S U S T A I N A B L E J E R S E Y
SUSTAINABILITY SUMMIT
DUKE FARMS • HILLSBOROUGH, NJ • SEPTEMBER 18, 2013

Climate Change Adaptation and Natural Hazards

Climate change is expected to create weather-related stresses on our communities and natural resources. Natural disasters are an existing stress and expected to be a greater issue due to climate change into the future. This brief is distinct from other *Sustainability Briefs* addressing related, broader issues, specifically including: Energy (including mitigation of greenhouse gases); Water Availability; Water Quality; Water Infrastructure; Agriculture and Food Security; Quality of the Built Environment; Air Quality, Indoor Environmental Health Hazards; and Biodiversity and Habitat. For this reason, only sustainability issues directly related to natural hazards and climate change adaptation needs (as differentiated from methods to reduce the severity of climate change) are addressed within this brief.

1 Background Information

Strong scientific evidence and models indicate that greenhouse gases from fossil fuel use, agriculture and other sources have been rising dramatically (IPCC 2007). These greenhouse gas emissions are indirectly driving global climate change, as increased global temperatures affect climate and weather patterns. There are many likely repercussions regarding ecosystem viability, agricultural production, disease incidence, glacial and sea ice melt, sea level rise, ocean acidification, precipitation patterns (including monsoonal patterns), weather extremes, water availability, primary productivity, etc. (IPCC 2007). These in turn impact our communities both in their day to day functioning, their response to increased natural disasters and impacts and in their physical viability in locations severely impacted by the changes. The sustainability of society will be affected. There is the need for adaptation policies and actions to address changes that can no longer be avoided.

1.1 Effects on Communities

Many of the direct effects of climate change on communities will involve heightened natural hazards, as a warmer atmosphere and oceans are projected to power both increased precipitation intensity (more rainfall per storm), on one hand, and more frequent and severe droughts, on the other (IPCC 2007). Historically, development in this country occurred in coastal and riverine locations to benefit from water transportation routes (and on rivers), water supply and water power. Today, coastal and riverine development is more associated with quality of life and the new trend of traditionally seasonal communities transforming to year round communities. This brings some increased densities but more importantly places additional lives at risk and increasing property and public health damages from catastrophic events. These large events have generated efforts to mitigate damages through many programs, from enhanced building codes to structural protections to removal of at-risk structures. (FEMA 2000a)

Public health and safety threats from land uses in hazardous locations can range from stress and illness to physical injury and mortality. Threats come also from disaster-related loss of water supply, wastewater treatment, power and transportation systems; release of chemicals from manufacturing sites, chemical stockpiles, railroads, and toxic waste sites; structural damages to buildings and other facilities; and indoor conditions related to mold and other pollutants (FEMA, 2000b). Threats also come from the rebuilding process, to the extent that the resulting structures remain subject to future catastrophic events (Kirkham and Rudolph, 2012; FEMA, 2000b) or exposure to toxins or other hazardous substances.

A critical factor for mitigation is the accurate, defensible and effective identification of hazards, hazardous areas and mitigation measures. For example, FEMA is developing updated flood hazard area mapping for both coastal and riverine flood areas, using more modern topography (e.g., LiDAR) and models. The assessment of risk is often very confusing to lay persons. In part this confusion is due to the use of the term "100-year" event which equates in many people's minds to "once in one hundred years" but is actually a statistical evaluation of annual risk. "A house in the 1 percent annual chance (100-year) floodplain has a 26 percent chance of being damaged by flooding during a 30-year mortgage." (NRC, 2009) Risks are evaluated through models; storms are not required to fit our models, and our models are too often outdated, excluding significant areas that should be mapped as hazardous.

A major conflict is brewing between FEMA's needs to have National Flood Insurance Program rate-based income match expenditures, the desire of the insured population to have affordable rates or affordable mitigation measures or both, and the potential that some will forgo NFIP coverage (due to costs) and risk losing everything in future events.

