules retain 30-50% of the original value, and that can be exhausted by repair costs.

Another challenge is that the modules being recycled today are not made with the same cell chemistry as new models entering the market today. That mismatch may limit the potential reuse opportunities.

What novel recycling methods may increase solar PV recycling efficiency?

Purity standards. Purity standards for commodities are much higher today than they were in the past for materials like silicon, and it becomes very difficult to attain such high levels of purity through the recycling process. However, a French company has created the first recycling facility dedicated to solar PV recycling. It claims that it will be able to achieve high purity silicon recycling.

Sorting methods. Affordable sorting methods are needed due to the varying PV cell chemistries. At what point does the time and effort required to manually sort various PV cell chemistries negate the profitability of recycling them?

Are regulations appropriately addressing disposal, and how is the U.S. EPA focusing on this?

EPA Regulatory Considerations. The EPA is considering how existing regulations apply to new technologies and materials. RCRA is a 45-year-old regulation framework and adapting it to modern solar materials is a recent challenge. Any possible revisions would require careful consideration.

Standardized Contaminant Testing. The determination of whether a module is classified as hazardous waste depends on a compositional analysis of contaminants leached out of modules during lab testing.

Due to a lack of guidance, it is possible for selective samples to be submitted for testing so that hazardous components are unintentionally or intentionally omitted or enhanced. The Electric Power Research Institute (EPRI) and Arizona State University are working on developing a standardized procedure for preparing samples for leachate testing that addresses these discrepancies. The methodology currently focuses on ways of supplying analysis laboratories with representative samples that include all components of the module. Standard operating procedures for this process are being prepared now and will soon be available to the industry. [Note: The new ASTM-E3325 Standard Practice for Sampling of Solar Photovoltaic Modules for Toxicity Testing, 2021 Edition, is now complete and accessible at https://www.document-center.com/standards/show/ASTM-E3325.]

Lead in PV modules*.* Lead is often the component that makes solar modules hazardous at end-of-life. There are lead-free solar panels being designed now, although current market availability is unclear. Broad availability of such modules at an affordable price would make handling end-of-life PV modules less problematic.

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Testing the 'Lake Effect' hypothesis for avian attraction to solar panels

Presenter: Bruce Robertson (Bard College)

Authors: Bruce Robertson (Bard College), Olivia Rothburg (Bard College), Jackson Barratt Heitman (Bard College), Devin Fraleigh (Bard College)

Abstract: Bird collisions with man-made structures are currently the second most important cause of avian mortality. The 'lake-effect' hypothesis posits that the polarized light reflecting from shiny, dark-colored structures (e.g. solar panels, glass buildings) causes birds to misidentify these solid vertical objects as natural water bodies at a safe distance. Songbirds can visualize skylight polarization patterns, but it remains unknown if they can use this same polarization sensitivity to locate water bodies and other terrestrial sources of polarized light. We exposed wild songbirds to bird feeders modified to manipulate their visual properties (color, brightness and degree of polarization), with the prediction that polarization will enhance their visual conspicuousness and enhance visitation rates. In a second experiment, we exposed wild birds to ground-based test surfaces that tested the ability of birds to use polarization cues to guide their behavior, outside of the context of feeding and without the ancillary cues that real water bodies possess (e.g. tactile cues). Finally, we exposed them to heated bird baths with three visual treatments (black, white, and aluminum substrates) with the prediction that birds would locate water bodies using polarized light cues and visit those treatments at a higher rate. Black-capped Chickadee (*Poecile atricapillus*) and Tufted Titmouse (*Baeolophus* bicolor) and all other songbird species increased their visitation rate to feeders with highly polarized light cues, independent of their color and brightness, and reduced visits in response to the addition of a depolarizing black paint. Songbirds exhibited no differential response in visitation rates to color and polarization cues associated with ground-based test surfaces. Songbirds visited black baths most frequently, consistent the use of broader-spectrum sources of polarized light to locate water. We also show that polycrystalline and thin-film solar panels are strong sources of polarized light that mimic the polarization properties of water bodies. Collectively, our results provide the first evidence that birds can visualize terrestrial sources of polarized light, and use them to locate water bodies and even guide their behavior in other contexts (e.g. feeding). These preliminary results support key assumptions of the lake-effect hypotheses and bolster the possibility that bird-solar panel collisions result from birds misidentifying solar panels as water bodies.

Photovoltaic Module Sampling Methods for Toxicity Testing and Drivers of Leaching Results

Presenter: Stephanie Shaw (Electric Power Research Institute)

Authors: Stephanie Shaw (Electric Power Research Institute), Cara Libby (Electric Power Research Institute), Govindasamy Tamizhmani (Arizona State University Photovoltaic Reliability Laboratory), Sai Tatapudi (Arizona State University Photovoltaic Reliability Laboratory), Bulent Bicer (Arizona State University Photovoltaic Reliability Laboratory)

Abstract: Photovoltaic (PV) modules may contain toxic materials (e.g., lead and cadmium), and landfill disposal may pose risks through breakage and elemental leaching into soil. In the U.S., decommissioned modules must pass the US Environmental Protection Agency's (EPA) Toxicity Characteristic Leaching

Procedure (TCLP) test, and any applicable state protocols, to avoid classification as hazardous waste under the Resource Conservation and Recovery Act (RCRA) and associated logistical and financial premiums. Thus, PV module toxicity must be determined in a precise and systematic way. This research pursues a standardized sampling protocol for PV modules by identifying and characterizing potential sources of variation in TCLP results due to module preparation. The research has had three main foci to date: (1) exploring sample extraction methods for crystalline silicon modules (2) drafting and refining a baseline standard operating procedure (SOP) for future sampling, and (3) application of the SOP to a variety of modules to understand their hazardous nature and drivers of that characterization.

The first focus area evaluated different mechanical sample removal methods, such as coring and stripcutting. Testing of 4 modules (3 poly-Si and one mono-Si), each from different manufacturers occurred. Results indicated the coring method had the least variability, though still significant (30%), and in some cases meant the difference between passing and failing EPA's 5 mg/L lead criteria. This variation might derive from the glass coverage on the pieces which affects leaching. An alternative method, waterjet cutting, was explored to reduce chipping and cracks. A high-pressure jet with abrasives produced cleaner module sample pieces with 100% glass coverage. Twelve samples each were sent to two laboratories, representing 2 samples per module from 4 separate modules from 3 manufacturers. Lead was detected in all modules (below TCLP threshold), but no other RCRA elements were detected. Lead standard deviations (mean 8%) were smaller than for mechanical extraction (mean 30%).

The second focus area was drafting an SOP. Only the PV module laminate was considered, as the frame, junction box, cables and connectors are recyclable with existing regulations and services. Representative module areas were defined (e.g., cell, cell ribbon, string ribbon, and non-cell non-ribbon), and proportional division of sample pieces across these calculated. Pieces were cut and proportionally combined up to the minimum sample weight (100g) for testing, along with a separate 5-10g of extra pieces for initial pH testing. Testing labs were instructed not to further reduce piece sizes. ASTM Solar Committee E44 is currently reviewing a detailed version of this protocol for potential conversion into a standard practice. The possibility of leaching during waterjet sampling was tested, and no indication found.

The third focus area is on application of the sample extraction method to a wide variety of module types and manufacturers, such as those with differing field exposure, substrates, and mono-facial vs. bi-facial designs. The anonymized results will be combined into a database to better understand drivers of TCLP testing results. This final phase is in progress, and results will be presented during the conference.

Solar Development & Habitat Compatibility on California's Working Lands

Presenter: Nicole Buckley Biggs (Stanford University)

Author: Nicole Buckley Biggs (Stanford University)

Abstract: Our study identifies factors influencing the habitat quality of solar arrays on California's farmlands and rangelands, based on a dual case study of working lands in California's San Joaquin Valley and the San Francisco Bay Area. Data collection and analysis were conducted in summer- fall 2021, and included 60 semi-structured interviews with farmers, ranchers, solar companies and relevant experts. We found that ongoing farmland fallowing is enabling both solar development and habitat restoration. While some solar developers increase habitat quality of solar arrays using approaches like native seed plantings and fencing modifications, most appear to eliminate habitat to prevent wildfire, reduce Endangered Species Act violations, avoid hosting rodent and weed populations that impact farms, and avoid complexities around grazing livestock. Comparing cropland versus rangeland solar, solar on impacted croplands raises fewer ecological concerns than rangelands, although rangelands often offer

better economics for solar. We present several recommendations and areas for future research based on these findings.

Forage as Vegetative Cover for Utility-Scale Solar in the Midwest

Presenter: Eric Romich (Ohio State University)

Authors: Eric Romich (Ohio State University), Christine Gelley (Ohio State University), James Morris (Ohio State University), Sarah Moser (Savion Solar)

Abstracts: While PV solar is an emission free renewable energy source, there have been growing concerns about the amount of land required for solar development and the impact on local habitat. In most instances, once the solar project is complete, developers' plant turfgrass and have the site periodically mowed during the growing season or in some cases integrate pollinator native seed plantings which provides ecological benefits to the surrounding area. However, there are other options for vegetative cover that also offer soil stabilization, carbon sequestration, pollinator value, and marketable products. Ohio and neighboring states are investigating cool-season pasture mixes as an option. Cool-season pasture mixes offer a mix of legume and grass varieties. Cool-season grasses and legumes can be utilized for their abundant ground cover, pollinator benefits, and livestock forage. Legumes also fix additional nitrogen for plant uptake.

This session will review a recently published fact sheet that provides developers and landowners information about alternative vegetative cover strategies including forage crops that offer legitimate benefits to the landowner and the solar developer over the project lifecycle. Core topics will include common vegetative cover strategies and how cool-season forage crops can provide the greatest environmental, social, and economic benefit. In addition, we will explore the requirements of utility-scale solar vegetative cover, species selection, establishment, and site maintenance.

Finally, we will review a recently established research partnership between Ohio State University and Savion Solar. The primary goal of this research partnership is to establish a series of test plots within an operating solar project to better understand best practices for the establishment and management of alfalfa, cool-season grasses, crimson clover, and teff grass. For each sample, we are evaluating the performance of various seeding rates including 75%, 125%, and 100% of the recommended rate. Our team is also monitoring the stand performance of each test plots with reoccurring measurements of soil quality, stand persistence, growth rate, forage quality and yield per acre.

While the research project is underway, we are currently in the first year of data collection and do not yet have results to share. However, this session we will explore the research partnership, study design, potential benefits and challenges of co-location of solar energy projects with hay production, and the vision for a second phase to expand on this research moving forward.

In this study we look to improve upon our understanding of ways to reduce the land use impacts of large- scale solar through co-location of agriculture. OSU Extension partnered with a utility scale solar developer and a farmer with an existing solar project to establish test plots of teff grass, alfalfa, cool-season hay mix, and crimson clover co-located on an existing solar filed. Our team established baseline soil measurements while monitoring ongoing soil health, forage quality, and yields to evaluate potential benefits and challenges of co-location of solar projects with hay production. The results from this study will have broad applications that can be replicated or modified on other solar energy installations across Ohio and beyond.

Can native seed mixes successfully establish and attract pollinators at solar facilities in the southeastern United States?

Presenter: Ashley Bennett (Electric Power Research Institute)

Authors: Ashley Bennett (Electric Power Research Institute), Claire Ike (Southern Company), Aaron Feggestad (Stantec)

Abstract: Pollinators are sensitive to habitat loss and are experiencing global population declines. To prevent further pollinator losses, many industries are contributing to the conservation of pollinators and their habitat. Power companies have identified the expansion of solar power generation as an opportunity to create habitat for pollinators by using regionally appropriate native seed mixes designed to support bees and other pollinating insects. However, the cost and establishment success of native pollinator seed mixes at solar generation facilities and their documented value to pollinators has not been evaluated in many regions of the United States. The goal of this study is to compare the establishment success and subsequent visitation by pollinators for two seed mixes: a native pollinator seed mix and a cool-season turf grass mix. This study is being conducted at an active solar generation facility located in La Grange, Georgia. Georgia Power Company (GPC), a Southern Company Subsidiary, installed the photovoltaic (PV) generating facility on a 4.6-acre portion of Georgia Department of Transportation (GDOT) right-of-way (ROW) in early 2020. One acre of the site was re-vegetated using the native pollinator seed mix and the remainder of the site was re-vegetated using the non-native turf grass mix. Vegetation and pollinator data were collected in 2020 along transects in areas planted with both the native pollinator seed mix and the non-native turf grass mix. Results revealed high establishment success of native annual and short-lived perennial species within the pollinator treatment. In 2020, the most abundant native annuals and short-lived perennials included Sensitive Partridge Pea (*Chamaecrista nictitans*), Plains Tickseed (*Coreopsis tinctoria*), Indian Blanket (*Gaillardia pulchella*), Beebalms (*Monarda* spp.), and Coneflowers (*Rudbeckia* spp.). Preliminary observations found pollinator visitation was 118% greater in the pollinator treatment compared to the turf grass treatment. The flowering annuals and short-lived perennials likely contributed to greater usage by pollinators within the pollinator treatment compared to the non-native turf grass treatment. Data collection is in progress for the 2021 field season and results from 2020 and 2021 will be presented.

The Long Island Solar Roadmap: Advancing Low-Impact Solar in Nassau & Suffolk Counties

Presenter: Jessica Price (The Nature Conservancy (former))
Authors: Jessica Price (The Nature Conservancy (former)), Aimee Delach (Defenders of Wildlife), Karen Leu (The Nature Conservancy), Chelsea Schelly (Michigan Technical University), Rupak Thapaliya (Defenders of Wildlife (former)), Catherine Morris (The Consensus Building Institute)
Abstract: Photovoltaic generation can play a significant role in helping address the climate crisis, and several states, including New York, have passed ambitious renewable energy goals that will necessitate substantial increases in solar energy. The Long Island Solar Roadmap, created by The Nature Conservancy and Defenders of Wildlife in partnership with a diverse group of Long Island stakeholders, shows how solar power can be scaled up while minimizing impacts to natural areas that are critical for wildlife, water-quality protection, and quality of life on Long Island.

This presentation will cover the three aspects of the Roadmap's research methodology: a public opinion survey of local ratepayers; an economic analysis of the costs and benefits of solar development; and a spatial analysis to identify low-impact sites, such as large rooftops, parking lots, and already-disturbed ground areas, for mid- to large-scale solar arrays (250 kilowatts and larger) and show their energy generation potential. These results are available as a public web map (http://solarroadmap.org/maps)

and can be used by municipal officials, property owners, and solar developers to identify potential sites for solar development with the least environmental impact. Long Island has enough low-impact siting potential to host nearly 19,500 megawatts (19.5 gigawatts) of solar capacity. This much solar could produce enough renewable electricity to power 4.8 million New York homes each year, more electricity than the Long Island region uses annually. Approximately one-third of that total potential is on parking lots and rooftops; the other two-thirds comes from ground-mounted installations on land that has already been impacted by human activities. Key findings also highlight Long Islanders' support for solar development in their communities and ways to reduce the costs and increase benefits associated with bringing more solar online. Working with stakeholders on Long Island, we developed a cohesive set of strategies and actions to help lower barriers to low-impact solar development. The strategies provided in the report aim to lower barriers to low-impact solar development and benefit the whole region.

This session will be available as an on-demand, pre-recorded panel of four individual presentations: Aimee Delach (Defenders of Wildlife) will provide an overview of the project's background, project elements, and stakeholder engagement process, and introduce the other presenters. Karen Leu (The Nature Conservancy) will describe the spatial analysis methodology and demonstrate the interactive web map. Chelsea Schelly (Michigan Technical University) will present the results of a ratepayer survey of Long Islanders' perspectives on solar development. Rupak Thapaliya (Defenders of Wildlife) will discuss the benefits of solar for Long Islanders and recommended strategies to achieve rapid expansion of low-impact solar.

Post-construction avian fatality monitoring at a utility-scale photovoltaic facility in California

Presenter: Jeff Smith (H.T. Harvey & Associates)
Authors: Jeff Smith (H.T. Harvey & Associates), Brian Boroski (H.T. Harvey & Associates), Dave Johnston (H.T. Harvey & Associates)
Abstract: California Valley Solar Ranch (CVSR) is a 250-MW photovoltaic facility comprising nine distinct panel arrays on 642 ha of disturbed grassland/scrub habitat in central California. The overall 1,896-ha project site encompasses intermixed and adjacent conservation lands. The project's Avian and Bat Protection Plan (ABPP) stipulated conducting bird and bat fatality surveys for 3 years (September 2011–November 2014) beginning with the onset of construction and continuing through 1 year of full operation. Here we focus on results from the final year of post-construction avian fatality monitoring (no bat fatalities were documented).

