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Impacts of Onshore Oil and Gas Development: Managing Societal and Environmental Risks

Center for Strategic & International Studies

Over the past decade, tight oil and shale gas output in the United States has rapidly risen from next to nothing to account for the majority of U.S. oil and natural gas production. A critical component for prudently developing these onshore resources relates to addressing concerns regarding societal and environmental risks. Three such fundamental concerns include efforts to:

- Protect and manage water resources
- Reduce methane emissions
- Monitor and manage induced seismic events

Given these concerns, the Center for Strategic & International Studies (CSIS) held a workshop focusing on determining how well industry, local and state regulators, and the federal government are managing these risks, sharing best practices, and effectively mitigating any adverse outcomes related to U.S. onshore production. The role of technology and the effectiveness of both regulatory change and operational best practices were also examined. This workshop built upon previous research conducted by the CSIS Energy and National Security Program and published in a 2013 report *Realizing the Potential of U.S. Unconventional Gas Resources*. In the five years since that report was written the process of producing shale gas and tight oil resources has changed in several important ways driven by the desire to reduce cost, improve well productivity and recovery, and manage the environmental and social impacts of production. Key takeaways include:

This report provides highlights from a one-day CSIS workshop held April 26, 2017, with government, state regulators, industry, and policy experts exploring ongoing efforts to minimize and manage upstream environmental, health, safety, and societal risks associated with U.S. onshore oil and gas production.

Water

- Water resource availability and conditions vary widely and regionally. States and local communities have made advancements in regulation to protect local water resources—although the regulatory environment is still not uniform, as is the data collection with respect to spills.
- Companies have made advancements in the chemistry and processes around reuse of produced water in drilling operations to reduce overall water consumption, but economic and logistical challenges still exist.

Methane

- Certain states and companies have taken leadership roles in measuring and managing methane emissions, but for a variety of reasons not all companies and states prioritize methane capture to the same extent.
- More data is needed to understand the stochastic nature of methane releases and determine how best to ensure that emissions capture from oil and gas operations is improved.

Seismicity

- Seismic risk is a function of both geologic conditions and operational practices. In these states that have prioritized reducing induced seismic events, diagnostic tools and regulatory and other best practices have combined to reduce the incidence of induced seismic events from water disposal and hydraulic fracturing.
- Not all states and companies take the same approach to managing induced seismicity issues and

problems tend to arise when heightened activity takes place near fault zones.

Societal

- Companies and local communities are still grappling with how to achieve optimal resource development while minimizing adverse effects on local communities.
- Service companies, by virtue of the cross-cutting role they play, can often facilitate technology transfer and improve operational practices across basins, but achieving a basin or communitywide solution is often complicated.
- Despite operational and technological progress, failure to manage these issues effectively will continue to create public concern for onshore oil and gas development.

Oil and Gas Development and Water Resources

The management of water resources utilized in developing onshore oil and gas reserves has become a key concern for fundamentally obvious reasons. Primarily these concerns relate to the fact that fresh water sources support our entire ecosystem and in turn the continued functioning of the economy. Concerns have also arisen for less obvious reasons related to the sourcing of available water, transport, storage, the impact that the use of water has on local communities, recycling, treatment, reuse, disposal and, in some areas, the link between disposal and induced seismicity.

Hydraulic fracturing is a water-intensive way to produce oil and gas, but water quantity and access issues are highly dependent on the local environment.

Today, hydraulic fracturing processes use approximately 1000 gallons of water per linear foot of horizontal well. An average of 5–6 barrels of water is used for every barrel of crude oil produced; however, in certain cases, use can be as high as 30 barrels. Due to the location and concentration of the wells, this use of water in the hydraulic fracturing process can have a significant impact on the water cycle, leading, in some geographic locations, to significant losses in typical surface water cycles.

The overall use of permitted water withdrawal by the industry has continued to fall since the shale boom began, but withdrawal is becoming concentrated.

While these figures represent large volumes of water use, hydraulic fracturing represents a small amount of overall freshwater use. During the height of the shale boom, 20 percent of permitted take of water was utilized by the industry. Taking into consideration the declines in drilling activity in 2016, along with the strides made in several states to recycle water, the total withdrawal of permitted water use is estimated to be below 5 percent. That said, with the move to longer laterals (current frack lengths are now in the 12,000- to 15,000-foot range), a single well today is effectively three to five times the size of those when the shale boom began (though the number of wells in terms of surface footprint has declined); the use of water, especially within particular regions, is therefore becoming more concentrated. Ten years ago a typical frack job utilized some 3–5 million gallons per well. However, with the longer laterals being drilled, we are now typically seeing 12–15 million gallons per well and in certain cases this figure can be as a high as 25 million gallons.

In Texas, hydraulic fracturing accounts for only 0.5 percent of total state water use. However, with the majority of wells concentrated within confined regions of the Eagle Ford and the Permian, water usage is a decidedly more local issue. In the Eagle Ford (South Texas), drilling activity in some counties accounts for over 50 percent of total water use. For regions that are arid or have experienced recent droughts, the issue of use and reuse of water becomes a larger concern.

Recent U.S. Geological Survey (USGS) studies suggest that unconventional oil and gas development is currently not a significant source of contamination of fresh water sources.

Apart from the effects that sourcing water can have on the local and regional water cycle, another key concern is related to the possible contamination of freshwater sources. This includes brine spills, as well as how waste water produced from the hydraulic fracturing process (which often contains chemical fracturing fluids, stray gas, and leaks from casings) is handled, treated, and ultimately effectively and safely disposed of. Prevention of contami-

nation to ground water aquifers from drilling operations can be managed through proper well design, casing, and ensuring well integrity. Regulation and industry protocols have worked to incorporate best practices in this regard, but high-profile incidents of groundwater contamination still influence public perception of the effective management of this issue.

Options for treating, recycling, and reusing water make sense in certain places but obstacles exist.

Concerns related to fresh water availability, as well as costs associated with disposal, have led some producers to increasingly look for economic ways to treat, recycle, and reuse water or find alternatives to water for fracking operations. The reuse of water in certain circumstances can reduce the level of community impacts, and may also represent an opportunity for cost reductions by operators. However, where ample amounts of water are available, there are often compelling economic reasons why recycling is unpractical. First and foremost, as alluded to earlier, the overall use of water in fracturing is small when compared to availability of the resource in most regions. Furthermore, in the United States, mineral rights are privatized and so it is often the case that the sale of water represents a significant source of income for surface owners. Probably the most significant barrier to increased use of recycled water, however, is that operators face economic and logistical challenges, with filtration and retreatment processes often required before reuse can occur, meaning that for certain operations, treatment, recycling, and reuse is significantly more expensive than simply sourcing new water. However, at the back end, limited or costly disposal operations can also serve to encourage recycling. The increasing level of evidence tying waste water disposal, under certain conditions, to induced seismicity may also serve to encourage greater levels of recycling.

Where economically feasible, it is important that the reuse of water is encouraged in the hydraulic fracturing process to minimize impacts on freshwater sources, particularly in those regions prone to drought.

In some areas of the country treatment is economically viable, especially when the water has sufficiently low levels of total dissolved solids after it is utilized in the fracturing process, thus allowing for reuse by

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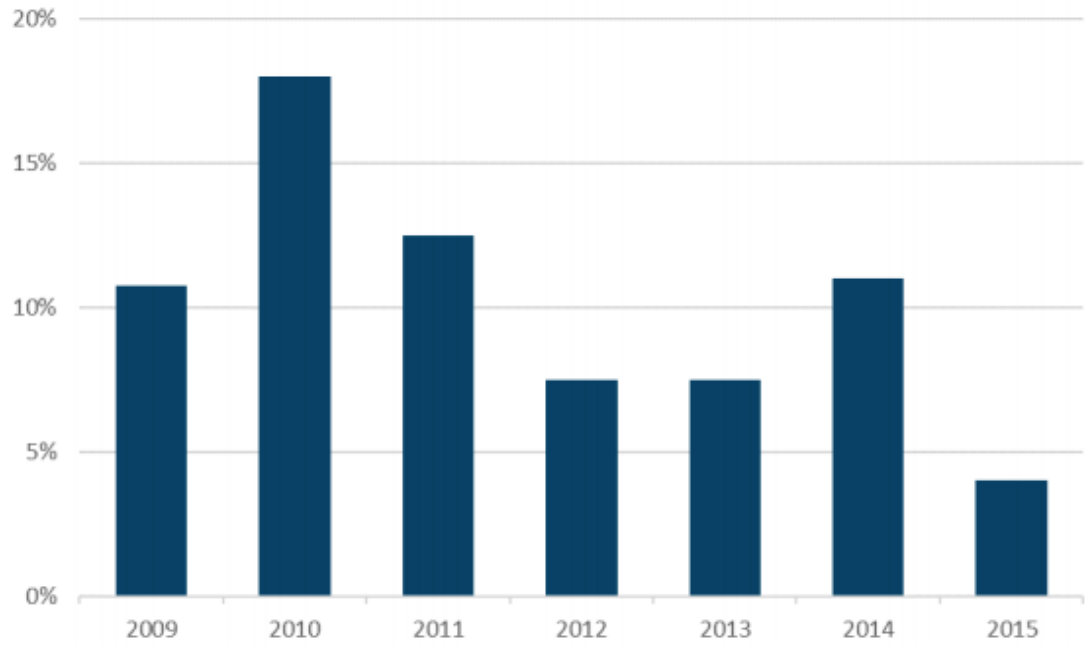
the operator or by other sectors. In those areas, treatment and reuse is more likely to be adopted to minimize the disruptions on the water cycle and to reduce the levels of freshwater use. Where it is not possible, permitted Class II injection wells are used. As discussed in the final section, the wells can be monitored and regulated for seismic proclivities and operational practices to minimize seismic risk. A reduction in the use of freshwater by the industry may help to reduce the level of perceived risks associated with the effects of proximity and intensity of drilling. One study showed that in areas where water wells provide fresh water to residents, there is a correlation between lower property values and proximity to heavy drilling operations, leading the researchers to identify a concern over groundwater contamination, although factors such as noise pollution and congestion may also affect values.

As the reuse of water continues to rise within the industry, it is important that related issues such as spills and leaks continue to be addressed.

Recycled water use is on the rise and is becoming more and more feasible as new methods are developed to address high-salinity water, and as portable technologies are advanced, which help to alleviate logistical issues. Cost is once again the primary barrier to reusing produced water (due to salinity, contaminants, etc.) but increasingly the economics make sense. The increased use of brackish water is particularly important in those regions prone to drought. For example, fracturing operations in the Mississippian Lime now use 100 percent produced water because of the highly arid region and the high probability of drought. It should be noted, however, that the increased use of brackish or produced water gives rise to other issues that need to be addressed including the need for segregated storage, handling, and transport. In such instances, increased use of brackish water can also lead to a rise in contaminated water spills and leaks. The reporting standards in place for addressing issues related to contamination and spills vary between states, which complicates the process of monitoring root causes and identifying sources on a national level. The reporting of brine spills standards has a one-barrel threshold in North Dakota, but in other states, such reporting standards are set at a higher threshold. Consequently,

Water Withdrawals of Total Permitted Withdrawals



Center for Strategic and International Studies | Energy and National Security Program
Source: Adapted from Resources for the Future (May 2017)

there are concerns that the precise scale of the spill problem is not well known.

As development continues, water transportation and logistics also present challenges.

Another major issue that requires further attention is that of transportation. In certain basins of the country, there is a need for backbone infrastructure to support the transport and storage of large volumes of water. However, this often runs into difficulties even in the areas where this is warranted because there are no eminent domain rights for water infrastructure. In some cases, specific areas would benefit from "basin wide" planning practices in terms of water sourcing, transport, storage, recycling, and use. Such efforts, however, are often frustrated by the sheer number of producers, drillers, and wells. This partially leads to habitat fragmentation and exacerbates the overall problem concerning the need to more effectively monitor the use of water and incentivize efficiencies in its use.

Regulators and operators have stepped up efforts to improve water protection and management, but heterogeneity persists.

While all parts of the water cycle are regulated, the standards vary between jurisdictions (quite considerably in some cases) based on water availability and infrastructure. The issue is primarily addressed at the state level and so permitting standards with respect to water withdrawal and reporting of brine spills vary along with the likes of pre-drilling water testing, fracture fluid disclosure requirements, casing and cementing depth regulations, and pit regulations to name but a few.

The advancement of technology and new chemistries is continuing to make the reuse of water a more viable option for the industry.

In an attempt to mitigate adverse impacts on the water cycle, some industry operators have sought to deploy best practices. While extended laterals have increased the use of water per well, several operators have significantly enhanced their efficiency of use. As technology continues to advance, reducing surface impacts through increasing the reuse of water is becoming more economically viable. Furthermore, several operators have developed new techniques to work with high-salinity water, which is also allowing for greater reuse. As operators further develop these technologies and techniques, an emphasis has also been placed on monitoring the movement of water and reducing risks of spills. However, this practice is not uniform across the industry and so measures encouraging further uptake in these activities are important.

Managing and Reducing Methane Emissions

As U.S. onshore oil and gas production has risen over the last decade, with increased climate-related concerns, the issue of managing methane emissions from the oil and gas sector has become a concern for regulators and operators alike, as the industry now accounts for approximately one-third of total methane emissions. Methane is emitted not just in the exploration phase but all along the oil and gas supply chain, with over a third of emissions associated with processing, distribution, transmission, and storage. However, the scope and stringency of methane regulation or industry management are still subject to questions and opinions, which vary on the reasoning for reducing methane emissions as well as the potential cost implications of doing so. As such, regulation of methane emissions is still an open question for many within the industry. For some producers, the added cost of managing methane emissions is not worth the expense. For others, reducing methane is worthwhile because of the economic incentive and concerns related to reputational damage of the industry, as well as the role of natural gas as a "transition fuel" if emissions are not effectively managed along the value chain.

Reducing methane emissions is important for both environmental and economic reasons.

