NYSERDA Environmental Research Program Plan

Research Area 2: Climate Change Adaptation

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NEW YORK STATE OF OPPORTUNITY. | NYSERDA

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NYSERDA provides resources, expertise, and objective information so New Yorkers can make confident, informed energy decisions.

Mission Statement:

Advance innovative energy solutions in ways that improve New York's economy and environment.

Vision Statement:

Serve as a catalyst – advancing energy innovation, technology, and investment; transforming New York's economy; and empowering people to choose clean and efficient energy as part of their everyday lives.

NYSERDA Environmental Research Program Plan
Research Area 2: Climate Change Adaptation

Final Report

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1 Introduction

1.1 Overview

Electricity generation is responsible for adverse environmental and economic impacts, including degradation of lakes, streams, forests, and buildings from acid deposition; elevated levels of mercury in fish and other wildlife; human morbidity and mortality from poor air quality related to ozone and particulate matter; climatic changes that impact health, ecosystems, and the economy; and direct and indirect environmental effects from alternative energy development. Although emission reduction efforts have resulted in some improvements, these impacts continue to affect New York State's sensitive ecosystems, vulnerable populations, and environmental justice (EJ) communities.

New York State Energy Research and Development Authority's (NYSERDA) Environmental Research Program monitors and assesses environmental conditions and fosters technological innovation, providing objective, science-based information to help address immediate and long-term energy-related environmental challenges across New York State. The program aims to increase the understanding and awareness of the environmental and public health impacts of energy choices and emerging energy options, and to provide a scientific, technical foundation for creating effective and equitable, energy-related environmental policies and resource management practices.

1.2 Research Planning

NYSERDA's Environmental Research Program conducts comprehensive planning efforts to guide policy-relevant research projects. Through this process, working groups of science and policy experts identify critical gaps and research needs in NYS focused on the major issues related to energy-related environmental impacts.

This plan can be used by NYSERDA; other New York State, regional, and national research funding organizations; the scientific community; local governments and municipal stakeholders; and policymakers to address research gaps and needs in New York while maximizing available resources to serve the State's needs.

This document focuses on the climate change adaptation component of the comprehensive research plan. It updates a 2014 version and should be viewed as a continual work in progress. As research findings become available and policies are implemented, the plan will be updated approximately every five years with input from State agencies, research institutions, and others. Each update provides an opportunity to revisit, revise, and reconsider NYS research priorities to ensure that the plan effectively addresses the current and future environmental issues of concern.

1.3 Climate Change Adaptation

Since its inception, the climate change adaptation component of NYSERDA's Environmental Research Program has significantly increased the understanding and awareness of the environmental impacts of energy choices and emerging energy options. It will continue to provide a scientific foundation for formulating effective, equitable, energy-related environmental policies and resource management practices that can guide strategies to prepare for a changing climate. The program builds upon the environmental research capabilities in NYS, addresses critical climate change-related issues facing NYS and the region, including the needs of environmental justice (EJ) communities, and creates opportunities for innovation. The program supports research studies, policy research and analyses, and outreach and education efforts related to the following questions:

- What are the current and projected impacts of climate change on all of New York State's sectors, and how can risks associated with climate change be cost-effectively managed and minimized? Additionally, how can the State take advantage of opportunities related to a changing climate?
- What are the key parameters that need to be monitored to establish baselines and assess climate change impacts in NYS?

The research needs discussed under this component of the plan are grouped generally by sector:

- Agriculture
- Coastal zones
- Ecosystems (in process)
- Energy
- Inland water resources
- Local governance and communities
- Public health
- Transportation
- Buildings

However, in reality, many of the topics touch on multiple sectors. To the extent possible, research should consider the implications, co-benefits, and unintended consequences to other sectors, as well as the implications for EJ communities.

1.4 About the Research Plan

To update this component of the comprehensive plan, NYSERDA gathered stakeholder input through several channels, including interviews, a workshop, and a webinar. This plan reflects the research needs that stakeholders identified through these processes. Within most sectors, stakeholders also prioritized three to four "top research priorities" based on (1) the feasibility of being able to implement a research idea (in terms of resources and time) and (2) the impact of the research on helping NYS adapt to climate change and build resilience. Where applicable, this plan also references regional or national research relevant to a particular topic, as well as organizations that are doing related research in the sector. These related research projects can help leverage resources, inform any work that is undertaken, and avoid duplication of effort. These related projects are only examples of ongoing or completed research on which to build and likely do not include all activities that may be of interest to new research projects.

2 Crosscutting Themes

Research topics do not always pertain solely to one sector or another. In fact, sectors themselves are intricately linked to one another in complex ways. This section describes crosscutting research ideas that were identified by multiple sectors or that reflect themes that came up numerous times across different sectors. Also captured in this section are ideas that are not necessarily considered research but are an important aspect of the research process.

2.1 Key Research Ideas

2.1.1 Data and Tools

- Synthesize climate information that has been collected at county and regional levels and connect the work done so far. Compile and present the information to help local planning and adaptation strategy development.
- Continue updating ClimAID and other studies in light of the latest climate science information.
    - Develop a system to track projections against observations.
- Research and develop systems-thinking tools that consider interdependent ecological, social, and economic systems interacting at several nested scales (land parcel, watershed, local community, state, national, and global).
- Research LiDAR needs across different sectors. The NYS GIS Clearinghouse maintains a collection of existing and in-progress LiDAR coverage.
- Evaluate how the New York Climate Change Science Clearinghouse and other climate data are being used in making, implementing, and monitoring adaptation-related decisions. Investigate how the use of such data might be expanded.

2.1.2 Resilience Planning

- Conduct a multisector/scale/jurisdiction coastal resilience planning study that considers how resilience planning and decisions in the coastal zone affect other, adjacent localities and other sectors, including transportation, energy, buildings, and ecosystems.
- Conduct research on land use change patterns (from coastal migration to solar energy build-outs) to help local planners and governments assess the best land uses in the face of a changing climate.

2.1.3 Social and Behavioral Research

- Conduct research to better understand what trade-offs people are willing to make between climate change adaptation measures versus behavior/habit/convenience.

- Incorporate recent research on behavioral insights/economics to develop more accurate models for climate change education, decision-making, and behavior change. For example, research shows that providing new data or information may increase climate change literacy, but it is not adequate for changing behavior.

2.1.4 Policy Assessment

- Assess the NY Rising Community Reconstruction (NYRCR) program process and status. Synthesize asset-risk information from NYRCR and develop a statewide database structure and metadata guidance. New York State Department of State (DOS) has already developed metadata guidance for its Geographic Information Gateway.
- Compile what actions have been implemented under the Community Risk and Resiliency Act (CRRA) and identify what legal or other barriers still exist. Propose potential ways to resolve the barriers.
- Assess the impacts of federal policies and programs on NYS climate adaptation policy objectives.

2.1.5 Cross-Sector Risks and Impacts

- Study the two-way relationship between the environment and the electric system. Environmental changes affect the electric system, but changes in the electric system also affect the environment.
    - Research the climate and resilience risks of expanded cross-sector electrification (e.g., electric vehicles and heat pump market penetration).
    - Research synergies between buildings and electric sources, such as electric vehicles with batteries and charging timing.
    - Research how successful electrification within multiple sectors might impact greenhouse gas emissions and energy infrastructure resilience, particularly when the infrastructure is stressed or damaged, such as during an extreme heat or storm event.
- Research best management practices (BMP) across all sectors to slow water movement through watersheds during storm events.
- Research food security vulnerabilities in NYS, such as food storage and access in areas prone to flooding from coastal storms or extreme precipitation events.
- Investigate streamflow and groundwater depletion issues with regard to a changing climate and more frequent or intense drought conditions. Determine populations and areas that are most vulnerable and preventative steps to be taken. Also, identify what types of irrigation withdrawal infrastructure and guidelines are recommended to meet social, agricultural, and environmental objectives.
- Inventory the preparedness of and adaptive capacity of State water systems, chemical storage facilities, and petroleum storage facilities for extreme weather events.

Related Research

- The New York Department of State (DOS) is undertaking a county-wide resilience planning effort, and the Department of Homeland Security and Emergency Services (DHSES) is updating the State Hazard Mitigation Plan every three years.
- The New York City Mayor's Office of Recovery and Resiliency is implementing several projects to rebuild and reduce the risks of a changing climate, including planning and policy studies, legislative actions, and infrastructure investments.
- The Department of Homeland Security (DHS) Regional Resiliency Assessment Program (RRAP) works with federal, state, and local partners to analyze critical infrastructure and address resilience issues that may have national or regional significance. DHS selects projects each year with input from these partners.

2.2 Ideas that Support Adaptation and Resilience

The stakeholders who were engaged in contributing to this plan had many non-research related ideas that nevertheless support adaptation and resilience. These ideas coalesced around building local capacity, sharing information, facilitating better communication, leveraging data and tools, and improving access to funding.

2.2.1 Local Community Capacity Building

- Support State and regional staff and experts in working one-on-one with local and regional government officials to assess and understand local needs and limitations. Promote peer-to-peer learning across communities.
- Support adoption of the National Flood Insurance Program. Regional councils are often overloaded with requests from communities on how they can reduce the flood insurance costs.
- Create a climate extension officer position or network of community liaisons to serve as a conduit between cutting-edge climate science and State/federal programs available to local communities.
- Explore how State/local government collaboration is able to connect context-driven risks, costs, and capacities to higher tiers of policymaking (i.e., bridging the gap between local nuances and federal resources).
- Explore opportunities to increase stakeholder engagement in climate change adaptation planning at the local level.
- Synthesize research and real-world experience to help bridge institutional and industry knowledge as key experts in the field retire.

- Improve dam management and safety by facilitating better communication and information sharing among entities that manage them. Establish an integrated management network of dams to share information and better manage flood risks, excess water, water storage, droughts, and other impacts. This type of information could also be helpful for droughts, or when dams might hold more water than usual and release it for power generating.

2.2.2 Funding

- Alert communities about new and upcoming grants and funding opportunities. Build capacity in communities, particularly those with limited resources and staff, to help them discover and obtain grants.
- Provide enough State matching funds so that the Federal Emergency Management Agency (FEMA) can update its flooding maps across the State, especially in areas that don't have digital maps.

2.2.3 Data Access

- Improve access to Mesonet data, which is a network of real-time atmospheric and weather observations used by many federal, state, and local agencies. These data can then be used across sectors and to improve early warning systems for weather events such as frost, drought, and extreme precipitation.
    - If such data are used, address how the data will be accessed and archived within NYS.

2.2.4 Financing and Insurance

- Investigate how the actors in the bonds rating, insurance, and reinsurance industry are obtaining and using information on climate change and accounting for uncertainties in hazard mitigation to inform their policies. Conduct research to determine if:
    - Their projections align with NYS's expectations.
    - Their sources, criteria, and policies are based on credible and current scientific consensus.
    - They account for issues such as public health and EJ concerns related to air-conditioning, pollen-induced allergies, and Lyme disease, which are not necessarily characterized by events such as hurricanes, floods, or health outbreaks, but yet have insidious and long-term impacts on many sectors.
- Consider creating watershed insurance to deter "bad" developments in source water areas.
- Research the viability of environmental impact bonds (EIB) to pay for sustainability and climate resilience projects. Washington, DC, is using the proceeds from its EIB to fund the construction of GI to manage stormwater runoff.