Year-round weekly fatality surveys covered at least 20% of each solar array, 20% of all perimeter fences, a medium-voltage overhead (MVOH) power line, a generation-tie (gen-tie) line, an evaporation pond, and background-mortality control plots on the conservation lands. Other supplemental surveys achieved ancillary objectives. Quarterly field trials involved placing bird carcasses and feather spots to estimate first-opportunity searcher efficiency (SE) and carcass persistence (CP; monitored with cameras over 6-week periods). We used the USGS Data-Series 729 estimator to model SE/CP and produce adjusted fatality estimates.

Modeled CP depended on carcass size/type but not season, estimated as 9 and 22 days for all placed small and large birds, respectively, whereas persistence of feather spots alone varied from averages of 18–45 days depending on the ground cover. Documented scavengers included primarily ravens, but also mammals and a few raptors. Modeled SE depended on carcass size/type (27% for small feather spots up to a high of 73% for large carcasses) and visibility within substrates (57% in high visibility and 45% in moderate visibility areas). The fatalities found during the final year included 36 species, but five common species composed 77% of the total. Of 360 fatalities found during standardized weekly searches, 65% were in arrays, 18% along the gen-tie line, 7% along the MVOH line, 4% along fences, 1%

at the evaporation pond, and 5% on control plots. The fatality rate was highest in winter in the arrays, but was highest in late summer/fall along the gen-tie line, where migratory species were most commonly found as fatalities. The estimated fatality rate in the arrays was 2.24 fatalities per tracker block (90% CI: 1.83–2.87) and in the control plots was 1.72 fatalities per equivalent area (90% CI: 1.05–2.68), which yielded an estimated annual, background-adjusted fatality rate of 0.51 fatalities per tracker block, or 526 total bird fatalities uniquely distributed across 1,176 acres (476 ha) of solar arrays comprising 1,032 tracker blocks.

Full-coverage surveys conducted in two arrays for 1 year indicated fatalities were randomly dispersed, which contributed key understanding that weekly surveys of randomly selected plots covering 20% of each array produced robust fatality estimates for small and large birds. In addition, the results of concurrent ABPP surveys indicated parallel tracking of trends in avian activity and fatality rates. We summarize other key insights generated following this study, focused on research and additional measures needed to improve the design of future fatality monitoring studies at utility-scale solar facilities.

Frameworks to facilitate assessment of cumulative and population-level consequences to wildlife from fatalities at solar energy facilities

Presenter: Todd Katzner (US Geological Survey)

Authors: Todd Katzner (US Geological Survey), Tara Conkling (US Geological Survey), Hannah Vander Zanden (University of Florida), David Nelson (University of Maryland Center for Environmental Science, Appalachian Laboratory), Taber Allison (American Wind Wildlife Institute), Thomas Dietsch (US Fish and Wildlife Service, Carlsbad Fish and Wildlife Office), Jay Diffendorfer (US Geological Survey), Adam Duerr (Bloom Research Inc.), Amy Fesnock (Bureau of Land Management), Christine Hayes (US Geological Survey), Rebecca Hernandez (University of California, Davis and Wild Energy Initiative, John Muir Institute of the Environment), Scott Loss (Oklahoma State University), Patricia Ortiz (US Geological Survey), Robin Paulman (University of Maryland Center for Environmental Science, Appalachian Laboratory), Krysta Rogers (California Department of Fish and Wildlife Service), Peter Sanzenbacher (US Fish and Wildlife Service, Palm Springs Fish and Wildlife Office), Julie Yee (US Geological Survey)

Abstract: Rapid expansion of solar energy facilities has created concerns regarding potential environmental impacts. Although rates of wildlife fatality at solar facilities are estimated reasonably well, cumulative and population-level effects of these fatalities are generally not addressed. As a consequence, managers are constrained to make difficult policy and management decisions with inadequate information. Our presentation consists of three parts to assess the geographic origin of avian fatalities, use that origin information to evaluate cumulative and population-level consequences to wildlife at solar facilities, and build conceptual and logistical frameworks to estimate these cumulative and population-level consequences continent-wide.

First, the geographic extent of impact of solar energy on avian populations is largely unknown. Identifying the origin of carcasses is needed to assess demographic resilience of populations to mortality www.awwi.org/solar-symposium | solar@awwi.org 10 from renewables. We performed geospatial analyses of stable hydrogen isotope data obtained from feathers of 480 individuals of 18 bird species found dead at six solar-energy facilities in California. Individuals were classified as having local or nonlocal origins relative to the site of death. Preliminary results suggest that all species were composed of at least some portion of non-locally originating individuals, ranging from 25 to 100%. Minimum distances to regions of likely origin for nonlocal individuals were as close as 90km to greater than 1,250 km.

Second, we used the geographic data in demographic models to assess vulnerability to solar energy development, and we identified taxonomic or ecological correlates of that vulnerability. Of the 15 avian species evaluated via Bayesian hierarchical population modeling, preliminary analyses suggested that populations of 10 species were unlikely to be vulnerable, and the other five species were vulnerable to population-level effects from added fatalities from solar energy and other anthropogenic sources. Most vulnerable species were terrestrial and aquatic nonlocal migrants, suggesting that facility placement along a constricted portion of a major migration flyway may increase vulnerability of species engaged in long-distance migration. Additionally, when the potentially affected subpopulation was small or geographically restricted, vulnerability was high. Our results highlight the species- and region-specific nature of the demographic patterns in vulnerability of these populations. They also illustrate the importance of obtaining baseline demographic data for species that occur near solar energy facilities.

Third, we describe the vision and initial implementation for the infrastructure and frameworks we have developed to estimate continent-wide cumulative and population-level effects of renewable energy facilities for wildlife. Geolocation requires collecting biological samples from wildlife, but most animal carcasses found dead at renewable facilities are discarded. We are addressing this problem through a growing archive biological samples (fur, feathers, organs) from wildlife killed at renewable energy facilities in North America. These samples can be used for geolocation or other research relevant to wildlife interactions with renewable energy. Subsequently, we demonstrate how some of the >70,000 samples stored in our growing facility have supported ongoing novel research. These archived samples are a public good – a freely available source of readily available information for managers and researchers to assess cumulative and population-level impacts on wildlife from solar energy development.

Pollinator-Friendly Solar Scorecards: A Comprehensive Analysis of Scorecard Attributes

Presenter: Chris Rochon (EPRI)
Authors: Chris Rochon (EPRI), Jessica Fox (EPRI)
Abstract: The push toward carbon-free and renewable energy sources has precipitated a nationwide (United States) trend to increase solar generation via ground-mounted photovoltaic (PV) arrays. Beyond carbon benefits, one possible way to provide additional ecological value of solar PV projects is to co-locate pollinator habitat when site conditions permit.

Around 2015, the concept of a "scorecard" emerged that could assess the value of a solar project to pollinator species. The development and application of these scorecards, to date, has not been controlled by any central organization. Scorecards are being developed on a state-by-state basis using various processes, by a variety of subject matter experts, and using a range of oversight and review approaches. As such, there is variation between different state scorecard programs and divergent opinions regarding the scorecards themselves. Given that developing state and local laws and incentive programs are linked to the pollinator-friendly solar scorecards, it is important to consider the basis of the scorecards themselves. With interest in co-location of solar with pollinator habitat, this comprehensive study of existing pollinator solar scorecards considers the level of consistency across the scorecards, analyzes the specific scorable elements and their relative weighting, and investigates the factors that influenced scorecard development.

Specifically, EPRI conducted a desktop study to analyze scorecard attributes, including the level of consistency, associated programs (including state laws, if present), and factors that influenced scorecard development. A total of 15 state scorecards and one nonspecific scorecard available as of April 2021 were reviewed to identify common and differentiating features. A categorization system for individual scoring elements was created to facilitate numeric assessment across the available scorecards. Further,

in order to understand the unique motivations and processes that influenced the design of the scorecards, interviews were conducted with 34 experts involved in scorecard design, policy development, and use, including university professors, state agency staff, and solar project developers, owners, and operators.

Research uncovered a general lack of rigor, consistency, and oversight for scorecard design methodology, version control, and use. However, if the scorecards can be predictive of ecological outcomes – healthy pollinator habitat – then they may still be meeting their primary purpose. Field-based research is necessary to determine if there is a correlation between the points received on a pollinator-friendly scorecard and the actual solar PV site habitat conditions.

Applying Genoscape Network Models to Inform Population-Level Risk to Bird Species from Solar Energy Facilities

Presenter: Ryan Harrigan (University of California, Los Angeles)

Authors: Ryan Harrigan (University of California, Los Angeles), Kristen Ruegg (Colorado State University), Cristian Gruppi (University of California, Los Angeles), Christen Bossu (Colorado State University), Thomas Smith (University of California, Los Angeles)

Abstract: While there are known interactions between wildlife and solar facilities, understanding how species and populations are impacted by such activities, and relative to other anthropogenic changes, is paramount. New methodologies that combine information from 1) genetic markers captures across all chromosomes of an organism (genomes), and 2) the migratory connectivity of avian populations across their full life cycle, allow for a relative risk assessment to be conducted for specific populations of migratory species due to interactions with solar facilities. We highlight these "Genoscape Network Models" (Ruegg & Harrigan et al. 2020) and their results for two species of migratory birds whose feather spots have been found at solar facilities and for whom genomic information has been gathered as part of the Bird Genoscape Project (https://www.birdgenoscape.org). Preliminary findings suggest that the effects of alternative energy activities can vary dramatically based on a number of factors, including the a) connectivity of nodes affected, b) geographic and population size of particular nodes, and c) location of the alternative energy site relative to migratory pathways. By combining the genomic markers of wildlife with the geographic locations of individuals, populations, and installations, informed management and mitigation strategies can be made based on quantitative assessments of risk to particular wildlife species. These strategies can be bespoke for particular regions or species, and allow for a comparison of relative risks to wildlife from anthropogenic forces, including those from the development of alternative energy, to help lead conservation of wildlife in a rapidly changing world.
Ruegg, K.C., Harrigan, R.J., Saracco, J.F., Smith, T.B. and Taylor, C.M. (2020), A genoscape-network model for conservation prioritization in a migratory bird. Conservation Biology, 34: 1482-1491.

The Interface of Solar Power and the Endangered Species Act

Presenter: Matt Ihnken (Environmental Consulting & Technology, Inc.)

Authors: Matt Ihnken (Environmental Consulting & Technology, Inc.)

Abstract: Solar facilities at various scales have the potential to affect a variety of types of wildlife. Often those that present the biggest challenge to project development are threatened and endangered species. The Endangered Species Act prohibits the take of listed species, but for solar projects, the potential impacts to species can be hard to quantify. Data on rare species is by nature limited, and data sets can be held by multiple organizations and may not be publicly available. Here we lay out the best

management practices for evaluating impacts to threatened and endangered species, when and where agency coordination is necessary, and how programmatic thinking can streamline coordination, compliance, and project delivery

Response of endangered San Joaquin kit foxes to solar farms

Presenter: Brian Cypher (Endangered Species Recovery Program, California State University-Stanislaus)

Authors: Brian Cypher (Endangered Species Recovery Program, California State University-Stanislaus), Brian Boroski (H.T. Harvey & Associates), Daniel Meade (Althouse and Meade, Inc.), Tory Westall (Endangered Species Recovery Program, California State University-Stanislaus), Kenneth Spencer (Althouse and Meade, Inc.), Robyn Powers (H.T. Harvey & Associates), Erica Kelly (Endangered Species Recovery Program, California State University-Stanislaus), Jason Dart (Althouse and Meade, Inc.), Marianne Huizing (H. T. Harvey & Associates), Jacquelyn Maher (H. T. Harvey & Associates)

Abstract: Photovoltaic solar facilities have rapidly increased in abundance in California in recent years and this has generated concern regarding associated environmental impacts, particularly to rare species. In 2014, construction was completed on two utility-scale photovoltaic solar facilities in the northern portion of the Carrizo Plain in California. The Topaz Solar Farms (TSF; 1,421 ha) and the California Valley Solar Ranch (CVSR; 721 ha) were constructed on lands that are considered “core habitat” for the endangered San Joaquin kit fox (*Vulpes macrotis mutica*). Separate 3-year (2014-2017) investigations were conducted on the TSF and CVSR to assess various demographic and ecological responses of kit foxes to the facilities. In the TSF study, 52 foxes were collared and monitored. Survival rates did not differ between the solar site (0.65) and a nearby reference site (0.49). Predators (coyotes, bobcats, and golden eagles) were the primary cause of mortality on both sites. Reproductive success was similar between the solar (100%) and reference (88.9%) sites. Foxes on the reference site selectively used untilled habitat, which supported a higher abundance of rodents, while foxes on the solar site mostly used habitats in proportion to their availability. Mean home range size was larger on the solar site compared to the reference site (9.4 km2 versus 5.1 km2). The TSF encompassed a higher proportion of lands that were disturbed prior to construction of the facility and therefore had fewer prey. Den use patterns and food habits were similar between the sites. Both the mean number of dens used annually per fox (11.2 versus 8.4) and mean rate of den switching by foxes (14.2 versus 9.9) were similar between the solar and reference sites, and mean mass of foxes did not differ. Similar results were obtained in the CVSR study where 50 foxes were collared and monitored. Fox survival was not different between the solar site (0.76) and nearby reference site (0.66), and predators were the primary sources of mortality on both sites. No foxes died within the fenced arrays. Reproductive success was identical (86.7%) on the two sites, and mean home range size did not differ between the solar and reference sites (2.5 km^2 versus 3.2 km^2). Den use and food habits were similar on the two sites as was mean mass for females, but mean mass was actually higher on the solar site for males. Few differences were found between solar and reference sites, and the differences that were found were attributable to differences in habitat condition due to land uses just prior to construction of the solar facilities. We emphasize the important caveat that numerous conservation measures were implemented on both the TSF and CVSR solar sites, and this undoubtedly mitigated potential adverse impacts to foxes. The TSF and CVSR solar sites serve as models for solar farm design strategies that can help reduce or avoid adverse impacts to San Joaquin kit foxes as well as other species of conservation concern.

Response of birds in flight to utility-scale photovoltaic facilities

Presenter: Robb Diehl (US Geological Survey)

Authors: Robb Diehl (US Geological Survey), Todd Preston (US Geological Survey)

Abstract: A lake- or oasis-effect hypothesis has been proposed to explain avian fatalities associated with utility-scale photovoltaic (USPV) facilities in the desert southwestern US. The hypothesis proposes that passing birds perceive these facilities as water or some other oasis, alter course toward and attempt to occupy those facilities, and may succumb from impacts with structure or, in the case of some water-obligate birds, are behaviorally unable to take flight once landing. This component of the project examines whether and how birds respond while in flight to the presence of USPV facilities. A pair of portable radars, one operating in the horizontal and another in the vertical domain, were deployed at each of two USPV facilities and associated control areas in southern California. Lateral and altitudinal movements of flying animals were recorded. Attempts were made to discriminate bird from insect radar targets, although the effort proved challenging and some insect contamination is likely. The majority of animals showed no response to USPV facilities. Although evidence of lateral reorientation toward USPV was unclear, there was a disproportionate tendency for animals to exhibit descent over facilities relative to control areas. These descents were concentrated around the midday hours and may indicate refuge-seeking behavior among birds and insects facing intense summer heat. Overall, a small proportion of passing animals exhibited attraction behavior consistent with the lake-/oasis-effect hypothesis, and this level of response is consistent with the degree of mortality documented at many USPV facilities. Attraction is not occupancy, however, and it remains unclear what proportion of animals that respond to the presence of USPV facilities while in flight actually land or attempt landing.