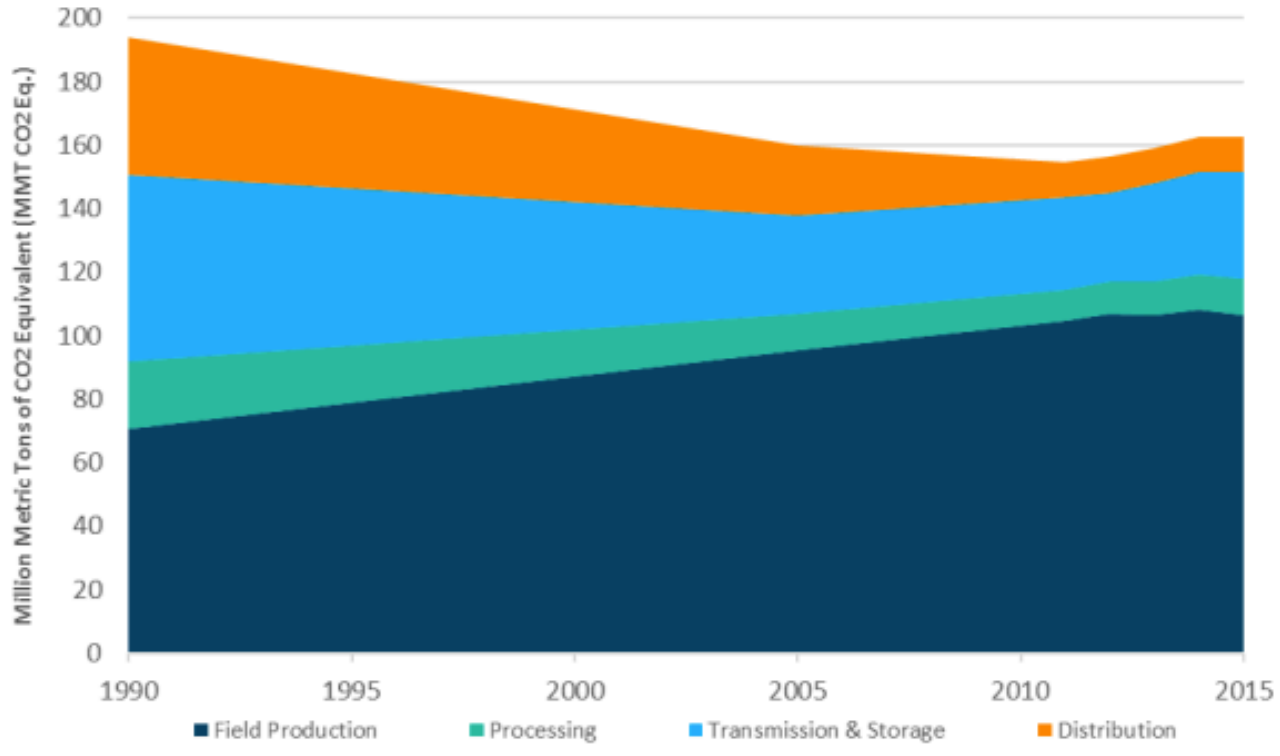
Concern over methane emissions first arose in relation to safety, and more recently in connection with climate change. While methane has a much shorter half-life then carbon dioxide, it is a more potent greenhouse gas (and accounts for approximately 15 percent of anthropogenic greenhouse emissions globally). As U.S. oil and natural gas production has risen, the United States has also made significant strides in reducing greenhouse gas emissions. While fugitive methane emissions are

viewed by many as an environmentally harmful side effect of oil and gas production, this methane is the same natural gas that producers are trying to develop and sell. Consequently, one of the leading economic justifications for reducing methane emissions is that oil and gas companies would generate additional revenue by capturing more of the resource they are developing. This is an important point for those who reject the environmental reasons for capturing methane emissions but take a conservation minded approach to resource development.

Regulatory measures and new monitoring technologies have made strides in recent years.

With increased levels of data through improved monitoring, recent EPA studies now suggest that emissions from oil and gas operations are greater than originally thought. In fact, lack of data is part of the reason that methane management languished as an issue. Despite this uncertainty (discussed below) new federal rules under the previous administration and pilot projects to test diagnostic technologies have set a new course of action for monitoring potential emissions and the operationality of new oil and gas infrastructure. Several states have also individually risen to the challenge by implementing their own comprehensive frameworks to reduce emissions. These include California, Colorado, Ohio, and Pennsylvania. Finally, at the international level the United States has committed, along with Mexico and Canada, to cut methane emissions from the oil and gas industry by up to 45 percent below 2012 levels by 2025. However, some of the federal regulations set forth by the Obama administration are currently under review by the Department of Interior and the Environmental Protection Agency to ensure that they do not unduly impede the development of domestic energy resources. In fact, the EPA has already implemented a stay on portions of the 2016 New Source Performance Standards for the oil and gas industry, which included methane emission standards.

U.S. Methane (CH4) Emissions from Natural Gas Systems, 1990-2015



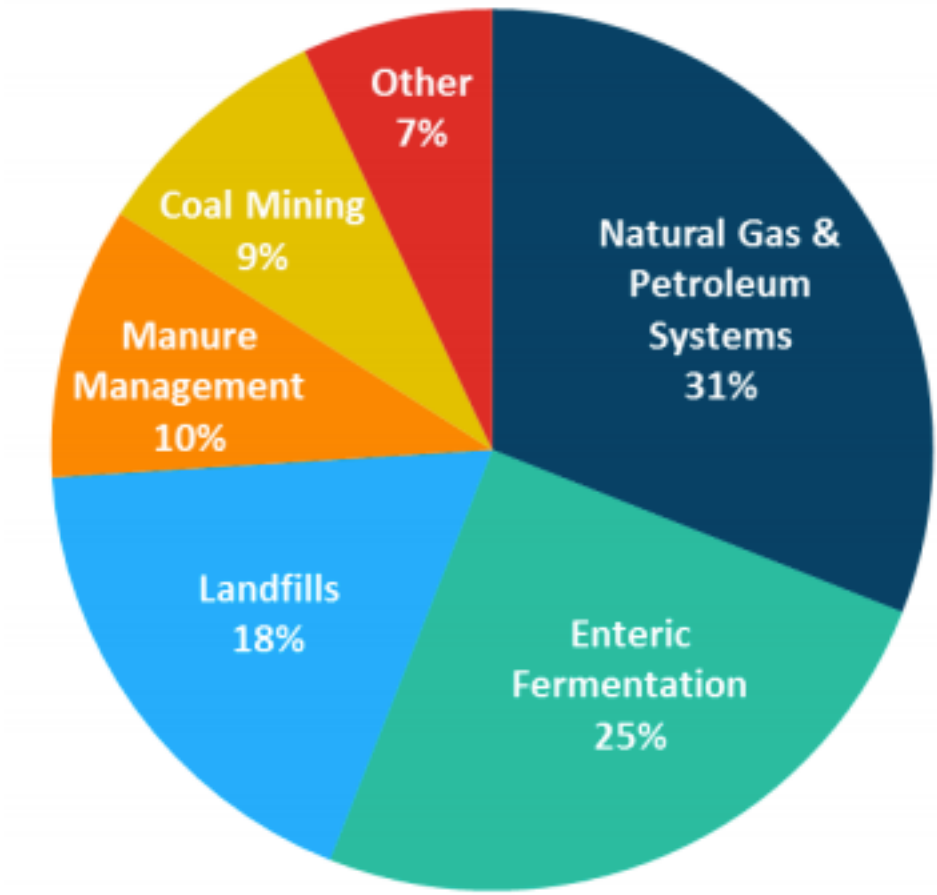
Center for Strategic and International Studies | Energy and National Security Program
Source: Adapted from U.S. Geological Service Data (May 2017)

Some industry players are acting to address methane emissions, but better data can improve these efforts.

Recognizing the intent for regulation to reduce methane emissions as much as possible, some operators appear to be meeting or exceeding the standards required of them by deploying further means to tackle this issue. As a result, we are increasingly seeing voluntary efforts being made by operators to deploy upstream leak detection and repair programs, as well as upgrading or replacing equipment to ensure reductions. Other steps include measures to continuously improve their understanding of operational emissions, to further engineer vented emissions out of facilities and processes, to improve methods utilized in locating fugitive emissions and fixing leaks, to partner with midstream operators for efficient gathering and processing, and to further innovate for economic solutions. In fact, several operators have already actively engaged with the Department of Energy (DOE) to collaborate on improving measurement and have taken further proactive steps toward mitigating root causes. These strides in deploying the measures have not only been made to gain first-mover advantages, but have also come as a result of the issue being increasingly viewed as one of waste, with the capture of methane becoming more economically viable as technologies advance (even with lower prices).

The nature of the problem of methane emissions in the oil and gas industry today is a stochastic one, with a small group of

U.S. Anthropogenic Methane Emissions by Sector in 2015



Center for Strategic and International Studies | Energy and National Security Program
Source: Adapted from Environmental Protection Agency Data (May 2017

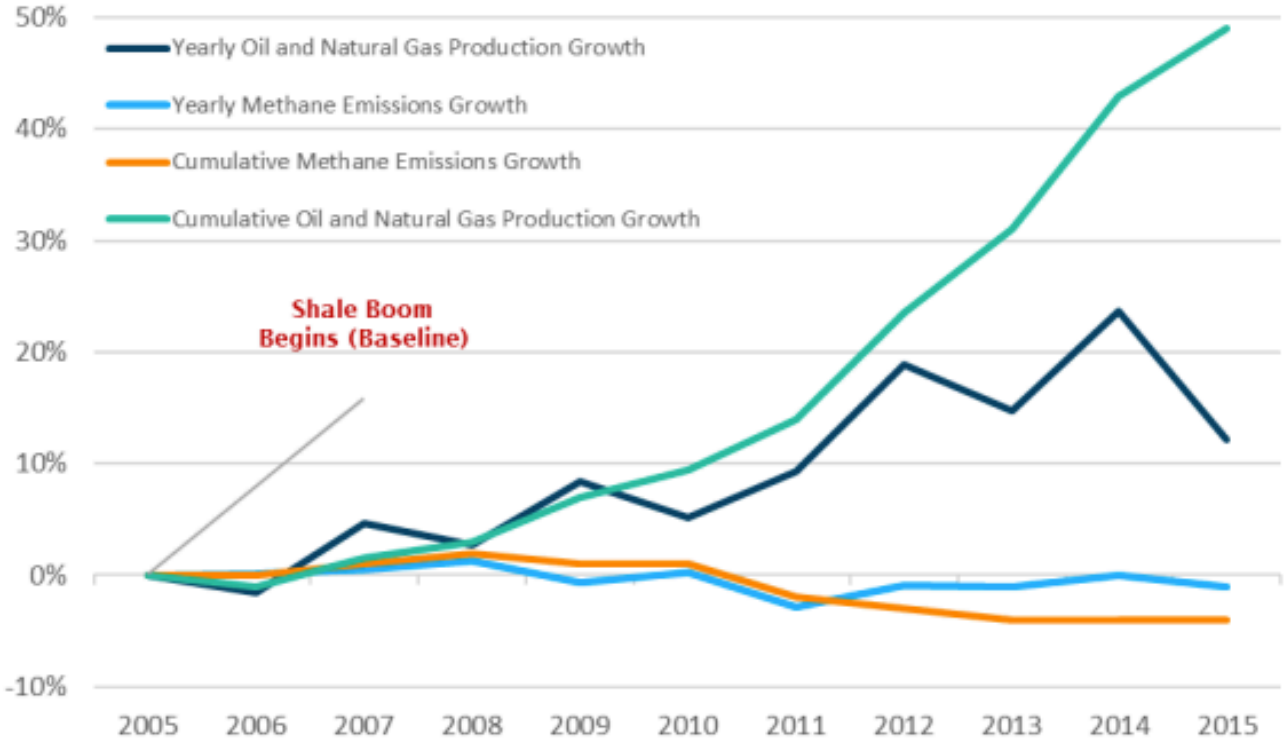
operators accounting for the bulk of emissions.

With a small number of operators accounting for a significant proportion of emissions, it has been suggested that the focus of further regulation should be solely directed toward eliminating those "super emitters" in the industry. While useful, this approach may or may not be effective in preventing new emission sources from cropping up. Alternatively, some commentators have suggested that if it is economic to capture methane emissions, then the industry will eventually adapt toward engaging in this activity and self-regulate. The counter argument here, however, is that in the absence of effective regulation, "better economics" alone will not guarantee capital deployment to reduce waste.

More data can improve mitigation techniques and avoid a "can't manage what you don't measure" situation.

An increasing number of studies examining this issue point to the importance of improved data collection and analysis to effectively address the challenge of methane emission reduction. With incomplete data, emissions may be going unaddressed. As such, cooperation and collaboration with the Department of Energy by all players involved in the market is of critical importance to improve the quality of data. Furthermore, many are now calling for operators to focus their efforts on developing more preventative, predictive, and ultimately proactive maintenance measures, to install corrective actions aimed at tackling root cause failure. Adopting these approaches could represent a more cost effective means of tackling emissions rather than relying on reactive or remedial action. As such, calls have been made to further efforts to encourage the development and use of new technology and practices in addressing this challenge, while also enforcing regulations set at the federal level to set a minimum standard for late adapters.

U.S. Oil and Natural Gas Production and Methane Emissions Growth, 2005-2015



Center for Strategic and International Studies | Energy and National Security Program
Source: Adapted from Energy Information Administration and Environmental Protection Agency Data (May 2017)

While U.S. natural gas production has risen by over 50 percent since 2005, overall methane emissions have fallen. Nonetheless there are still significant opportunities for further reductions to be made.

Despite the enormous rise in production of natural gas, methane emissions from natural gas systems specifically have risen by less than 2 percent from 2005 levels when the shale boom began. Some of the lowest-cost opportunities to reduce methane emissions are found in the oil and gas industry. Due to the stochastic nature of the problem, individual episodes can alter the trajectory of emissions reduction; and as emissions occur at multiple stages along the value chain, there appears to be ample room for improvement.

Managing and Reducing Induced Seismic Events

Since the onset of the unconventional oil and gas revolution over a decade ago, the rate of seismic activity has increased in several producing states, most notably in Oklahoma. Induced seismicity falls into three main categories of activity: injection based, geothermal based, and depletion based. Induced seismic activity caused by the development of onshore oil and gas falls into the injection based category, where large amounts of water are pumped underground in the production and postproduction waste water disposal phases of development. The injection of water leads to increased levels of fluid pressure below the surface and can alter subsurface stresses, which in turn can produce seismic activity in areas where preexisting fault lines lie. In the central United States, the number of earthquakes of level 3 magnitude or greater has risen from less than 50 in 2008 to over 1,000 in 2015, with nearly 3,000 earthquakes of level 3+ magnitude recorded in total from 2009 to May 2017. As such, the impacts of onshore oil and gas development in terms of induced seismicity have become, for a number of communities, a major area of concern.

The evidence now indicates that induced seismicity is primarily, but not solely, a water disposal issue.

While there are examples of the process of hydraulic fracturing itself, under certain conditions, inducing seismic activity, a growing body of evidence consistently suggests that the primary cause of induced seismic activity in the United States has been related to the practice of injecting saline waste water into disposal wells. As such, the consensus now is that induced seismic activity in the oil and gas industry of magnitude 3 and above is primarily linked to water disposal operations. The reason is that waste water wells typically operate for longer durations and inject greater volumes of fluid than the process of hydraulic fracturing itself. Waste water wells are typically located at deep levels, where sandstone or other porous formations are found, which when combined with these large quantities of salt water over an extended period of time in areas where preexisting fault lines lie can cause induced seismicity. As such, induced seismic activity from waste water disposal is not an issue that is entirely unique to the hydraulic fracturing business, but rather a general issue for the oil and gas industry as well as other activities that involve disposing of large volumes of waste water under pressure.