Related Research

- OPTrust/OPSEU Pension Plan in Ontario, Government Pension Investment Fund (GPIF) in Japan, and the New Zealand Super Fund are building climate risk over time into investment analysis and portfolio construction.

2.2.5 Cost Benefit Analysis (CBA) and Informed Investment

- Research the feasibility of conducting incremental, cost-effective resilience investment strategies. Consider design and investments in smaller increments, with flexible pathways for future enhancements (e.g., investigate the option of installing a three-foot flood wall today with the ability to expand to a five-foot wall in the future rather than investing in a five-foot wall today).
- Better characterize future investments in terms of real-world benefits. Evaluate past investments in terms of loss prevention studies.
- Create a methodology to estimate the costs of undertaking adaptation measures versus taking no action (e.g., avoidable costs of treating health outcomes) to help prioritize projects. Incorporate co-benefits in the methodology.
- Develop new or use existing CBA tools that include more externalities, including ecosystem services valuation, non-discounted future rates and multigenerational equity tradeoffs, and a resilience dividend. Also quantify costs and benefits of projects over longer time frames (e.g., 10-15 years).
    - Consider including both costs and benefits to numerous sectors and communities when conducting CBAs. What are the secondary and tertiary costs and benefits beyond direct damages or damages avoided in a CBA?
    - Develop ROI studies from projects that capture and quantify the benefits accrued to diverse groups of stakeholders across various sectors and communities.

2.2.6 Climate Change Communication

- Research the impact and influence of case studies (versus other traditional environmental communication) on stakeholder groups that are disinterested in climate change.
- Compile existing best practices for communicating climate change and environmental topics to stakeholders who are not influenced by most current climate change messaging.
    - Identify key messages, issues, and appropriate communication strategies that local community stakeholders can use to reach diverse audiences.
    - Incorporate behavioral insights research, narratives-norms approaches, and better behavior change and social change models.
- Synthesize existing communications research on how to translate complex, scientific data into information that State and local decision-makers can use to talk about adaptation issues. Develop training based on this research.

3 Equity and Vulnerable Populations

Certain communities are disproportionately affected by climate change and are less able than others to adapt to or recover from climate change impacts. Many of these communities already experience multiple environmental burdens, and climate change exacerbates these injustices. Understanding these communities' unique vulnerabilities to climate change can help in planning for these risks, developing adaptive strategies, and building community resilience.

3.1 Key Research Ideas

3.1.1 Vulnerability Assessment and Planning

- Conduct research to define, identify, and prioritize communities across NYS that are at greater risk to climate change risks, including increased exposures to hazards already present (e.g., people living near toxic chemical facilities) and existing exposure to climate hazards (e.g., NYC metro area during Hurricane Sandy and certain neighborhoods vulnerable to heat).
- Conduct research to better understand how current and projected occurrences of extreme events, such as heat waves, impact EJ communities to inform migration, adaptation, and resilience planning.
- Consider how to incorporate the NYS heat vulnerability index (HVI—New York City also has its own HVI) into adaptation and resilience plans. The HVIs consider both environmental aspects (e.g., access to green spaces, higher surface temperatures) and community/individual characteristics (e.g., socio-economics, health status) to identify and map risks to heat for communities and populations during extreme events.
    - Also, consider how the HVI work can be replicated with other climate hazards.
- Research the climate vulnerability of agency-specific types of low-income housing (such as New York City Housing Authority [NYCHA] residences) and develop potential solutions to reduce these vulnerabilities. Different agencies have their own rules, guidelines, and regulatory limitations pertaining to housing stock and tenants.
- Map proximity of EJ communities to brownfields, chemical bulk storage facilities, hazardous waste facilities, landfills, State Pollution Discharge Elimination System (SPDES) permit locations (for combined sewer overflows), and heavily industrial areas to understand potential exposures to toxic chemicals/emissions that could occur due to releases from an extreme event, such as in a coastal zone under a storm surge/flooding scenario.
    - Research potential long-term impacts such as soil contamination and cumulative or long-term impacts to water quality (especially for source waters that serve as public drinking water supplies). This research can help illuminate the additional climate change risks to EJ communities already facing disproportionate exposures to environmental contamination.

- Inventory existing policies and interventions (e.g., flood mitigation, green infrastructure (GI)) that enhance (and detract from) resilience, including where capital investments have been made. Compare the locations of these existing policies and interventions against the identified vulnerable communities to understand where to make the case for investment.
- Conduct more research into the climate change vulnerabilities and potential impacts on low-income populations in rural communities. For example, research could be conducted on the following:
    - How extreme events are affecting the electric grid and communications networks in rural communities and how populations could be impacted (e.g., heat and cold exposure, access to medical equipment) during such events.
    - What climate change means to rural communities looking at every sector in the NYSERDA ClimAID report; for example, some of these communities are very tourism- and agriculture-dependent, so research could be conducted to evaluate the climate change impacts on low-income, rural communities dependent upon those industries.
- Identify methods to quantify the deeper resilience benefit of hardening essential assets in EJ communities (e.g., a grocery store in a food desert). Identify possible incentives to encourage investments in these assets.

Related Research

- The Governor's Environmental Justice and Just Transition Working Group is developing a statewide mapping tool to identify disadvantaged communities, similar to the CalEnviroScreen in California.
- The University of Rochester has conducted a study that overlaid NYS outpatient data of asthma-driven emergency room visits against the HVI, which showed a strong correlation between these factors.
- NYSERDA partnered with DNV GL and NYCHA to develop a resilience assessment tool for multifamily housing.
- The 2018 NYC Climate Justice Agenda provides research and recommendations on how to equitably address climate resilience for EJ communities in NYC. While the focus is NYC, much of the content speaks to statewide policies and adaptation issues (with sections on heat, GI, waste, energy, transport, and other topical areas).
- The Climate and Community Protection Act (CCPA) and partnering Climate and Community Investment Act (CCIA) provide comprehensive recommendations on equitable climate adaptation solutions for disadvantaged communities in NYS. Section 74-0103 of the CCPA defines Disadvantaged Communities.

3.1.2 Co-benefits

- Research the co-benefits and unintended consequences of adaptation strategies and projects in targeted communities and in neighboring communities (which may or may not be EJ). For example, planting trees in a community can lower climate hazards *and* encourage people to get more exercise. However, this can also improve property values and lead to population displacement. As another example, when a microgrid is brought into a community, consider if it is powered by renewable energy or fossil fuels and the consequent impacts on air quality.
- Research the potential for clean energy projects (e.g., solar panel rooftops) and GI prospects in EJ communities that have vacant brownfield sites. Research if buildings in EJ communities are solar ready, such as those that may operate as shelters during a coastal storm.

Related Research

- The New York Community Greenworks Initiative (Department of State) trains local residents to undertake GI projects in their own communities.

3.1.3 Displacement/Integration

- Inventory policies and interventions to quickly remedy the temporary displacement of residents during extreme climate events. For example, research relevant ideas or lessons from other EJ communities (e.g., in New Orleans and Puerto Rico) that have experienced such displacements.
- Conduct research to better understand existing displacement pressures (e.g., gentrification, speculative building) and how these might interact with investments for climate resilience or increased frequency of extreme events. This research could also inform how pronounced forms of displacement could happen as the climate changes or as interventions/policies to improve resilience are implemented.
    - Displacement pressure maps exist for a variety of cities; for example, the Association for Neighborhood and Housing Development (ANHD) has a displacement map for NYC.
- Research best practices on how to absorb and integrate climate refugees who could migrate to NYS communities if displaced from other areas.
- Research long-term displacement impacts, including the economic/social impacts of planned retreat of distressed floodplain communities and how to develop programs/resources to help populations move to safer areas.

3.1.4 Public Health

- Research the intersection of public health and climate change impacts to understand how the health of at-risk residents of EJ communities might be affected. For example, in communities where there are many cases of respiratory and heart diseases, research the ability of individuals to secure critical medical equipment during an extreme weather event.

- Conduct research on adaptation strategies for extreme heat and other extreme weather events that could benefit EJ communities, including but not limited to deep energy efficiency retrofits, weatherization, enhancing/expanding green spaces and GI, developing community-specific preparedness plans, resilient energy and backup power, and distribution of special populations such as the elderly.
- Research strategies to incentivize landlords to increase energy efficiency and provide air conditioning (AC) in EJ communities with low-rent/low-property-value housing.
    - Explore strategies or policies to assist with electricity costs in low-income households with residents who have a medical need for AC (to address the cost of operating AC).
    - Conduct research to better understand indoor/outdoor temperatures and implications for heat exposure. This research is needed, for example, to determine maximum indoor temperature thresholds and consequences of implementing those thresholds under any policy that mandates AC be provided by landlords.
    - Explore how to support landlords of one- and two-family homes with limited resources who do not qualify for existing resources to achieve winter heating security.
    - Research ways to balance the need for AC for vulnerable populations versus the need to reduce greenhouse gas emissions from electricity use.
- Conduct research to quantify the health benefits (e.g., reductions in asthma cases) of improving or implementing place public health interventions in communities at increased risk to extreme heat (or other climate hazards).
- Assess the resilience and effectiveness of cooling centers and other community-serving resilience hubs that support residents and coordinate resource distribution and services before, during, or after a natural hazard event.
    - Conduct ground-up research to identify additional resilience hubs in EJ areas that communities trust and would be willing to visit during a major event.
    - Evaluate the potential for solar and storage systems at these facilities as a cleaner alternative to diesel generators.

3.1.5 Energy

- Research the impact of storm events (before and after) on EJ communities' energy demand and supply.
- Assess the energy grid impacts under an assumption that everyone in the residential sector has access to AC and how much a reduction by high-use customers, such as commercial users, is needed to ensure grid resilience and an equitable distribution of AC.
    - As part of this work, conduct a cost and needs assessment to determine who uses AC now and the extent of that use as compared to those who need access to AC but do not currently have it.
    - Include an analysis of how greenhouse gas emissions would or would not change or could be reduced.

- Conduct financial projections of recommendations and solutions that have already been suggested through state-sanctioned processes; for example, NYSERDA has published a roadmap with recommendations on how NYS can meet new energy-efficiency targets, including a pay-as-you-save pilot program to bring energy-efficient retrofits to high-need buildings, primarily low-income households. Financial projections can demonstrate the financial viability of these recommendations to utilities (or others) making these investments.
- Research utility circuit priorities during extreme weather events to understand which energy hubs are prioritized and where adaptation strategies are needed (i.e., in communities that won't be the first to have their power restored), and how these may or may not overlap with EJ communities or other vulnerable populations.
- Evaluate the financial gaps and other barriers that inhibit deployment of resilient distributed energy resources in EJ communities. Identify mechanisms, including capital financing, loan guarantees, and additional value streams, and evaluate their potential for filling the identified financial gaps.
- Consider EJ issues associated with shifting away from decentralized emissions (such as from vehicle tailpipes and refineries) to alternative models (such transitioning to a renewable energy power grid) that may affect local communities more so than current approaches.