Finding Common Ground: Incorporating Stakeholder Values into Energy Siting Decisions

Presenter: Michael Young (University of Texas at Austin)

Authors: Michael Young (University of Texas at Austin), Billy Tarrant (Sul Ross University), Kei Sochi (The Nature Conservancy), Jon Paul Pierre (University of Texas at Austin), Patricia Harveson (Sul Ross University), Louis Harveson (Sul Ross University), Joe Kiesecker (The Nature Conservancy), Melinda Taylor (University of Texas at Austin)

Abstract: Projecting landscape impacts from development of renewable energy, communicating potential impacts to communities, and incorporating conservation values into siting decisions are all important when considering where to place infrastructure on the landscape. Done separately, with the different groups working in isolation, opportunities for updating each other are missed, leading to poorly informed decisions. Working together, these activities represent a bottom-up approach that can better inform and empower stakeholders and energy companies throughout the decision making process. In this presentation, we report on the approach and outcome of the Respect Big Bend (RBB) coalition, a team of researchers, communications specialists and local representatives who, together, are helping to improve how decisions on energy development are made. We based our activities on the Development by Design program, created by The Nature Conservancy, and applied them to the Big Bend region of west Texas, USA. We developed parallel workflows that included a Stakeholder Advisory Group (SAG) to help identify land aspects of greatest value, and a science team that quantified ecological aspects of land across an 18-county area of Texas, approximately 113,900 km2 (28 million acres). The SAG was comprised of local landowners, community members, and conservationists who were charged with identifying shared conservation and social values. Over the course of two years, this group met 14 times and identified seven values that were the foundation of a shared conservation vision for the region. Combining these aspects into a rubric of conservation values, a geosciences team then used

future solar energy capacity scenarios and a statistical approach to help identify land areas that were more or less suitable for placement of new solar energy plants, while reducing alteration of higher valued lands. Robust and ongoing discussions were maintained between each group to ensure nobody worked in a vacuum. The capacity expansion modeling resulted in three scenarios of potential solar energy development (low, medium, high) that result in an estimate of 106, 110, and 135 solar facilities, respectively. Assuming each facility directly alters 2.9 km2 (713 acres) of land area, we estimate a range of new direct land alteration of between 306 – 390 km2 (75,614 – 96,371 acres), between today and 2050. We found that this represents between 1.0 and 1.3% of land area that is both suitable for solar energy and identified as either Very Low or Low asset class. This outcome represents an opportunity for energy companies to develop projects that contribute to their bottom line, and while avoiding the potential alteration of higher value lands could be irreparably damaged. Further, given the importance of transmission infrastructure to siting decisions (i.e., facilities proximal to transmission lines could be more valuable to grid operators, and hence more lucrative to energy companies), considering land asset quality at the transmission line siting stage could lead to long-term preservation of high valued landscapes.

Online Planning Tools for Solar Project Siting

Presenter: James Kuiper (Argonne National Laboratory)

Author: Jim Kuiper (Argonne National Laboratory)

Abstract: In this session we present two online tools designed to support utility-scale solar project siting and related land-use planning, both with a strong emphasis on environmental siting factors. Both the Energy Zones Mapping Tool (EZMT) and the Solar Energy Environmental Mapper (Solar Mapper) provide large mapping catalogs including solar energy resource, existing infrastructure, environmental, and wildlife data. The EZMT includes utility-scale PV and concentrating solar models that output "heat maps" of suitability based on multiple siting factors. Users can adapt the pre-configured models to their own requirements, or create new models, using any of over 110 solar resource, infrastructure, and environmental, demographic siting factors from the modeling library. In the Solar Mapper users can request location-specific reports on protected lands, USGS GAP protected areas, and other development exclusions for areas of interest. We describe the capabilities of each tool for identifying suitable locations for new projects, and assessing potential impacts of planned or existing projects, both in the context of minimizing impacts to wildlife and other environmentally sensitive resources.

Can rotational grazing be an alternative to traditional mechanical mowing at solar sites?

Presenter: Ashley Bennett (Electric Power Research Institute)

Authors: Ashley Bennett (Electric Power Research Institute), Aron Patrick (LG&E and KU), Michael Moore (Shaker Village of Pleasant Hill)

Abstract: Standard practice at most large solar farms is the use of non-native cool season grasses to vegetate the site. Cool season grasses require frequent mowing to ensure shading of panels does not occur and reduce energy output of the site. Traditional vegetation management techniques rely on the use of mechanical mowing or the use of herbicides to suppress growth, which is costly, labor intensive, and poses safety risks to workers. Many power companies are increasingly interested in developing vegetation management plans that reduce maintenance costs while also providing a community and environmental benefit. One alternative to traditional vegetation management practices at solar sites is the use of grazing with small ruminants, such as sheep. The overall goal of this project was to demonstrate the ecological and economic feasibility of using sheep to replace mechanical mowing at solar sites. Project objectives included: 1) developing a regenerative rotational grazing plan, 2) assessing the ability of grazers to maintain vegetation at appropriate heights across the site, 3) record costs associated with initiating a grazing plan, and 4) create an opportunity to partner with a local agricultural producer.

A demonstration project was initiated in 2020 using a 10-acre section of a 50-acre solar site owned and operated by LG&E and KU in Mercer County, Kentucky. During 2020, nine 1-acre paddocks were established in the demonstration area, and sheep were introduced and rotated across the site from April through November. A regenerative rotational grazing plan was developed for the solar site that included a stocking density of 35 ewes in 2020 that would graze 1-acre paddocks for five days with 45 days of recovery after a grazing event. Preliminary data from the first study year indicated a stocking density of 35 female sheep with a stocking duration of five days was sufficient to adequately maintain vegetation below the height of the solar panels. Sheep were able to successfully maintain vegetation both in the alleys between solar panel arrays as well as under panels. After the first year of grazing, some problematic plant species such as Johnson grass (Sorghum *halepense*) persisted in the grazed area of the solar site. In 2021, stocking density was increased to 52 total sheep made up of ewes and lambs at the beginning of the grazing season in an effort to improve control of undesirable species. The stocking duration was every five days during the spring but was increased to every three days in early summer to reduce the recovery period of undesirable species. Economic data is still being collected for this project, and a cost comparison between traditional mechanical mowing and grazing will be performed at the conclusion of the study to determine the feasibility of using grazing as a vegetation management strategy. Data collection is in progress for the 2021 field season and results from 2020 and 2021 will be presented.

Environmental Considerations for PV Module Design

Presenter: Cara Libby (Electric Power Research Institute)

Authors: Cara Libby (Electric Power Research Institute), Stephanie Shaw (Electric Power Research Institute), Chris Powicki (Water Energy Ecology Information & Design Services, Inc.)

Abstract: Solar is generally considered to have low adverse environmental impacts, but there are opportunities for enhanced environmental stewardship throughout the life cycle, starting with module procurement. Solar photovoltaic (PV) modules are designed for low cost and reliable performance over the 20-30-year warranty period. Current designs are difficult to dismantle, repair, or recycle in an efficient manner. Module compositions vary by manufacturer, product, serial number bin, and other factors, and use of hazardous materials like lead is prevalent. In response to consumer demand, anticipation of future regulations, and other factors, some manufacturers are taking steps to minimize or avoid use of toxic materials or conflict minerals in modules; reduce energy, water, chemical use, and emissions during the manufacturing process; increase recycled content in new modules; deploy reusable or degradable module packaging materials; and consider compatibility with end-of-life (EoL) management processes in product designs. While most solar modules today are not designed with EoL in mind, increasing product lifetimes to delay EoL and designing products that can be repaired, upgraded over time, reused, or recycled are some of the proposed approaches to improve circularity. Researchers are developing new product designs that have the potential for easier dismantling and rapid recovery of high-purity materials with less waste. Such solutions may reduce the energy and other resources required to recycle end-of-life materials or facilitate reuse in secondary markets. Several manufacturers offer take-back services or extended producer responsibility (EPR), or carry sustainability certifications. Module procurement decisions can influence the lifetime environmental impacts of a solar project.

Regulations and policies may drive changes in product designs. For example, in the EU, a future revision to the WEEE Initiative is expected to require lead-free products. There are some indications that module manufacturers are proactively reducing lead in their products through use of lead-free soldering and conductive adhesives [ITRPV: Results 2018, Tenth Edition, March 2019].

There are also changes in manufacturer business models, such as provision of take-back services or EPR, in response to state (e.g., Washington) or country (WEEE Initiative) requirements. Additionally, utilities and energy companies, PV project developers, and other stakeholders are driving product changes through procurement requirements and purchasing decisions. The Electric Power Research Institute (EPRI) is conducting a study to identify opportunities to lessen PV module environmental impacts during the cell and module design process. Options will be informed by reported manufacturer efforts, literature review of new module designs, and experiences of energy companies. Results are expected in late-2021.

End-of-Life Management Considerations for Solar Photovoltaic Projects

Presenter: Cara Libby (Electric Power Research Institute)

Authors: Cara Libby (Electric Power Research Institute), Stephanie Shaw (Electric Power Research Institute)

Abstract: Experience with decommissioning solar photovoltaic (PV) plants is limited. Roughly 96% of plants operating today were installed within the past decade, and plant lifetimes are typically at least 20 years. Early deployments of PV systems may be decommissioned when they reach natural end of life and other plants may be decommissioned for economic reasons, such as underperformance, high maintenance costs, damage from weather, fire, or vandalism, or for safety issues. Best practices must be established for project decommissioning, including assignment of responsible parties, provisions for financial assurance, and plans for dispositioning PV modules and other equipment. Planning for decommissioning often starts during project development. No federal regulatory framework for PV recycling exists in the United States, but some states have passed legislation, and decommissioning regulations may be present at the county or local level. This presentation describes research conducted by the Electric Power Research Institute (EPRI) on decommissioning planning, considering applicable policies and regulations and cost estimation. The state of science around plant-level EoL management will be described, along with long-term R&D needs.

Solar Facility Impacts on Birds: Genetic Identification of Avian Remnants

Presenter: Cristian Gruppi (University of California, Los Angeles)

Authors: Cristian Gruppi (University of California, Los Angeles), Teia Schweizer (Colorado State University), Karina Balekjian (University of California, Los Angeles), Rachel Hagar (University of California, Los Angeles), Sierra Hagen (University of California, Los Angeles), Peter Sanzenbacher (US Fish and Wildlife Service), Kristen Ruegg (Colorado State University), Thomas Smith (University of California, Los Angeles), Ryan Harrigan (University of California, Los Angeles)

Abstract: Renewable energy production and the associated decrease of carbon dioxide emissions is likely to reduce the impact of climate change, the main threat to wildlife in the future (Urban 2015). The development of new alternative energy infrastructures is expected to increase in the years to come, with a large proportion of this growth dedicated to solar energy production. Given this rapid expansion of utility-scale solar energy, it is important to quantify and understand the dynamics of the impacts of solar facilities on avian populations, in order to better plan and mitigate the potential impacts of future utility-scale solar infrastructures. An important source of information to enhance the understanding of

avian interaction patterns are the avian samples collected at solar facilities themselves. Hampering this data acquisition is the fact that individual interactions at solar structures can be subsequently affected by a variety of other phenomena, including additional interactions, predation, or scavenging by other animals, and the quality of observed "feather spots" can greatly vary. Previously collected remains of avian individuals have been categorized as either identifiable to species (either as a full or partial carcass) or as unidentifiable, largely based on the amount of sample remaining on site. At some facilities, up to 32% of the collected samples can be left unidentified in the field, leading to a significant loss of data that could otherwise add to our understanding of the dynamics of avian species and populations at solar facilities.

To address this limitation, we developed a rapid, cost-effective DNA-based approach to identify samples that can be utilized in parallel with morphology-based identification of species in the field. After DNA extraction from unidentified "feather spots", we amplify a specific target region in a mitochondrial gene (mt-CO1 gene) using developed primer sets. We then sequence the purified PCR products and search for sequence similarity from an open-access, national genome database (GenBank), to identify the sample to species, and in many cases, individual. Through this molecular strategy we have been able to identify, to the species level, over 88% of previously unidentified samples collected at solar facilities. Interestingly, the genetically-identified specimens not only added samples to be used in data analysis (in combination with morphological identification), but in some cases actually presented a different picture of the types and proportions of species affected by industry activities, suggesting that combining and utilizing results from each of these methods would serve as a best practice.

Most importantly, we see this developed pipeline as a tool that will allow any unidentified samples of avian origin collected at alternative energy sites (e.g., wind farms) or other human-impacted areas to be efficiently (both in terms of cost and time) identified and added to the scientific record, and therefore contributing to informed management and siting strategies.

REFERENCE: Urban MC. Accelerating extinction risk from climate change. Science, 2015.

Detection and analysis of food, energy, water, carbon, and economic impacts of solar photovoltaic co-location in California's Central Valley

Presenter: Jacob Stid (Department of Earth and Environmental Sciences, Michigan State University)

Authors: Jacob Stid (Department of Earth and Environmental Sciences, Michigan State University), Siddharth Shukla (Department of Civil and Environmental Engineering, Michigan State University), Annick Anctil (Department of Civil and Environmental Engineering, Michigan State University), Anthony Kendall (Department of Earth and Environmental Sciences, Michigan State University), David Hyndman (Department of Geosciences, School of Natural Sciences and Mathematics, The University of Texas at Dallas)

Abstract: Crops and solar panels require similar conditions for maximum yield, thus land use competition is increasing as solar photovoltaic (PV) system deployments expand globally. Understanding agriculturally co-located solar PV installation practices and preferences is imperative to foster a future where solar power and agriculture co-exist with limited impact on food production. The recent boom in solar photovoltaics is increasingly causing cropland replacement, yet contemporary literature lacks important spatiotemporal details that would help inform and improve future array installations. To fill this gap, we investigate the impacts of co-locating solar PV and agriculture on the broad food, energy, water (FEW), carbon nexus of agricultural fields in California's Central Valley. We recently developed a comprehensive remotely-sensed dataset of commercial-scale PV installations across California's Central Valley. These crystalline silicon fixed and 1-axis tracking installations have been spatially and temporally

delineated; 694 arrays (with 2,052 MW capacity) are agriculturally co-located. Arrays were identified spatially using the National Agriculture Imagery Program 0.6 meter imagery and object-based segmentation. The installation year of each array was estimated from Landsat 5 TM, 7 ETM+ and 8 OLI 30 meter imagery via the LandTrendr algorithm between 2008 and 2018. For each array, we calculated the food production, electricity generation, change in water consumption, and life cycle carbon emissions relative to the prior agricultural land use for the expected 25 year lifespan of each array. There was a dichotomy of crop conversion preferences with commodity crops (pastureland) dominating area converted and high value specialty crops (orchards) having a large number of solar installations on cropland with less area converted. Amongst all converted cropland, we calculated that there was enough kcal removed from production to feed 92,000 people per year of the solar lifespan. We also estimated the expected value of generated electricity and show that these installations are profitable, with profits typically exceeding lost revenue from agricultural production by a factor of 15. High value perennial land such as orchards tends to be climatically constrained and can take years to go from planting to production. Unregulated conversion of high value land could have impacts on future crop prices and availability. However, converting irrigated orchards rather than non-irrigated pastureland could reduce overall water consumption. Overall, solar co-location was shown to be highly profitable, and thus likely to continue to expand without regulation, this could have significant impacts on food production and water availability. Thus, our research suggests the need to account for location-specific food and water resources when co-locating solar PV to reduce impacts on U.S. agricultural production and water as solar becomes more prevalent.

Collaborative conservation: Success stories from the Rights-of-Way as Habitat Working Group

Presenter: Caroline Hernandez (University of Illinois Chicago)

Authors: Caroline Hernandez (University of Illinois Chicago), Iris Caldwell (University of Illinois Chicago), Dan Salas (Cardno)

Abstract: The Rights-of-Way as Habitat Working Group formed in 2015 as a forum for industry partners to collaborate and build capacity for habitat conservation on energy and transportation landscapes, particularly within linear rights-of-way (ROW). Today, more than 400 organizations from across the transportation, energy, government, and non-profit sectors in the U.S. and Canada are engaged in the Working Group. The Working Group and its partners recognize the important role that energy and transportation lands play in advancing pollinator conservation and strive to find collaborative methods to support habitat implementation.

The Working Group has helped to drive a number of key successes over the past several years, including developing the first nationwide voluntary conservation agreement for the monarch butterfly, a standard cross-sector pollinator habitat assessment tool for use on a range of energy and transportation lands, a geospatial habitat database to report and track pollinator habitat on energy and transportation lands, and a variety of other tools, resources, and strategies to support habitat projects across the U.S. and Canada.

This presentation will provide a short of the history of the Working Group and highlight several of the tools and collaborative projects that the Working Group has facilitated. In December 2020, the U.S. Fish & Wildlife Service (USFWS) announced that the monarch butterfly was “warranted for listing” under the Endangered Species Act, but precluded due to higher priority needs. A final listing determination will be made in 2024.

Solar companies are increasingly asked to support co-benefits at project sites. However, these co-benefits may face a changing regulatory climate as species like the monarch butterfly are considered for

potential listing under the Endangered Species Act. In response, an innovative new conservation agreement has been developed to engage companies in voluntary conservation and provide much needed habitat benefits to the species. Over two years, more than 40 partners from the Rights-of-Way as Habitat Working Group at the University of Illinois-Chicago (UIC) have developed the first nationwide Candidate Conservation Agreement with Assurances (CCAA) to promote voluntary conservation for the monarch butterfly on energy and transportation lands. The CCAA encourages landowners and managers to adopt conservation practices in exchange for incidental take coverage and regulatory assurances if the monarch butterfly becomes listed.