Oklahoma has now surpassed California as the most seismically active state (in terms of the number of earthquakes of 3+ magnitude) in the lower 48 because of the dramatic rise of induced seismic events from increased waste water disposal.

There are over 35,000 salt water disposal wells in the United States and up to a million barrels a month are injected into some of these wells. In some cases, this activity has been going on for years. That said, the incidence of seismic events nationwide is actually quite small with recent activity concentrated in only a few areas of Oklahoma, Ohio, Colorado, and California. In fact, most induced seismicity is now occurring in Oklahoma, with 90 percent of the over 1,000 earthquakes that occurred in central United States in 2015 being accounted for by that one state. Before 2009 Oklahoma was a relatively quiet zone in terms of seismic activity but it is now one of the most seismically active regions in the world. The rise in the number of earthquakes in Oklahoma caused by waste water injection was particularly dramatic because of the geology of the region, where the Arbuckle rock formation is found.

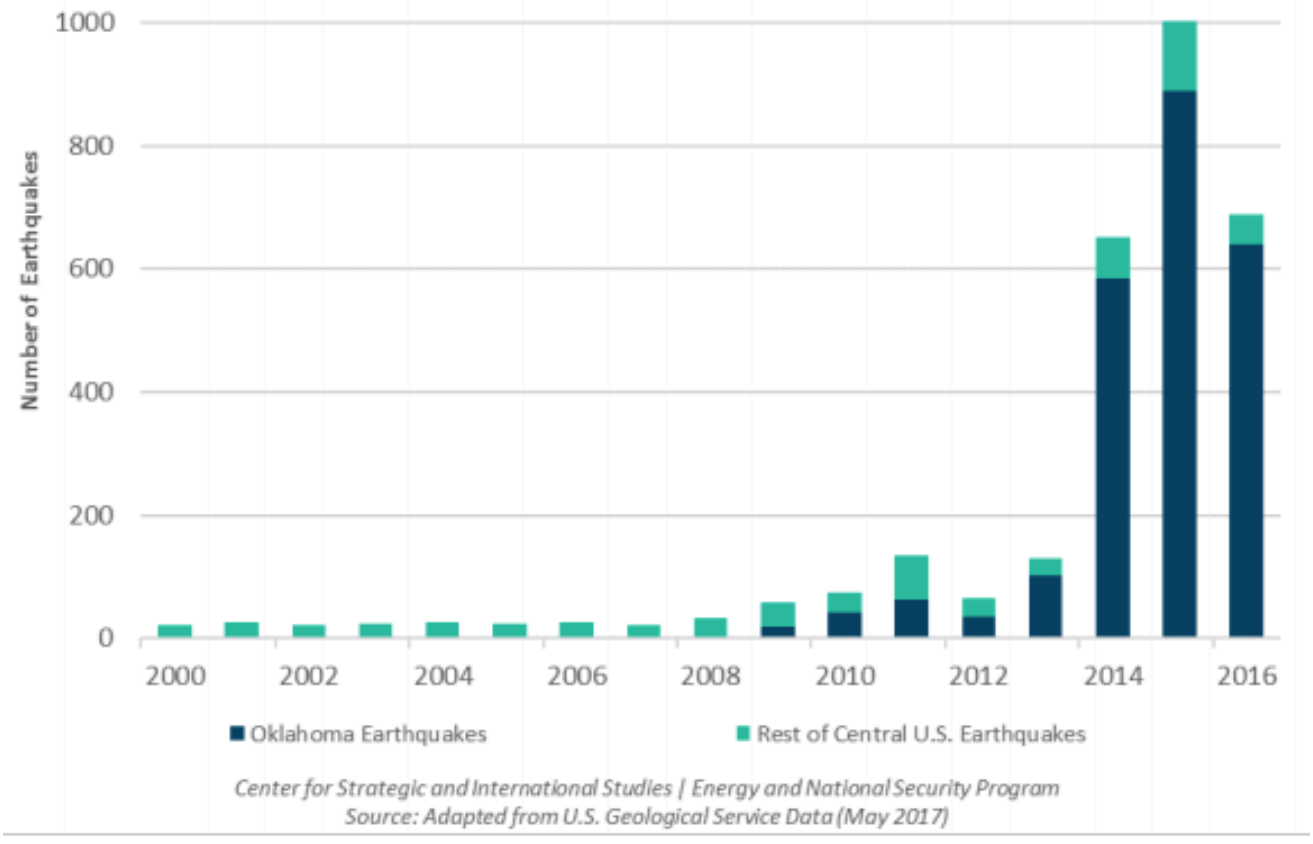
Given the differences in subsurface conditions and oil and gas operations, states are taking the lead in managing induced seismicity issues.

The upsurge in Oklahoma's seismic activity prompted state policymakers and regulators to act to address the attendant concerns. In 2015, Governor Mary Fallin requested that the industry make voluntary cutbacks in waste water injection activity. But it was the 5.8 magnitude earthquake in Pawnee (September 2016) that triggered the issuance of emergency orders for cutbacks in waste water disposal. The earthquake rate has since fallen by approximately 30 percent from 2015 to 2016, due to the combination of the decline in activity following the oil price collapse and the requested cutbacks. Induced seismic activity has continued to decline in 2017. However, three of the four magnitude 5 and above earthquakes since 2009 occurred last year. Furthermore, despite the continuing decline, the earthquake rate is still estimated to be at level far beyond historical averages, and local community as well as insurance industry concerns are growing.

While most of the recent induced seismic activity in the United States has been occurring in Oklahoma, it is not entirely confined to this region. Another example where induced seismic events have occurred is Colorado, where seismicity has increased primarily due to the rise of activity in Paradox Valley, the Raton Basin, and Greeley. While an induced sequence of seismic events in Greeley began in 2013, regulatory action appears to have reduced the rate of events. However, two 5+ magnitude earthquakes have occurred in the Raton Basin alone since 2005 and regulatory actions have yet to be taken to directly tackle this issue. Another state where induced seismicity has occurred is Ohio. The Ohio Department of Natural Resources has, however, been very responsive in taking action to address the issue by introducing permitting conditions for injection wells and has heavily invested in monitoring diagnostics and early warning systems.

Ohio represents a case in point where early intervention and proactive measures have likely led

Magnitude 3+ Earthquakes in Oklahoma and Rest of Central United States, 2000 – 2016



to cost savings and reduced public concerns surrounding induced seismicity.

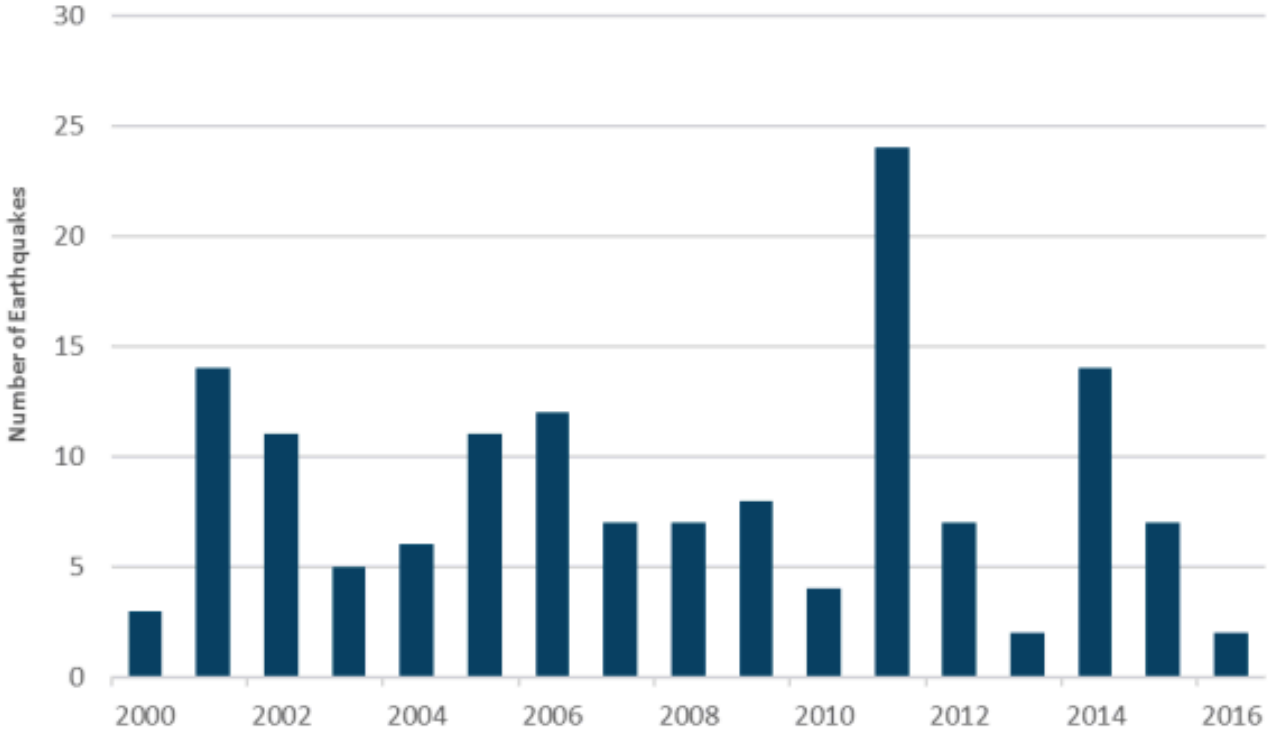
In Ohio, Governor John Kasich set a goal that no more injection-related seismic events should be felt and so regulators devised a system to achieve that objective. The state now maintains a real-time information system that monitors seismicity, traceable to individual wells. The data is used to alert companies if their operations are found to be inducing seismicity. If operators do not adjust their activity accordingly, operations will be shut down until they can figure out the root cause and address the issue. The investment that Ohio has made in implementing the infrastructure necessary to monitor seismicity, as well as the implementation of strict standards has likely saved the state considerable time, money, and public angst by tackling root causes before they became serious issues like those seen in Oklahoma.

An increasing number of states are now considering or have already enacted regulations to address seismic concerns. These include Oklahoma, Kansas, Ohio, Texas, California, Arkansas, and Colorado. To facilitate this process, USGS and the Environmental Protection Agency (EPA) have published guidelines surrounding the key risks associated with induced seismicity, which include total volume of water injected, the rate of injection, the depth of injection, the proximity of the injection to faults, and conduits to crystalline basement rock. The EPA guidelines, along with the efforts by the USGS in this area (with their earthquake monitoring and statistical analysis) are helping regulators and industry alike to better mitigate risks of inducing seismic activity.

In some regions, industry is working with regulators and academia to better understand regional seismicity and improve practices.

Some operators are making strides in minimizing risks associated with induced seismicity, often going be-

Magnitude 3+ Earthquake in Colorado, 2000 – 2016



Center for Strategic and International Studies | Energy and National Security Program
Source: Adapted from U.S. Geological Service Data (May 2017)

yond the remits of state legislation in developing diagnostic techniques and deploying best practices. For example, several operators have teamed up with TexNet Research and the Center for Integrated Seismicity Research (TexNet – CISR) to collaborate on detecting, cataloging, and characterizing seismicity in Texas. This has helped operators to understand fault-triggering mechanisms in the state and to mitigate risks associated with their activity. This partnership has also allowed for the seismogenic potential of basins in the state to be assessed. This assessment can then be factored into an operator's decision whether to engage in activity in that area. This partnership has also invested in research efforts to improve fluid disposal operations and to better communicate data, knowledge, and risk. This is just one example of a number of ongoing initiatives in the industry that should be further encouraged to help minimize induced seismic hazards and mitigate risks.

In a similar fashion to the water and methane issues outlined earlier, the collection and monitoring of data along with prescriptive and performance-based standards is of key importance to address root causes before they become major issues that have potentially dangerous implications. The need for effective monitoring of data as well as regulatory standards in producing regions is becoming increasingly important as the industry enters a period where global oil and gas markets are rebalancing. With the recent price increase, a rise in activity levels of onshore oil and gas development has already been recorded across U.S. basins and so the risk of increased levels of induced seismicity has also risen. Consequently, it is important that standards or best practices be adopted to mitigate this risk.

Conclusion

This note examined a limited set of environmental, health, safety, and societal concerns associated with onshore oil and gas development in the United States. The risks associated with properly managing water resources, fugitive methane emissions, and induced seismicity in the development of onshore resources are at the forefront of these concerns. With the onset of the shale revolution over a decade ago, addressing the risks associated with each of these areas has markedly improved from when the boom began, thanks to state and federal regulations, as well as the initiative of certain operators within the industry. While progress has been made, in certain areas of the country issues persist while other associated risks within these areas have arisen as production continues to increase. Furthermore, the areas of water, methane, and induced seismicity represent only three such risks of overall environmental, health, safety, and societal concerns associated with onshore oil and gas development in the United States. For these reasons, continuous improvement in efforts of data collection and the monitoring of this data, as well as continued research efforts, are critical components in ensuring that issues are effectively identified and addressed in a timely and effective manner by regulators and operators alike in order to ensure the prudent development of these onshore resources.

Wind Turbine Interactions with Wildlife and their Habitats: A Summary of Research Results and Priority Questions

American Wind Wildlife Institute

Wind energy's ability to generate electricity without carbon emissions is expected to reduce the risk of potentially catastrophic effects to wildlife from unmitigated climate change. Wind energy also provides several other environmental benefits including substantially reduced water withdrawals and consumption and decreased emissions of mercury and other sources of air and water pollution associated with the burning of fossil fuels (NRC 2010).

The siting and operation of wind energy facilities also present a risk of adverse impacts to wildlife, particularly to individual birds and bats (Arnett et al. 2008; Strickland et al. 2011). The potential for biologically significant impacts to wildlife continues to be a source of concern as populations of many species overlapping with proposed wind energy development are experiencing long-term declines due to habitat loss and fragmentation, disease, non-native invasive species, and increased mortality from numerous other anthropogenic activities (NABCI 2009; Arnett and Baerwald 2013).

In order to maximize wind energy's benefits while addressing the risk to wildlife, a first step is to better understand the extent of the risk and impact of wind energy development to wildlife. This report summarizes publicly available information about the adverse impacts of land-based wind power on wildlife in North America and the status of of regarding how to avoid or minimize these impacts.

The amount of research in the peer-reviewed literature continues to grow, reflecting the ongoing interest in understanding wind-wildlife interactions. In order to maintain the highest level of scientific rigor, this report has emphasized research that has been published in peer-reviewed journals as well as publicly available reports that have undergone expert, technical review.