Related Research

- An article in Energy Policy offers a framework for siting and dispatch of emerging and resilient energy resources to mitigate environmental burdens from polluting infrastructure.

4 Local Governance and Communities

Climate change adaptation funnels down to the local level where impacts cannot be separated or isolated by sector. However, often local decision-makers at this level are data providers to State-level research and have limited resources, staffing, funding, and training to synthesize research data from the different sectors and apply them to their community. Some of these ideas are not strictly research but are needs that must be addressed in order for communities to effectively adapt to climate change.

4.1 Key Research Ideas

4.1.1 Data and Tools

- Work with local decision-makers to catalog existing data and tools and to synthesize current needs assessments that have been conducted using established methods (focus groups, interviews, etc.).
    - Conduct research, such as through a workshop or survey, to discern how people use data and tools at a local level and which ones are valuable. Involve social scientists and regional planning associations if a workshop is held.
    - Use the feedback collected to improve products (iterative process) and to inform future technical studies so that they are useful for decision-making.
    - Ensure that decision-makers at all levels understand the scientific research and have access to the best-available data to assess and communicate risks in their communities.

Related Research

- The Northeast Regional Climate Center at Cornell and the Consortium for Climate Risk in the Urban Northeast (CCRUN) have conducted research on how climate change information products are influencing decision-making and adaptation, including modifications to the products that would better meet the needs of different stakeholders.

4.1.2 Planning

- Map and identify local institutional barriers to making and implementing effective climate change adaptation measures based on evidence. Identifying barriers may not remove the barriers but may highlight challenges that should be resolved in order to allow for effective adaptation, or may prevent investments of time, funding, and personnel in situations where success is highly unlikely.
- Conduct statewide research to monitor and evaluate the effectiveness of approaches to reduce climate change risks, particularly natural and nature-based approaches, so this information can be incorporated into local planning.

- Identify best practices for institutionalizing decision-making processes that focus on proactive planning rather than event response-driven planning. In particular, conduct research on how providing technical knowledge about natural resources, planning for open space, and keeping land in agriculture can increase ecosystem services and lessen effects of extreme weather events.
- Research models and processes for participatory future scenario planning with simulation exercises for considering complex, unpredictable, uncertain, and constantly changing systems, especially for anticipating climate change impacts with microscale ecosystem collapses and options for building resilience and adaptation.

4.1.3 Financing and Investments

- Research options to change or supplement funding sources related to disasters from reactive and responsive to more proactive and preventive. Although communities currently only have access to post-disaster assistance from FEMA, there has been some expressed interest in preventive investment funds. Conduct policy research to determine the barriers to reframing the FEMA program in this way.
- Develop evaluation criteria and a mapping tool (displaying open space which qualifies as Community Rating System [CRS] credit) to determine if a community is eligible and would benefit from enrolling in FEMA's CRS.
- Research the impact of climate change vulnerability on State and local economies, such as on credit ratings and bond values, to help inform resilience planning.
    - Develop guidance for local communities on the impacts of changing financing, bonding, insurance, and reinsurance costs and liabilities related to resilience (or lack of) investments.
    - Investigate if and how a threat of downgraded bond ratings influences climate change adaptation at a local scale.
- Recognizing the limited capacity for funding local needs, research existing local finance models that can help generate stable, continuous, and equitable local funding.
    - This research should include the use of local laws for watershed protection improvement districts with equitable runoff impact fee assessments; recent regulatory changes that now allow GI to be financed through bonds; payments for ecosystem services; and other best practices from communities with solutions that are working.
- Research the NYS Common Retirement Fund to discern what evidence would help communities make resilience investments that accurately price risk for an investor with a long-time horizon and what investments have measurable benefits. Pension funds have long-term liabilities to pensioners and accordingly are starting to match long-term assets and long-term liabilities.

Related Research

- The University of Pennsylvania has conducted a few studies on how resilience investments affect bond ratings and capital investments.

4.1.4 Cost Benefit Analysis (CBA) to Inform Investment

- Develop market-based models and government regulation models, as well as case studies that use "the third way," a commons-based approach to local management, governance, and decision-making. Highlight case studies that focus on:
  - Both initial costs and comparative long-term costs for maintenance of resilience measures.
  - Monitoring efforts that examine the long-term viability of resilient investments.
- Research capacity challenges at the local level that are hampering planning/implementation of resilience efforts. Evaluate the costs and benefits of home rule, including the loss of money due to duplicative services and how not changing the current system exacerbates risk in the long term.
  - This research could also analyze policy options to maintain local independence while promoting more sharing of planning resources at the county or regional level.
  - Identify, document, and promote successful adaptation projects that demonstrate the viability and worth of infrastructure investments in resilience and ways to link disaster risk reduction, climate change adaptation and economic development, as well as climate mitigation.

Related Research

- The commons-based approach has been used successfully by local communities throughout the United States and the world to mobilize and engage. It is based on Nobel-prize winning work on effective governance by Elinor Ostrom.

4.1.5 Climate Smart Communities

- Conduct a formal evaluation of New York State Department of Environmental Conservation's (DEC) Climate Smart Communities (CSC) program.
  - Research the extent to which communities that have adopted CSC's pledge have acted.
  - Include a comparative analysis of progress by communities with a regional coordinator, citizens' advisory council, or volunteer group versus those that do not have one.
  - Research how CSC work dovetails with other environmental planning work.
- Study the most impactful climate issues on NYS communities and how communities are responding. Identify common, easy-to-do adaptation measures and how results might inform communication regarding the CSC program.

4.1.6 Prioritization Criteria

- Compare the most impactful prioritization approaches for supporting for local communities. Are there certain communities that would be considered higher climate risk? Equity and environmental justice issues should be considered.
- Better understand or quantify the importance of a holistic approach to climate change and its effects on communities as a whole, rather than a segmented approach to homes, businesses, and infrastructure as separate elements.
- Identify potential opportunities/best practices for developing permanent climate adaptation capacity within communities and local/municipal governments and acknowledging climate change as a permanent issue for communities to address.

5 Agriculture

Climate change will pose risks and challenges to New York's agricultural sector but may also bring new opportunities. In the short term, higher carbon dioxide (CO_2) levels and warmer temperatures may increase the yield of some crops, such as grape crops in the Hudson Valley, or extend the season of others, such as specialty crops. However, because higher temperatures may favor invasive species at the expense of indigenous species that cannot adapt to changes in climatic conditions, or may allow novel disease and pest organisms into the New York ecosystem, increased pesticide and herbicide use and loss of biodiversity are expected, while short-term droughts are likely to increase the need for artificial irrigation and improved soil health in the region and increase stressors on farm animals.

5.1 Top Research Priorities

- Conduct long-term biophysical research on agricultural land practices to identify co-benefits (e.g., economic stability for farmers, carbon sequestration). Develop toolkits, BMPs, incentives, and communication methods to encourage farms to adopt adaptive and resilient measures.
- Conduct on-farm research for modelling of drought, pest, disease, and invasive species. Develop systems for delivering this information in real-time to farmers in order to make their operations more resilient to these pressures.

Related Research

- The Cornell Institute for Climate Smart Solutions has conducted extensive research in the area of agriculture and climate change, with strong stakeholder engagement in the agricultural community. One of the projects includes development of the Climate Smart Farming toolkit that provides various tools and resources for farmers, including county-level climate data and projections to help farms become more resilient to local impacts.

5.2 Other Research Ideas Related to Agriculture

5.2.1 Water Modeling, Management, and Conservation

- Research and improve models of seasonal drought forecasts to improve early warnings to farmers and inform coping capabilities.
- Research and improve predictive, contextual models of in-season risks of flooding, manure pit overflow, surface runoff and erosive soil losses. Alerting systems could be developed via phone applications for specific risks to farming operations.
- Develop toolkits and Best Management Practices (BMPs) for water management and agricultural practices to help farms and agricultural assets (crop and livestock) adapt to extreme weather events.

- Research soil and water management practices (tilling, cover crops, etc.) and their implications in the context of expected climate change.
- Research potential tradeoffs that may exist between water management conservation practices and greenhouse gas (GHG) emissions.

5.2.2 Pests and Diseases

- Research how climate change will impact agricultural diseases and pests on NYS crops.
- Investigate what additional pests and diseases will mean for pesticide usage and if additional controls or guidance will be necessary.

5.2.3 Land Use

- Research adaptive and resilient qualities of adding trees to agricultural systems (i.e., agroforestry).
- Develop toolkit-scale climate-smart agriculture (CSA) practices: for example, BMPs, or U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) conservation standards for farmers to assess impacts on their own and/or upgrade their practices.
- Study impacts of local/community land use changes on the agricultural sector in the context of climate change. Improve coordination of research and BMPs with local decision-makers so that climate change and agricultural issues are accounted for in land use decisions.

5.2.4 Adaptive Farm Management

- Study social and financial barriers to climate adaptation in agricultural decision-making. Assess the efficacy of current incentives for adaptive and resilient farm management. Facilitate the implementation of a social norms campaign that promotes adaptive strategies.
    - Investigate financial tools that would be most effective in incentivizing BMPs, including for conservation and resilience, for farming on rented lands.
- Develop BMPs and prioritization strategies for changing and diminishing work windows (e.g., changes in fair-weather days for farming). Research if improvements could be made or new strategies/technologies implemented that could better position farmers to complete their tasks.

5.2.5 Data Access

- Research ways to improve farmers' access to good, local weather data. For example, research how to improve access to real-time Mesonet data and enhance the applicability of these data for farmers. As part of this work, research opportunities or strategies to support free and open access to grid-interpolated data (farmers currently must pay for data access). Also, investigate ways to implement more on-farm weather stations for data monitoring, observing, modeling, and predicting weather events.
- Research climate and agricultural models and tools to inform decision-making for farms.

5.2.6 Crops

- Conduct research on crop diversification and develop guidance on field-level diversification (temporal and spatial) to increase resilience and adaptation. Study the diversity of crops as a risk management strategy for uncertain climate conditions.
- Assess the impact of insurance options and other positive incentives for implementing the most resilient practices for crops.

5.2.7 Soils

- Conduct on-farm research to quantify the impacts of soil health function on water storage, runoff/erosion reduction, nutrient management, crop yield and profitability, broad-scale watershed peak storm flows, and carbon storage.
- Study and demonstrate the return on investment (ROI) for farms that have invested in resilient soils.
- Model and demonstrate the benefits from increasing soil organic matter.

5.2.8 Outreach and Education

- Research best practices to engage farmers and rural communities on climate change issues. Identify the platforms, networks, language, and messaging that are relevant and trustworthy.
- Educate, train, and engage local stakeholders who support farmers working on climate change adaptation and mitigation (e.g., agriculture advisors). Stakeholders need to be aware of resources (financial and research) for development.
- Research how to use traditional/trusted communication channels to disseminate research findings about climate change impacts on agricultural diseases and pests to farmers in a timely way to help them plan their season to maintain yields.