The CCAA allows for enrollment of solar sites into the agreement. In doing so, developers or owners commit to some amount of conservation practices on an annual basis and commit to tracking, monitoring, and reporting those efforts to UIC as the Program Administrator. Participation brings much needed conservation for monarch butterflies, but also helps reduce a company's regulatory risk, promotes low-cost vegetation management, and can contribute to a company's sustainability or environmental goals. After more than a year of implementation of the first voluntary agreement of this scale, the Monarch CCAA includes several partners managing solar assets. In this session, we will introduce the Monarch CCAA, how it addresses many of the ESA uncertainties for solar sites with pollinator habitat, and demonstrate what enrollment looks like on solar sites.

Considerations for assessing the technical potential of floating solar: A systematic review

Presenter: Emma Forester (University of California - Davis, CA)

Author: Emma Forester (University of California - Davis, CA)

Abstract: Floating solar photovoltaics (FPV), or solar photovoltaic (PV) systems that float on bodies of water, are a rapidly expanding renewable energy source emerging as an alternative to land-intensive ground-mounted solar arrays. The applications of this technology are still being explored through technical potential assessments, a vital step in the development of renewable energy resources that allow for the identification of feasible installation sites and provide an estimation of costs, power generation, and capacity (NREL 2018). These assessments are carried out to aid planners, policymakers, and other decision-makers in predicting and achieving goals related to renewable energy development; however, some considerations may be overlooked. Assessing the technical potential of solar energy without a standardized methodological framework for site selection may lead to an inconsistent range of generation outcomes, adding to the confusion and lack of confidence that has been a significant barrier to the growth of renewable energy in recent years (Seetharaman 2019).

This study systematically reviewed criteria in the published literature emphasizing assessment of FPV technical potential and related siting studies, especially those using geographic technologies. The systematic review was performed in alignment with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.

Preliminary findings of this systematic review suggest that FPV site selection criteria can be categorized into social, environmental, and techno-economic considerations. Based on the current literature, we aim to elucidate which criteria within each classification are important to include in an FPV siting study. For example, many technical potential assessments limit their scope of analysis to water bodies occupied by existing hydropower plants due to their connection to transmission infrastructure and prior consideration for logistical factors such as permitting or compliance with environmental regulations, indicating that it is best practice to include waterbody type and function in the site selection process.

Results from this analysis will inform the standardization of a site-selection framework used in future technical potential studies, which may, in turn, improve the accuracy of generation estimates and offer a

meaningful and realistic idea of how FPV installations could transform the direction of renewable energy science and development.

Major Challenges and Opportunities in Solar Module Recycling

Presenter: Meng Tao (Arizona State University)

Authors: Meng Tao (Arizona State University), Vasilis Fthenakis (Columbia University), Burcak Ebin (Chalmers University of Technology), Britt-Marie Steenari (Chalmers University of Technology), Evelyn Butler (Solar Energy Industries Association), Parikhit Sinha (First Solar Inc.), Richard Corkish (University of New South Wales), Karsten Wambach (bifa Umweltinstitut GmbH), Ethan Simon (DuPont Photovoltaic and Advanced Materials)

Abstract: This talk examines some of the basic questions about solar module recycling: 1) What can be recovered from solar modules? 2) What recycling technologies are needed? 3) What are the potential revenues for different recycling scenarios? 4) What are the major challenges for different recycling scenarios? Three recycling scenarios are considered: 1) module reuse, 2) component extraction, and 3) material extraction. Recycling process sequences for different scenarios are outlined. The discussions conclude that module reuse generates the highest revenue with the fewest processing steps, while material extraction leads to the lowest revenue with the most processing steps. Gentle and clean separation of solar cells from glass pane is a critical technology. Two low-concentration metals must be recovered from solar modules: silver as a scarce material and lead as a toxic material. Their recovery requires chemical methods, while bulky materials including glass cullet, aluminum frame, and copper wiring can be recovered with physical methods. The silicon in the cells can be extracted with different qualities: ferro-silicon, metallurgical-grade silicon, or solar-grade silicon, with a higher revenue and more complicated recycling process for purer silicon. Markets outside the solar industry for the recovered silicon should be explored. The biggest challenge for module reuse is to find a large and sustained market for hundreds of gigawatts peak of decommissioned modules a year, and the biggest challenge for component extraction is the many different module and cell structures on the market, and cell efficiency variability. For all the three scenarios, the cost of collecting and processing waste modules is a common challenge.

Building the toolbox: Industry tool development under the Evaluating Economic, Ecological, and Performance Impacts of Pollinator Plantings at Large-Scale Solar Facilities project

Presenter: Dan Salas (Cardno)

Authors: Dan Salas (Cardno), Chris Kline (Cardno), Iris Caldwell (University of Illinois Chicago)

Abstract: The co-location of pollinator plantings at large-scale solar facilities (10 MW or larger) face challenges from uncertainties around their cost-effectiveness and performance success. A three-year project, funded by the U.S. Department of Energy Solar Energy Technology Office, is bringing together leading researchers, large-scale solar developers and practitioners to investigate the ecological and economic benefits as well as performance impacts of co-located pollinator plantings at utility-scale solar facilities.

In the summer of 2021, researchers began collecting micro-climate, ecological, and energy performance data from 6 solar sites in the Midwest ranging in size from 54 to 2,000 acres. Analysis of this data will help solar developers better understand the costs and benefits of various site vegetation approaches, particularly relating to pollinator species. An additional outcome of this project is a suite of guidance and decision tools to assist solar developers and other stakeholders when considering pollinator plantings at

large-scale solar facilities. The suite of tools envisioned include a planning and implementation guidance manual, cost-benefit calculator, seed selection tool, and a habitat field assessment protocol.

The team will leverage existing and new research, collaborative partnerships, and industry and other stakeholder involvement to elicit input and supporting data to inform the development of these tools over the next three years. The team began initial scoping and industry outreach in 2021. Input received will inform the development of these tools under the next phase of their development. This session will introduce the tools envisioned under this project, the outreach conducted to date, preliminary feedback received from industry and technical stakeholders, and how it will be applied to the next phase of tool development.

Lessons from the past: How decades of integrated vegetation management (IVM) on rights-of-ways can inform solar site maintenance

Presenter: Dan Salas (Cardno)

Authors: Dan Salas (Cardno), Stan Vera-Art (Grow With Trees)

Abstract: The increasing development of utility-scale solar, design constraints, and the demand for managing vegetation for environmental co-benefits has presented a perplexing problem for many solar site managers. How feasible is it to maintain co-benefitting vegetation? How do we maximize the benefits of diverse vegetation? How do we minimize long-term operational costs?

Integrated vegetation management (IVM) has been used for more than four decades to maintain electric utility rights-of-way. The use of IVM has also expanded to other land managers working in other non-utility sectors as well. IVM has proven itself to be a cost-effective approach to managing vegetation where it's applied. We hypothesize that expanding the use of IVM in solar vegetation management planning can help address these questions facing solar operations today. To test this theory, we reviewed the lessons learned from the use of IVM in rights-of-ways, and then considered how they could be applied to solar site management using the best practices outlined in the recently published Managing Compatible Vegetation for Targeted Species and Biodiversity: A Companion Guide Addendum to the IVM Best Management Practices Manual, 3rd Edition.

These preliminary findings provide an example of how IVM can be used to plan cost-effective site management for solar sites incorporating environmental co-benefits into vegetation management plans. This session will also introduce the recently published guidance on IVM planning for target species and biodiversity. The results of this work can encourage more robust vegetation management programs for solar sites.

Best practices for wildlife assessments at solar facilities

Presenter: Jason Collins (Normandeau Associates)

Authors: Jason Collins (Normandeau Associates), Greg Forcey (Normandeau Associates)

Abstract: Environmental assessments and review are required as part of a solar facility siting and permitting process. Environmental work surrounding solar facility siting primarily revolves around three areas: rare species assessments, historical and culture resources, and wetland identification and delineation. Here we focus on rare species assessments and provide guidance on a recommended approach to avoid, minimize, and mitigate impacts to wildlife by solar development.

Mitigating impacts to at risk wildlife species: Lessons learned from Western Canada

Presenter: Derek Ebner (Stantec)

Author: Derek Ebner (Stantec)

Abstract: Impacts to wildlife are generally viewed as one of the primary concerns of industrial development. However, for the most part, federal and state guidance continues to focus primarily on reducing the potential effects of wind power projects and disregarding the impacts that the increased nation-wide footprint of solar may have on wildlife and their habitats. For this reason, it is useful to review and discuss the effectiveness of existing guidance and/or project-specific examples and their relevance and applicability to the solar industry as it proceeds into the future. In Western Canada, the Province of Alberta has been proactive in developing guidance for solar power projects at all stages: planning, pre- and post-construction surveys, and construction and operations. The application of this guidance still requires project-specific solutions due to the variety of wildlife-related issues that are encountered (e.g., species, habitat features, staging/stopover habitat). As most of the solar projects in Alberta occur in the northern Great Plains, habitat loss due to agricultural and industrial activities has resulted in a number of wildlife species being ranked as "at risk". For these reasons, recent solar power applications in Alberta have provided useful examples on how to mitigate potential effects on wildlife species (e.g., ferruginous hawks, sensitive amphibians) and their habitat (e.g., wetlands, native grasslands). The focus on this presentation will be on these examples, relating to them to Alberta guidance, and their applicability to US-based solar development.

Photovoltaic solar farms can provide conservation benefits for rare and other species: examples from California

Presenter: Brian Boroski (H.T. Harvey & Associates)

Authors: Brian Boroski (H.T. Harvey & Associates), Brian Cypher (Endangered Species Recovery Program, California State University-Stanislaus), Robert Burton (California State University-Monterey Bay), Daniel Meade (Althouse and Meade, Inc.), Scott Phillips (Endangered Species Recovery Program, California State University-Stanislaus), Erica Kelly (Endangered Species Recovery Program, California State University-Stanislaus), Tory Westall (Endangered Species Recovery Program, California State University-Stanislaus), Jason Dart (Althouse and Meade, Inc.)

Abstract: Photovoltaic solar power generating facilities are proliferating rapidly in California and elsewhere. While this trend is welcomed for many reasons (e.g., reducing greenhouse gas emissions), these facilities also can have profound environmental impacts, particularly to local natural communities. These impacts become more significant when species of conservation concern are affected. In the San Joaquin Desert region in central California, a number of conservation measures have been routinely implemented on solar facilities to accommodate use of the facilities by species of conservation concern, including state and federally listed species. Some of the more significant measures include permeable security fences, vegetation management, movement corridors, avoidance of critical features such as dens and burrows, and vehicle speed limits. Consequently, at least 12 special-status species are known to occur on seven large solar facilities (65-1,902 ha in size) in the San Joaquin Desert. These species include San Joaquin kit fox (Vulpes macrotis mutica), giant kangaroo rat (*Dipodomys ingens*), San Joaquin antelope squirrel (*Ammonspermophilus nelsoni*), American badger (*Taxidea taxus*), Swainson's hawk (*Buteo swainsoni*), burrowing owl (*Athene cunicularia*), northern harrier (*Circus hudsonius*), loggerhead shrike (*Lanius ludovicianus*), blunt-nosed leopard lizard (*Gambelia sila*), California tiger salamander (*Ambystoma californiense*), San Joaquin coachwhip (*Masticophis flagellum ruddocki*), and Kern mallow (*Eremalche kernensis*). Strategies employed in the San Joaquin Desert potentially could be implemented

in other regions for the benefit of other species, although additional research is needed. Vegetation management is vital to ensuring that habitat maintenance or enhancements achieve stated goals and objectives that may vary within different areas of a utility-scale solar installation. For instance, lower-growing grasses and forbs may be managed within arrays while taller species, such as some milkweeds (*Asclepias*) that support monarch butterflies (*Danaus plexippus*), are encouraged around the perimeter of arrays. Benefits of siting utility-scale solar facilities with a multiple-use intention of maintaining electrical productivity and meeting wildlife conservation goals will be greatest when developments are sited in areas with degraded habitat conditions. In some cases, even sites with moderate habitat value may be developed and contribute to broader conservation benefits through increased landscape connectivity and increasing habitat patch size. In areas with high solar development potential and fragmented habitat patches occupied by rare species, there exists potential for improving conditions for species by providing habitat within solar arrays and thereby increasing habitat connectivity. Any such effort would be facilitated by a collaborative relationship between solar developers and natural resource agencies. Regulatory agencies have statutory requirements related to take that must be met. To fulfill these requirements, solar facility developers may incur substantial costs during the permitting and construction phases of the project. Incurring additional costs of implementing on-site conservation and land management measures during the operational period could be substantial. Identifying conservation approaches that benefit species on solar facilities, meet regulatory requirements, and are cost effective will be challenging and require innovation and collaboration, but worth the efforts when the magnitude of the potential benefits is considered.

A case study of land management and wildlife compatibility at a utility-scale photovoltaic facility in California

Presenter: Brian Boroski (H.T. Harvey & Associates)

Authors: Brian Boroski (H.T. Harvey & Associates), Raymond Kelly (Clearway Energy Group), Jacquelyn Maher (H.T. Harvey & Associates), Matt Wacker (H.T. Harvey and Associates)

Abstracts: Understanding the interface between utility-scale solar energy development and wildlife conservation is increasingly important. Construction and operation of solar energy facilities can modify wildlife habitat and have direct and indirect effects on wildlife. The manner in which a solar facility is operated and maintained may also have effects on landscape connectivity because those activities can directly affect habitat values. In some cases the majority of a solar facility site may remain in a condition that can sustain habitat capable of supporting a diverse array of native plants and wildlife. We provide a case study where best management practices during construction and operation has perpetuated wildlife habitat and occupancy by three state and federally listed mammal species. California Valley Solar Ranch is a 250-MW photovoltaic facility consisting of nine distinct panel arrays on 642 ha of disturbed grassland/scrub habitat in central California. The overall 1,896-ha project site encompasses intermixed and adjacent conservation lands. Surveys within this area identified seven plant species of conservation concern, three state and federally listed mammal species (giant kangaroo rat, San Joaquin kit fox, and San Joaquin antelope squirrel), and designated critical habitat for vernal pool branchiopod species. Initial design was revised through an iterative process to avoid construction near these resources, including all San Joaquin antelope squirrels and the majority of giant kangaroo rat precincts. Two hundred and twenty-one giant kangaroo rats were translocated from construction areas, and avoidance of 261 giant kangaroo rat precincts occurred through engineered redesign or by modifying construction methods. Measures for avoiding and protecting San Joaquin kit fox dens include restricted entry buffers and use of one-way doors to protect dens in place for future use; den excavation is a last resort for dens directly impacted by construction. The design of the array fencing allows passage of San

Joaquin kit fox between solar arrays and adjacent conservation lands. Managed sheep grazing is primarily used in arrays to manage vegetation height and biomass, with some supplemental mowing to reduce wildfire risk. Grazing occurs in spring and usually includes at least 1 rotation through each array. Bedding locations are located away from sensitive biological resources. Suitable bedding and watering locations are identified by a biologist and coordinated in advance with the sheep herder. Once cleared of kangaroo rat precincts during construction, we currently estimate that a population of over 2,000 giant kangaroo rats occupies the arrays. The number of natal and escape dens within arrays indicates a persistent use of the arrays by San Joaquin kit fox, and a three-year telemetry study confirmed the species' ability to use the facility similar to adjacent conservation lands. Originally absent from arrays, the distribution of San Joaquin antelope squirrels has been expanding and the species currently occupies 7 out of the 9 arrays. The management of biological resources within a solar generating facility without impairment of electrical generation is a worthy goal and this case study is an example of how a multiple-use perspective that manages habitats within developed environments can aid conservation efforts.

A Research Roundtable Discussion: The future of research on pollinator habitat at solar sites

Presenter: Iris Caldwell (University of Illinois Chicago)

Authors: Iris Caldwell (University of Illinois Chicago), Ashley Bennett (Electric Power Research Institute)

Abstract: Pollinators are experiencing global population declines and habitat loss is one factor contributing to their decline. To prevent further pollinator losses, innovative solutions are being explored to integrate pollinator habitat across the landscape. The energy industry is one sector that can contribute to the conservation of pollinators. With the rapid expansion of solar power generation, solar developers and power companies have an opportunity to create habitat for pollinators by using regionally appropriate native seed mixes designed to support bees and other pollinating insects. However, there are gaps in our understanding of the best management practices, associated costs of pollinator habitat establishment and maintenance, and the conservation value of solar sites to pollinators, which can hinder the establishment of pollinator habitat at solar sites. The University of Illinois Chicago (UIC) and the Electric Power Research Institute (EPRI) are organizing a webinar and roundtable discussion on the topic of solar-pollinator research in November 2021 as part of an ongoing webinar series. The webinar will highlight solar-pollinator research in progress and generate discussion on knowledge gaps that future research should address. The on-demand panel proposed here will provide a summary from the November research roundtable hosted by UIC and EPRI and include a discussion on the research needs and knowledge gaps identified during the webinar. Panel leads will facilitate a question and answer discussion with the 3-4 researchers who will present during the research roundtable webinar. Researchers will be assembled from academia, government research labs, industry, and research-focused non-profits to represent multiple stakeholder groups. The panel will be asked to comment on the outcomes of the research roundtable and provide additional input on the knowledge gaps and research needs on pollinator habitat at solar sites. Anticipated topics this panel may be asked to discuss: 1) research needs identified around habitat establishment, 2) knowledge gaps around solar habitat management, and 3) the use of pollinator scorecards.