Literature citations supporting the information presented are denoted in parentheses; full citations can be found online at http://awwi.org/resources/summary-of-wind-wildlife-interactions/

Organization of this Report

Concerns about adverse impacts can be grouped broadly as direct or indirect impacts. Direct impacts are defined to include fatalities resulting from collisions with turbine blades or towers. Indirect impacts result from the effects of the construction and operation of a wind energy facility on a species' use of habitat. These impacts may include displacement of a species from suitable habitat or demographic effects due to fragmentation of habitat or disturbance from the construction and operation of a wind facility. Statements about what is known and what remains uncertain regarding the adverse impacts of wind energy on wildlife are organized in the following categories:

- Direct mortality
- Population level consequences of collision fatalities
- Avoidance and minimization of collision fatalities
- Habitat-based impacts on birds

Within each section, statements are ordered in decreasing level of certainty. The level of certainty reflects the "weight of the evidence" from multiple published studies on a subject of interest. A single study, although informative, is usually in-

The American Wind Wildlife Institute, located in Washington, D.C., is a partnership of leaders in the wind industry, wildlife management agencies, and science and environmental organizations who collaborate on a shared mission: to facilitate timely and responsible development of wind energy while protecting wildlife.

sufficient for drawing broad conclusions. Although more information is available on direct impacts to individual birds and bats, substantial uncertainty remains regarding potential population-level consequences of collision mortality and the ability to predict collision risk.

Direct Mortality

At many wind facilities, regular searches are conducted for birds and bats that may have collided with turbines. The number of studies reporting results of collision fatality monitoring at operating landbased wind energy facilities has increased substantially over the years, and studies conducted at more than 100 projects are publicly available (Arnett and Baerwald 2013; Loss et al. 2013a; Erickson et al. 2014). Protocols for carcass searches have become more standardized, facilitating comparisons of results from separate studies. Much uncertainty remains as to the distribution, timing, and magnitude of collision fatalities of both birds and bats. Some of this uncertainty reflects the lack of data from particular regions of the country, such as the southwestern U.S., where only a few publicly available fatality reports are available.

This section outlines what is known and where there is remaining uncertainty about the patterns of bird and bat collision fatalities, particularly in the continental U.S. Patterns that apply to both birds and bats will be examined first, and then patterns specific to birds and specific to bats will be described.

Birds and Bats

Fatalities of birds and bats have been recorded at all wind energy facilities for which results are publicly available.

Most bird and bat collisions presumably involve rotating turbine blades, although collisions with turbine towers are also possible. Fatality estimates of individual studies vary in how raw counts are adjusted for known sources of detection error and sampling intensity (Huso et al. 2016). Understanding of these sources of error is improving, but comparisons or aggregations of fatality estimates, especially if they include older studies (2006 or earlier), should be interpreted cautiously.

For birds, adjusted fatality rates from most studies range from three to six birds per MW per year1 for all species combined, and no publicly available study has reported more than 15 bird fatalities per MW per year (Strickland et al. 2011; Loss et al. 2013a; Erickson et al. 2014). There is relatively little variation in bird fatalities across regions for all species combined, although fatalities at sites in the Great Plains appear to be lower than sites in the rest of the U.S., and fatalities in the Pacific region may be significantly higher (Loss et al. 2013a). It is unknown to what extent these differences reflect the sample bias discussed earlier.

Adjusted bat fatality rates may be substantially higher than bird fatality rates, especially at facilities in the upper Midwest and eastern forests: two facilities within the Appalachian region reported fatality levels of greater than 30 bats per MW per year, but there are also reports as low as one to two bats per MW per year at other facilities in the eastern U.S. (Hein et al. 2013). Studies have not found a consistent pattern of fatalities across landscape types: fatality rates can be equally high in agricultural or forested landscapes, or in a matrix of those landscape types (Jain et al. 2011). On average, reported bat fatality rates are substantially lower at facilities in the western U.S. (Arnett and Baerwald 2013; Hein et al. 2013).

The lighting currently recommended by the Federal Aviation Administration (FAA) for installation on commercial wind turbines does not increase collision risk to bats and migrating songbirds.

The FAA regulates the lighting required on structures taller than 199 feet in height above ground level to ensure air traffic safety. The number of bat and songbird fatalities at turbines using FAA-approved lighting is not greater than that recorded at unlit turbines (Kerlinger et al. 2010; Bennett and Hale 2014). One study (Bennett and Hale 2014) recorded higher red bat fatalities at unlit turbines compared to those using red aviation lights; no differences were observed for other bat species between lit and unlit turbines. For wind turbines, the FAA currently recommends strobe or strobelike lights that produce momentary flashes interspersed with dark periods up to three seconds in duration, and they allow commercial wind facilities to light a proportion of the turbines in a facility (e.g., one in five), firing all lights synchronously (FAA 2007). Red strobe or strobe-like lights are frequently used.

The effect of turbine height and rotor swept area on bird and bat collision fatalities remains uncertain.

Some studies have suggested that bird and bat fatalities increase with tower height (Barclay et al. 2007; Baerwald and Barclay 2009; Loss et al. 2013). However, tower height was found to not affect levels of bat fatalities at Canadian facilities (Zimmerling and Francis 2016), and studies on birds suggest that the relationship between tower height and bird collisions is more nuanced (Smallwood and Karas 2009). Taller turbines often have much larger rotor-swept areas, and it has been hypothesized that collision fatalities will increase due to the greater overlap with flight heights of nocturnal-migrating songbirds and bats (Johnson et al. 2002; Barclay et al. 2007). The vast majority (>80%) of avian nocturnal migrants typically fly above the height of the most common rotor-swept zone (<500 feet; <150m) (Mabee and Cooper 2004; Mabee et al. 2006), and there is no evidence to date that nocturnal migrants form a disproportionately high number of collision fatalities during migration (Welcker et al. 2017).

It is unknown whether collision risk at stand-alone turbines is comparable to risk at individual turbines within large wind energy facilities.

Construction of single utility-scale turbines (1.5-2 MW) is growing rapidly in some regions of the country, especially where opportunities for large utility-scale projects are limited or municipalities often supply their own electricity (e.g., Massachusetts). Fatality monitoring at single-turbine facilities is often not required, and published reports have not been available.

Birds

A substantial majority of bird fatalities at wind energy facilities are small passerines.

Approximately 250 species of birds have been reported as collision fatalities at wind energy facilities for which data are available (Loss et al. 2013; Erickson et al. 2014). Raw counts of small passerines (<31 cm in length) account for approximately 60% of fatalities reportd in publicly available studies at U.S. wind facilities (Erickson et al. 2014). Small passerines comprise more than 90% of all landbirds (Partners in Flight Science Committee 2013. Searcher efficienty trials indicate that small birds have significantly lower detection rates than large birds (Peters et al. 2014), and the true proportion of passerine fatalities of all collision fatilities is uncertain. Most small passerine species are migratory, resulting in spring and fall peaks of bird fatality rates at most wind facilities (Strickland et al. 2011; Erickson et al. 2014).

Diurnal raptors are relatively frequent fatalities, particularly in the western U.S. where these species are more cmmon. Because these groups are far less abundant than passerines, there is concern that the potential relatively high fatality rates are reflective of a higher vulnerability to collision. These higher raptor fatality estimates may be partially due to the higher searcher efficiencies for large birds as described above (Peters et al. 2014). The vulnerability to collision of native game birds (e.g., sage grouse and prairie chickens) is unknown, although pheasants have constituted a large proportion of reported fatalities at wind energy projects in the western U.S. (Strickland et al. 2011). Fatalities of waterbirds and waterfowl, and other species characteristic of freshwater, shorelines, open water, and coastal areas (e.g., ducks, gulls and terns, shorebirds, loons and grebes) are reported infrequently at land-based wind facilities (Kingsley and Whittam 2007; Gue et al. 2013), although this could change as more wind energy development occurs offshore or in regions where waterfowl abundance is high (Graff et al. 2016). The infrequent rate of fatalities of coastal birds at U.S facilities is somewhat different than that reported at coastal facilities in the Netherlands (Winkelman 1992; Stienen et al. 2008; Everaert 2014), but this could be due to the limited information from coastal wind facilities, particularly in the U.S. (Kingsley and Whittam 2007; NAS 2007).

Repowering with newer, larger (≥ 1 MW) turbines may reduce raptor collision rates at wind facilities compared to older, smaller (40-330kW) turbines.

The number of raptor fatalities on a per MW basis appear to be declining substantially (67-96% depending on the species) at the Altamont Pass Wind Resource Area as a result of repowering: smaller, low-capacity turbines are being replaced with taller, higher-capacity turbines

(Smallwood and Karas 2009; ICF International 2016). Larger turbines complete fewer rotations per minute, which may be partly responsible for reduced raptor collision rates (NAS 2007). In addition, older turbines that use lattice support towers offer more perching sites for raptors, encouraging higher raptor occupancy in the immediate vicinity of the rotor swept area (NAS 2007) than large, modern turbines on tubular support towers.

Bats

Migratory tree-roosting bat species are vulnerable to colliding with wind turbines.

At least 24 species of bats have been recorded as collision fatalities, but a large majority of fatalities reported to date are from three migratory tree-roosting species (the hoary bat, the eastern red bat, and the silver-haired bat) which collectively constitute 70-80% of the reported fatalities at wind facilities for all North American regions combined (Kunz et al. 2007; Arnett et al. 2008; Arnett and Baerwald 2013; Hein et al. 2013).

It is unclear to what extent this conclusion reflects sample bias, as there are few reports available from the southwestern U.S. (especially Texas and Oklahoma where there is high installed wind capacity) where a very different bat fauna is present than at most other facilities in the U.S. Higher percentages of cave dwelling bats have been recorded at wind energy facilities in the Midwest compared to other facilities in the U.S. (Jain et al. 2011), and the few available studies indicate that Brazilian free-tailed bats can constitute a substantial proportion (41–86%) of the bats killed at facilities within this species' range (Arnett et al. 2008; Miller 2008; Piorkowski and O'Connell 2010). However, it is uncertain whether this species is at greater risk than other species because the Brazilian free-tailed bat is a very abundant species where it occurs.

Bat fatalities peak at wind facilities in the northern U.S. during the late summer and early fall migration.

Several studies in the northern U.S. have shown a peak in bat fatalities in late summer and early fall, coinciding with the migration season of tree bats (Kunz et al. 2007; Arnett et al. 2008; Baerwald and Barclay 2011; Jain et al. 2011; Arnett and Baerwald 2013), and a smaller peak in fatalities during spring migration has been observed for some bat species at some facilities (Arnett et al. 2008).

Some bat species may be attracted to wind turbines.

It has been hypothesized that the relatively high number of recorded fatalities of migratory tree bats may be explained by attraction to wind turbines (Horn et al. 2008; Cryan and Barclay 2009); several factors that might attract these bats have been proposed, including sounds produced by turbines, a concentration of insects near turbines, and bat mating behavior (Kunz et al. 2007; Cryan 2008; Cryan and Barclay 2009). Infrared imagery has shown bats exploring the nacelles of wind turbines from the leeward direction, especially at low wind speeds (Cryan et al. 2014). Analysis of bat carcasses beneath turbines found large percentages of mating readiness in male hoary, eastern red, and silver-haired bats, indicating that sexual readiness coincides with the period of high levels of fatalities in these species (Cryan et al. 2012).

Barotrauma does not appear to be an important source of bat mortality at wind energy facilities.

Forensic examination of bat carcasses found at wind energy facilities suggests that the importance of barotrauma, i.e., injury resulting from rapidly altered air pressure caused by fast-moving wind turbine blades (Baerwald et al. 2008), is substantially less than originally suggested (Rollins et al. 2012; Grodsky et al. 2011). The barotrauma hypothesis remains inadequately tested at this time.

Weather patterns may influence bat fatalities.

Bat activity is influenced by nightly wind speed and temperature (Weller and Baldwin 2012), and some studies indicate that bat fatalities occur primarily on nights with low wind speed. Other weather-related variables such as temperature, wind direction, or changing barometric pressure may also be important (Baerwald and Barclay 2011). Additional research on weather patterns as a predictor of bat activity and fatalities could support mitigation efforts to reduce bat fatalities (Arnett et al. 2008; Baerwald and Barclay 2011; Weller and Baldwin 2012; Arnett and Baerwald 2013).

It is uncertain whether collision risk is higher for male migratory tree bats than female tree bats.

Examination of external characteristics of bat carcasses collected at wind energy facilities indicated that the sex ratio of migratory tree bats was skewed towards males (Arnett et al. 2008), although other studies had shown female-bias or no bias (Baerwald and Barclay 2011). Bats can be a challenge to age and sex from external characteristics, especially when carcasses have decomposed or have been partially scavenged. Molecular methods used to sex bat carcasses indicate that sex ratios in fatalities of tree bats are not male-biased, although male bias in fatalities may exist in other species such as evening bats (Korstian et al. 2013).

Population-Level Consequences of Collision Fatalities

Reported levels of fatalities for some bird and bat species have raised concern for potential adverse impacts to populations.

The estimated total number of bird collision fatalities at wind energy facilities is likely several orders of magnitude lower than other leading anthropogenic sources of avian mortality.

Several recent estimates indicate that the number of birds killed at wind energy facilities is a very small fraction of the total annual anthropogenic bird mortality and two to four orders of magnitude lower than mortality from other anthropogenic sources of mortality, including feral and domestic cats, power transmission lines, buildings and windows, and communication towers (Longcore et al. 2012; Calvert et al. 2013; Loss et al. 2014a,b,c; Loss et al. 2013a,b; Erickson et al. 2014).

Fatality rates at currently estimated values do not appear likely to lead to population declines in most bird species.

For small passerine species, current turbine-related fatalities constitute a very small percentage of their total population size (typically <0.02%), even for those species that are killed most frequently (Kingsley and Whittam 2007; Kuvlesky et al. 2007; Erickson et al. 2014). However, detailed demographic modeling indicates a potential for population-level impacts at current or projected levels of collision fatalities of certain raptor species (Carrete et al. 2010; Bellebaum et al. 2013; Hunt et al. 2017).

The status of bat populations is poorly understood and the ecological impact of bat fatality levels is not known.

Bats are long-lived, and many species have relatively low reproductive rates, making populations susceptible to localized extinction (Barclay and Harder 2003; Jones et al. 2003). Population sizes for migratory tree bat species are unknown, as are nd we don't know whether current or future collision fatality levels represent a significant threat to these species (Kunz et al. 2007; Arnett et al. 2008; Arnett and Baerwald 2013). Studies have focused on estimating effective migratory tree bat population sizes from genetic data, and these estimates might be useful as baselines for evaluating future impacts of collision mortality and other threats to bats (Korstian et al. 2015; Vonhof and Russell 2015; Sovic et al. 2016). Detailed demographic modeling indicates a potential for population-level impacts at current or projected levels of collision fatalities for hoary bats (Frick et al. 2017).

The ecological implications of White-Nose Syndrome and collision fatalities for bats are not well understood.