Organizations Doing Related Research

Agricultural research projects would benefit from coordination with the following:

- Cornell Institute for Climate Smart Solutions
- Cornell Cooperative Extension
- New York Department of Environmental Conservation's (DEC) Invasive Species Council
- New York Farm Viability Institute
- NYS Soil and Water Conservation Committee

6 Coastal Zones

Rising sea levels, strong winds, and heavy precipitation resulting from severe coastal storms already cause billions of dollars in damages and disrupt transportation and power distribution systems. Sea-level rise (SLR) will greatly amplify risks to coastal populations and will lead to permanent inundation of low-lying areas, more frequent flooding by storm surges, and increased beach erosion. Barrier islands are being dramatically altered by strong coastal storms as ocean waters overwash dunes, create new inlets, and erode beaches. Loss of coastal wetlands from SLR will reduce species diversity, including fish and shellfish populations upon which the fishing industry relies and will also reduce natural protection from storms and erosion. Saltwater could reach farther up the Hudson River and into estuaries, as well as into groundwater in coastal areas, contaminating drinking water supplies.

6.1 Top Research Priorities

- Conduct a statewide shoreline characterization (natural conditions, hardening, land use, socio-economic information, environmental legacy).
    - Consider resolution, scale/extent, data available versus needed, how/why the information will be used, database structure, and metadata. Indicators and monitoring should be established to ensure sustained evaluation.
    - Identify areas that are hardened where a nature-based approach may be sufficient and could be considered in the future.
- Conduct a comprehensive, long-term, and detailed cost/benefit analysis of coastal adaptation strategies, looking at factors such as co-benefits, ecosystem services maintenance costs, disruption costs (e.g., people who use a particular area for fishing), and ROI. Consider both the costs of adaptation versus the costs of not adapting. Integrate new analysis to support decision-making.

Related Research

- New York State Department of State has begun a shoreline characterization that could inform a statewide effort.
- Data were collected years ago for the Hudson River, and a change analysis could now be conducted.
- The Nature Conservancy has conducted cost/benefit analyses that consider ecosystems services.

6.2 Other Research Ideas Related to Coastal Zones

6.2.1 Tidal Wetlands

- Conduct a valuation of blue carbon (sequestration of carbon in freshwater and marine tidal wetlands). This could include identifying either particular wetlands in NYS that are most effective and/or the characteristics of wetlands that make them effective at sequestering carbon. Also, conduct more research on freshwater wetland sequestration potential.
- Conduct research on sediment budgets for littoral cells within coastal areas. Knowing how much sediment is in the system and where it goes is critical to inform shoreline management decisions. For example, this research could help permit staff to evaluate the potential effects of a shoreline stabilization project and inform how to design nature-based features in a way that is most consistent with existing natural processes. Improved Light Detection and Ranging (LiDAR) data are needed as part of this research.
- Conduct research into how wetlands respond to SLR, including under different nutrient/sediment regimes, to develop more accurate predictive models. Include changes in land use or barrier removal scenarios, that is, how much natural resource management is needed once structures/barriers are removed to create successful wetland migration. This research will require the collection of significant amounts of baseline data like sediment budgets, current shoreline conditions/treatments, and ecological data like invertebrate and fish populations.
- Improve Sea Level Affecting Marshes Model (SLAMM) and other predictive models for the Hudson and Long Island to more accurately predict tidal wetland migration and use these models to identify land parcels for acquisition for wetland pathways.
- Investigate the feasibility of thin layer placement (TLP) to restore wetlands where appropriate.
- Analyze tidal wetland trends to demonstrate how much these areas have changed/moved since they were last mapped to support the need to remap wetlands. Start with a statewide change analysis between the 1974 maps and the National Wetland Inventory maps to justify the need for high-accuracy NYS tidal wetland mapping inventories at regular intervals.
- Research methods for preventing marsh edge retreat using sills or other structures.

Related Research

- Some reserves in the National Estuarine Research Reserve System (NERRS) have conducted blue carbon studies. The Waquoit Bay NERR has completed Bringing Wetlands to Market Study: Nitrogen and Coastal Blue Carbon.
- Woods Hole Oceanographic Institution has a high-resolution sediment model of the Hudson River and New York Harbor.
- The U.S. Army Corps of Engineers (USACE) and the Environmental Protection Agency (EPA) are collecting LiDAR data for about 16 priority wetlands in Lake Ontario. USACE is planning on repackaging data from the south shore of Lake Ontario into an online viewer.
- Scenic Hudson has used predictive models to identify land parcels for acquisition for wetland pathways for the Hudson River. TLP has been used in Jamaica Bay, and preliminary research has started at the Hudson River NERR.

Related Research

- The University of South Carolina has developed a sediment cohort model for tidal wetlands, and the Hudson River NERR (HRNERR) is seeking funding to collaborate with them. Sediment Elevation Table (SET) observations are being collected in Hudson River at Tivoli Bay (HRNERR) and Iona Island (PIPC) Constitution Island Marsh (Audubon); there also are some studies in Long Island and NYC.

6.2.2 Coastal Flooding

- Enhance modeling and data visualization of compound flood risks (coastal surge, SLR, groundwater, and stormwater). Develop modeling of compound flood impacts (e.g., extreme precipitation + high tide + storm event).
- Develop up-to-date and accurate predictions of groundwater and saline intrusion into groundwater in coastal areas and into the Hudson River, which is the water supply for several Hudson River towns.
- Model the increase in flood vulnerability associated with the loss of freshwater wetlands and/or floodplains in build-out scenarios. This modeling effort could support CRRA guidance and possible efforts to remap freshwater wetlands and/or update State building codes.
- Map the risk areas identified in DEC's New York State Flood Risk Management Guidance for Implementation of the Community Risk and Resiliency Act (base-flood elevation plus freeboard extended horizontally to intersection with the ground) to ease and expedite implementation of the guidance. This would require tributary modeling.
- Create a probabilistic-based risk assessment for all properties along coastal areas (for example, along the Hudson River in NYC, on Long Island, Lake Ontario-St. Lawrence region) for the next 50 years to get a sense of the risk to the real estate sector. Make this information available to counties/towns for planning purposes.

Related Research

- NYSERDA funded work on SLAMM to understand the potential effects of accelerated SLR on the New York Coast. SLAMM was applied to 1.43 million acres of coastal NYS under various SLR projections to show possible future outcomes.
- The NYS GIS Clearinghouse maintains a collection of existing and in-progress LiDAR coverage.
- FEMA Region 2 will be working with NYC to develop future condition flood hazard analyses that include long term and storm-induced erosion hazards.

6.2.3 Shorelines

- Conduct research to understand the cumulative impacts (e.g. multiple individual direct and indirect impacts that collectively and over time affect the same resource) of riparian and shoreline hardening/de-vegetation and development versus the benefits/ecosystem services of natural areas. Develop a methodology to assess cumulative impacts, which are also required to be considered in project review under the State Environmental Quality Review Act.
- Evaluate social/societal effects of large-scale barrier systems globally. Discern if they encourage development in high-risk areas and if residents protected by these systems devalue monitoring and maintenance of them over time because they assume, they are safe. Also determine how residual risk is affected over the long term.
- Build on work already begun to evaluate the performance of nature-based and other shoreline management features. Conduct more pilot testing of monitoring protocols already developed for sustainable shorelines, and of the monitoring framework developed for coastal areas across the State. Look at changes or trends at individual locations and cross-site comparisons. Support the collection of annual monitoring data using the protocols.
- Model shoreline change/erosion vulnerability/damages on Long Island under scenarios that vary by SLR, storm intensity, currents, development intensity, or other factors. Model the value of policies (the Coastal Erosion Hazard Area Permit Program (CEHA), building code updates, buyout programs, etc.) to reduce this risk.
- Conduct a legal analysis of the public trust doctrine and how it will be impacted by SLR, that is, if the legal demarcation of the shoreline rolls landward, who owns the land under water?

Related Research

- The Hudson River Sustainable Shorelines Project and the Jamaica Bay Science and Resilience Institute (JBSRI), along with DOS and NYSERDA, have piloted a monitoring framework to evaluate the performance of nature-based and other shoreline management features that achieve socio-ecological-economic benefits across varying coastline conditions in NYS.
- NOAA's Environmental Sensitivity Index (ESI) Maps have been completed for the NY/NJ metro area, Hudson River, and South Long Island; these maps show whether the shoreline is hardened or natural and can be used as baseline.
- The DEC has conducted a comprehensive shoreline analysis of where hard shoreline is failing for the Hudson River and opportunities exist for nature-based replacement. These datasets could be utilized as a template/blueprint for future data collection efforts by NYSERDA and/or other state agencies.

6.2.4 Great Lakes

- Compile more data on climate projections and impacts for the Great Lakes. In particular, compile water-level projections, impacts, and adaptation scenarios for different water levels, wave height and runup, and seiche effects. As part of this work, consider the potential for both increasing and decreasing water levels (since many communities on the Great Lakes may be interpreting water-level change impacts from high water only). Also consider parameters such as water quality and water temperature.
- Collect Sediment Elevation Table (SET) observations, sediment cores and/or model how tidal and Great Lakes wetlands are affected by coastal storms. How much do these features benefit from increased sediment mobilized by storms and how does that affect their persistence over time as sea levels rise? Are they accreting vertically?
- Conduct research into how extreme fluctuations in Great Lakes affect coastal wetlands under different nutrient/sediment regimes to develop more accurate predictive models.
- Secure a better understanding of coastal erosion and flooding impacts from SLR and extreme fluctuations in Great Lakes water levels and develop adaptation strategies.

Related Research

- The University of Michigan has several research centers devoted to the Great Lakes. These include the Cooperative Institute for Great Lakes Research (CIGLR) and the Great Lakes Integrated Sciences + Assessments (GLISA); The Consortium for Climate Risk in the Northeast (CCRUN) at Columbia University has a connection to GLISA. The Great Lakes-St. Lawrence River Basin Water Resources Council also has some data and research.
- The LIAA has several resources focused on community-based planning efforts along the Great Lakes.
- Various International Joint Commission (IJC) proposals (including the one that was ultimately implemented), include impacts on ecosystems, infrastructure, and improved property.
- NYSERDA funded a project with the State University of New York (SUNY) Stony Brook on seiching and adaptation in Lake Ontario (ongoing as of 2018).

6.2.5 Quantitative Analyses and Tools

- Develop tools for stakeholder-driven "if-then" analysis to study potential effectiveness of coastal adaptation measures under different scenarios of change; for example, a tool that assesses the actual resilience of a proposed project considering the tradeoffs across the community.
- Conduct a quantitative analysis of storm energy reduction benefits of different types of natural infrastructure, for example, seagrass, shellfish reefs, wetlands, etc.
- Conduct a quantitative analysis of adaptation potential of natural and nature-based features (NNBF) and grey infrastructure to gain a more holistic understanding of management options. This analysis would also reinforce the CRRA guidance on natural resilience measures and provide inputs for cost-benefit analyses.

Related Research

- The NY/NJ Harbor and Tributaries Study (USACE, NY, NJ) has evaluated the ecological, social, and economic implications of large-scale surge barriers in NY NJ Harbor and the East River.
- HRNERR, with the University of Florida and others, are conducting a study of the buffering capacity of Piermont Marsh on the Hudson River.
- FEMA Region 2 has done some limited benefit costs analyses to incorporate mitigating effects of sea grass on wave attenuation.