Habitat connectivity mapping - innovative tool for siting incentive programs

Presenter: Samantha Horn (The Nature Conservancy in Maine)

Authors: Samantha Horn (The Nature Conservancy in Maine), Dan Coker (The Nature Conservancy in Maine)

Abstract: Habitat Connectivity is broadly defined as the degree to which the landscape facilitates or impedes animal movement and other ecological processes. Roads and development fragment the natural landscape and create patterns of areas (blocks) of habitat that can become too small or degraded to support healthy populations of some area-sensitive and habitat specialist species. They can also create barriers to movement for both individuals and populations that may need to shift their ranges to find more hospitable habitats as our climate changes.

We are already seeing remarkable changes in species ranges in response to climate change. Studies have shown that many species ranges are shifting 10-20km per decade and upslope at rates of 11m per decade in response to climate change. In many parts of the world, conservation organizations and planners are forced to stitch together remaining fragments of habitat with the extremely expensive band-aid strategy of wildlife corridors. In most regions of Maine, we have the opportunity, with thoughtful planning and strategic investments, to maintain a relatively intact, well-connected landscape before it’s too late and we have to resort to stitching the landscape back together.

Maine has new, aggressive renewable energy goals and there is a real sense of urgency for rapid deployment. In response to these aggressive goals, there has been remarkable growth in the number of solar developments requesting permits through the state DEP. The Nature Conservancy (TNC) strongly endorses both the goals and the need for rapid renewable energy deployment but we also believe that the ‘how and where’ of renewable energy development are critical. The state DEP has a host of site-specific considerations in place that influence this ‘how and where’ (things like wetlands, rare natural communities, and endangered species), but there is currently no consideration that speaks to the bigger picture, the cumulative impacts that developments might be having on landscape connectivity. Our proposed mapping tool can be used for guidance purposes, but the key advancement of this project is that the mapping system is straightforward and replicable enough to introduce landscape connectivity considerations into the regulatory process by creating incentives for preferred siting of solar facilities.

TNC Maine’s Undeveloped Habitat Blocks Connectivity Map is a portrayal of the connected network of the largest, most intact remaining undeveloped natural habitat in southern and Central/Midcoast Maine. Large, intact habitat blocks with significant core area support a greater abundance of wildlife species compared to smaller blocks and maintaining connectivity within and between these blocks is an essential component of planning for climate resilience. Rather than taking a species-specific approach, we use a more holistic ‘structural’ connectivity approach that maps the patterns of the entire suite of natural landcover types across the landscape. Choices of core block sizes for each region are an attempt to strike a balance between species needs, block size distributions, and the need to provide a useful regulatory framework that will encourage rapid renewables deployment.

Developing Avian Monitoring Systems for Solar Photovoltaic Facilities Using Edge-Computing Camera, Computer Vision, and Machine/Deep Learning Approach

Presenter: Yuki Hamada (Argonne National Laboratory)

Authors: Yuki Hamada (Argonne National Laboratory), Adam Szymanski (Argonne National Laboratory), Xijun Wang (Northwestern University), Aggelos Katsaggelos (Northwestern University), Yuri Balasanov (University of Chicago), Lee Walston (Argonne), Heidi Hartmann (Argonne National Laboratory), Andrew Ayers (Argonne National Laboratory), Nicola Ferrier (Argonne National Laboratory)

Abstract: Accurate understanding of interactions between birds and solar infrastructure is important for continued deployment of utility-scale solar energy facilities. Solar infrastructure related avian fatalities are a particular concern. Current monitoring methods for avian fatalities at solar facilities rely on periodic ground surveys for bird carcasses, which may be subject to errors. The goal of this project is to develop a technology for automated monitoring of avian-solar interactions. More specifically we attempt to automatically detect avian fly-through, perching, and collisions with solar energy facility infrastructure using a machine/deep learning (ML/DL) approach in conjunction with a high-definition camera and edge computing to complement the field-based monitoring methods. The objectives of this project are to (1) design and assemble camera systems that enable continuous video collection, execution of ML/DL models, and AI-enable edge computing to perform avian monitoring, (2) develop ML/DL models that detect presence of birds in video at solar energy facilities and classify their interactions with solar energy infrastructure (e.g., perching, fly-through, and collisions), and (3) deploy the system in a pilot program at a limited number of partner solar energy facilities to test its bird detection and interaction classification capability and performance in real-world environments. When developed, this technology will improve the ability to collect a large volume of accurate data on avian-solar interactions and facilitate understanding of solar-related avian impacts.

Since March 2020, we have collected nearly 8,000 hours of daytime video at five operational solar energy facilities, two located in the U.S. Desert Southwest and three in the U.S. Midwest, using high-definition true-color cameras. Using the video, we have generated more than 76,000 tracks of training data of birds and their activities using a combination of computer-based tracking algorithm and manual labeling methods. We have trained a ML/DL model using approximately 45,000 tracks of training data consisting of ~1,000,000 images to differentiate birds from other moving objects in video. Although it is preliminary, our latest model shows ~92% bird detection accuracy, but there are challenges. In this talk, we will present an overview of our modeling framework, latest progress, and challenges and our plan for overcoming those challenges to accomplish our goal.

Mapping Ephemeral Streams in Desert Lands Using Remote Sensing and Artificial Intelligence

Presenter: Yuki Hamada (Argonne National Laboratory)

Authors: Yuki Hamada (Argonne National Laboratory), Max Zvyagin (Argonne National Laboratory), Thomas Brettin (Argonne National Laboratory), Arvind Ramanathan (Argonne National Laboratory)

Abstract: Ephemeral streams play an important role in desert environments. The spatial patterns of such streams are crucial for understanding how hydrologic processes influence the abundance and distribution of wildlife habitats in desert landscapes. In 2011, we attempted to map detailed ephemeral stream networks in the Southwestern U.S. where utility-scale solar energy development is occurring using an artificial neural network method and 1-m resolution aerial imagery. While producing promising results, insufficient computational power prevented us from scaling the method. In 2015, using 15-cm resolution aerial imagery, we developed an image-processing algorithm that applies landscape

information to map ephemeral stream networks of the same area. The algorithm integrates knowledge about landscape features and structures using a series of spectral transformation and spatial statistical operations. The algorithm extracted ephemeral streams at a local scale, with the result that approximately 900% more ephemeral streams were identified in comparison to the U.S. Geological Survey's National Hydrography Dataset. The accuracy of the algorithm in detecting streams was as high as 91% when compared to a subset of stream networks that were recorded in the field and manually digitized in the imagery. The challenge of scaling this knowledge-based approach to a watershed was to account for the subtle spectral variation of streams in the image and heterogeneity between landscape features and structures.

To overcome this challenge and complement the knowledge-based approach, we are developing deep segmentation approaches that allow us to automatically identify ephemeral streams in the high-resolution aerial imagery collected for our previous study. Utilizing manually digitized ephemeral stream networks in the imagery for a portion of the study area, a standard UNet network was trained to perform pixel-wise binary classification, achieving 68% accuracy on the test set as a preliminary result. This approach has been tested on different hardware – the NVIDIA A100 offers an additional speedup in training when compared the NVIDIA V100. We plan to further accelerate the training process by porting the code to next-gen hardware accelerators, including SambaNova Systems and Cerebras Systems devices. Furthermore, we have found that overall segmentation accuracy can be increased to 80% by using a multi-scale attention network (MA-net) with a ResNet34 backbone and dataset augmentation. However, more work is needed to determine the optimal model architecture.

In this talk, we will present lessons learned from our previous work for mapping detailed ephemeral stream networks in desert landscapes and the new approach being developed using artificial intelligence including the recent progress. We will also share our current thoughts on the usefulness of ephemeral stream maps derived from our model for the solar energy industry, regulatory agencies, and conservation groups and seek their feedback for types of information needed and specific concerns regarding dryland ephemeral streams and their preference for information sharing.

The power of connection: Mojave Desert tortoise habitat loss, movement and gene flow in the Ivanpah Valley

Presenter: Amy Vandergast (U.S. Geological Survey, Western Ecological Research Center)

Authors: Amy Vandergast (U.S. Geological Survey, Western Ecological Research Center), Todd Esque (U.S. Geological Survey, Western Ecological Research Center), Kenneth Nussear (Department of Geography, University of Nevada, Reno), Kirsten Dutcher (Department of Geography, University of Nevada, Reno), Steven Hromada (Department of Geography, University of Nevada, Reno), Corey Mitchell (Department of Geography, University of Nevada, Reno)

Abstract: Understanding the cumulative effects of solar development and other threats on long-lived species is a difficult problem, but one of high importance particularly for ensuring protection of declining species. The Mojave desert tortoise (*Gopherus agassizii*), is an arid adapted herbivore found in the Mojave Desert and parts of the Sonoran Desert of the United States. It is federally listed as threatened and receives state protection range-wide (California, Nevada, Arizona and Utah) because of population declines linked to numerous factors including habitat loss, degradation, and fragmentation due to an expanding human footprint throughout its range. Here we report on results from the first five years of a long-term study describing movement patterns, demography and genetic connectivity of desert tortoise populations in and surrounding the Ivanpah Valley which is on the California-Nevada border between Las Vegas, NV and Barstow, CA. In this region, tortoise habitat has been altered and fragmented by

utility-scale solar, urbanization, transportation and energy delivery corridors, and intensive off-road recreation. Results to date from field surveys, telemetry, and genetic analysis support several trends. First, analysis of telemetered tortoise movements suggests that tortoises avoid moving in areas of high slope, low perennial vegetation cover, and near low-trafficked roads, and travel along linear fences and flood control berms. Habitat characteristics and presence of roads also impact home range size. Second, spatial capture recapture models suggest that density varies substantially across the study area, but remains relatively stable in most locations over short time periods. Third, population genetic connectivity appears to be disrupted by railroad and highway barriers as well as constricted through mountain passes. Fourth, genetic analyses suggest there is measurable decline in local breeding population size and genetic diversity over the past two generations. While relocation of tortoises out of solar development areas may have contributed to localized signals of high diversity and genetic neighborhood sizes in adjacent receiver sites, simulations suggest that restrictions to movement and loss of habitat from development are predicted to lead to longer term declines in connectivity and diversity. Although data collection is ongoing and anticipated to continue for the next decade, integration of our results to date begins to provide insight on individual and population-level effects of solar and other development on the Ivanpah Valley tortoises.

If You Build It, Will They Come? Monitoring the Ecological Performance of Pollinator Habitat at Solar Energy Facilities

Presenter: Heidi Hartmann (Argonne National Laboratory)

Authors: Heidi Hartmann (Argonne National Laboratory), Lauren Jenkins (Argonne National Laboratory), Lee Walston (Argonne National Laboratory), James McCall (National Renewable Energy Laboratory), Jordan Macknick (National Renewable Energy Laboratory), Rebecca Hernandez (University of California - Davis, CA), Yudi Li (University of California - Davis, CA), Adam Dolezal (University of Illinois Champaign-Urbana), Tristan Barley (University of Illinois Champaign-Urbana), Ashley St. Clair (University of Illinois Champaign-Urbana)

Abstract: The expansion of utility-scale solar development across the U.S. has increased the pressure on land resources for energy generation and other land uses (e.g., agriculture). To address this growing issue, greater emphasis has been placed on development strategies that maximize the benefits of energy generation and multiple ecosystem services, such as combining solar energy development with biodiversity conservation. Compared to other types of site management, the restoration of native grassland habitat at solar energy facilities ("solar-pollinator habitat") has the potential to improve habitat quality for pollinating insects and other native wildlife, while also providing other ecosystem service benefits. As more solar developments are being managed for solar-pollinator habitat, there is a need for monitoring projects to inform questions around ecological performance, scalability, and management considerations. In this presentation, we share our ecological performance monitoring strategy for nine solar energy facilities in the Midwest that include solar-pollinator habitat. Three of these solar facilities have been systematically monitored over the past 4 years to measure habitat and insect pollinator responses over time, while research is just beginning at the other sites. The primary ecological performance measures we are investigating include: (1) vegetation establishment and habitat composition; (2) on-site insect pollinator abundance and diversity; and (3) off-site pollinator visitation to nearby agricultural areas. Preliminary findings from monitoring efforts show temporal increases in habitat diversity and onsite pollinator abundance and diversity. There are also some temporal trends in pollinator visitation to nearby soybean fields. In addition to these findings, we will also discuss designs for research at new large-scale facilities (>10 MW) to monitor vegetation establishment and pollinator effects considering the scale and configuration of the plantings.

Solar vegetation management and pollinator habitat; lessons learned in vegetation selection and maintenance

Presenter: Susan Opperman (Olsson)

Author: Susan Opperman (Olsson)

Abstract: The alarming decline of native bees, monarch butterflies, and other pollinators has prompted widespread interest in planting pollinator friendly vegetation within the footprints of utility-scale solar facilities, for good reason. This emerging approach to solar vegetation management can directly support pollinators that are essential to biodiversity and an estimated $18 billion per year in domestic food production, according to the U.S. Department of Agriculture. However, pollinator friendly solar vegetation management must take a holistic approach that supports the successful operation and maintenance of a facility. A desire to pair solar energy with pollinator habitat has led some local jurisdictions to require pollinator friendly vegetation management plans for proposed utility-scale installations. These local regulations increasingly incorporate scorecards that award higher "scores" to facilities that, for example, incorporate a higher diversity of native wildflowers over naturalized or non-native vegetation. Target scores are then required to secure local permitting. Potential increased costs, limited species availability, untested methodology, increased insurance, and other constraints may make it difficult for some utility-scale facilities to meet target scores. Olsson will present lessons learned in developing pollinator friendly solar vegetation management plans, solar vegetation selection, and navigating the multi-faceted considerations involved in balancing pollinator requirements with a successful facility. Discussion will include vegetation selection, species characteristics, establishment and persistence, maintenance schedules, weed pressure, and operational goals.

Foundational Issues in Integrated Vegetation Management at Solar Facilities: Setting the Stage during Construction Contracting

Presenter: Elizabeth Markhart (Western EcoSystems Technology, Inc. (WEST))

Author: Elizabeth Markhart (Western EcoSystems Technology, Inc. (WEST))

Abstract: At the interface of the built and natural environment, be it ground-mounted solar, a commercial campus, or highway development is the "how to manual" for the built features and restoring the disturbed land footprint. Whether it be the ecological restoration or civil engineering trade, the "how to manual" is found within the Plans and Specifications, the guidance used by construction and/or restoration contractors and the Owner to verify the quality and completeness of the work through clearly spelled out items and expectations for payment and conditions for acceptance. This on-demand presentation will cover the importance of the construction contracting process, including all too common mistakes and inefficiencies, and the bid items to be included in a good contract to set the stage for integrated vegetation management at new solar facilities. The contracting technical items covered will include the bid form, standards for interim and final acceptance points for payment, and oversight responsibilities. We will also cover the differences and interplay between the short-term Clean Water Act obligations for any land disturbance and the potential longer-term goal of promoting cost-effective, desirable, and stable vegetation at a solar facility that advances secondary ecosystem services (e.g., wildlife habitat, soil improvements, carbon sequestration, water quality improvements, etc.).

North Carolina leading the way on low-impact solar siting and design

Presenter: Liz Kalies (The Nature Conservancy)

Authors: Liz Kalies (The Nature Conservancy), Daniel Brookshire (NC Sustainable Energy Association), Gabriela Garrison (NC Wildlife Resources Commission), Katie Hill (Strata Clean Energy)

Abstract: Solar farms show great potential in reducing carbon emissions and mitigating climate change, but if sited improperly, can have negatives consequences to wildlife habitat and biodiversity. Solar farms generally use fencing that acts as a total barrier to wildlife movement, and in-farm habitat usually consists of non-native grasses that are easy to maintain via mowing and herbicides. In North Carolina nearly 50,000 acres of solar facilities have been rapidly developed, with potential to create small but numerous fragmenting features. NC is the third largest state in installed solar energy, but there are very few regulations mitigating the impact of solar farms on wildlife. Our question was: How do we site and design solar farms to minimize impacts to wildlife and habitat? First, we conducted a spatial analysis of existing solar farms overlaid with core/protected natural systems and key corridors for connectivity, compatible lands (agricultural fields, degraded lands), and known wildlife movement/pathways, and developed solar farm siting principles. Concurrently, we have been working with solar developers in an adaptive management framework to implement and test best management practices on the ground, including pollinator vegetation, wildlife-permeable fencing, and wetland restoration. Working in collaboration, we sampled 10 solar farms between 2018-2021 for presence and diversity of native vegetation, pollinators, and wildlife species. Our results show that restoring the structure and composition of grassland vegetation results in positive impacts to pollinators, and that wildlife movement is facilitated by the permeable fencing. We continue to refine these best management practices in mitigating solar farm impacts to wildlife. But our greatest success has been the collaboration of conservation and energy NGOs, state/federal agencies, and the solar development industry in working to create a win-win situation for clean energy and wildlife.