White-Nose Syndrome (WNS) is a fungus-caused disease that is estimated to have killed more than six million bats in North America (Frick et al. 2010; Turner et al. 2011; Hayes 2012). Cave-dwelling bats are most at risk, and it is unknown whether WNS will be a significant source of mortality in migratory tree bats that appear to be most vulnerable at most wind energy facilities in the U.S. Migratory tree bats rarely occur in caves, and their solitary nature may not facilitate the spread of fungal spores (Foley et al. 2011). Because cave-dwelling bats represent a higher percentage of fatalities at midwestern wind energy facilities, there is concern about the added mortality of wind turbine collisions to WNS-vulnerable bat species in this region, some of which have declined in numbers by more than 90% (Frick et al. 2010). Because of these precipitous declines in numbers, fatality rates in these species could decrease, although the relationship between bat abundance and collision risk has not been established.

Avoidance and Minimization of Collision Fatalities

Siting

Substantial effort is made to estimate collision risk of birds and bats prior to the siting, construction, and operation of wind energy facilities under the premise that high-activity sites will pose an unacceptable risk to these species and should be avoided. Many wind energy companies choose to apply a tiered decision-making process as outlined in the Land-based Wind Energy Guidelines issued by the U. S. Fish and Wildlife Service in 2012. This approach, developed with input from multiple stakeholders, outlines a series of steps companies can take to identify potential risk to species thought to be at risk from wind energy development.

Siting individual turbines away from topographic features that attract concentrations of large raptors may reduce raptor collision fatalities at wind energy facilities.

Some analyses have indicated a relationship between raptor fatalities and raptor abundance (Strickland et al. 2011; Carrete et al. 2012; Dahl et al. 2012), although studies also suggest that raptor activity as measured by standard activity surveys may not correlate with fatality rates (Ferrer et al. 2012). Large raptors are known to take advantage of wind currents created by ridge tops, upwind sides of slopes, and canyons that are favorable for local and migratory movements (Bednarz et al. 1990; Barrios and Rodriguez 2004; Hoover and Morrison 2005; de Lucas et al. 2012; Katzner et al. 2012).

The relationship between bird behavior and bird collision risk, especially in the vicinity of the rotor swept area, is complex and not well understood.

Certain species that forage for prey in close proximity to turbines (e.g., red-tailed hawk and golden eagle) appear to have higher fatality rates, while other species that actively fly around wind turbines (such as common raven) appear to avoid collisions with turbines (Kingsley and Whittam 2007; Kuvlesky et al. 2007). High prey density (e.g., small mammals) is presumed to be a principal factor responsible for high raptor use and collision rates at the Altamont Pass wind resource area (Kingsley and Whittam 2007; Kuvlesky et al. 2007; NAS 2007; Smallwood and Thelander 2008). Bayesian models of raptor collision risk have been developed to predict fatalities based on observed raptor activity in the area and estimated collision probability (New et al. 2015).

The ability to predict collision risk for birds and bats from activity recorded by radar and acoustic detectors, respectively, remains elusive.

The use of radar and bat acoustic detectors is a common feature of pre-construction risk assessments for siting wind energy facilities (Strickland et al. 2011). To date, studies have not been able to develop a quantitative model enabling reasonably accurate prediction of collision risk to birds and bats from these surveys (Hein et al. 2013). Predicting bat collision risk using pre-construction activity measures would be further complicated if bats are attracted to wind turbines (see above).

Variation in bat fatality rates may be influenced by landscape features affecting activity and migration routes.

Migratory-bat activity may be influenced by landscape features such as valleys, ridgelines, and riparian systems and the variation in activity among these features may be related to the geographical variation in fatality rates (Baerwald and Barclay 2009). Relating fatality rates to landscape features around a wind energy facility could be useful in siting wind farms to avoid higher-risk areas (Kunz et al. 2007; Kuvlesky et al. 2007; NAS 2007; Arnett et al. 2008).

Operations

Wind energy companies are also employing a variety of technologies and operational techniques to minimize fatalities of vulnerable species at operating wind energy facilities.

Curtailing blade rotation at low wind speeds results in substantial reductions in bat fatalities.

An examination of ten separate studies (Baerwald et al. 2009; Arnett et al. 2011; Arnett et al. 2013b) showed reductions in bat fatalities ranging from 50 to 87% when compared to normally operating turbines. These studies indicate that reductions in bat fatalities were

achieved with modest reductions in power production under the conditions at the facilities where experiments were conducted. Further study to identify times when bat collision risk is high could optimize timing of curtailment and minimize power loss (Weller and Baldwin 2012; Martin et al. 2017).

Selective shutdown of high-fatality turbines may be an effective strategy for reducing fatalities of some raptor species.

Some of the highest raptor fatality rates have been observed in southern Spain where raptors congregate to cross the Strait of Gibraltar to Africa during migration (Ferrer et al. 2012). One study (de Lucas et al. 2012) reported a substantial reduction of griffon vulture fatalities (mean of 50.8%) at a facility due to selective shutdown of turbines where the greatest number of fatalities was observed.

The use of ultrasonic transmitters may deter bats away from rotor swept areas and reduce bat fatalities.

Experimental trials have shown that ultrasonic devices can reduce bat activity and foraging success, and evaluation of similar devices installed on wind turbines has shown some reduction in bat fatalities over control turbines (Arnett et al. 2013a). Development of bat deterrents using both acoustic and visual stimuli remains an active area of research.

Efforts intended to increase turbine visibility and reduce collision fatalities have met with limited success.

Impact minimization methods that are assumed to make turbine blades more visible to birds have been proposed to reduce collisions with wind turbines. For example, it has been hypothesized that towers and blades coated with ultraviolet (UV) paint may be more visible to birds, making them easier to avoid. In the only known test, Young et al. (2003) compared fatality rates at turbines with UV coatings to turbines coated with standard paint and found no difference. Several raptor species have shown little response to ultraviolet light (Hunt et al. 2015). Few data are otherwise available on the effectiveness of these and other potential methods for making turbines more visible to birds.

Habitat-Based Impacts on Birds

Species' use of habitat can be affected by the construction and operation of a wind energy facility. Impacts can include disturbance, displacement from suitable habitat, or demographic effects due to fragmentation of habitat. The section below outlines what is known and where there is remaining uncertainty about habitat-based impacts on birds. S We are unaware of studies on any habitat-based impacts of wind energy on bat species were not found.

Operating wind energy facilities can reduce abundance of some bird species, but the effect is not consistently observed in all studies.

Studies have indicated displacement of bird species in response to wind energy development, with some species showing consistent decreases in abundance in proximity to turbines, while other species showed no effect (Hatchett et al. 2013; Loesch et al. 2013; Stevens et al. 2013; Shaffer and Buhl 2016).

It has been suggested that high site fidelity in some grassland bird species may reduce displacement effects in the short-term and displacement would become more pronounced over time, but this effect was not apparent in a 10-year study of grassland birds (Shaffer and Buhl 2016). It is also unknown whether bird species will habituate to wind energy facilities and whether disturbance effects diminish over time (see Shaffer and Buhl 2016). In a UK study, three species declined in abundance during construction of wind energy facilities; the effect persisted for two of the species, both shorebirds, but red grouse density returned to preconstruction levels after the facility became operational (Pearce-Higgins et al. 2012).

There is concern that prairie chickens and greater sage-grouse will avoid wind energy facilities because of disturbance or because they perceive turbine towers as perches for avian predators.

Research indicates that close proximity to roads, utility poles or lines, trees, oil and gas platforms, and/or human habitations causes displacement in prairie chickens and sage-grouse (Robel et al. 2004; Kingsley and Whittam 2007; Kuvlesky et al. 2007). It is hypothesized that similar effects would re-

sult from wind energy development, but few published studies have tested this hypothesis (Walters et al. 2014). An extensive and comprehensive multi-year study of greater prairie chickens in a fragmented Kansas landscape showed neutral, positive, and negative responses to wind energy development as measured by a variety of demographic parameters. There was little or no response in nesting females (Winder et al. 2013; Winder et al. 2014); lek persistence appeared to be lower in proximity to turbines, but there was no detectable effect of turbine proximity on male body mass (Winder et al. 2015).

A multi-year study of greater sage-grouse in Wyoming found that many demographic and habitat use factors, including selection of nest sites and nest, brood, and female survival were not influenced by proximity to turbines (LeBeau et al. 2017a). However, selection of brood rearing and post-rearing habitat was negatively influenced by ground disturbance related to roads and turbine pads (LeBeau et al. 2017a). Negative trends in male lek attendance were not detected (LeBeau et al. 2017b).

It is unknown whether wind energy facilities act as barriers to landscape-level movements by big game and other large terrestrial vertebrates.

There are a small number of studies that have evaluated the hypothesis that land-based wind energy facilities negatively affect non-volant, i.e., non-flying, wildlife. Proximity to a wind energy facility did not affect winter survival of pronghorn in Wyoming (Taylor et al. 2016). Development and operation of a wind energy facility in Oklahoma had no measurable impact on radio-collared Rocky Mountain elk (Walter et al. 2006). Long-term studies of desert tortoise at a California wind energy facility have found no negative effects on tortoises using the area encompassed by the facility (Lovich et al. 2011; Ennen et al. 2012); survival of tortoises was higher within the area of the facility than in an adjacent undisturbed area (Agha etal. 2015).

Buy-In for Buyouts: The Case for Managed Retreats

The Lincoln Institute

Introduction

Approximately 1.2 million residents of the New York metropolitan region—New York, New Jersey, and Connecticut—live in coastal surge zones and riverine floodplains at greatest risk of inundation. The number of vulnerable residents is expected to nearly double by 2050 due to rising sea levels, increasing frequency and intensity of storms, and a growing population.

The most frequently applied recovery and adaptation measures—rebuilding resiliently, reinforcing hard infrastructure, utilizing green infrastructure, and restoring or enhancing natural systems—can do much to reduce the risk of flooding. However, none of these measures can eliminate all risk. Therefore, some communities are practicing managed retreat through the use of buyout programs that relocate people away from the most vulnerable areas. These programs provide ways for residents to sell their homes in high-risk zones and move to safer locations.

This report was adapted from Buy-In for Buyouts: The Case for Managed Retreats, authored by researchers at Lincoln Institute of Land Policy in Cambridge, Massachusetts, as a part of its Policy Focus Report series.

Managed retreat has long been an unpopular adaptation strategy because of the obvious social and political challenges it poses. Buyout programs, in particular, create numerous hurdles for individual residents, communities, municipalities, and administrators. But the likelihood of extreme weather events is increasing. Without intervention, many communities eventually will have to retreat from flood-prone zones because they will not be willing or able to afford the costs of repairing or rebuilding their homes. In the face of increasingly frequent and powerful storms, buyout programs can be designed and implemented to yield successful outcomes for residents and government entities alike.

Buyout programs were employed in New York, New Jersey, and Connecticut following Hurricanes Irene and Sandy, but they were considered politically unfeasible and thus were available to only a handful of communities. Of the billions of federal aid spent on resilience and recovery in the New York metropolitan region, at least $750 million has been spent on buyouts, which alleviated the flood risk for more than 1,500 homes. However, the vast majority of recovery efforts focused on other measures of adaptation.

As an increasingly vital instrument in the adaptation toolbox, buyout programs must be improved to provide viable and appealing strategies that factor in the needs of individuals, communities, and municipalities. The programs must be expanded to include all willing and eligible communities. Analyzing the buyout programs in the New York metropolitan region can provide lessons and resulting recommendations for the whole nation. This report provides such recommendations to increase the appeal of buyouts.

NY Rising

In 2013, New York State established the New York Rising Buyout and Acquisition Programs (NY Rising) to address the damage caused by Irene and Sandy and Tropical Storm Lee. Under these programs, the Governor's Office of Storm Recovery determined priority areas for buyouts, enhanced buyout zones, where owners of one- and two-unit dwellings were eligible to receive the pre-storm fair market value of their homes, plus incentives. Structures purchased in these enhanced areas would be destroyed and the land would be restored to natural floodplain functions (Governor's Office of Storm Recovery 2014). As of June 2015, the enhanced buyout areas were limited to three communities on Staten Island—Ocean Breeze, Oakwood Beach, and Gra-

ham Beach—and Suffolk County on Long Island (Governor's Office of Storm Recovery 2015).

In many communities, homeowners outside of these priority zones were eligible for property acquisitions and were offered the post-storm fair market value of their homes. They were also eligible for incentives to make up the difference between the pre- and post-storm property values. Unlike homes acquired in the enhanced buyout areas, these properties could be redeveloped. In May 2015, approximately 150 state-owned properties in Nassau and Suffolk counties purchased through the acquisition program were sold at auction. The desire to prevent checkerboarding vacant or demolished neighborhood properties motivated the decision to sell these properties and provide possible redevelopment. Some properties purchased as part of the acquisition program were deed-restricted as open space and maintained by cities and counties.

Within the enhanced buyout zones, the NY Rising Program has facilitated community-wide participation. In Oakwood Beach, 99 percent of residents have submitted applications for the buyout program (Governor's Office of Storm Recovery 2015). Although this community is a rather unique case, the high participation rate reflects NY Rising's success in identifying the communities most interested in buyout programs and reducing any potentially negative impacts of buyouts on the property values of surrounding homes. Furthermore, after the Oakwood Beach buyouts began, other communities along the southeastern shore of Staten Island expressed interest in buyouts. By April 2014, both Ocean Breeze and Graham Beach were incorporated into the enhanced buyout areas. However, the enhanced areas on Staten Island and in Suffolk County represented only a fraction of the areas most heavily impacted by Hurricane Sandy and most vulnerable to the future impacts. A notable aspect of the NY Rising Program is that the 25 percent nonfederal match normally passed on to individual municipalities is paid at the state level, thereby reducing the burden of buyout participation on local municipal finances. This helps to make buyouts more financially viable for municipalities, since they need to accommodate only the loss in tax revenue.

Risk

The perception of risk is hugely important to property owners and municipalities deciding whether to participate in a buyout program. Different stakeholders have different perceptions of risk. Buyout program staff may view risk in terms of the probability of future losses of life and property, while homeowners may focus on the possibility of losing their homes and financial stability or moving farther away from their jobs, families, or friends. For elected officials, risk may involve the possibility of lost property tax revenue, inability to service debt, or the death of first-responders. Each stakeholder requires information and decision tools tailored to their specific concerns. The goal is to more closely align perceptions of risk across these groups so that participants and program designers recognize shared priorities.

Flood insurance policies and rates represent and communicate risk. Increases in flood insurance rates have driven many homeowners to pursue buyouts outside of a post-disaster context. Nevertheless, there is an important balance between adequately communicating risk and placing undue financial burdens on homeowners. In 2012, the passage of the Biggert-Waters Flood Insurance Reform Act ushered in a new model for the National Flood Insurance Program (NFIP). The act catalyzed the transition of the NFIP from a subsidized program to a beneficiary pays system, which helped to make the program financially soluble and more able to communicate risk to homeowners. However, the Homeowner Flood Insurance Affordability Act of 2014 delayed the adoption of some of the Biggert-Waters statutes due to concerns over the very high costs they would impose on homeowners (FEMA 2015c). Instead, the NFIP will move toward this model more gradually, careful not to overburden households while providing more accurate risk information.