6.2.6 Managed Retreat

- Review the literature and/or conduct additional social science research (such as surveys in the wake of a storm about the response, impacts, etc.) to better understand coastal residents' risk perceptions and decision-making about managed retreat. Use research outcomes to develop and pilot communications and marketing products, such as video vignettes, that acknowledge community values and sensitivities.
- Develop tools for community, framing, projecting, planning, and managing equity/identity issues associated with retreat.
- Conduct research to understand the implications of managed retreat on local economies and tax bases as well as legacy environmental issues.
- Research possible market mechanisms to incentivize retreat from rising sea levels and other at-risk areas.
- Develop tools to help communities make decisions on adaptation alternatives, such as when to raise a house or when to move away, as well as how to choose a shore solution under various tide, wind, waves, SLR scenarios.
- Evaluate the value to NYS of a long-term buyout program (in terms of acquisition costs and reduction in damage/emergency services). Assess and map which areas might have the greatest value to the State from that perspective. This could include modeling to estimate the value of these areas returning to more naturalized conditions (supporting fisheries, recreation, carbon sequestration, water quality, etc.).

Related Research

- JBSRI has done some initial social science work related to managed retreat.
- The NYC Department of City Planning has recently designated three areas within NYC as "Special Coastal Risk Districts"(Howard Beach, Broad Channel, and Hamilton Beach) that limit future development; information from this project could be used in a case study.
- DOS has done work looking at transport development rights (TDR) as a way to provide municipalities in NYS with an effective and flexible technique for land use control.

7 Energy

Climate change is impacting both energy demand and supply. Climate change will adversely affect system operations, increase the difficulty of ensuring adequate supply during peak demand periods and worsen problematic conditions, such as the urban heat island effect. More frequent heat waves will cause an increase in the use of air conditioning, stressing power supplies and increasing peak demand loads. Increased air and water temperatures will decrease the efficiency of power plants, as they decrease cooling capacity. Coastal infrastructure is vulnerable to flooding as a result of SLR and coastal storms. Hydropower is vulnerable to projected increases in summer drought. Transformers and distribution lines for both electric and gas supply are vulnerable to extreme weather events, such as heat waves and flooding. Higher winter temperatures are expected to decrease winter heating demand, which will primarily affect natural gas markets, while increases in cooling demand will affect electricity markets.

7.1 Top Research Priorities

- Quantify the potential impacts of climate change across the energy system. Then, prioritize these impacts and establish a resilience strategy to address them. To do so, improve the characterization of potential climate change impacts on current and future energy systems, such as from increased, longer, and more intense extreme cold, heat, and precipitation events, which have caused surges in demand as well as in power disruption and electric system recovery/resilience. Also characterize the impacts on the energy system from renewable energy production and market penetration, and investigate the following:
    - How increased temperature and moisture (humidity) in the atmosphere and higher wind speeds affect wind energy production.
    - How changes in water temperature and availability/levels in lakes and rivers affect cooling processes in thermal and hydro plants.
    - How changes in water availability affect the production of electricity, and how the use of water in energy production can affect water quality and availability.
- Develop an alternate cost-benefit analysis (CBA) and a standardized data collection mechanism that quantifies climate adaptation/resilience investments and includes co-benefits and unintended consequences and costs.
- Research barriers and incentives to resilience planning and investment. Develop a framework for decision-makers to use to identify barriers that are impeding progress in resilience planning and policies that incentivize investments (the framework should consider both asset/network levels).

Related Research

- NYSERDA is currently funding a project with the Electric Power Research Institute (EPRI) on the potential impacts of climate change on NYS's electric generation system, as well as a study with SUNY Albany on the potential climate impacts on renewable energy generation.

7.2 Other Research Ideas Related to Energy

7.2.1 Policies

- Assess policy risks (i.e., changes to policy context) that would undermine energy system planning. When evaluating policies, consider the possibility that policy targets may not be fulfilled on time (as is the case with siting/permitting delays). For example, research what happens to the existing power system if renewables do not come online as scheduled.
- Assess risks to the energy system from changes in policies in other sectors. For example, if FEMA changes its flood maps in the future, how would the risk factors and planning for the energy sector be affected?

Related Research

- The Public Service Commission (PSC) adopts policies that establish incentives and removes barriers for utilities and could serve as a model for creating a policy framework for guiding public investments in adaptation and resilience measures.

7.2.2 Retrospective CBAs

- Scope a retrospective review of CBAs for hazard mitigation projects that examines benefits captured by projects that initial CBAs missed.
    - Characterize benefits (quantitative and qualitative) of resilience investment, both past and projected. Utilities submit information to the New York State Department of Public Service (DPS) for resilience/hardening planning, which can be used as a starting point to characterize benefits of resilience investments.
    - Quantify benefits from past resilience efforts to estimate the benefits of future investments.
    - Conduct region-specific CBAs by reviewing technologies that already exist, as well as those that may be appropriate for future investments.

7.2.3 Adaptation Strategies for Extreme Weather Events

- Research strategies to adapt the energy system to sequential extreme weather events (e.g., predecessor rain events, coastal storms plus intense rainfall, heat/cold waves after big storms) and multiple/joint hazards, including non-natural threats (e.g., cybersecurity events).

- Determine how extreme events may impact energy supply and demand, today's grid, and renewable and traditional energy generation across NYS and regionally within the State.
    - Assess how renewable energy generation and microgrids can help the current energy grid adapt to power outages and interruptions during extreme weather events.
    - Compare the value of distributed renewable energy generation and microgrids with the time and costs involved in repairing current grid failures during extreme events.

Related Research

- Experiences in Texas during Hurricane Harvey may provide insights into how energy companies protected their assets. DOE's report on Energy Resilience Solutions for the Puerto Rico Grid may provide additional information.
- The Electric Power Research Institute has a study that NYC is leveraging to identify benefits of adaptation measures using the Value of Distributed Energy Resources (VDER) process.

7.2.4 Energy Storage and Transmission

- Expand research on energy storage capacity, specifically optimal storage needs for renewables that will improve their reliability.
- Assess what would be needed to allow battery storage and photovoltaic systems to be designed for use as an emergency generator system *and* for use for daily energy needs.
- Study the impact of climate change on energy storage and any implications for reaching Governor Cuomo's 2025 energy storage target.
- Conduct research to ascertain if a next generation energy system is more or less resilient than the current system.
- Examine the role/reliability of transmission in supporting grid resilience in the future as the climate changes. Also, transmission plays a huge role in supporting renewable build-out, but it is faced with siting issues and long lead-times for development.

Related Research

- NYSERDA's Energy Storage Roadmap identifies near-term policies, regulations, and initiatives needed to realize the energy storage target.

7.2.5 Data

- Improve development and tracking of climate projections for the energy sector.
- Update methane emission factors for pipeline materials.
- Collect more data on energy usage on high cooling/heating days.

8 Inland Water Resources

Rising air temperatures intensify the water cycle by driving increased evaporation and precipitation. The resulting altered patterns of precipitation include more rain falling in heavy events, often with longer dry periods in between. Increases in heavy downpours will cause an increase in localized flash flooding in urban areas and hilly regions. Flooding has the potential to increase pollutants in the water supply and inundate wastewater treatment plants and other vulnerable developments within floodplains. Less-frequent summer rainfall is expected to result in additional, and possibly longer, summer dry periods, potentially impacting the ability of water supply systems to meet demands, as well as the quantity of flow needed to sustain some water bodies. Reduced summer flows on large rivers and lowered groundwater tables could lead to conflicts among competing water users. Increasing water temperatures in rivers and streams will affect aquatic health and reduce the capacity of streams to assimilate effluent from wastewater treatment plants.

8.1 Top Research Priorities

- Conduct research to better understand the temporal and spatial structure of precipitation and its relationship to streamflow, flooding, drought, and water quality. Consider including warming temperatures, ice cover, and scour and sediment dynamics as research components.
- Provide support for a multiscale (local, regional, State), integrated vulnerability assessment for flooding, including data, tools, communication strategies, and risk-reduction methods.
- Conduct research to support a statewide water accounting and data dissemination system to better understand where water is being withdrawn, by whom, how much is being returned, and who is using it. The system must be easily available, usable, and transparent to help decision-makers account for uncertainty in water supplies caused by climate change.
    - Build on information already collected by DEC and the USGS.
    - Learn from other states how to develop and deploy a statewide mechanism to collect water demand and usage data for both underground and surface water.
    - Refer to existing international guidelines and standards on how to collect, maintain, and disseminate data.
- Conduct research on interventions to control/manage inland flooding.

Related Research

- Utah, Texas, Colorado, Oregon, Nevada, Pennsylvania, and many other states across the U.S have state-level platforms that offer data visualizations or databases to track current, past, or projected water use. Researchers at the Columbia Water Center have performed a systematic review of various water data platforms offered in all conus states.
- The Australian Water Accounting Standards are internationally known for systematically tracking and communicating information about the amount water being traded, extracted for use, recovered, and managed for other environmental use.

8.2 Other Research Ideas Related to Inland Water Resources

8.2.1 Precipitation Data Needs

- Extrapolate data from existing collection stations in areas that have experienced extreme precipitation events to longer time frames and regional levels to gauge the scale of potential flooding and impacts.
- Invest in statewide LiDAR data to support research related to modeling future precipitation scenarios and land use and watershed changes to help develop adaptation strategies. Currently, LiDAR data and other imagery are available in fragmented formats, which gives researchers a limited understanding of the topographical landscape of precipitation and its potential impacts.
- Research the possible effect of higher ambient temperatures on water quality and on aquatic ecosystems and communities.

8.2.2 Monitoring River and Stream Data

- Research and synthesize best approaches for identifying and protecting river and stream corridors and active river channels, which can assist with planning and reduce flood damage.
- Develop safe or sustainable yields for all source waterbodies or reservoirs, particularly in light of projected precipitation and drought changes.
- To improve monitoring of stream flow and provide real-time data transmission, install more riverine gauges and increase funding for maintaining them. Stream gauges, in particular, need a longer dataset. However, the existing gauges provided by the federal government are not sufficient for monitoring, projecting, and preparing for riverine flooding caused by extreme precipitation. Consider installing gauges that are solar-powered.
- Research strategies for handling natural and manmade debris from storms.

Related Research

- The NYS GIS Clearinghouse maintains a collection of existing and in-progress LiDAR coverage.
- NYSERDA has supported research by Dewberry on debris loads in streams.

The following resources examine the role and importance of floodplains, riparian zones, or setbacks for sustaining stream system stability:

- A fact sheet developed by Ohio State researchers examines the role and importance of floodplains, riparian zones, and streamway or riparian setbacks for sustaining or establishing stability in stream systems.
- A research study conducted in Quebec used a sustainable management approach to enhance river resilience based on hydrogeomorphology concepts. The study looked at different levels of "freedom space" for different-sized flood zones.