Aquatic habitat bird occurrences at photovoltaic energy development in Southern California, U.S.

Presenter: Karl Kosciuch (Western EcoSystems Technology, Inc. (WEST))

Authors: Karl Kosciuch (Western EcoSystems Technology, Inc. (WEST)), Daniel Riser-Espinoza (Western EcoSystems Technology, Inc. (WEST)), Cyrus Moqtaderi (Western EcoSystems Technology, Inc. (WEST)), Wally Erickson (Western EcoSystems Technology, Inc. (WEST))

Abstract: The development of photovoltaic (PV) utility-scale solar energy (USSE) in the desert Southwest has the potential to negatively affect birds through collision mortality. Based on early patterns in fatality monitoring data, the lake effect hypothesis (LEH) was developed and suggested that birds misinterpret PV solar panels for water. As the LEH was only recently defined and inference beyond bird mortality is limited, our research objective was to examine the species composition, abundance, and distribution of live and dead aquatic habitat birds at five PV solar facilities and paired reference areas in southern California. Further, we collected data from a small regional lake as an indicator of the potential aquatic habitat bird community that could occur at our study sites. Using an ordination analysis, we found the lake grouped away from the other study sites. Although the bird community (live and dead) at the solar facilities contained aquatic habitat species, Chao's diversity was higher, and standardized use was more than an order of magnitude higher at the lake. Finally, we did not observe aquatic habitat bird fatalities in the desert/scrub and grassland reference areas. Thus, the idea of a "lake effect" in which aquatic habitat birds perceive a PV USSE facility as a waterbody and are broadly attracted is likely a nuanced

process as a PV solar facility is unlikely to provide a signal of a lake to all aquatic habitat birds at all times.

Power Lines, Substations, and Solar Energy Generation: Emerging Issues to Address Bird Electrocution and Collision Risks, System Reliability, Legal Liability, and Regulatory Compliance through Design, Engineering, and Suggested Practices

Presenter: Lori Nielsen (Western EcoSystems Technology, Inc. (WEST))

Author: Lori Nielsen (Western EcoSystems Technology, Inc. (WEST))

Abstract: The design and operation of electrical infrastructure supporting solar energy development may potentially increase risk to areas birds, risk to system operations, and a company's legal liability. These risk components include aboveground electrical collector line operation (avian electrocution and collision) within the solar array, substation operation and potential outages from wildlife contacts, raven and owl interactions with power infrastructure and the potential for bird electrocutions and wildfires, and collision risk to birds along the transmission gen-tie lines that connect the solar facility to the grid. We have developed processes to address potential communication disconnects among the Developer, Operator, and Engineering specific to minimizing risk of bird contacts; new facility Owner expectations; the role the Avian Power Line Interaction Committee (APLIC) plays in planning; and what this means for advance design and communications. We discuss historical issues observed, including the prevalence of wildfires (multiple) from bird contacts (damage and liability), short- and long-term substation outages that affect facility reliability, and common multi-circuit collector lines that may present a high risk of both electrocution and collision within a solar facility.

Drivers for Co-locating Pollinator Habitat at Solar Facilities

Presenter: Iris Caldwell (University of Illinois Chicago)

Authors: Iris Caldwell (University of Illinois Chicago), Lee Walston (Argonne National Laboratory), Chris Kline (Cardno), Andrew Pinger (EDP Renewables North America), Sean Gallagher (Solar Energy Industries Association)

Abstract: The rise of pollinator-friendly solar has caught the attention of solar developers, energy companies, government agencies, conservation groups, and academic researchers, particularly with the rapid growth of solar energy development across the U.S. and increasing general public awareness and concern about pollinator population declines and habitat loss. The University of Illinois Chicago (UIC) is leading a three-year study to investigate the economic, ecological, and performance impacts of pollinator plantings at large-scale solar facilities. In that context, UIC will convene this panel to discuss the drivers (and barriers) associated with co-locating pollinator habitat at solar facilities from four different stakeholder perspectives. Each panelist will provide a short 5-minute presentation highlighting the drivers and barriers they have experienced or studied. Following each of the presentations, UIC will facilitate a panel discussion on the themes covered, including secondary benefits, sustainability reporting, solar scorecards, and land use change.

Solar Energy & Pollinator Benefits: managing the uncertainty of a new model

Presenter: Peter Berthelsen (Conservation Blueprint)

Author: Peter Berthelsen (Conservation Blueprint)

Abstract: As new solar energy systems continue to expand rapidly, projects are increasingly being designed to consider the health and habitat benefits for pollinator species. Establishing these projects strategically thinking about how multiple benefits can be incorporated is an important consideration, but comes with a significant amount of uncertainty for the solar industry. As a new initiative, there is not a long history or set of examples to address the primary questions associated with projects designed to include pollinator-friendly vegetation:

- Are pollinator-friendly seed mixes cost-effective?
- What are the future O&M costs and activities associated with pollinator-friendly vegetation?
- Does the installation of pollinator-friendly vegetation require different techniques?
- Can seed mixtures be designed to work with a lower panel height of 20" to 24"?
- How challenging is it to meet the requirements listed in a Solar Pollinator Score Card?

Multiple benefits can be designed and included in new solar energy systems by strategically designing seed mixtures and vegetation management plans to consider the many co-equal objectives of the project. When seed mixtures are being designed, it is critical that all of the important project objectives are considered and applied to seed mixture design in a co-equal fashion. Some of the more common project objectives that need to influence seed mixture design include:

- Lower panel height that determines vegetative height restrictions of the seed mix.
- Ordinance and/or permit language and requirements.
- Ease of establishment to work with CUP and SWPPP requirements.
- Pollinator value
- Commercial availability of the seed mixture.
- Cost-effectiveness of the seed mixture.
- Meeting state score card and/or guideline requirements.
- Plant species response to annual mowing activities.
- Ability of plant species to persist in a planting for 20-30 years.
- Adaptation to the region, soil type and site.

Failure to consider all of these project objectives often results in a seed mixture and vegetative management plan that is overly expensive, requires additional future O&M inputs, may not be commercially available and produces a less-than-desirable vegetative outcome.

The lessons learned to date offer a very optimistic set of answers to these questions and considerations. Real-world examples are showing that solar + pollinator-friendly seed mixtures can be designed that are very comparable to turf-type grass in both cost and establishment. In addition, seed mixtures have been able to meet every state Solar Pollinator Score Card designation of meeting pollinator habitat and often meet the designation of providing exceptional pollinator habitat.

Species and Solar Energy: How Pollinator-Friendly Practices Can Impact Endangered Species Act Compliance Strategies

Presenter: Brooke Marcus (Nossaman LLP)

Authors: Brooke Marcus (Nossaman LLP), Rebecca Barho (Nossaman LLP)

Abstract: Solar projects are increasingly incorporating pollinator-friendly practices into project design and operations. Fostering pollinator activity within a project area has many benefits for all stakeholders. However, maintaining and attracting pollinator species can have implications for a project's Endangered Species Act (ESA) compliance strategy. This presentation will provide background on how species are protected under the ESA as well as regulatory and practical tools available to help anticipate, plan, and manage federal wildlife risk at solar projects.

- ESA listing process: How a species becomes protected under the ESA and resources to understand which species may be under review for listings.
- ESA prohibitions: What protections apply for a species that is listed or proposed for listing?
- ESA federal triggers: How federal approvals and funding, such as Nationwide Permits and federal interconnections can trigger ESA section 7 obligations and associated compliance, mitigation, and litigation risks.
- ESA tools: What tools are available under ESA section 7 and ESA section 10 as potential options when developing an ESA compliance strategy?

Advancing a Framework to Increase Community Support for Utility-Scale Solar Photovoltaics

Presenter: Ron Meyers (Virginia Polytechnic and State University)
Authors: Ron Meyers (Virginia Polytechnic and State University), William Ford (US Geological Survey, Blacksburg), Terry Clements (Virginia Polytechnic and State University)
Abstract: If done well, renewable energy projects can improve wildlife/natural resources conditions and community socioeconomic equality in some settings. However, in practice, utility-scale solar photovoltaics (USS PV) siting decisions are often fraught with conflict. Community members have serious concerns about wildlife/natural resources impacts, social impacts (including visual impacts, loss of agricultural character, distribution of benefits and costs, process issues, et al.), and other potential consequences.

We build on siting approaches designed to increase social acceptance, particularly community acceptance, of USS PV through a site planning process designed to increase the likelihood that community members and natural resources and agricultural interests will support a proposed project. Core to our approach is concurrent stacking of multiple uses (i.e., wildlife habitat and riparian zone enhancement, agricultural PV, etc.) and values on proposed sites. The objective of this research is to identify a set of factors and a robust site planning process to develop a comprehensive voluntary standards/scorecard for USS PV site selection and planning. Our hypothesis is that site selection and planning processes are more likely to succeed in fostering community support if they engage a diverse groups of stakeholders through robust processes that emphasize meaningful co-research and co-decision making. We further hypothesized that developing a preliminary set of standards/scorecard that incorporates three pillars of sustainability – wildlife/natural resources, social/equity, and economic concerns – would be useful in facilitating meaningful co-research and co-decision making by stakeholders.

The project team is developing and piloting a new siting approach in multiple locations, including: Milton Airfield (University of Virginia); Catawba Sustainability Center (Virginia Tech), and Clarke County, VA. The Milton site is an abandoned airfield currently used for multiple purposes. It is in an ex-urban area in the

Monticello viewshed. Bordered by the Rivanna River, it is home to multiple endangered and threatened species. The Catawba Sustainability Center is adjacent to the Appalachian Trail's (AT) highly prized iconic "Triple Crown". A review of journals and grey literature from natural resources, civic, and for-profit organizations was conducted. Two pilot studies were conducted in 2018-2020. A third is in process. These pilots are gradually increasing the MW of projects, number of factors, and specificity of the stakeholder engagement processes.

Research is in progress, finding few studies documenting the potential adverse impacts of siting a USS PV facilities on natural resources. A growing number of studies address how to increase community acceptance through consideration of natural resources and social impacts. The pilot testing results are very encouraging. Diverse stakeholders engaged in broad ranging meetings on the need for renewable energy and the ability to equitably develop USS PV in the Catawba Valley. The stakeholder engagement process maintained productive discussions amongst participants despite strongly held interests perceived to be threatened. Ongoing pilot studies are further refining and testing different criteria and approaches to engagement.

Effects of solar energy development on desert ecosystems and their services

Presenter: Steve Grodsky (U.S. Geological Survey, New York Cooperative Fish and Wildlife Research Unit, Department of Natural Resources and the Environment, Cornell University, Ithaca, New York, USA)

Authors: Steve Grodsky (U.S. Geological Survey, New York Cooperative Fish and Wildlife Research Unit, Department of Natural Resources and the Environment, Cornell University, Ithaca, New York, USA), Joshua Campbell (United States Department of Agriculture, Agricultural Research Service, Northern Plains Agricultural Research Laboratory, Sidney, MT USA,), Amy Fesnock (Bureau of Land Management), Laura Franklin (School of Natural Resources, California State University, Monterey Bay, Monterey Bay, CA, USA), Marie Hardouin (Department of Natural Resources and the Environment, Cornell University, Ithaca, New York, USA), Rebecca Hernandez (University of California, Davis and Wild Energy Initiative, John Muir Institute of the Environment)

Abstract: Solar energy development is a contemporary driver of land-use change that may induce novel and complex interactions among ecosystems and people. Deserts are increasingly prioritized as recipient environments for ground-mounted solar energy development. In addition to abundant solar resources, deserts support a great diversity of plants, pollinators, wildlife, and ecosystem services. Given current knowledge gaps pertaining to solar energy development and biological conservation in deserts, our objective was to elucidate relationships between solar energy development decisions, including site preparation practices and retention of undisturbed habitat patches in solar fields, and desert ecosystems in the Mojave Desert. We conducted over 3 years of ecological fieldwork, spanning the fall and spring seasons 2017 - 2019, at Ivanpah Solar Electric Generating System (ISEGS)—a 392 MW concentrating solar power facility covering ~1,400 hectares of previously undeveloped creosote bush scrub in the Ivanpah Valley of California's Mojave Desert. We defined treatments in ISEGS representing three unique solar energy development decisions as follows: (1) bladed, intensive site preparation via blading (bulldozing) with above- and below-ground biomass removed; (2) mowed, moderate site preparation intensity via mowing, aboveground biomass retained up to a height of ~0.30 m; and (3) "halo", a pre-construction, plant-conservation decision that designated buffer zones around rare desert plants within the solar fields at ISEGS, which were roped off and left undisturbed (i.e., no site preparation, no heliostats), creating isolated habitat patches (average area = 22 m^2). We compared ecosystem responses in treatments to those documented in controls in undeveloped desert surrounding ISEGS. We employed a variety of abiotic and biotic sampling regimes and novel analyses to test effects of solar energy development on the desert plant community and ecosystem services of desert plants,

queen butterfly (*Danaus gilippus thersippus*)-Mojave milkweed (*Asclepias nyctaginifolia*) host plant interactions, non-bee insect pollinators, and native bee pollinators. Our results indicate that disturbance from solar energy development negatively affected the desert plant community and significantly reduced cultural, provisioning, and regulating ecosystem services of desert plants. We determined that cacti species and Mojave yucca (*Yucca schidigera*) are particularly vulnerable to both blading and mowing, whereas invasive annual grasses (e.g., *Schismus spp*.) are promoted by blading. We also determined that pollinators were less abundant in ISEGS than in undeveloped controls. We found that halos were efficacious for Mojave milkweed conservation and maintenance of Mojave milkweed-queen butterfly trophic interactions, but ineffective for non-bee insect pollinator management. Disruption of pollinator communities from solar energy development in deserts may lead to cascading effects on biodiversity, including potential decreases in imperiled cacti populations dependent on insect pollination. Generally, the unintended consequences of solar energy development in deserts can reduce biodiversity and socioecological resources available for humans, especially indigenous peoples of the Desert Southwest. Loss of biodiversity and ecosystem services from solar energy development in deserts may be eliminated by alternative siting (e.g., contaminated lands), while gains may be achieved by sustainable decision making guided by solutions-oriented, collaborative research and techno-ecological synergies.

Oregon Renewable Energy Siting Assessment (ORESA)

Presenter: Kaci Radcliffe (Oregon Department of Energy)

Authors: Kaci Radcliffe (Oregon Department of Energy), Sarah Reif (Oregon Department of Fish and Wildlife), Diane Brandt (Renewable Northwest), Jon Jinings (Oregon Department of Land Conservation and Development), John Cornwell (Oregon Department of Energy), Ruchi Sadhir (Oregon Department of Energy)

Abstract: ORESA explores opportunities and constraints that come with increased renewable energy development in Oregon. The project is funded through a $1.1 million U.S. Department of Defense Office of Local Defense Community Cooperation grant awarded to the Oregon Department of Energy, working with the Department of Land Conservation & Development and Oregon State University's Institute for Natural Resources. Project partners include state, local, federal, and tribal governments, along with input from industry, community organizations, military and technical advisors.

The motivation for this project is to address increased renewable energy development anticipated in Oregon in the coming decades due to strong climate and clean energy policies in the state. Developing these resources involves balancing issues related to natural resources, land use, and infrastructure, among other considerations, through processes requiring interaction between federal, military, state, and local organizations. Key project goals and objectivesinclude development of relevant educational tools for stakeholders, managers, and policymakers about renewable energy, military training and operational areas, economic and community benefits, land use considerations, natural resources, and regulatory requirements. The project scope and setting is the state of Oregon, including jurisdictional waters, as well as renewable energy technologies of wind energy, solar, geothermal, marine, and associated transmission infrastructure.