Timing

Stakeholder interviews suggest that the timing of information is critical in determining whether homeowners choose to participate in a program. Homeowners who have experienced multiple floods are more likely to participate in a buyout program than those who have experienced one or none. In addition, many homeowners may not hear about buyout programs immediately after a disaster. For example, Congress did not approve the 2013

Disaster Relief Appropriations Bill until nearly three months after Hurricane Sandy occurred. Buyout programs were not announced in New York State until February 2013. By then, many homeowners had already submitted applications to FEMA for individual assistance or started to repair their homes. Homeowners who had already received other federal aid were subject to limitations to prevent duplication of benefits or were entirely ineligible to receive a buyout. This is a challenging issue, as most buyout funds are mobilized through Stafford Act Appropriations after a disaster strikes. As a result, program administrators are tasked with designing buyout programs while also responding to immediate disaster recovery needs.

Community Organizing

Many of the most successful buyouts began as community-driven efforts. Oakwood Beach residents formed the Oakwood Beach Buyout Committee in the aftermath of Hurricane Sandy to advocate for a program in the neighborhood. Shortly after the storm, many residents sought buyouts and wanted the land to be returned to its natural floodplain function to protect more inland communities. This community-planning effort helped to spur similar groups in adjacent Staten Island neighborhoods, such as Ocean Breeze and Graham Beach. In addition to conducting outreach efforts with residents, the Oakwood Beach Buyout Committee surveyed the most at-risk neighborhoods in order to map the areas that should be returned to floodplains. Residents were empowered by mapping these areas as a community rather than having the maps imposed by outside experts (Rush 2015).

As of June 2015, nearly 99 percent of Oakwood Beach residents participated in the buyout program. This effort reflects the power of community-driven buyouts as compared to programs imposed by external parties. However, grassroots efforts do not always develop. In such cases, it is especially important to actively support residents through the buyout process. Stakeholders have reported that homeowners are more satisfied with the outcome of a buyout if they feel engaged and consulted and if information is clearly presented during multiple stages of the program.

Costs

Homeowners consider a number of financial issues when they choose whether to participate in a buyout program. An offer at the pre-storm value of the home may not be sufficient for homeowners who owe more on their mortgage than the property's value. Banks that hold foreclosed properties want to be made whole and will only accept offers close to the amount that is actually owed on the property. In many cases, speculative investors make offers that compete with buyout programs. To prevent speculators from purchasing flood-ravaged homes and then selling them back to the state, only people who owned the properties before the storm are eligible to receive the pre-storm value of their home. Although land speculation can pose a challenge for all buyout programs, it can be particularly problematic in coastal areas where land is highly valuable and property values tend to recover more quickly. This suggests that buyout programs are most successful when relocation costs and housing counseling are provided and when pre-storm value is more competitive. These factors, along with the timing of assistance and the need to make purchase offers before housing markets fully recover, are critical to successful buyout programs.

Disposition of the Land

The subsequent use of the land acquired through buyouts is a concern for both homeowners and municipalities. While Federal Emergency Management Act (FEMA)- and Housing and Urban Development (HUD)- funded buyouts must become deed-restricted for open-space uses, buyouts that use other funding sources are not required to restrict future development on these sites. Knowing that properties will remain undeveloped can reassure some homeowners that others won't profit from the sale of their homes (Rush 2015). One Staten Island resident reported, "If the land wasn't going back to nature, watching my house be demolished would have been very hard to swallow" (Rush 2014).

Developing and implementing a strong plan for the reuse of acquired properties can also encourage buy-in from municipal elected officials. A plan for reuse that adds value to the municipality will lessen the burden of acquired properties. For example, the Cuyahoga Falls Rain Garden Reserve in Ohio is constructed on four flood-damaged residential properties acquired through a FEMA Hazard Mitigation Grant Program. The garden landscape im-

proves groundwater recharge, minimizes flooding during rain events, and provides a public amenity. FEMA is already starting to encourage states and cities to factor reuse into their benefit-cost worksheets. Once a proposed project has reached a benefit-cost ratio of 0.75, environmental benefits such as groundwater recharge can increase the ratio to 1.0 or higher. Planning for the reuse of acquired properties before and during a buyout program can help improve participation rates in the short term and ensure that costs to neighborhoods and municipalities are minimized in the future.

In some cases, redevelopment of acquired parcels can be a necessary or beneficial move. This is especially true in areas where properties were acquired in a checkerboarding fashion, where it isn't possible to create clusters of open space. In these cases, vacant and demolished properties are likely to lower surrounding property values and create zones of disinvestment. This concern led the NY Rising Program to sell 150 of its acquired properties at auction in May 2015. Properties that were clustered or located adjacent to existing open spaces were turned over to open-space uses. However, other isolated properties in the midst of residential neighborhoods were sold. Buyers of these formerly bought-out properties were allowed to repair existing structures or completely rebuild as long as they complied with strict building codes and elevation requirements.

Fiscal Impacts

Not all development is positive. Although certain land uses may generate large amounts of tax revenue, servicing those uses can be costly and drain resources from cities and towns. The overall impact of development will depend on a municipality's fiscal structure—how it collects money and reallocates it to provide services and amenities such as schools, roads, garbage collection, and water treatment. Numerous people—supported by empirical studies—who have experienced costly disasters question whether development in flood-prone areas is fiscally responsible.

When a city or town considers implementing a buyout program, it weighs three choices: (1) rebuild to replicate the previous structure; (2) rebuild to reduce future flood damage; or (3) relocate development to remove the risk of future damage. Each of these options carries different costs and benefits, which accrue to local governments, homeowners, county governments, and federal taxpayers. What is a benefit to one unit of government may be a cost to another. In order to decide among these three options, a city or town would want to confirm the following:

- Which types of land use generate the highest revenue and the lowest costs?
- What are the costs and benefits of removing a development from the city budget?

To answer these questions, local governments can conduct fiscal impact analyses. At the most basic level, fiscal impact analyses reveal the costs and benefits of new development. Officials can better examine and address long-term needs by understanding the costs and benefits involved in recovery choices, particularly amid flood risks that continue to grow. The results can "make a community's ability to pay transparent" (Kotval and Mullin 2006, 4) and help people understand that redevelopment may not be feasible without reducing the quantity or quality of the services and amenities to which residents are accustomed.

What Types of Land Uses Generate Revenue?

In the 1950s and 1960s, dozens of cities emerged or expanded around the use of the car. Following the Federal-Aid Highway Act of 1956, highways were built and roads were widened to give people quick access to the whole country (Weingroff 1996). Single-family homes outside the city center dominated the landscape, and thus the city-suburb rivalry was born. Over time, many started to suspect that this sprawling urban form was inefficient and expensive to maintain. It increased the cost of transportation and sewer infrastructure while creating congestion and pollution. Starting in the 1970s, cities and researchers began to evaluate the costs and benefits of such sprawl. These fiscal impact analyses and cost of community service studies demonstrated that different types of development impacted a city's overall budget in varying ways.

Numerous studies have found that certain land uses simply do not provide net benefits to local governments. While there is bound to be local variation, empirical studies have determined that mixed-use, multifamily, and open-space configurations have positive fiscal impacts (Burchell et al. 1998; Cervero and Duncan 2004; Deller 2001; Marlow

2008). Additionally, properties in and near areas with multiuse zoning had higher property values than those in areas zoned only for single-family homes.

Studies that evaluate the impact of urban growth boundaries on property values may also be relevant for places that are considering buyouts. Urban growth boundaries concentrate development within allowable areas, limiting where development can occur. Likewise, buyouts prohibit development in flood-prone areas and locate growth elsewhere. Economic theories and empirical studies suggest that restricting land use and creating scarcity of developable land increase property values in developable areas (Marlow 2008; Jaeger and Plantiga 2007; Escheverria 2007).

A study by the Trust for Public Land found that Long Island's parks and open spaces provide direct economic benefits of $2.74 billion per year by encouraging tourism, reducing government costs, and improving air quality and public health. In terms of direct government savings, conserved lands in Long Island save $23.9 million every year in storm water management costs (Trust for Public Land 2010). The study also found that residential properties near parks and protected open space were worth at least $5 billion more than those lacking these amenities, increasing tax revenues by $58.2 million a year.

What Types of Land Uses Generate Costs?

As discussed, all forms of land use generate costs because they place demands on the government. There is a general consensus that residential land generally requires the most services, and that the revenue generated by residential uses does not balance out these demands. In this sense, residential land uses produce a negative net impact for local governments.

A study by fiscal expert Dr. Robert Burchell indicates that residential properties generally do not generate more tax revenue for municipalities than they cost, whereas nonresidential properties do (Burchell 2014). Dr. Burchell also finds that the impact of a development depends on its use and form. For instance, two-bedroom townhouses have a better net impact on property taxes than three-bedroom single-family homes. Both of these typologies have a more positive fiscal impact than four-bedroom single-family homes. This is partially due to the fact that home size corresponds to household size and the presence of school-aged children places additional demands on the city.

Most fiscal impacts and cost-of-service calculations focus strictly on routine or predictable government expenditures—policing, public education, and road maintenance, etc. Emergency services, such as the cost of removing debris or dispatching first responders, may not make it into the calculation. These fiscal impacts are also more likely to focus on a single point in time rather than a long-term scenario or one in which other factors are considered. For example, regular flooding may require an increase in road maintenance and street repairs. The quality of local water can be compromised by a high water table or more frequent flooding in areas lacking sewer systems where waste is contained in shallow storage and septic tanks. Dynamic and less predictable risks make each residential property more costly to the local government over time.

How Buyouts Impact Revenues and Costs

Removing a residential property from the floodplain generates fiscal impacts for local governments as well as taxpayers. Figure 1 illustrates the sources of revenue and costs associated with that decision. Although revenue and costs may accrue to the municipality, many accrue to other governmental entities as well, including the county or federal government. Therefore, public officials must consider the effects of buyouts on multiple levels of government in order to provide a complete picture of the fiscal impacts of buyouts.

The most immediate effects occur when a flood-prone property is purchased. Direct and immediate costs include pre-acquisition costs, purchase price, property maintenance, and demolition. As figure 1 shows, these are one-time expenditures that, under the current funding regime, primarily accrue to the federal agency that is funding the buyout program. When local matches are required, local governments also carry a portion of these costs. However, in some cases, buyout programs can mix and match federal funding sources into a "global match," in which the local match requirement is actually covered by other federal funding.

When a property is removed from the floodplain, it is also removed from the local government's tax

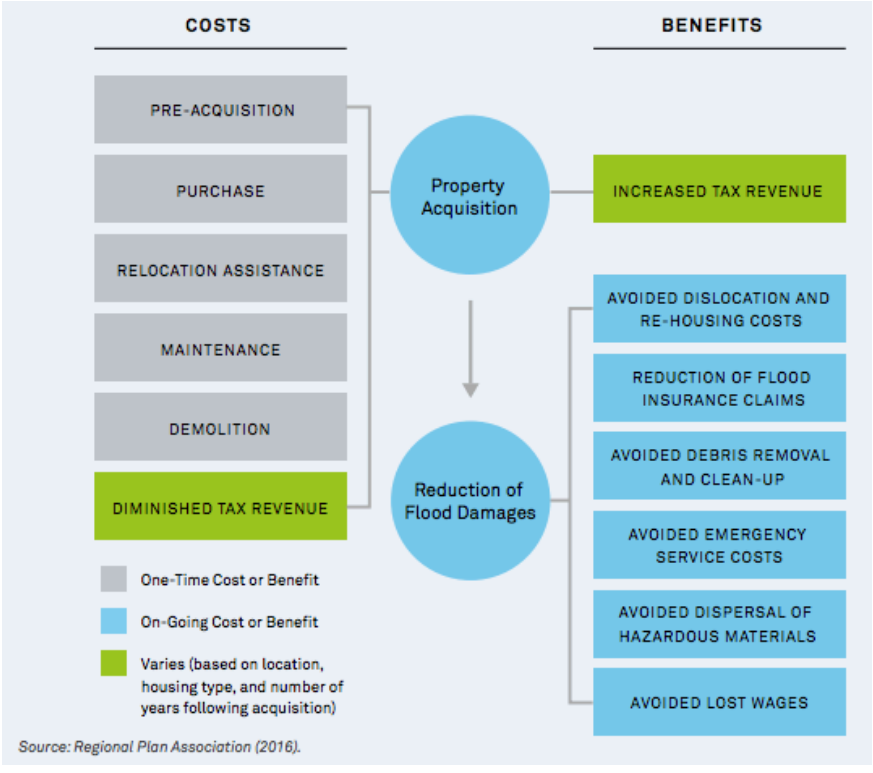
rolls. The magnitude of this impact varies but is often less significant than public officials project. Since disasters cause damage that lowers property values, homeowners can have their properties reassessed to account for this decline, thereby providing tax relief in the years immediately following a flood. Thus, local governments do not lose taxes that are calculated as a share of the pre-flood value of the property; they lose taxes on the post-flood value of the property. The difference can be substantial. When NY Rising purchased properties for their acquisition program after Hurricane Sandy, they paid the pre-storm values. At auction, the acquired properties were sold at their current market value—often only 20 to 30 percent of their value before Hurricane Sandy (Chaban 2015).

Removing a property from the floodplain can provide local government revenue over time. Buyouts can create value if the local government takes appropriate steps to turn purchased parcels into local amenities, such as restoration areas or parkland, while embracing more intense residential development in areas without flood risk. Restricted land use coupled with new amenities can increase property values and, in turn, increase local revenue. If local governments plan properly, homeowners can relocate within the municipality and thereby maintain, and even enhance, the tax rolls. Second-order fiscal impacts occur because removing properties from flood-prone areas reduces future flood damages. In this scenario, the fiscal impacts are not calculated as revenue, but rather as avoided costs. These costs accrue to different stakeholders—including homeowners, local government, and the federal government—and also accumulate over time.

Because flood damage costs increase with the severity of a flood, avoided costs increase in kind. If homes are rebuilt in flood-prone areas without elevating or flood-proofing, the cost of flood damage will change depending on the flood intensity. For example, a 2 percent (1/50-year) flood is less damaging than a 1 percent (1/100-year) flood. These floods are both less damaging than a 0.2 percent (1/500-year) flood. The United States Army Corps of Engineers (USACE) calculates flood damage based on the estimated flood depth (inundation), height of wave crests (wave damage), and the percentage of the property compromised (erosion). The Corps develops depth-damage functions that illustrate the estimated damage for a given level of inundation, wave impact, or erosion for a range of building types. For instance, the structural damage from one foot of inundation in a two-story residential building with no basement is estimated at 9 to 20 percent of the building's value. The structural damage from three feet of inundation would be approximately 32 to 60 percent of the building's value (USACE 2015a).