Once hazards and hazardous areas have been identified, the operative question is how to address the certainty of future damages. Two concepts apply: hazard mitigation and resilience.

> "*Hazard mitigation* is defined as the actions taken to reduce or eliminate long-term risk to people and property from hazards and their effects. This definition distinguishes actions that have a long-term impact from those that are more closely associated with immediate preparedness, response, and recovery activities. Hazard mitigation is the only phase of emergency management specifically dedicated to breaking the cycle of damage, reconstruction, and repeated damage." (FEMA 2000a)
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> "*Resilience*: The ability to prepare and plan for, absorb, recover from, or more successfully adapt to actual or potential adverse events." (National Academies, 2012)

1.2 Effects on Water Resources

Climate change and natural hazards affect water resources. Storms and floods can damage dams for reservoirs and lakes. Droughts can greatly reduce stream flows, harming aquatic ecosystems in streams, rivers, lakes and estuaries. Industrial uses of surface waters, including cooling water for electric power generation, may be constrained. Reduced stream flows also can harm agriculture, which often uses surface waters for irrigation water and livestock. Some agricultural needs are provided by natural precipitation, but irrigated agriculture is the second largest water uses in the United States after electrical power generation, and the largest single consumptive water use (Kenny et al., 2009). Finally, reduced stream flows stress public water supplies and harm water quality, as less water is available to dilute both natural and anthropogenic pollutant loads.

For further discussion on water sustainability issues see the *Water Availability, Infrastructure and Quality Sustainability Briefs*.

1.3 Effects on Agriculture

Agriculture "encompasses the entirety of the system that grows, processes, and provides food, feed, fiber, ornamentals, and biofuel for the nation." (NRC, 2010) As such, agriculture includes both products that are fundamental to life (e.g., staple foods, lumber) and products that provide "quality of life" benefits but for which substitutes are readily available (e.g., native plantings rather than turf grass, domestic food products rather than exotic foods). Climate change and natural hazards affect agriculture in several ways. Severe storms can damage crops directly through flooding, excessive moisture at the wrong time, or high winds. Agricultural production cycles can be altered by early onset of warmer temperatures, and by excessive heat during the summer that slows plant growth. Elevated temperatures can combine with shifts in rainfall patterns (for instance, to less frequent but more severe storms) to reduce soil moisture, which increases plant stress and irrigation needs; irrigation demands increase with decreasing rainfall and increasing temperatures. Each of these effects can increase production costs and therefore reduce the economic viability of agriculture.

For further discussion on agricultural sustainability issues see the *Sustainability Brief* on that topic.

2 Sustainability Issues

2.1 Unsustainable Impacts of Climate Change and Natural Hazards

The National Academies (2012) notes: "Unless [the] current path in the nation's approach toward hazards and disasters is changed, data suggest that the cost of disasters will continue to rise both in absolute dollar amounts and in the losses to the social, cultural, and environmental systems that are part of each community." Where water resources are not managed in a sustainable fashion, society can expect to incur costs and economic inefficiencies including but not limited to: insufficient water for users; loss of water system values; economic disruption; and social disruption. Unsustainable agriculture in the face of climate change and natural hazards will be seen in reduced farm profitability due to additional stresses, or in practices with short-term economic benefits but long-term damage to soil resources and other aspects of sustainable agriculture.

2.2 Assessment of Climate Change Adaptation and Natural Hazards

In many ways the critical assessment with climate change and natural hazards is that New Jersey will face the same risks as before, but more so. A major concern is that we can no longer use the past to predict the future, as conditions are fundamentally changing, but we will need to predict future conditions so that we can adapt to them successfully. Modeling using scenarios will be a critical tool. Projections from global climate change models as applied to the New Jersey indicate roughly the same average precipitation, but in fewer events with higher precipitation per storm and worse droughts when they occur. Warmer temperatures will increase evaporation and transpiration, so less water will recharge aquifers and runoff into streams; plants will face more stress absent irrigation. As irrigation needs are greatest during the driest and warmest periods, water supplies will be least available when crops are most stressed. Warmer temperatures and more moisture in the air will drive more powerful storms. Southern species, including pest species, are likely to move into New Jersey, as has already occurred with the southern pine bark beetle into the Pine Barrens.