Project methods included cross-sector information collection through three topic-based assessments, supported by expert consulting firms, on renewable energy markets and industry, military interests and needs, and development opportunities and constraints. These assessments involved topic-based research, stakeholder input, and analysis to create an Oregon baseline. A procedures review was also conducted by agency staff and was reviewed by agencies and local governments to document

development requirements and processes. The Mapping and Reporting Tool and final ORESA report will serve as a baseline of data and perspectives using a transparent, consistent collection of trusted, accurate information. The project will not include recommendations or endorsements, and will note where information may be imprecise or uncertain. The timeframe for this project is October 2019 through March 2022. The project resources and results will be near-final, with a functioning Mapping & Reporting tool ready for demonstration, in time for this symposium. Manager and analysts across sectors and disciplines can use these findings and tools as a way to build and enhance their understanding of the opportunities and constraints that come with specific locations for current and future renewable energy development. While the Mapping and Reporting Tool will not be mandatory in decision-making processes, the project team is using detailed input from state agencies, local governments, federal agencies, tribes, utilities, developers, and NGOs to inform the design and functionality to ensure it is useful and relevant to their work and needs. Project information and updates available at https://www.oregon.gov/energy/energy-oregon/Pages/ORESA.aspx

Assessing soil carbon and insect diversity in three distinct plant communities established in a community solar development in Central Michigan

Presenter: Brendan O'Neill (University of Michigan)

Authors: Brendan O'Neill (University of Michigan), David Petrie (Consumers Energy)

Abstract: The burgeoning development of large areas of ground-mounted solar arrays presents a unique opportunity to establish plant communities which contribute a range of ecosystem services, from support of pollination services to the potential for soil carbon sequestration. Here we report on baseline monitoring of ecosystem services on newly-established vegetation mixes, as part of a new (spring 2021), utility-developed ground-mounted solar array in Central Michigan. Specifically we compare three different vegetation mixes - a grass mix traditionally used by the utility on project sites, and two pollinator mixes of different average heights.. We assessed soil health prior to plant establishment, including metrics of soil carbon and nitrogen, water infiltration, and soil aggregation in both full sun and under solar array canopy for all plant mixes. We also monitored invertebrate diversity for pollinator species and using ground-based pitfall traps. By measuring total productivity of the plant mixes and assessing soil carbon dynamics at the end of the growing season we estimate the potential for soil carbon accrual under different mixes into the future. Finally we assess the potential impact on solar arrays performance from changes in albedo from different vegetation mixes, and on maintenance and operations cost from different plant mixes. Our goal is to synthesize metrics for ecosystem services and solar array performance and identify potential trade-offs and synergies from different ground covers, which provides a useful guide to optimize a suite of benefits on other sites in the region.

Large-scale Solar Development: Water Quality Risk, or Green Infrastructure? The PV-SMaRT project

Presenter: David Mulla (University of Minnesota)

Authors: David Mulla (University of Minnesota), Brian Ross (Great Plains Institute), Jennifer Daw (National Renewable Energy Laboratory), Lauren McPhillips (Penn State University), Robert Goo (U.S. Environmental Protection Agency), Greg Hoffman (Center for Watershed Protection)

Abstract: Solar energy is now the least expensive form of electric energy generation in world. Consequently, the market for solar energy projects is surging, with large-scale projects being proposed in every state in the nation. Large-scale PV solar projects, in particular, present unique and uncertain risks and opportunities to water quality and watershed functions. The U.S. Department of Energy

funded the Photovoltaic Stormwater Management Research and Testing (PV-SMaRT) project to evaluate water quality impacts of large-scale solar development. The study will create solar-specific runoff coefficients that consider type of ground cover, soil type, hydrology, slope, and solar array design based on field testing across the nation and 3-D modeling. The project will also engage permit jurisdictions (authorities having jurisdiction, AHJs), from local to federal, to disseminate the findings and identify permitting best practices to make permitting transparent and predictable and improve water quality outcomes in our nation's surface waters.

Project hypothesis: Large-scale solar development has distinct development and surface characteristics that pose unique challenges and new management opportunities for post-construction stormwater management, including the opportunity for creating green infrastructure in rural watersheds where the predominant use is agriculture.

Project methodology: Collect field data at 5 existing solar installations over a two-year period to create and validate a model for predicting runoff specific to solar farms under a variety of design storm conditions. The analysis is modeling the post-construction infiltration and runoff outcomes of large-scale PV for different design storm events under a variety of hydrologic conditions and site configurations. The field research focuses exclusively on the impact of ground cover choices and use of disconnection to mitigate for stormwater volume and velocity at the drip edge of the panel. Ground cover choices have mitigating effects, but which could vary substantially under different site conditions, site designs, and design storm events.

The first year of data allowed calibration of the Hydrus 1 dimensional model. The second year focuses on creating 2-D and 3-D versions of the model and validating model results with additional field testing. Deliverables include lookup tables and nomegraphs for use by developers, permit officials and other water quality regulators. The project will be completed by the end of 2022. Validated interim findings from the 1-d modeling, show:

- Standard NRCS curve numbers can overestimate the runoff from a site with recently established pollinator habitat, and can significantly overestimate runoff from fully established pollinator ground cover for all soil types.
- For a typical (slope less than 5%) site with Class A soils, there is no runoff for any design storm modeled (2-, 10-, and 100-year frequency)
- Soil density is a critical variable to enabling use of ground cover as a BMP, as is maintaining vegetation under the solar arrays.

One potential implication of the study is understanding the conditions under which conversion of agricultural or disturbed land to solar development with appropriate ground cover could meet green infrastructure goals of improving water quality outcomes within impaired watersheds.

Golden Eagle Breeding Response to Utility-Scale Solar Development – A Case Study

Presenter: Eric Hallingstad (Western EcoSystems Technology, Inc. (WEST))

Authors: Eric Hallingstad (Western EcoSystems Technology, Inc. (WEST)), Daniel Riser-Espinoza (Western EcoSystems Technology, Inc. (WEST)), Cecily Foo (Western EcoSystems Technology, Inc. (WEST)), Todd Mattson (Western EcoSystems Technology, Inc.)

Abstract: WEST monitored Golden Eagles (*Aquila chrysaetos*) at the utility-scale California Flats Solar Project (Project), a 280-megawatt photovoltaic (PV) facility located in Monterey County, California, to determine how Project construction and operation affected nest occupancy, success and productivity (collectively, breeding performance). We monitored 12 territories located within 3.5 km of the Project

(Study Area) over nine years during three development phases (study period): pre-construction (2013-2015), construction (2016-2019), and post-construction (2020-2021). We tested whether nest proximity to the Project (1.6 km vs 1.6 km), development phase, or drought levels (ranging from 0 to 5) affected breeding performance. We confirmed relatively consistent nest occupancy rates within the Study Area during all phases of Project development (79%, 82%, and 83% during pre-construction, construction, and post-construction periods, respectively), and detected the establishment of two new nesting territories as the Project entered the operation phase. Occupancy rates were slightly higher within 1.6 km of the Project, but were negatively impacted under elevated drought conditions (levels 4 and 5). Overall nest success (measured as the proportion of laying pairs that raised at least one young in a given season) increased from 0.62 prior to construction to 0.88 during both the construction and post-construction development phases. Neither proximity to the Project, development phase, nor drought level were significant (α=0.10) predictors of nest success. Overall nest productivity also increased during the study period, from 0.73 young produced per occupied nest during pre-construction to 1.0 and 1.2 young produced per occupied nest during construction and post-construction, respectively. Productivity was lower at nests within 1.6 km of the Project; however, nests closest to the Project produced fewer young during all three phases of development and development phase was not a significant (α=0.10) predictor of nest productivity. Drought level showed an inconsistent effect on nest productivity; the lowest productivity occurred in the lone year of extreme drought (level 4), while nests produced comparatively more young during both less and more severe drought levels. Our findings suggest that Project development and the first two years of Project operation did not adversely affect golden eagle breeding performance within the Study Area. Comparable data are needed from additional facilities in other regions to evaluate potential influences of PV development on golden eagle breeding performance.

Benefits, challenges, and lack of cross-sector cooperation in dual-use solar design

Presenter: Sharlissa Moore (Michigan State University)

Authors: Sharlissa Moore (Michigan State University), Jen Fuller (Arizona State University), Hannah Graff (Michigan State University)

Abstract: As utility-scale solar energy deployment is accelerating across the country—particularly on agricultural land—academics, planners, government officials, and some solar developers are experimenting with dual land use initiatives. A relatively small body of academic literature has evaluated the potential of planting pollinator habitat, growing crops, beekeeping, and grazing animals on solar sites. Most of this literature focuses on small test sites without analyzing the challenges of deploying dual land uses to scale in real-world contexts, such as cost and market feasibility, stakeholder perceptions, on-the-ground complexity, and government policies. This social science research study inquires: What technological and social challenges are involved in dual land uses (e.g., pollinator habitat, agrivoltaics) for utility-scale solar power facilities? What are the benefits, trade-offs, and opportunities for optimization across the technical, social, and economic pillars of feasibility? As a qualitative study, the research does not test hypotheses, but rather allows themes to emerge from in-depth interviews, free of preconceived notions.

In fall 2020, 50 videoconference interviews with 59 people were conducted in Michigan, representing five stakeholder groups: academic experts with PhDs who research pollinators, utility companies and solar developers, public decision-makers and regulators, farmers and farm organizations, and community organizations. Interviews were transcribed and coded using Atlas.ti (qualitative data analysis software) and compiled into themes. An additional 50 interviews are being conducted this summer and fall in other regions of the country to capture regional differences (southwest, southeast, and Midwest). The results identify the feasibility issues associated with pollinator habitat and agrivoltaics. This research

identifies a lack of cross-sector and cross-disciplinary communication and collaboration on solar pollinator habitat and agrivoltaics. Therefore the proposed solutions skirt difficult questions about the uncertainty of the agricultural benefits, the long-term costs, and the definition of and requirements for success. In terms of management, public funding and deeper cross-sector collaboration would aid in identifying workable solutions.

Floating Solar and Natural Resource Issues, An Overview

Presenter: Tracy Brunner (Western EcoSystems Technology, Inc. (WEST))

Authors: Tracy Brunner (Western EcoSystems Technology, Inc. (WEST)), Christopher Farmer (Western EcoSystems Technology, Inc. (WEST))

Abstract: Floating solar photovoltaics (FPV) are an emerging technology that provide renewable energy in locations where land may be at a premium or unavailable for traditional ground-mounted solar farms. This technology has been in use in Asia and Europe since 2007 and is becoming increasingly considered for use in the U.S. Placing solar panels on bodies of water that may be used as industrial water sources, drinking water supplies, or for recreation creates new environmental and regulatory challenges not experienced with terrestrial installations. Impacts to natural resources from these projects differ from land-based systems. In addition, while some land-use and/or environmental permitting for FPV is similar to land-based systems, some regulatory requirements and approaches can be quite different and may involve new applications of existing regulations. In addition, linking to land-based points of interconnection and associated facilities can create additional impacts to sometimes sensitive shoreline habitats. We will illustrate key natural resource and other environmental resource impacts for consideration at FPV projects, such as impacts to fish communities, benthic habitats, water quality, and indirect effects on terrestrial species as well as beneficial uses such as evaporation reduction and habitat creation. We will bring to light some of the permitting challenges such as water rights, impaired waters, and additional federal permitting needs, as well as the complexities of adapting federal, state, and local regulations and ordinances that were not designed for FPV. Finally, we will present examples of potential natural resource and environmental resource issues from three states with varying potential resource concerns and potentially complex regulatory environments for development of FPV: New Jersey, Texas, and California.

Obtaining an Estimate of Western Joshua Tree Abundance from Digitized Imagery when Field Survey Data are Available

Presenter: Leigh Ann Starcevich (Western EcoSystems Technology, Inc. (WEST))

Authors: Leigh Ann Starcevich (Western EcoSystems Technology, Inc. (WEST)), Wally Erickson (Western EcoSystems Technology, Inc. (WEST)), Ryan Anderson (Western EcoSystems Technology, Inc. (WEST)), Diem Pham (Western EcoSystems Technology, Inc. (WEST)), Karl Kosciuch (Western EcoSystems Technology, Inc. (WEST))

Abstract: The California Department of Fish and Wildlife recently responded to a listing petition for the western Joshua tree (Yucca brevifolia) and is reviewing the status as threatened under the California Endangered Species Act. To help inform this decision, Western EcoSystems Technology, Inc. (WEST) was tasked by several solar energy companies to examine existing data from solar facility field surveys to determine if an estimate of western Joshua tree abundance within its southern range could be calculated. WEST used digitized imagery to obtain counts of Joshua trees across the range and within project boundaries where existing field survey data was available. By quantifying the relationship between digitized counts and field data within solar projects, the digitized counts obtained from a

spatially balanced sample across the range will be used to obtain an estimate of the total number of western Joshua trees in the range by and across size classes. We discuss the statistical methods, scope of inference, and broader applications for this method.

Floating Photovoltaic Solar Energy: metrics for potential land sparing and wildlife interactions

Presenter: Alexander Cagle (University of California, Davis and Wild Energy Initiative, John Muir Institute of the Environment)

Authors: Alexander Cagle (University of California, Davis and Wild Energy Initiative, John Muir Institute of the Environment), Alona Armstrong (Lancaster Environment Centre, Lancaster University, Lancaster, LA1 4YQ, UK), Giles Exley (Lancaster Environment Centre, Lancaster University, Lancaster, LA1 4YQ), Steve Grodsky (U.S. Geological Survey, New York Cooperative Fish and Wildlife Research Unit, Department of Natural Resources and the Environment, Cornell University, Ithaca, New York, USA;), Jordan Macknick (National Renewable Energy Laboratory), John Sherwin (Florida Solar Energy Center, University of Central Florida, Orlando, FL, 32922), Rebecca Hernandez (University of California, Davis and Wild Energy Initiative, John Muir Institute of the Environment)

Abstract: Floating photovoltaic solar energy installations (FPVs) represent a new type of solar energy development that may potentially spare land needed for conservation and agriculture. Siting renewable energy installations on previously undisturbed lands competes with land for conservation efforts, a process which may be obviated by siting large solar photovoltaic installations atop human-made bodies of water, such as irrigation ponds, hydropower dams, and water treatment reservoirs. However, standardized metrics for quantifying the land sparing and resource use efficiencies of FPVs are currently underdeveloped. These metrics are critical to further understanding the impacts that FPVs may potentially have on wildlife and ecosystems. Here, we compared techno-hydrological and spatial attributes of four FPVs spanning different climatic regimes in California, Colorado, and Florida. We defined and quantified the land sparing and water surface use efficiency (WSUE) of each FPV. Last, we coined and calculated the water surface transformation (WST), using generation data at the world's first commercial FPV located at the Far Niente Winery in Napa, California. The terms 'water surface use efficiency' and 'water surface transformation' were purposefully developed to represent relationships between resources and capacity-based and generation-based FPV data, respectively, and to align with the prevailing preference of terminology for describing solar energy-land relationships ('land use efficiency' and 'land use transformation') based on a systematic literature review. We determined that the four FPVs cumulatively spared 59,555 m^2 of land and have a mean land sparing ratio of 2.7:1 m^2 compared to average ground-mounted utility-scale PV solar facilities. Mean direct and total capacity-based WSUE across the four FPVs was 94.5 ± 20.1 SD Wm^{-2} and 35.2 ± 27.4 SD Wm^{-2}, respectively. Direct and total generation-based WST at Far Niente was 9.3 and 13.4 $m^2\ MWh^{-1}\ yr^{-1}$, respectively, which is 2.3 times less area than average ground-mounted utility-scale PV solar facilities. Our results reveal diverse techno-hydrological and spatial attributes of FPVs, the capacity of FPVs to spare land for conservation, and the utility of the WSUE and WST metrics. This standardized set of FPV resource use efficiency metrics may better inform the siting and design of future FPVs to further optimize efficient use of existing water body surfaces and better inform FPV deployment decision-support tools. The alignment of these metrics with current ground-mounted solar energy-land relationship metric preferences also allows for the direct comparison of resource use efficiency of FPV installations to comparable ground-mounted PV installations. We conclude the presentation by relating our results on water surface transformation to potential impacts on wildlife and by describing a roadmap for future FPV research to further quantify environmental and ecological impacts.