8.2.3 Mapping

- Update flood maps and wetland delineations (freshwater versus tidal) in maps. Underlying FEMA base maps are outdated for planning and do not incorporate climate change projections.
- Research the best way to understand and map stream erosion hazards that are not currently included in NYS hazard mitigations plans (only inundation damage from flooding is included).
- Develop mapping and assessment tools for communities to identify impacts and risks from landslides due to increased erosion and extreme precipitation under climate change.
- Review the Vermont Agency of Natural Resources (VANR's) riverine flooding models and compare with NYS modeling efforts. VANR is working with towns to identify and map river corridors and implement protection strategies designed to mitigate river-based erosion hazards.
- Map the risk areas identified in DEC's New York State Flood Risk Management Guidance for Implementation of the Community Risk and Resiliency Act (base flood elevation plus freeboard extended horizontally to intersection with the ground) to ease and expedite implementation of the guidance. This would require tributary modeling.

8.2.4 Green infrastructure (GI)

- Study the potential for GI to help reduce flood hazards and study the effectiveness of different types of GI in a given location under various scenarios.
    - Improve understanding of GI benefits for adaptation planning, including long-term costs and benefits.
    - Evaluate potential negative implications of GI that may become more prominent under anticipated climate conditions in the future.
    - Better define what GI means using specific examples, specifically for state-funded projects that have GI as a requirement for local communities.
    - Provide guidance for local communities to build appropriate GI design and long-term monitoring technology.

- Research GI and other resilience investments that can reduce runoff and nitrogen loading in waters under EPA consent decrees, thereby avoiding expensive fines and penalties.
    - Measure and value reduced flows of nitrogen from stormwater management and the capacity of GI to reduce nitrogen levels; this research could support the case for resilience investments and financing mechanisms with investor return tied to reductions in nitrogen levels.
- Research land development impacts on impervious surfaces and land cover as a contributing factor to increased flooding.
    - Research available guidance to local communities about their flood risks resulting from certain land development patterns.

Related Research

- The City of Rochester, with support from county, State, and federal partners, developed a Green Infrastructure Retrofit Guide, which provides guidance on how to successfully incorporate GI practices in retrofits and redevelopment projects.
- The Capital District Regional Planning Commission has developed a GI toolkit to provide green alternatives to traditional stormwater management on small sites.

8.2.5 Water Supply

- Assess the financial and physical health of facilities that extract, treat, and manage water to better understand the vulnerability of NYS's water dissemination system.
- Collect data that captures seasonal variability of water supply.

8.2.6 Drinking Water

- Survey private citizens to understand if and how drinking water gets filtered or treated before being consumed.
- Research policy and conduct focus groups to determine the best approaches to improve planning/management for source water protection, particularly from runoff that could increase with extreme precipitation events. For example, many communities whose source water is in a neighboring community rely on land use decisions in those neighboring communities to protect their drinking water; however, there is no State- or county-level incentives or regulations in place to encourage them to protect another community's drinking water source or watershed.
- Research and recommend a standardized way for communities to evaluate climate change risks to water and drinking water infrastructure, such as wastewater treatment plants, piping systems, and pumping stations.
- Research the susceptibility of drinking water supplies to contamination due to flooding and heavy rainfall events; specifically track potential contamination from:

- Wastewater treatment plants and sewer infrastructure
- Chemical bulk storage
- Petroleum storage
- Solid waste management/landfills

8.2.7 Harmful Algal Blooms (HABs)

- Expand research in studying, monitoring, and addressing nutrients, harmful algal blooms (HAB), and emerging contaminants. Conduct research to better understand the cause of increasing HABs (such as those measured in the Finger Lakes) and study approaches for adaptation.

8.2.8 Dams and Culverts

- Assess existing culverts to better understand flooding issues where roads cross streams and to help prioritize culvert replacement or upgrade work.
- Research how culvert right-sizing or other actions might impact flooding across a watershed scale.

8.2.9 Risk Assessment, Planning, and Communication

- Investigate market-based or government-sponsored incentives to encourage communities to evaluate climate risks and develop long-term resilience plans. Research has characterized the risks from developing/urbanizing areas that are vulnerable to climate change, but local planners or constituents may not be fully aware of these risks. Incentives can spur planners and citizens to understand these risks and proactively develop long-term resilience plans. Incentives could do the following:
  - Encourage the use of FEMA tools that allow users to assess climate change vulnerability at a block-by-block level.
  - Encourage riparian protection and managed retreat from flood zones.
  - Establish full geomorphological assessment programs for stream systems that can evaluate changes in flood and erosion risks and recommend solutions.
  - Adapt DEC's risk communications efforts for the CEHA program as well as riverine risk assessment programs developed by Vermont.
- Develop an objective system or tools for communities to identify and measure their vulnerabilities in terms of ensuring long-term water quality and quantity.
- Conduct social science research to help translate probabilistic riverine data (e.g., 10-year floods don't necessarily occur every 10 years) to local decision-makers and communities so they can better understand their risks.

Related Research

- A model project by the Canal Corporation and the New York Power Authority (NYPA) integrates weather data and other information from multiple sources both upstream and downstream of dams.
- DEC has developed Dam Removal and Barrier Mitigation in New York State, a resource for private and municipal landowners interested in removing a dam or implementing an aquatic barrier mitigation project.
- The Hudson River Estuary Program and many partners are working on several culvert and aquatic barrier projects to prioritize those that are the most detrimental to fish and communities. It has created a map that provides both regional- and location-specific information about the aquatic barriers the project has assessed.
- New York State Department of Transportation has assessed some bridges and culverts with regard to climate change in the Statewide Flooding Vulnerability Assessment. The Nature Conservancy has also conducted culvert vulnerability assessments in northern New York State.

9 Public Health

Demand for health services and the need for public health surveillance and monitoring will increase as climate continues to change. Heat-related illnesses and deaths are projected to increase and outweigh reductions in cold-related deaths. More intense precipitation and flooding along the coasts and rivers could lead to increased stress and mental health impacts, impaired ability to deliver public health and medical services, increased respiratory diseases such as asthma, and increased outbreaks of gastrointestinal diseases. Cardiovascular and respiratory illnesses and deaths will be affected by worsening air quality, including more smog, wildfires, pollens, and molds. Vector-borne diseases, such as those spread by mosquitoes (West Nile virus) and ticks (Lyme, babesiosis, etc.), may expand or their distribution patterns may change. Water supply, recreational water quality, and food production will be at increased risk due to increased temperatures and changing precipitation patterns.

9.1 Top Research Priorities

- Study how energy is used across social strata and its public health implications (e.g., access to AC) and identify barriers to access a more equitable use of energy.
- Conduct an economic valuation of health outcomes from adaptation measures.
    - Understand the acceptable or unacceptable social trade-offs between health risks and climate adaptation measures.
- Establish a standardized, more centralized, more integrated, and more accessible monitoring system for pollen count and pollen-induced health data. Research the feasibility of setting up automated pollen counters and classifiers.

9.2 Other Research Ideas Related to Public Health

9.2.1 Climate Impacts on Health

- Study how projected changes in temperature, precipitation, seasonal variation, and climate events will affect various disease trajectories (e.g., Blastomycosis, Legionnaire's disease) and pollen exposure.
- Research how changes in severity and frequency of high-impact climate events (such as wildfires, hurricanes, coastal and inland flooding, and HABs) will affect public health issues.
    - Consider how these events may be impacted by shorter-term climate variability (e.g., changes to the El Niño Southern Oscillation).
    - Consider natural climate variability as a component of the research.
- Assess health benefits in connection to nature, including increase in use of natural day lighting and natural ventilation; such measures can, for example, both reduce energy demand and increase building capabilities during power outages.

- Conduct research to measure or predict potential health impacts from more than one stressor or more than one pollutant at a time, and how those multiple stressors may change under climate change. Because people are exposed to multiple stressors/pollutants simultaneously, research should address how stressors and pollutants interact with each other and the implications for human health outcomes. There also is a need for a multi-taxa model of exposure and health impacts, such as EpiModel, that provides the ability to look at impacts in different species that reside in the same habitat/climate.
- Collect and make available long-term environmental, health, and power outage data.
    - Develop models or mechanisms to compare multiple health outcomes under the influence of various conditions (temperature, humidity, etc.).
- Develop dose-response estimators for vulnerable populations (such as children and the elderly).
- Study how weather factors interact with or mediate particulate matter-health associations and how those might change under climate change.
- Study the health impacts from the urban heat island effect and how GI can help mitigate them.
- Study the impact of higher temperatures on reproductive and miscarriage rates.

9.2.2 Social Issues

- Investigate how to better communicate to the public (e.g., phone application, citizen science outreach, online learning, or other methods for socially isolated older adults or people with disabilities) the relationship between climate change and health impacts and how to prepare for these potential impacts.
    - Create tools to help communities become better aware of and prepared for medium—and small-scale weather and emergency events that could trigger health impacts.
    - Develop an early warning system for climate and weather factors that can impact public health, perhaps through machine warning.
    - Promote cross-sectoral research to ensure better coordination of health and climate outreach events and strategies. Establish special task forces within existing institutions to focus on this coordination.
- Research iterative mechanisms that allow researchers to disseminate information to local end users from those who use climate change and health research data and, conversely, seek input and local data from the same end users.
- Assess the ability of hospitals, nursing homes, and similar institutions to effectively adapt to climate change (e.g., how will energy and water usage change, how will emergency protocols change).
- Analyze potential health impacts (especially on/from/to NYC) of climate-related migration.

Related Research

- Be a Buddy is a pilot program funded by NYC in three neighborhoods that are vulnerable to extreme heat emergencies. Each neighborhood is fostering buddy systems between social service and community organizations, volunteers, and vulnerable residents. Buddies make phone calls, go door-to-door, or conduct building checks during emergencies to check on and assist vulnerable individuals.

9.2.3 Water Issues

- Improve understanding of impacts associated with impaired water quality from sewage overflows after heavy rainfalls and upstream flooding (for example, increased sediment inputs) and how this might alter under climate change. Determine how to communicate these risks to impacted populations.

9.2.4 Vector Diseases

- Improve understanding of vector-borne diseases, specifically how climate change affects the lifespan and spatial distribution of ticks and mosquitoes in NYS. Research how vulnerability to vector-borne disease has been changing and the relative contribution of climate and non-climate factors to vector distributions. Map vector populations as secondary indicators of risk. Research migration of pathogens such as *Naegleria fowleri and Vibrio bacteria.*
- Investigate the link between climate change and emerging infectious diseases (Dengue, Lyme, West Nile, and others).
- Assess the efficacy of vector-control measures for tropical diseases that may become more commonplace in NYS under climate change.
- Expand research and outreach on Integrative Pest Management practices, including those addressing possum populations, which may be an effective means to control ticks.

9.2.5 Vulnerable Populations

- Define and identify vulnerable populations and develop a climate change/adaptation "vulnerability index" for climate change impacts (e.g., extreme weather events, temperature changes, power outages, etc.).
- Study how to effectively reach out to those who are dependent on life-sustaining equipment during and after severe weather events that can lead to power outages.
- Study exposures and health risks in correctional facilities from changes in temperature, relative humidity, and storms. Identify barriers and strategies for interventions in these facilities.
- Study the long-term social changes resulting from climate change and adaptation on aging populations.

- Research the mental health impacts (including costs) of climate change migration, relocation, post disaster trauma, and long-term climate impacts (for example, increased pollens from warmer temperatures).
    - For climate-induced migration and relocation, study impacts beyond mental health (for example economic, societal, cultural etc.).
- Research the potential exposures and vulnerability of NYS outdoor workers in the face of more extreme climate events; these are individuals who must work outside in both the summer and the winter.