2.3 Challenges in New Jersey

New Jersey is not greatly affected by tornadoes, earthquakes or landslides, though they do occur periodically. Our greatest hazards in terms of damages are wind (nearly 40%) and severe weather (28%; winter and other) (HVRI 2012). Just in 2011-2012, enormous damage has been caused by winds, riverine flooding, coastal surge flooding and wave action, and major snowstorms – the last despite two winters with below-average snow fall. New Jersey has a legacy of considerable floodplain development along rivers in northern and central New Jersey. Barrier Island and coastal development has dramatically increased in density and value over the last decades despite coastal development regulations (Wood et al., 2010). Even our historic cities were shown by Hurricane Sandy to be vulnerable to major coastal flooding. In all of these events, damage to electrical, water supply, wastewater, storm water and transportation infrastructure systems have shown glaring problems with the sustainability and resilience of each. These issues can be mitigated through improved practices, thoughtful redevelopment, planning and major investments. However, given the scope of the problems, it likely will take decades and continuing damage from future natural disasters to create the political will and opportunity to make improvements. New Jersey is not at the national state of the art for natural disaster planning and mitigation, nor even for natural disaster response. Reaching that level will require enormous changes in expectations and approach.

Water resources in New Jersey are frequently subject to minor to major droughts, with streams and shallow aquifers most affected by losses. Climate change is likely to exacerbate drought conditions, stressing our economy and natural resources. Our agricultural sector differs significantly from the national norm, with NJ farm average size (71 acres) less than one-fifth of the US average, and a much smaller share of large farms (USDA 2007). As such, NJ has a disproportionate number of farms relative to farm acreage. Gross receipts from non-food, non-fiber products such as sod, ornamental trees and shrubs, and flowers constitute a much higher share than nationally; all rely on irrigation to some extent (USDA 2007; NJDA 2011). During severe droughts, irrigation for these purposes is likely to have a lower priority than potable water supplies. Adaptation to these climate change effects will be required.

3 Sustainability Responses

Climate change is a global issue; as such, many of the current sustainability responses are happening at the international and national levels.

- **Emission Targets**: The Kyoto Protocol, adopted on December 11, 1997, is an international agreement linked to the United Nations Framework Convention on Climate Change, which commits its Parties by setting internationally binding emission reduction targets. Nationally, while the United States was one of the original 83 signatories of the Kyoto Protocol it was never ratified by Congress and is thus not enforced. The 2005 U.S. Conference of Mayors Climate Protection Agreement urges participating cities to strive to meet or beat the Kyoto Protocol targets (7 percent reduction) established for the United States and to urge the U.S. Congress to pass bipartisan greenhouse gas reduction legislation.
- **Cap-and-Trade Programs**: The European Union Emission Trading System (EU ETS) launched in 2005 is the first large emission trading scheme in the world. Covering 31 countries the installations regulated by the EU ETS are collectively responsible for close to half of the EU's carbon emissions and 40 percent of its total greenhouse gas emissions. While the U.S. has successfully used cap-and-trade programs to reduce sulfur and nitrous oxides there is no national program carbon trading

program, despite the passage of the American Clean Energy and Security Act of 2009 by the House of Representatives.

- **Regulation**: On June 25, 2013, President Obama issued a Presidential Memorandum directing the EPA to work expeditiously to complete carbon pollution standards for the power sector. Starting in 2009 the agency has used its authority under section 111 of the Clean Air Act to issue standards, regulations or guidelines, as appropriate that address carbon pollution from new and existing power plans. The Presidential Memorandum specifically directs EPA to build on state leadership, provide flexibility and take advantage of a wide range of energy resources and technologies towards building a cleaner power sector. (EPA, 2013)

  In 2007, New Jersey adopted a progressive piece of legislation, the Global Warming Response Act; which mandates aggressive reductions in greenhouse gases within the state, including a reduction to 1990 levels by 2020, and a reduction to 80% below 2006 emission levels by 2050. See the *Energy Sustainability Brief* for further information. The State's 2011 Energy Master Plan has five overarching goals: to drive down the cost of energy for all customers; promote a diverse portfolio of new, clean in-State generation; reward energy efficiency and conservation and to reduce peak demand, capitalize on emerging technologies for transportation and power production; and maintain support for the renewable energy portfolio standard of 22.5 percent of energy from renewable sources by 2021.