Waterbird interactions with floating photovoltaic solar facilities: Considerations for conservation

Presenter: Jocelyn Rodriguez (University of California, Davis, Department of Land, Air and Water Resources, Davis, Ca & Wild Energy Initiative, John Muir Institute of the Environment | The Energy and Efficiency Institute, Davis, CA)

Authors: Jocelyn Rodriguez (University of California, Davis, Department of Land, Air and Water Resources, Davis, Ca & Wild Energy Initiative, John Muir Institute of the Environment | The Energy and Efficiency Institute, Davis, CA), Alexander Cagle (University of California, Davis, Department of Land, Air, and Water Resources, Davis, Ca & Wild Energy Initiative, John Muir Institute of the Environment | The Energy and Efficiency Institute, Davis, Ca), Steve Grodsky (U.S. Geological Survey, New York Cooperative Fish and Wildlife Research Unit, Department of Natural Resources and the Environment, Cornell University, Ithaca, New York, USA;), Tara Conkling (U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center, Boise, ID), Todd Katzner (U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center, Boise, ID), Sandor Kelly (University of Central Florida, Department of Biology, University of Central Florida Collection of Arthropods (UCFC), Orlando, FL), Rebecca Hernandez (University of California, Davis, Department of Land, Air and Water Resources, Davis, Ca & Wild Energy Initiative, The John Muir Institute of the Environment | The Energy and Efficiency Institute, Davis, CA)

Abstract: Floating photovoltaic solar energy (FPVs) presents an opportunity to mitigate climate change by shifting away from fossil-fuel based energy and sparing land for additional uses relating to the United Nations Sustainable Development Goals. However, the ecological impact of FPVs remains unknown. Of particular interest by decision makers and stakeholders is how FPVs may intersect with the ecology and habitat of water birds. Here, we use a literature review and preliminary field observations to identify seven key considerations for conservation by examining how FPV structures and materials may impact water birds. We report on observations made of water birds at FPV sites in Orlando, Florida and Napa, California over two seasons. We present the following considerations for FPVs and conservation: FPVs as novel aquatic infrastructure, the use of FPVs by birds, the potential impacts of FPVs on birds, the potential impacts of birds on FPV performance, siting considerations, the role of bird monitoring and surveys in environmental assessments at FPV, and potential long-term effects of FPV structures and materials across food webs. We used results from these methodological approaches to identify critical questions for future research and performed an expert survey to prioritize research needs. Understanding these considerations and anticipating future environmental concerns relating to FPVs may mitigate environmental degradation and biodiversity loss as this technology becomes a more prominent renewable energy source.

Monitoring Wildlife Responses to Pollinator Habitat at Solar Energy Facilities

Presenter: Lee Walston (Argonne National Laboratory)

Authors: Lee Walston (Argonne National Laboratory), Heidi Hartmann (Argonne National Laboratory), Lauren Jenkins (Argonne National Laboratory), Katherine Szoldatits (Argonne National Laboratory), Megan McGhee (Argonne National Laboratory)

Abstract: As more solar developments are being managed for solar-pollinator habitat, there is a need for monitoring projects to inform questions around ecological performance, scalability, and vegetation management. In this presentation, we complement previously-shared information on insect pollinator monitoring at solar energy facilities to discuss other ecological performance monitoring plans for terrestrial wildlife. For current DOE SETO funded research projects at several Midwestern solar facilities, we will deploy passive wildlife monitoring devices such as acoustic recorders, ultrasonic recorders, and

motion-triggered cameras to detect the presence of birds, bats, and other wildlife within the solar facilities. Our goal is to determine whether pollinator plantings established at solar facility test sites increase the diversity and abundance of wildlife over time as compared to control sites without pollinator plantings.

The use of passive monitoring devices for wildlife monitoring is becoming more widespread as the recorders have become cheaper and software and tools to accurately analyze the data are being refined and made available. This presentation will discuss the data types and analysis methods that will be developed, along with expected challenges and limitations. Acoustic recordings coupled with machine learning algorithms can provide an in-depth analysis of species diversity and abundance at solar sites. The *Kaleidoscope Pro* software by Wildlife Acoustics will be used to automatically recognize bird vocalizations in each recording. *Kaleidoscope Pro* uses a supervised clustering technique via Hidden Markov Models to detect similar vocalizations in a collection of recordings. This software gives us the capability to identify and group specific bird species at each site and their relative abundance. However, without video captures of each of these birds, this acoustic analysis approach limits us from identifying the number of birds of a given species that are present. With this approach, we are only able to calculate diversity as a function of the number of species that are present. We will also use the *soundecology* package in R to estimate Acoustic Diversity (ADI) for each of the recordings. The ADI is measured by calculating Shannon indices for each of the recordings. This is a general calculation, compared to the analyses possible in *Kaleidoscope Pro*, but will be beneficial to comparatively analyze the approximate diversity of each recording. This presentation will also discuss our plans for the analysis of data obtained from ultrasonic recorders and motion-triggered cameras.

Developing a Pollinator-Friendly Certification Program for Solar PV in Massachusetts

Presenter: Zara Dowling (UMass Amherst)

Authors: Zara Dowling (UMass Amherst), Dwayne Breger (UMass Amherst), River Strong (UMass Amherst)

Abstract: In the absence of experimental data, it can be difficult to determine appropriate criteria for designing pollinator-friendly solar PV facilities. In this presentation, we will provide an overview of the approach we took to designing and implementing a pollinator-friendly certification program for solar PV facilities in Massachusetts. We will include a description of the tools and documents developed to help solar developers and environmental consultants through the planning process, and common questions and concerns that arise. Massachusetts is unique in providing a financial incentive to solar facility owners who chose to establish certified pollinator-friendly habitat at their site, which has encouraged the development of pollinator-friendly solar arrays across the state. The establishment of these types of sites is quite new in Massachusetts, with the first facilities seeded in fall 2020; however, we will discuss goals for upcoming research once the sites have been established. This presentation should be of interest to those in states considering development of a pollinator-friendly certification program, or those who are considering updating existing programs and criteria.

Unmanned Aircraft Systems (UAS) and Light Detection and Ranging (LiDAR)/Camera Technologies to Detect Avian Events and Other Environmental Measures at Utility-Scale Power Plants

Presenter: Christian Newman (Electric Power Research Institute)

Authors: Christian Newman (Electric Power Research Institute), Arun Pandey (EDM International, Inc.), Richard Tennis (Southwest Research Institute), Michael Gerringer (Western EcoSystems Technology, Inc. (WEST)), Mikey Tabak (West)

Abstract: Monitoring and differentiating avian activity of concern at utility-scale solar facilities, such as collisions and associated fatalities, is challenging and costly because it relies on surveys of bird carcasses conducted by human observers. As the solar industry grows, technological solutions are needed as a solution for long-term and short-term monitoring. Technological solutions show promise to reduce environmental compliance monitoring costs and may also increase certainty related to whether solar facilities are having a significant impact on avian life. The Electric Power Research Institute (EPRI) received funding in 2020 to develop and validate two complementary, cost-effective remote sensing technologies to monitor avian fatalities at utility-scale solar facilities: fixed platform (Animal Activity Monitoring-AAM) and aerial-based (Unmanned Aerial System-UAS). AAM is a 2-dimensional camera-based monitoring system used for monitoring transmission lines for avian activity and recording video clips of the activity. This project will integrate LiDAR to enable 3-dimensional (3-D) avian detection and recording in order to identify potential collision events at solar facilities. UAS includes an unmanned aerial vehicle (e.g., UAV or drone), a sensor package (e.g., cameras), and software to fly the vehicles. This project will use these features with machine learning to automate the detection of avian carcasses and nests at solar facilities. The project team will concurrently deploy the two technologies at solar facilities to test in a field setting and compare them to human monitoring efficacy and cost. The project is a collaborative effort that includes EDM International, Inc. (EDM), Western EcoSystems Technology Inc. and Southwest Research Institute (SwRI) as well host site support from NextEra. The presentation will include an overview of the project as well as technical updates on the current efforts from the technology leads.

Plan for change: flux in the environmental regulatory framework and its implications for solar development

Presenter: Sarah Skigen-Caird (GEI Consultants Inc.)

Authors: Sarah Skigen-Caird (GEI Consultants Inc.), Lucy Harrington (GEI Consultants Inc.)

Abstract: The objective of this presentation is to illuminate the potential impacts of environmental regulatory changes on solar development and provide navigation tools for streamlining the permitting process. Whether contemplating development of a utility-scale solar power plant or installation of photovoltaics, both land use conversion and disturbance activities are frequently required. The physical modifications to the landscape for new facilities, including grading, vegetation removal, and distribution line establishment often comes with local, state, and federal environmental permitting requirements. The regulatory framework guiding these requirements is in constant flux, particularly during periods of administrative turnover. To better prepare for and navigate these changes, a well-formulated project execution plan (PEP) can help to identify regulatory obstacles early in the process to more effectively design and efficiently permit a site for solar development. This presentation will highlight relevant regulatory changes proposed for protected species covered under the Endangered Species Act, the Migratory Bird Treaty Act, the Bald and Golden Eagle Protection Act and various other state regulations on the horizon. We will also review revisions currently underway for state and federal jurisdiction of

wetlands and other waters. Recommendations as to how best to integrate and account for these changes within the PEP, and potential impacts for solar development will be discussed. Several alternative energy case studies will be presented with a focus on relevance to solar development in Colorado, New Mexico, and California. Additional information will be presented regarding wildlife and wetland mitigation pre-planning which allows for alleviation of regulatory requirements while providing environmental benefits throughout the project lifecycle.

OregonSmart Siting Collaborative: Engaging Oregon stakeholders and Tribes on interests and best practices for siting renewable energy to conserve wildlife, resources, and land use values

Presenter: Diane Brandt (Renewable Northwest)

Authors: Diane Brandt (Renewable Northwest), Mark Salvo (Oregon Natural Desert Association), Rupak Thapaliya (Defenders of Wildlife (former)), Josh Axelrod (Natural Resources Defense Council)

Abstract: The project team proposes to offer updates on an ongoing locally-driven and stakeholder-engaged effort that aims to develop consensus-based voluntary siting guidelines for wind and solar energy development in Oregon. Kicking off with a steering committee (SC) meeting in September 2021, this effort will engage a broader group of stakeholders as identified by the SC and project team to gather inputs on renewable energy siting best practices, concerns, and considerations. By December, the project team hopes to have preliminary inputs on areas of concern and emerging points of consensus on siting renewables in Oregon.

Oregon's ambitious renewable energy goals and legacy of strong conservation values make the siting and permitting of renewable energy facilities challenging and sometimes contentious. In an effort to find a path of least-conflict forward, a group of organizations - Renewable Northwest, Oregon Natural Desert Association, Defenders of Wildlife, and Natural Resources Defense Council - is convening a collaborative effort to develop voluntary guidelines for the siting and operation of renewable energy facilities. Facilitated by Oregon Consensus, an impartial body, the effort aims to engage a broad group of stakeholders from around Oregon to develop these siting guidelines over the coming months.
The project team believes that renewable energy development and conservation of wildlife and existing resources are not mutually exclusive, and that proactive planning and stakeholder engagement can help avoid, minimize, and mitigate impacts on natural and cultural resources, agriculture, forestry, and other fundamental public values. By engaging multi-sector stakeholders, including local communities and Tribal representatives, this effort aims to develop voluntary state-wide siting guidelines and best practices for renewable energy development in Oregon.

The potential value of these best practices and voluntary guidelines offers a collaborative way forward that acknowledges the value in protecting existing resources and activities while also allowing for progress towards clean energy goals. This proactive, stakeholder-driven approach offers the potential benefits of avoiding lengthy disputes resulting from community conflicts; greater awareness and consideration of community needs, values, and benefits; and generally protecting Oregon's natural and cultural resources while meeting its renewable energy goals.

Stakeholder engagement begins September and will continue until a consensus is reached drawing on a set of flexible operating principles. A smaller group of stakeholders, or steering committee, will help guide stakeholder outreach. Steering committee members were selected based on project team inputs, and feedback from initial interviews conducted in 2020 to gauge interest in the project - which was strong.

Using drones and AI for wildlife surveys: preliminary results detecting avian carcasses and desert tortoises

Presenter: Matthew Bandy (Resi Solutions)

Author: Matthew Bandy (Resi Solutions)

Abstract: Small unmanned aerial vehicles ("drones") and computer vision techniques ("AI") have the potential to revolutionize the field surveys used to evaluate project impacts on wildlife and their habitats. Hyperspatial image acquisition combined with AI object detection methods promises faster and safer collection of better data at a lower cost than traditional methods. Resi has developed a data collection methodology based on convolutional neural networks and commodity aerial platforms. This paper reports on a series of preliminary detection trials on two resource classes: avian carcasses and desert tortoise burrows. Trials were undertaken in appropriate environments in California, Nevada, Utah, and New Mexico. The AI-assisted aerial survey approach is compared to traditional pedestrian fieldwalking methodologies in terms of effectiveness (detection rates) and efficiency (level of effort). The results indicate that the drone/AI methodology is characterized by detection rates comparable to or even slightly better than traditional methodologies. The drone/AI methodology is also shown to be faster and significantly more cost-effective than legacy approaches.

Avian use of operational photovoltaic (PV) solar energy facilities in New York State and western Massachusetts – preliminary results and next steps

Presenter: Amanda Klehr (UMass Amherst and DNV)

Authors: Amanda Klehr (UMass Amherst and DNV), David King (USFS Northern Research Station and UMass Amherst), Kimberly Peters (DNV)

Abstract: According to recent reports, climate change impacts are some of the greatest threats to migratory birds; however, renewable energy has great potential for reducing those risks by mitigating greenhouse gas emissions. While the rapid expansion of ground-mounted, photovoltaic (PV) solar energy facilities across the U.S. may be beneficial to combat climate change effects, it requires modification of land cover that may affect its value as habitat for birds. Land modifications will likely result in habitat loss for some species, but there is also potential for solar projects to maintain or create new habitat for others. In the northeastern U.S., PV solar energy facilities are typically installed on agricultural land and forested and early successional habitats that were once farmland, many bird species associated with these habitats are in decline, and avian use of PV sites are currently unknown. We initiated a two-year research study in May 2021 to identify and document avian species and communities breeding at operational solar facilities and paired reference sites in New York State and western Massachusetts. As of September 2021, we have completed one year of surveys at nine operational PV solar sites and paired reference sites across New York and western Massachusetts. Although there was much variation among facilities, preliminary results indicate that many passerine species were more abundant at the PV solar facilities compared with the paired reference sites, particularly the reference sites that were mowed in early June or regularly maintained by grazing livestock. Species richness also differed between solar sites and the paired reference sites, with more species observed at solar facilities in grassland and agricultural lands, whereas more species were observed at reference sites in shrubland and forested habitats. Some species were recorded nesting on structures or on the ground within the solar facilities. A second year of surveys will be completed in 2022. Our research will help to inform future PV siting decisions and spatial planning, and to identify effective management practices that will improve benefits to birds while reducing potential negative

impacts from PV solar energy development in the northeastern U.S.

A Smart Solar Approach: Managing for Soil Health and Vibrant Farming Communities

Presenter: Ethan Winter (American Farmland Trust)

Author: Ethan Winter (American Farmland Trust)

Abstract: American Farmland Trust's presentation by Ethan Winter (Northeast Solar Specialist) will highlight AFT's Farms Under Threat report and summarize principles and goals guiding AFT's work on smart solar siting, including research, state-level analyses, and policy considerations for dual use solar. A well informed, holistic approach to solar energy siting, project design, operations and decommissioning can minimize or even eliminate the impact of a renewable energy facility on farmland, and thus increase net environmental benefits. One potentially promising way to minimize trade-offs and optimize land use efficiency is through "dual-use" solar installations. Such projects are developed and designed to integrate modified solar arrays with active farming operations on the same ground (also referred to as agrivoltaics).

Done right, solar energy facilities can offer a means to provide additional financial support to farmers and ranchers in a way that doesn't replace agricultural production, but rather, complements it. AFT believes that dual use solar installations have the potential to generate solar energy at the same time that they maintain viable agricultural operations, enhance conservation practices, and retain farmland for both current and future use.

This effort also dovetails with and enhances upcoming Farms Under Threat research results, which models where new development will convert agricultural land between now and 2040. When this analysis is complete, AFT will have the ability to identify which lands are most important to protect from development, both for wildlife habitat and for agricultural production.

The Solar AquaGrid Initiative

Presenter: Robin Raj (Solar AquaGrid)

Authors: Robin Raj (Solar AquaGrid), Jordan Harris (Solar AquaGrid), Roger Bales (University of California, Merced), Brandi Kuhn (University of California - Santa Cruz)

Abstract: A recent study conducted by researchers from UC Merced and published in Nature Sustainability reports that covering the 4,000 miles of California's open water canals with solar panels could reduce evaporation and save upwards of 63 billion gallons of water annually, while providing the state approximately 13 gigawatts of renewable power. The study also exposed numerous compounding advantages to be gained including increased panel efficiency; GHG mitigation; reduced aquatic weed growth and maintenance costs; utilization of already disturbed lands; integrated energy storage; and new market opportunities through RECs and EV charging station adjacencies – all in an effort to accelerate California's climate targets. This panel will feature the authors of the study and the social entrepreneurs behind the initiative as they discuss plans for the first pilot project in the Central Valley and their efforts to make this a new model for public private collaboration.