Related Research

- New York State and New York City each have their own heat vulnerability indexes (HVI). The HVIs consider both environmental aspects (e.g., access to green spaces, higher surface temperatures) and community/individual characteristics (e.g., socio-economics, health status) to identify and map heat risk for communities and populations during extreme events.

9.2.6 Other Topics

- Research the effectiveness of adaptation measures such as heat warning systems, cooling shelters, and other methods to alleviate health impacts from high temperatures.
    - Expand research beyond urban areas and to more vulnerable populations, such as outdoor workers.

Related Research

- NYSERDA has supported research with the New York State Department of Health on mapping cooling centers and population vulnerabilities to extreme heat.

10 Transportation

New York State's transportation infrastructure is vulnerable to climate change impacts in a variety of ways. For example, low-lying transportation systems, such as subways and tunnels, especially in coastal and near-coastal areas, are at particular risk of flooding as a result of SLR, storm surge, and heavy precipitation events. Materials used in transportation infrastructure, such as asphalt and train rails, are vulnerable to increased temperatures and frequency of extreme heat events. Ventilation and HVAC systems in buses, trucks, trains, and tunnels will need recalibration. In addition, resilience measures must also factor changes in transportation patterns resulting from both short-term events as well as long-term trends, which could stress roads, transit systems, and other infrastructure as populations evacuate and migrate. Possible evolutions in transportation technology aimed at reducing emissions, such as the electrification of the light-duty and transit fleets, may have unintended climate-related impacts on other sectors, such as the State's electric load and grid capacity and manufacturing base.

10.1 Top Research Priorities

- Research NYS transportation assets for their vulnerabilities to future climate impacts. Identify resilience needs and communicate them to local stakeholders. New York State Department of Transportation (DOT) has done some work in this area.
- Research costs and benefits of an expanded public transportation footprint designed to increase resilience of high-population density areas.
- Research how various improvements and innovations to the composition of materials commonly used to build and maintain transportation-related infrastructure could benefit NYS's transportation infrastructure and NYS-based industries. Research and assess how building materials used to construct transportation systems (e.g., piers, pavement, runways, tunnels, etc.) will fare under future climate change scenarios, including both extreme weather events (e.g., higher winds, submerged in sea water, etc.) and lower but more persistent conditions (hotter, drier summers, etc.). Consider the following:
    - The impacts of heat waves on transportation materials as well as transportation users, especially people walking and biking.
    - The emissions benefits from recycling concrete pavements.
- Research how to maximize resilience benefits and minimize impacts of grid-connected and emerging transportation technologies.

10.2 Other Research Ideas Related to Transportation

10.2.1 Vulnerability

- Create a database of NYS transportation infrastructure vulnerabilities.
    - Identify and inventory potential watershed-level flooding vulnerabilities across the State, starting with culverts, to identify at-risk transportation-related infrastructure and communicate these to local planners and decision-makers. DOT has done some work in this area.
    - Assess coastal NYC transportation systems (harbor services, subway, airports) to determine how vulnerable they are to sea-level rise and storm surge; determine if these assets/routes/systems need protection or adaptive strategies and how much that would cost; and assess viability of these systems for the future.
    - Define preexisting transportation network vulnerabilities for communities that do not have multimodal (e.g., walking, biking, transit infrastructures and systems) balance or access if roadways become impassable.
- Synthesize datasets and create a comprehensive NYS multimodal transportation database. Gather data on the usage of different transportation modes (airports, train stations, subways, buses, rail, roadways, etc.) to help prioritize vulnerable assets.
- Deploy a statewide network of real-time sensors (beyond what the Road Weather Information System [RWIS] has traditionally looked at) to support transportation network planning and resilience. Gather and share data on road weather, conditions, temperatures, etc. to help understand how these changes affect the system.
- Research projections of and provide data for sub-hourly precipitation rates for extreme weather events to guide urban drainage design for transportation infrastructure.

Related Research

The U.S. DOT's Federal Highway Administration has developed resources for planners that integrate resilience into the transportation planning process.

- Integrating Resilience into the Transportation Planning Process: White Paper on Literature Review Findings. This white paper describes how State and municipal planners are defining and integrating resilience into their long-range plans and programming documents.
- Resilience and Transportation Planning. This fact sheet outlines updates to metropolitan and statewide transportation planning regulations to reflect new resilience and natural disaster requirements.

10.2.2 Adaptive Capacity, Iincluding Planned Retreat

- Evaluate whether transportation systems (including airports, ports, rail, roadways, etc.) should be retired, dismantled, decommissioned, retreated from, hardened, etc. when SLR and storm surge suggest they are no longer viable. Compare the cost and benefits of different strategies using statewide CBA methodologies and protocols. Complement ongoing efforts to calculate costs for "climate proofing" NYS's transportation infrastructure.
- Develop implementation plans and actionable policies for NYS transportation stakeholders to carry out protective and adaptive measures.
- Develop scenarios that evaluate the potential for relocating critical transportation systems or hubs, such as JFK or LaGuardia airports, that are at high risk of flooding. Determine mechanisms to help incentivize coastal retreat from these assets when it is needed.

10.2.3 Low-Carbon, Enhanced-Mobility Strategies

- Map and plan for public transportation expansion strategically across NYS by identifying areas that have historic precedent for transit (e.g., Buffalo), are in close proximity to existing systems (e.g., White Plains), or meet other criteria.
- Study how to implement a gradual and planned entropy of highways, which would allow underutilized, excessively redundant, vulnerable, or very costly highway infrastructure to "return" to nature.
- Research how to better integrate water travel into the State's public travel network to provide more redundancy and resilience in the roadway, railway, and air systems.
- Research how enhanced bike infrastructure (including bike sharing), more walkable communities, etc. can help the State transportation system and individual communities to be more resilient to climate change impacts.

10.2.4 Emerging Technologies

- Investigate and model the resilience of shared-use and automated vehicles in disaster scenarios—both how the technology would fair and how these technologies would affect human behavior and mobility. What are the resilience risks associated with other new fueling infrastructure (e.g., how might inductive vehicle charging react to a storm surge?)?
- Investigate how design parameters should evolve to be sufficiently capable of withstanding different stresses in the future from climate change.

10.2.5 Grid Issues

- To accommodate a growing population of electric vehicles, investigate grid resilience and power outages and their impact on communities and mobility.
- Research the impacts on transportation resilience of a 100-percent renewable energy power grid.
- Research the implications of climate change on evacuation scenarios given emerging technologies (e.g., alternative fuel vehicles). Consider the role of sheltering in place and the strategies that can be implemented to make that a possibility.

10.2.6 Land Use

- Research how broad demographic trends could be affected by climate change and how the transportation sector needs to change and adapt to accommodate these trends.
- Identify and evaluate innovative strategies to use nature-based or ecologically enhanced shoreline stabilization or infrastructure components in the construction and stabilization of transportation infrastructure and to enhance carbon sequestration, underwater habitats, and other co-benefits without greatly increasing cost.

Organizations Doing Related Research

Transportation sector projects would benefit from coordination with the following:

- NYS Water Resources Institute
- FHWA
- New York State Department of Transportation
- Port Authority of New York and New Jersey
- National Cooperative Highway Research Program

11 Buildings

Because residential and commercial buildings use 39% of the total energy in the United States,[1] most climate change assessments focus on reducing greenhouse gas emissions from the buildings sector. However, because Americans spend 87% of their time indoors,[2] the New York State building stock is valued at over 2.34 trillion dollars, and climate-related events like Hurricane Sandy have caused more than 25 billion dollars in damage to buildings since 1960,[3] more research is needed to help the building stock adapt to a changing climate. This research is inherently interdisciplinary; the buildings sector overlaps with issues of environmental justice, energy use, water resources, local governance, public health, and the transportation sector.

As with the previous sectors in this plan, the buildings sector includes numerous research needs identified by stakeholders, as well as several top research priorities. However, this sector is slightly different because a separate workshop was held that focused exclusively on the buildings sector. Workshop participants were divided into sub-sectors, resulting in three to four top research priorities for each sub-sector rather than just for the buildings sector as a whole.

11.1 Top Research Priorities

11.1.1 Residential Sector

- Create an inventory of the New York State housing stock that defines buildings by sector, type, and region. This inventory should collect additional information that could be relevant to adaptation implementation, such as the current condition of the infrastructure, heating and cooling type, first-floor elevation, etc.

    - A follow-on study could assess how resilient the buildings are to the current climate, and project how resilient they will be to future climate impacts by using building fragility curves or other assessment methods.

[1] U.S. Energy Information Administration: https://www.eia.gov/tools/faqs/faq.php?id=86&t=1

[2] Klepeis, Neil E., et al. "The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants." Journal of Exposure Science and Environmental Epidemiology 11.3 (2001): 231.

[3] Ray, Paul, Nicholas B. Rajkovich, Michael E. Tuzzo, Martha Bohm, and Bart Roberts. 2018. Regional Costs of Climate-Related Hazards for the New York State Building Sector. NYSERDA Report 18-11b, Albany, New York.

- The inventory could potentially build on NYSERDA's Commercial Statewide Baseline Study.

- Study the behavior, attitude, and motives of homeowners as it relates to adapting their homes to climate change. Include factors such as how and when homeowners make major capital investment decisions or insurance purchases.

  - Based on this work, identify and communicate climate change issues to homeowners and builders to help them make more informed decisions.

- This should align with the crosscutting themes research referred to in section 2 of this report to better understand what trade-offs people are willing to make between climate change adaptation measures versus behavior/habit/convenience.
- Determine what climate adaptation strategies are appropriate for different typologies of residential homes in New York State. This study would identify and assess cost-effective measures for various housing typologies, factors to consider when deciding on a climate adaptation strategy, and how these adaptations could work with other strategies (e.g., greenhouse gas mitigation, savings on insurance, etc.). Factors to consider should include type of climate hazard addressed and time period over which the measure would be effective. Strategies should include consideration for building-owner type.

Related Research

The Building America Program conducts applied research, development, and deployment in residential buildings. Building America projects are led by U.S. Department of Energy national laboratories and expert building science teams in partnership with leading industry players (e.g., builders, contractors, and manufacturers).

11.1.2 Indoor Air Quality (IAQ) and Health

- Conduct a baseline health and safety study of indoor air quality, allergens, and thermal comfort in buildings across New York State. The study should assess the different environmental control systems being used such as air conditioning, natural ventilation, air infiltration, etc. The study should parse out the information based on the region, outdoor air quality, and building typologies as well as information on the effects on absenteeism and health before and after storms. The study could build on existing efforts like the New York State Building Condition Survey required for school facilities and should include factors identified in the Harvard School of Public Health's Schools for Health report produced by their Healthy Buildings team.

  - Information from this study should be aligned with any baseline building inventory work that is performed.

- This study should align with the public health research in section 9 of this report relating to how energy is used across social strata and its public health implications.