Buying out flood-prone properties precludes many future costs. As Figure 1 highlights, these include avoided emergency costs, such as dispatching first responders. Buyouts also eliminate or lower costs related to evacuation, sheltering, and

Figure 1: Fiscal Impacts of Buyouts: Costs and Benefits



long-term displacement, as well as debris removal, repair, and maintenance. Buyouts can also prevent other harmful consequences of flooding, such as the dispersal of sewage and other hazardous materials into bodies of water—a significant environmental benefit. The value of avoided costs far outweighs the value of immediate costs. More importantly, these costs are avoided more than once. Every future flood represents a net savings if people and properties remain out of harm's way. The challenge is that many of the avoided costs do not accrue directly to local governments and therefore may not be included in traditional fiscal impact analyses.

Oakwood Beach Case Study

Communities in the New York metropolitan area faced a variety of challenges in the wake of Hurricane Irene and Hurricane Sandy. Community demographics, along with certain fiscal impact indicators that drive decision-making around buyouts were compiled and studied. The Oakwood Beach community, considered a highly successful example of a buyout program, is featured in this adaptation of the Lincoln Institute's report.

Oakwood Beach is located on the central part of Staten Island's South Shore. The neighborhood is 31 percent low-to-moderate income, 16 percent nonwhite, and 69 percent owner-occupied. The lowest lying part of the neighborhood is situated next to the marshes of Great Kills Park. The most serious flood risks come from storm surge off the Raritan Bay and Lower New York Harbor. Additionally, sections of the neighborhood experience nuisance flooding following even modest rainfall. Along with the neighboring upland community of Oakwood, Oakwood Beach has a population of 22,000, and nearly 3,000 live in current FEMA Special Flood Hazard Zones. The number of people within high-risk flood zones is expected to increase nearly 150 percent to 7,300 by 2050.

Oakwood Beach is a middle-class community with a median annual household income of $89,000. The neighborhood was largely developed in the 1960s and 1970s; nearly half its residents have lived in the community for more than 25 years. In general, the homes built closer to the water are smaller and cheaper than those located farther upland. Single-family homes dominate the neighborhood, but there are a handful of apartment buildings inland.

Oakwood Beach was severely impacted by Hurricane Sandy. The storm surge overtopped the boulevard that runs along the coast and damaged the berm between the neighborhood and the Atlantic Ocean. The surge inundation was exacerbated by the floodwaters trapped within the "bowl" topography of the South Shore (SIRR 2013). Some homes were swept off their foundations; others were flattened. Staten Island as a whole was among the hardest hit areas, with 23 storm-related deaths in the borough (SIRR 2013; Koslov 2014). Prior to Sandy, there were several other historic floods in Oakwood Beach, including intense inundation from a nor'easter in 1992 and flooding from Hurricane Irene in 2011 (Oakwood Beach Buyout Committee 2015; Koslov 2014). After the 1992 storm, residents organized a Flood Victims' Committee to petition for better flood protection from the state and federal governments. Although the USACE somewhat addressed residents' concerns by constructing a berm, it was not completed until ten years after the nor'easter (Koslov 2014).

Oakwood Beach residents moved quickly to plan their recovery after Hurricane Sandy based on their experience organizing for flood protection in the 1990s. At an early community meeting devoted to immediate disaster response and aid, one organizer asked if residents would support a buyout program. Nearly all community members in attendance said yes. Residents then formed the Oakwood Beach Buyout Committee, which began to draft an application for a state buyout. The committee conducted outreach to gauge interest and provided information to residents about what a buyout program might entail. The committee collected signatures from nearly all the neighborhood's residents to indicate their interest in a buyout program (Lavey 2014). Additionally, committee members surveyed residents about where they felt safe living within the neighborhood in order to generate maps of priority acquisition areas. This mapping effort is a powerful tool for communities organizing to receive buyouts.

However, some populations that are deciding if buyouts are the best way to reduce risk are settling in marginal flood-prone areas because they have suffered government-imposed relocations and disinvestments in the past. If buyout program plans are not community-driven de-

spite being voluntary, they risk continuing this pattern of marginalization. As we observed in New Orleans, understandably there was strong community opposition to buyout programs proposed by outside planners because they did not consult the local population. Instead, Oakwood Beach residents collaboratively created their own "green dot" maps that showed targeted areas for buyouts to convey their goals for a buyout program and to confirm that they did not want redevelopment in their area.

The NY Rising Program heeded residents' requests and launched a buyout program for Oakwood Beach. As of June 2015, nearly 99 percent of the neighborhood's residents have participated in the buyout program. As of February 2015, the state owned 296 properties and had demolished 60 (Rush 2015; Governor's Office of Storm Recovery 2015).

The relative success of Oakwood Beach's program is not surprising considering the fiscal context. Factoring in the projected sea level rise by 2050, a single 100-year flood event could cause $261 million of damage across 1,837 properties, 830 of which would have to be demolished. A buyout of only those 830 properties would save community residents $817,000 per year in flood insurance premiums and an annualized average of $5.7 million in damages and dislocation costs. In terms of the potential costs to communities, Oakwood Beach benefits from being only one neighborhood in a very large city. The loss in tax revenue is quite negligible in the context of the city's $75 billion budget.

Conclusion/Recommendations:

Retreat has long been avoided in public dialogue as an adaptation strategy. Yet when weighed against the magnitude of risk faced by coastal and riverine communities, retreat must be included in the toolbox of strategies for climate adaptation. Buyout programs are can be viable and effective methods to enable retreat from flood zones. The varied experiences and levels of success of these programs is due to many factors discussed in this report, including the timing of the program, the level of program engagement with residents, the attachment of participants to place, and the availability of alternatives to retreat, such as elevation.

In order for buyouts to meet the needs of residents and municipalities, we must rethink the goals, strategies, and timing of these programs; improve the administration of program funding; reform the planning process; and ultimately design minimally disruptive buyout programs.

1. Rethink the purpose and timeline of buyout programs.
   - Design buyout programs as long-term adaptations to flood risk, not merely as short-term recovery tools.
   - Ensure that flood-prone communities finalize adaptation plans before the next disaster occurs.
   - Consider the long-term interests of buyout participants.
   - Address the long-term purpose of the land acquired through buyout programs.
2. Improve the administration of funding for buyout programs.
   - Standardize buyout program requirements at the federal level and enhance implementation at the local level.
   - Ensure that administering agencies have the capacity to implement buyout programs.
3. Consider alternative funding models for buyout programs.
   - Test pilot buyout strategies that can be executed incrementally, over time, and outside the context of the disaster.
   - Expand the use of open-space taxes to fund buyout programs.
4. Improve planning processes to anticipate and integrate buyout programs.
   - Municipalities should identify priority acquisition zones by analyzing high-quality data and community input.
   - Municipalities should submit integrated, longterm local adaptation plans rather than flood-only hazard-mitigation plans.
5. Make participation in buyouts easier and more attractive for municipalities.
   - State governments should not make municipalities responsible for paying the nonfederal match.
   - State and federal governments should provide technical assistance to municipalities to help them evaluate the fiscal impacts of buyouts.

6. Streamline buyouts to facilitate participation.
   - Buyout program staff should help homeowners understand the full range of available financial assistance and compensation.
   - When possible, pursue housing blocks where neighbors can relocate together through partnerships with developers.

The Lincoln Institute's entire report, *Buy-In for Buyouts: The Case for Managed Retreats from Flood Zones* can be accessed here: https://www.lincolninst.edu/sites/default/files/pubfiles/buy-in-for-buyouts-full.pdf

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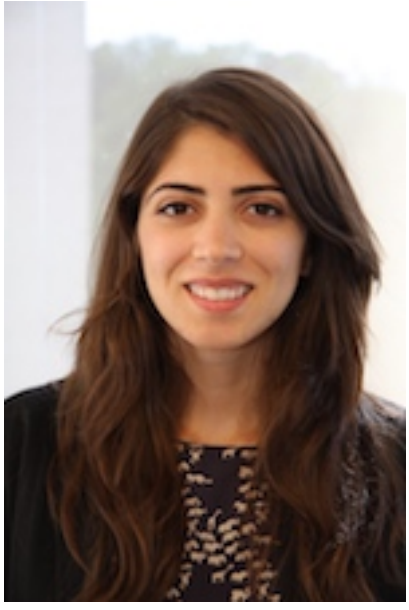
News and Announcements

Renewable Natural Resources Foundation

Attiya Sayyed Joins Staff as a Program Manager

Attiya Sayyed of Maryland has joined RNRF's staff as a program manager. She is a 2014 graduate of the University of Maryland (College Park) with a B.S. in environmental science and policy, with a concentration in society and environmental issues. She received an M.A. in global environmental politics from American University in 2017. On her way to earning a master's degree, she studied for a semester at the University for Peace, chartered by the United Nations and located in Costa Rica.

Sayyed served as an academic research assistant (at American), interned in the office of the Mayor of Denver (2016 Sustainable Denver Summit), interned and also worked full-time at Earth Day Network (communications tasks related to Global Citizen 2015 Earth Day), interned with The Palladium Group (researching bids for USAID projects), and interned at EcoPeace.



Sayyed works with RNRF committees in developing and implementing programs such as public policy conferences, congressional forums, RNRF's Washington Round Table on Public Policy, and the annual awards program. She also will have editorial responsibilities for the *Renewable Resources Journal*, Renewable Resources Report (RNRF's blog) and RNRF's website. She will be collaborating with other program staff and board members in charting the expansion of RNRF programs—including international initiatives.

David Conrad Meets with RNRF Washington Round Table on Public Policy

The RNRF Washington Round Table on Public Policy met with Association of State Floodplain Managers water policy consultant David Conrad at the Washington, D.C. office of the American Society of Landscape Architects on October 13, 2017. Conrad spoke about the challenges of crafting effective and impactful flood management policy at the national level. This talk was targeted towards solutions for Houston after Hurricane Harvey.

Conrad focused his talk on issues within the National Flood Insurance Program (NFIP). He observed that the vast majority of federal funds for the NFIP was going towards repetitive loss properties, with around 2% of properties claiming nearly 40% of NFIP funds. The best solution, therefore, is to buy back repetitive loss properties, ideally immediately after a recent storm. This would prevent losing more funds to reconstruct homes that will again be destroyed. Conrad also identified the "moral hazard" of subsidizing flood insurance costs for low-income households, as this may expose economically vulnerable people to untenable financial risk should their houses flood.

Additionally, Conrad noted that many of the Federal Emergency

Management Agency (FEMA) maps are inaccurate or out of date, and stressed the importance of updating flood maps to reflect actual risk. Maps also need to be developed for cities that face flooding risks but that do not currently meeting FEMA's minimum drainage area of 1 square mile. While he suggested that flood insurance costs should increase according to the updated maps, he recognized the difficulties of dramatically increasing insurance premiums– a move that is politically unpopular and frequently challenged in court by homeowners whose houses have subsequently lost value.

With these challenges in mind in the wake of Hurricane Harvey, Conrad recommends focusing buyout efforts on buildings most in danger of flooding again, and concentrating future building in the 70% of Houston that was not affected by Harvey flooding. He also suggests more transparent disclosure of flooding data so that potential homeowners or builders have a more complete understanding of their risks. Finally, Conrad lamented the repeal of the Federal Flood Risk Management Standard by the Trump Administration two weeks before Hurricane Harvey made landfall. The act would have helped federal planners build more flood-resistant public works projects.

Conrad served as a water resources specialist at the National Wildlife Federation (NWF) for 23 years. Since 2011, Conrad has been consulting with the Association of State Floodplain Managers on federal water resources policy.

During his time at NWF, Conrad led the "Higher Ground" project as the Federation's senior water resources policy specialist. This landmark report was conducted in response to the catastrophic Great Flood of 1993 in the upper Midwest, which killed 50 people and caused $15 billion in damage as hundreds of levees failed on the Mississippi and Missouri rivers. Major findings of the report included the extreme costs over time to rebuild, rather than remove, structures repeatedly damaged by flooding.

As discussed at the round table, many of the issues Conrad highlighted in "Higher Ground" still plague flood-prone cities like Houston today. Although flood risk mitigation comes with daunting political and social challenges, addressing the need for disaster mitigation and planning reform in Houston and other at-risk cities has never been more urgent or necessary.

Conrad's presentation is available for download here: http://www.rnrf.org/David_Conrad_RNRF_Presentation.pdf

American Geophysical Union

American Geophysical Union Urges Research Programs on Climate Intervention to Better Understand the Risks and Opportunities

On January 18, 2018 the American Geophysical Union (AGU) announced a revision and reaffirmation of its position statement, "Climate Intervention Requires Enhanced Research, Consideration of Societal and Environmental Impacts, and Policy Development."

The statement was updated to reflect changes in the current understanding of climate intervention approaches, notably updating "geoengineering solutions" to "climate intervention" and discussing the two distinct categories of climate intervention: carbon dioxide removal (CDR) and albedo modification (AM). Further, AGU affirms its endorsement of more substantial CDR and AM research programs to examine these strategies in more detail, including programs outlined by the U.S. National Academies.

"We know the climate is changing, humans are responsible for most of the increase in temperature over the past half century, and that emissions reductions must play a key role in policy moving forward," said David Victor, Ph.D., chair of the Climate Intervention Position Statement Task Force for AGU. "Climate intervention could play a key role in managing the effects of climate change but our scientific understanding of its impacts remains poor. More research to understand it's full risks and opportunities will be vital to a more informed public policy."

The nine-person panel that reviewed and revised the position statement included:

- David Victor, University of California San Diego and Brookings Institution (chair)
- Ken Caldeira, Carnegie Institution for Science Piers Forster, University of Leeds
- Ben Kravitz, Pacific Northwest National Laboratory
- Marcia McNutt, National Academies of Sciences
- Joyce Penner, University of Michigan
- Alan Robock, Rutgers University Naomi Vaughan, University of East Anglia

- Jennifer Wilcox, Colorado School of Mines

AGU maintains position statements to provide scientific expertise on significant policy issues related to the understanding and application of their members' scientific disciplines.

The revised position statement was adopted by AGU's Board of Directors on 12 January 2018. The statement is based on AGU's previous geoengineering statement adopted on 13 December 2009 in collaboration with the American Meteorological Society (AMS) statement which was adopted by AMS Council on 20 July 2009. AGU revised and reaffirmed that original statement in February 2012.