- Understand the opportunities and challenges to introducing new design concepts and implementing systems or designs that would lead to better indoor air quality from the top down (e.g., codes, code enforcement, etc.) and bottom up (e.g., better communication, toolkits, etc.).
- Conduct research into the current and future viability of air conditioning as a strategy for conditioning space under changing climate conditions. Conduct a need versus want comparison of air conditioning operation time versus interior thermal comfort. What are the current health, energy, equity, and environmental justice impacts, including the impacts of heat on children's thinking and learning? How do these shift with a changing climate?

  - Research alternative technologies for keeping building occupants cool, including natural ventilation design for large buildings.
  - Conduct research on human physiological adaptation of thermal regulation and how it may affect the need for cooling in the future.
  - Increase knowledge on air conditioning use, particularly by vulnerable populations. Perform a detailed equity evaluation of air conditioning use.
  - Conduct research to better understand what vulnerable populations know about indoor air quality and air conditioning.

Related Research

Climate Change, the Indoor Environment, and Health by the Institute of Medicine of the National Academies discusses the impacts climate change may have on the indoor environment and health.

11.1.3 Building Systems and Envelopes

- Research and revise/update relevant New York State building codes to increase the ability to shelter in place during extreme climatic events. This will relieve pressure on the grid/emergency facilities, and ultimately improve health, safety, and welfare in all building types in the future.
- Educate building owners and occupants on passive survivability strategies to reduce energy demand, expand the range of achievable comfort levels during a wider range of weather conditions, and better protect vulnerable populations against power outages.
- Identify issues within current systems that are preventing or limiting the implementation of innovative strategies, limiting communication between various parties (researchers, government, owners, occupants, etc.), or increasing the climate risk of the current building stock and its occupants. Examine the work of those who are making changes successfully and determine if those strategies would be applicable in other regions, building types, etc.

11.1.4 Community Scale

- Identify existing barriers between communities and State/county/local government that prevent climate adaptation in buildings, including zoning and building codes. Create case studies of successful implementation approaches and what barriers had to be overcome for action to occur. (This effort should align with the research discussed in section 4 of this report, Local Governance and Communities, to map and identify local institutional barriers to making and implementing effective climate change adaptation based on evidence.)
- Develop a plan to increase the ability of communities to meet energy demand during both acute and prolonged extreme climate events. This plan should include timeline-prioritizing interventions that have a high impact compared to time and the cost to implement. (This effort should also align with research discussed in section 4, Local Governance and Communities, relating to the most impactful prioritization approaches for supporting local communities.)
- Educate community residents on climate impacts at the personal level with the goal of building a broader, community scale, climate conscious culture. (This outreach should align with what is learned from the public health investigation in section 9 of the plan regarding how to better communicate to the public.)

11.1.5 Data & Modeling

- Gather building-level data on systems, structure, material, site, condition, age, history, occupancy, use patterns, and indoor conditions. This data could be collected by mining data from the Internet of Things (IOT), site surveys, tax assessor data, insurance data, and the Multiple Listing Service (MLS). Start data collection by establishing research partnerships, creating a modular data structure, and over time adding additional modules (e.g., indoor air quality, energy use) to update the database. Such a database of information would be useful in determining appropriate adaptation strategies and prioritization.
- Establish a framework to characterize and communicate climate uncertainty, sensitivity, and risk to the building sector, including building occupants. The framework should define systematic and acute risks, provide guidance on uncertainty and sensitivity as it relates to climate data, assist with setting probabilistic performance targets, and model building-level fragility. (This framework should align with the "Energy" research to quantify the potential impacts of climate change in the energy system.)

Related Research

- The NYC Climate Resiliency Design Guidelines provide step-by-step instructions on how to supplement historic climate data with specific, regional, forward-looking climate change data in the design of City facilities.
- With support from NYSERDA, the University at Buffalo School of Architecture and Planning's Resilient Buildings Laboratory recently published a series of reports to help New York's policymakers, architects, builders, building owners and managers, and residents understand the impacts climate change has on the State's building sector.

11.1.6 Cross Disciplinary

- Identify increased vulnerability in communities across New York State, particularly those susceptible to climate change related risks, whether they be health, financial, or life safety related risks. (This effort should align with the research discussed in section 3, Environmental Justice, to define, identify, and prioritize communities across NYS that are at greater risk to climate change risks.)
- Create definitions or baselines for adaptation and building performance that could be shared among organizations, local government, community groups, etc. to simplify communication and assist in developing shared goals. (This effort should align with the research discussed in section 2, Crosscutting Themes, on how to translate complex data into information decision-makers can use.)
- Create training programs to help bridge knowledge gaps between professions in the buildings (e.g., architects, engineers, planners), public health, and environmental sectors. Conduct a parallel study examining the effects of the training relative to the method of training and the participants involved.
- Investigate building buyouts as a strategy for reducing vulnerability in the built environment. Potential measures of success could be based on improvements to the social vulnerability index, poverty rate reduction, public access to green space, and public health (fiscal, physical, and environmental).

11.2 Other Research Ideas Related to Buildings

11.2.7 Residential Sector

- Identify existing tools that can help assess and provide recommendations for adaptation strategies for residential buildings.
- Develop or refine modeling tools for conducting a citywide, residential vulnerability analysis for climate hazards (extreme heat, flood, etc.)
- Conduct research to better understand the health impacts of passive-house building standards.
- Conduct focused research on the challenges, climate impacts, and adaptation strategies for low- to moderate-income (LMI) residential and affordable housing. Both single-family and multifamily housing should be considered. Include the particular challenges surrounding LMI historic preservation homes.
- Develop criteria for a resilient residential building.
    - Develop a taxonomy of potential building failures and acceptable risk of failure.
    - Gather data on the resilience performance of existing homes during hazard events, such as flooding.
- Identify synergies between residential energy upgrades and resilience/adaptation measures. Create a cost breakdown of new construction and renovations that incorporate a significant number of resilience strategies compared to standard home construction. Calculate the long-term energy/greenhouse gas emissions savings compared to a code home.
    - Similarly, gather data on the relative resilience performance of homes that are already high-performance homes in terms of energy use.
- Develop practical metrics for thermal comfort in residential buildings and, by extension, acceptable survivability standards.
- Determine the behavioral factors for and neighborhood impact of buyout or acquisition strategies.

11.2.8 Indoor Air Quality and Health

- Map the landscape of climate/health/IAQ tools. How accessible to everyone are the tools? How do users know which to use?
- Better understand interior material performance under predicated future climate conditions.
- Conduct research to better understand the IAQ health impacts on and adaptive capacity of vulnerable populations.
    - What are the short- and long-term impacts of climate disasters on the lives of people with disabilities and older adults? Better understand the ability of people with disabilities to use and implement indoor air quality adaptation strategies (e.g., use of windows).

    - Investigate IAQ climate adaptation strategies for people living with specific health conditions.

- Better understand the relationship between indoor and outdoor AQ and temperatures now and under future climate scenarios. How does the urban heat island effect play a role? How does passive design and building tightness affect IAQ under different temperatures and in different locations (e.g., urban versus rural)?
- Better understand how nuisance flooding impacts IAQ and health (e.g., mold) and how those impacts may change with future climate. Research mold-resistant materials for use in buildings.
- Develop a standard indoor health metric to be used in modeling.
- Develop better standard methods to model or estimate low indoor-air velocity. Computational fluid dynamics modeling is good but difficult to deploy at a large scale.

11.2.9 Building Systems and Envelope

- Research and develop standard methodologies and metrics to assess passive survivability in buildings that lose power. Identify the thermal and humidity conditions necessary to keep occupants safe in buildings during a power outage.
- Conduct continuous, fast, and iterative system tests to collect building-level data to learn more about the viability of current and newly implemented building systems. Create life-cycle performance evaluations of systems (e.g., health impacts) based on the data collected.
- Develop prototypes and case studies to help historic buildings adapt to climate change. Identify historic buildings or properties previously impacted by severe climate events across the State and in other locations, and identify what locational or other features have allowed them to withstand past weather events.
- Assess and improve occupant engagement in building operations. Determine the importance of giving building occupants control over building systems to assist with climate adaptation, and to what degree.
- Investigate how current passive-house, tight-envelope designs will work under future climate conditions. That is, if a building is designed tight under current conditions and parameters, how does performance change if those parameters change in a future climate? Consider how passive-house design may need to change to consider future climate conditions.
- Examine how solar and battery systems can most cost-effectively be designed and configured to serve backup power needs in buildings. Identify the most critical loads that should be provided with backup power systems.
- Better understand what “right sizing” of mechanical equipment will mean under future climate.
- Educate design leads to inform property owners of project requirements that should incorporate climate change.
- Assess and measure the resilience benefits of zero net energy buildings.
- Prioritize the research and development of climate adaptation strategies that work with a changing climate rather than strategies intended to resist the change (e.g., climate adapted buildings and systems).

11.2.10 Community Scale

- Compare the vulnerability of existing building stock to the vulnerability of occupant populations to help prioritize climate change interventions.
- Identify current and historical racial, gender, and ability inequalities and how they can be mitigated through improved building-level climate resilience. Explore opportunities to reduce racial and economic inequality through improved resilience.
- Explore the costs, benefits, and tradeoffs among housing affordability, zero-carbon standards, and resilience.

    - Examine how to adapt in communities with minimal to no economic growth.

- Research the interlinked effects on buildings of multi-hazard events, such as a wind event plus extreme cold; high heat plus extreme precipitation; hurricane plus high heat and other stressors.
- Quantify the benefits of alternative resilience strategies, for example, buildings versus electric grid and city versus neighborhood priorities. Examine interdependence and integration of strategies across scales as well. Evaluate the viability of climate resilience strategies based on local political structures (e.g., political system, political will, etc.).

11.2.11 Data and Modeling

- Make projected climate and weather data more accessible, including TMYs (typical meteorological year) for future decades.
- Predict and simulate building-level performance under extreme load given future climate conditions.
- Enhance existing or develop new models that integrate different data sets and account for interdependencies.

    - Integrate data related to vulnerable populations and inclusive build environments.
    - Incorporate utility-infrastructure-to-building and building-to-building interdependencies.

- Better understand the extent of urban microclimate effects, particularly in relation to a changing climate. Model future microclimate information, both real-time data and projections into the future.
- Develop models for determining the probability of damage to a building, to understand potential improvements due to implementation of green building technologies, being sure to account for human health risks.

11.2.12 Cross Disciplinary

- Evaluate what climate adaptation strategies we are familiar with now but are not acting on, and determine the source of the hesitation (e.g., change in behavior, lack of education, impracticalities with cost or scale).

- Determine what strategies are practical and respectful at different scales or locations (e.g., indigenous knowledge versus universal standards). Make clear that strategies developed for New York are viable beyond State boundaries and that strategies developed outside New York can also be effective in-State.
- Identify the possible unintended consequences of a strategy on disciplines not directly involved in the development of a strategy.
- Create a statewide or regional leadership structure to promote climate adaptation in buildings that can bring together diverse populations, climate zones, landscapes, and cities.

NYSERDA, a public benefit corporation, offers objective information and analysis, innovative programs, technical expertise, and support to help New Yorkers increase energy efficiency, save money, use renewable energy, and reduce reliance on fossil fuels. NYSERDA professionals work to protect the environment and create clean-energy jobs. NYSERDA has been developing partnerships to advance innovative energy solutions in New York State since 1975.

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