Read the press release here: https://news.agu.org/press-release/agu-urges-research-programs-on-climate-intervention/

Read the position statement here: https://sciencepolicy.agu.org/files/2018/01/Climate-Intervention-Position-Statement-Final-2018-1.pdf

American Meteorological Society

AMS Releases First-Ever Report Stating Anthropogenic Climate Change Caused Major Weather Extremes

Last year's record global heat, extreme heat over Asia, and unusually warm waters in the Bering Sea would not have been possible without human-caused climate change, according to new research in Explaining Extreme Events in 2016 from a Climate Perspective, a report published as a special supplement to the Bulletin of the American Meteorological Society (BAMS).

In the six years scientists have been producing this annual report, this is the first time they have found that extreme events could not have happened without human-caused warming of the climate through increases in greenhouse gases.

Human influence was found to have increased the intensity and likelihood of terrestrial heat events around the world, in addition to affecting the severity of the El Niño, the severity of coral bleaching in the Great Barrier Reef, and the warmth of the North Pacific Ocean that impacted fisheries and other resources in the Pacific.

The new report presents 27 peer-reviewed analyses of extreme weather across five continents and two oceans during 2016. It features the research of 116 scientists from 18 countries looking at both historical observations and model simulations to determine whether and by how much climate change may have influenced particular extreme events.

As revealed in this year's report, the influence of human-caused climate change has become strong enough to push some heat events beyond the bounds of natural variability alone. In addition, scientists are reporting increasing confidence in their findings that human-caused climate change is impacting temperature-related events on land and in the oceans.

Major findings of the report can be broken into three categories:

Global heat: The record mean surface temperature for the world in 2016 was found to be "only possible due to substantial centennial-scale anthropogenic warming."

Asia heat: "The 2016 extreme warmth across Asia would not have been possible without climate change." Although El Niño (warming tropical Pacific waters) was expected to warm Southeast Asia in 2016, the heat in the region was unusually widespread. Another study produced evidence suggesting that a deadly April heat in Thailand, which devastated crops and broke records for energy usage, "would not have occurred in the natural climate" unwarmed by human influences, "even under the influence of a strong El Niño."

Marine hot spots: Ocean temperatures in the Gulf of Alaska, Bering Sea, and off northern Australia were the most elevated in 35 years of satellite records, leading to massive bleaching of the Great Barrier Reef and one of the largest harmful algal blooms ever off the Alaska shore. Natural climate variations played a part, but one study finds "it was extremely unlikely that natural variability alone led to the observed anomalies," and another study finds the blob of sub-Arctic 2016 warmth "cannot be explained without anthropogenic climate warming."

Read the full report here: https://www.ametsoc.org/ams/index.cfm/publications/bulletin-of-the-american-meteorological-society-bams/explaining-extreme-events-from-a-climate-perspective/

American Society of Landscape Architects Fund

ASLA Releases Statement on Clean Power Plan Repeal

In response to U.S. Environmental Protection Agency Administrator Scott Pruitt's recent announcement to repeal the Clean Power Plan, Nancy Somerville, Hon. ASLA, executive vice president and CEO of the American Society of Landscape Architects (ASLA), released the following statement:

"ASLA is extremely disappointed in Pruitt's decision to repeal the Clean Power Plan, which was projected to cut U.S. carbon emissions 32 percent by 2030. It comes at a time when American communities are bearing the destructive effects of climate change, with ravaging wildfires in the West, disastrous hurricanes in Florida, Texas, other Gulf Coast states, and in the U.S. territories of the Virgin Islands and Puerto Rico.

"These catastrophic events are costing our nation billions of dollars in property and infrastructure damage, imperiling human health and well-being, and destroying fragile ecosystems.

"While Pruitt's announcement is devastating, it is not surprising. Since taking office in January, this administration has taken several steps to roll back critical environmental and climate change policies. However, ASLA continues to fight for federal, state, and local programs and policies that allow landscape architects to use sustainable design techniques to help communities become healthy, resilient, and climate smart.

"Recently, ASLA convened a Blue Ribbon Panel of planning and design experts to develop a set of policy recommendations for mitigating and adapting to climate change through resilient design. The panel will publicly present its findings and policy recommendations in the form of a report in January 2018.

"With the repeal of the Clean Power Plan, the EPA must soon go through a full notice and comment period on the plan—I hope that all landscape architects and others interested in protecting our communities from the damaging impacts of climate change will join ASLA in weighing in on this critical issue."

Read more here: https://www.asla.org/NewsReleaseDetails.aspx?id=51882

For more information contact ASLA, 636 Eye Street, NW, Washington, DC 20001; (202) 898-244, www.asla.org.

American Water Resources Association

AWRA's Spring Specialty Conference

AWRA's spring specialty conference Analysis of Watersheds: Ecological, Hydrological, and Societal Responses, will be held in Orlando, Florida on April 22-25, 2018.

This is the 10th in a series of conferences designed around geospatial solutions to water resources related problems. Innovative water resources scientists, engineers, modelers, software designers from the public/government agencies, academic and private sectors convene to exchange ideas, compare challenges and solutions. Professionals working in aquatic research, management, and conservation involving process models, geo-referenced field data, remote sensing, or geostatistical models are encouraged to attend and show their work.

This year's conference features two Technical Program Co-Chairs. Dr. Dan Ames of Brigham Young University (BYU) is well-known to regulars of this conference and brings his expertise and interests in GIS-based water resources modeling, open source GIS, and web apps. Dr. Mike McManus of EPA, Office of Research and Development is a fairly new member of our tribe. He organized two very successful topical sessions with an ecological focus for the 2016 AWRA GIS & Water Resources conference that was held in Sacramento, solidifying a place in our community for geospatial water-based analyses involving ecology.

Topical Sessions Chair, Dr. Norm Jones, of BYU, has a long history of GIS-based hydrologic modeling and helped co-author the Arc Hydro Groundwater tools. He is actively fielding topical session ideas ranging from remote sensing application to water resources, Ele-Hydro, drones, watershed conservation, and the National Water Model.

In additional to the specialty topics, the National Hydrography Dataset and NHDPlus, climate change, flood modeling and all the regular topics will be well represented at the conference.

Read more here: https://awra.org/meetings/Orlando2018/index.html

Geological Society of America

GSA Issues New Position Statement: Geoscience and Energy Policy

GSA's governing Council approved a new position statement, Geoscience and Energy Policy, at its October 2017 meeting in Seattle, Washington. "This has been a long

time coming," said GSA President Isabel Montañez. "I would like to thank the committee for their thoughtful work and GSA members for their valuable input. We have a document that we can be proud of."

The position statement summarizes the importance of the geosciences in developing fundamental data upon which sound energy policy should be based and the contributions geoscientists can make to the framing of energy policy.

Current Chair of GSA's Geology and Public Policy Committee (GPPC), Art Snoke, noted that energy issues in particular have relevance to, and are debated, at many levels of society and government. According to the new statement, "Most energy sources have important and distinct geologic factors that should be considered when analyzing the life-cycle impacts related to exploration, extraction, development, operations, human consumption, waste disposal, decommissioning, and reclamation."

The new position paper states, "Development of a comprehensive energy policy that significantly reduces greenhouse gas emissions is essential for the future economic vitality, environmental well-being, and health and security of the citizens of the United States as well as other nations. Geoscientists locate, quantify, and help develop energy resources, and, along with professionals in other disciplines, assess and mitigate the impact of energy-resource development, operations, and use on the environment. Accordingly, input from geoscientists must be an integral part of all energy policy deliberations."

GPPC member G. Warfield "Skip" Hobbs emphasized that publication of the GSA energy statement "aims to inform policy makers in Washington that the geoscience community -- experts in climate change and energy -- agree that for the good of planet earth and humankind, policies must reduce fossil fuel carbon and other greenhouse gas emissions, and facilitate the transition to renewable energy resources."

The statement continues, "The challenge for energy policy makers is to develop a plan that will provide cost-effective improvements for the efficient and sustainable use of Earth's energy resources, reduce carbon emissions, and provide secure and affordable energy to the world's developing economies as well as the developed nations of the world. The knowledge and expertise of geoscientists take on added importance as countries and industries worldwide adapt to climate change and work to reduce carbon emissions."

Read the full text of the position statement here: https://www.geosociety.org/GSA/News/Releases/GSA/News/pr/2017/17-62.aspx

Society of Environmental Toxicology and Chemistry

SETA Europe 28th Annual Meeting

SETAC Europe 28th Annual Meeting will take place May 13–17, 2018 in Rome, Italy. This 5-day event will feature a variety of training, networking and learning opportunities. This year's theme, Responsible and Innovative Research for Environmental Quality, will focus on emerging research, regulatory developments and the latest methodologies in environmental toxicology and chemistry. Between 2,000 and 2,500 scientists, assessors, regulators and managers from academia, business and government, representing an average of 60 countries will attend.

For more information visit: https://rome.setac.org/

American Society of Civil Engineers

ASCE Conducts International Conference on Sustainable Infrastructure

ASCE's International Conference on Sustainable Infrastructure (ICSI 2017) took place in New York City from October 26-28, 2017. The Department of Design and Construction of New York served as the lead organizer of the conference together with ASCE. This gathering of civil engineers, urban architects, policy makers, technology experts, and related professionals provided a showcase for the latest developments and advancements in design, construction, technology, policy and education related to sustainable infrastructure.

Conference topics focused on sustainable cities for an uncertain world, covering relevant engineering research and applications that contribute to competitiveness and well-being. ISCI 2017 also devoted time to address the UN Sustainability Goals of developing sustainable cities and building resilient infrastructure, while supporting ASCE's Grand Challenge of how "we can work towards the shared goal of re-

ducing infrastructure life cycle costs by 50% by 2025 and foster the optimization of infrastructure for society."

Conference topics of particular interest included:

- Sustainable urban transport planning and infrastructure construction.
- Emission reduction and environmental remediation.
- Big-data analysis for urban science and engineering.
- Climate change effects on urbanization and governance.
- Financing large projects: domestic and global.
- Policy issues in environmental development.
- Sustainability in engineering education.

Read more about the conference here:http://www.icsiconference.org/sites/icsiconference.org/files/ICSI-2017-Call-for-Papers.pdf

For highlights of conference research, vist: https://ascelibrary.org/doi/book/10.1061/icsi2017

International News

Institute of Marine Engineering, Science & Technology

Global Powers Ban Fishing in the Central Arctic Ocean

Nine nations and the European Union have agreed to ban commercial fishing in the central Arctic Ocean (CAO) for a minimum of 16 years.

The moratorium was signed by officials from Norway, Russia, Iceland, Greenland, Canada, the United States, South Korea, China, Japan, and the EU following a sixth negotiating session in Washington, D.C.

There are currently no fisheries in the CAO, which extends across 2.8 million square kilometres — an area roughly the size of the Mediterranean Sea. However, increased melting of sea ice in recent summers has created open water in up to 40% of the region covered by the moratorium.

International law currently permits fishing in these waters in the absence of an agreement.

The pact will allow scientists to study the existing marine ecosystem in the Arctic before it is impacted by commercial activity.

"For the first time, nations are committing to scientific research in a high seas area before commercial fishing begins," says Scott Highleyman, vice-president of conservation policy and programs at Ocean Conservancy who also served on the US delegation negotiating the agreement.

"This precautionary action recognizes both the pace of change in the Arctic due to climate change as well as the tradition of Arctic cooperation across international boundaries."

While the initial term of the moratorium is 16 years, it will automatically be extended every five years unless a country objects or until research-based fisheries quotas are established.

Read the original report by Jennifer Johnson on the IMEST website:https://www.imarest.org/the-marineprofessional/item/3882-global-powers-ban-fishing-in-the-central-arctic-ocean

Meetings

February 2018

2018 Midwest Energy Solutions Conference. February 7-9, 2018. Chicago, IL http://www.mwalliance.org/events

American Geophysical Union Ocean Sciences Meeting. February 11-16, 2018. Portland, OR https://osm.agu.org/2018/about-the-2018-ocean-sciences-meeting/

7th Annual Climate Leadership Conference. February 28-March 2, 2018. Denver, CO https://www.climateleadershipconference.org/

March 2018

MIT Energy Conference. March 2-3, 2018. Boston, MA https://www.mitenergyconference.org/

Design-Build for Water/ Wastewater. March 19-21, 2018. Portland, OR https://www.dbia.org/Conferences/water/Pages/default.aspx

Global Food Security Symposium. March 21-22, 2018. Washington, DC. http://www.cvent.com/events/global-food-security-symposium-2018/event-summary-5fd68ce29d1c4ff5a66b133f1b895cd3.aspx

Sustainability Summit 2018. March 22, 2018. London, England https://events.economist.com/events-conferences/emea/sustainability-summit-2018

Sustainable Water Management Conference. March 23-28, 2018. Seattle, Washington https://www.awwa.org/conferences-education/conferences/sustainable-water-management.aspx

Society of Environmental Toxicology and Chemistry 7th Young Environmental Scientists (YES) Meeting. March 26-29, 2018. Madison, WI https://yes2018.setac.org/

April 2018

American Water Resources Association 2018 Spring Specialty Conference: GIS and Water Resources X. April 22-25, 2018. Orlando, FL http://www.awra.org/meetings/Orlando2018/index.html

2018 American Meteorological Society Washington Forum. April 24-26, 2018. Washington, D.C. https://www.ametsoc.org/ams/index.cfm/meetings-events/ams-meetings/2018-ams-washington-forum/

Managing Rivers, Reservoirs, and Lakes in the Face of Drought. April 24-26, 2018. Fort Collins, CO http://www.instreamflowcouncil.org/conferences-flow-2018/

May 2018

Climate Adaptation Conference 2018. May 8-10, 2018. Melbourne, Australia. https://www.nccarf.edu.au/content/ca18-climate-adaptation-conference-2018

Society of Environmental Toxicology and Chemistry Europe 28th Annual Meeting. May 13-17, 2018. Rome, Italy https://rome.setac.org/

The Resilience of the Water Sector. May 15-18, 2018. Munich, Germany https://www.wef.org/events/conferences/upcoming-conferences/the-resilience-of-the-water-sector/

June 2018

American Society of Civil Engineers World Environmental & Water Congress. June 3-7, 2018. Minneapolis, MN https://www.ewricongress.org/

4th International Symposium: The Effects of Climate Change on the World's Oceans. June 4-8, 2018. Washington, D.C http://meetings.pices.int/meetings/

international/2018/climate-change/Background

U.S. Energy Information Administration Energy Conference. June 4-5, 2018. Washington, D.C.
https://www.eia.gov/conference/2018/

Annual Conference & Exposition: Innovating the Future of Water. June 11-14, 2018. Las Vegas, NV
https://www.awwa.org/conferences-education/conferences/annual-conference.aspx

American Society of Mechanical Engineers Energy Sustainability Conference. June 24-28, 2018. Lake Buena Vista, FL
http://www.asme.org/events/power-energy

Association for Environmental Studies and Sciences 2018 Conference. June 20-23, 2018. Washington, D.C.
https://aessonline.org/2018-conference/

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