- **Technological Responses:** In order to meet the various targets and emission reductions that are necessary to the above policy responses technological advances are necessary. Some technical responses are well developed and already applied to major sources of greenhouse gases. Other techniques such as carbon sequestration, which relies on capturing and storing CO2 in the ground, are still unproven at large scales.

4 Implications

There are several major implications regarding sustainability in this area. First and foremost, the effects of climate change and natural hazards come in their own time and are "predictable" only through risk assessments, which are hard for many people to understand or even trust. We cannot know whether a drought will begin next month, or whether a hurricane or major flood will come this year. Therefore, adaptation measures are based on probable occurrences over time; reality may be better or worse in any particular year.

Second, adaptation to climate change and natural hazards requires actions by literally millions of actors, at a scale from the household to the full state. Only some aspects of adaptation will be feasible through regulatory efforts – many more will require informed consent and implementation by individuals.

Third, climate change and natural hazards and the process of adaptation will occur within the context of overall societal evolution, development, redevelopment, economic competition, etc. A significant concern will be ensuring that adaptation measures are accommodated within the larger context, to avoid a waste of resources.

5 Defining and Tracking Sustainability

The following definition is offered for consideration with regarding to natural disasters:

> *Sustainable public safety* exists regarding natural disasters when New Jersey land uses are located and constructed such that personal safety is routinely assured; infrastructure remains largely undamaged and resilient; property damages are minimized through avoidance of natural hazards; and damage that does occur from natural events is at levels that allows for effective resilience and can be afforded by public and private property owners and renters.

For water resources, adaptation of natural systems is not likely to be successful. Rather the adaptation must be on the side of human uses and impacts, reducing stresses that are likely to be exacerbated by climate change and natural hazards. Likewise, agricultural practices will need to adapt, and must incorporate into these practices consideration of water resources and ecosystems that are likely stressed at the same times. Quantitative baseline information can be developed for many if not most major components of risk to safety, and those major components should be identified and agreed to as the dominant measures of sustainability. Other indicators can be used as well, but in a subsidiary capacity.

Regarding public safety from natural disasters, standard indicators are generally human health and safety (e.g., injury, mortality), property (e.g., damage or replacement costs) and economy (e.g., lost economic activity). These are means by which the public and private sectors assess the level of damage from a major event, and are routinely reported in agency reports, research studies and the news media. However, these indicators are retrospective and therefore of less value in sustainability work except as an indicator of pre-event risks. Much more difficult are indicators of potential risk, though some do exist and have been used, especially the number and assessed value of properties in riverine or coastal flood hazard areas. More difficulty to measure will be potential risks of infrastructure damage and failure – New Jersey has done little in this area.

Table 1 provides preliminary indicators and targets. Municipal action will be feasible with regard to: adoption of delineated hazard areas and development of effective hazard mitigation and emergency response plans; retrofit and improved construction of public facilities (including municipal infrastructure systems) and new development or redevelopment in hazard areas; tracking and mitigating health effects of natural hazards; and encouraging and requiring (as appropriate) water conservation and improved ground water recharge.

6 Conclusions

The effects of climate change on New Jersey will be seen most likely not in sudden shifts from previous patterns, but in an increased variation from previous norms toward new conditions – warmer in general, with moister and more violent storms at times and drier and more damaging droughts at other times. While the effects of climate changes will exacerbate our "normal" disasters, it may be difficult to parse out specific climate change impacts from normal weather extremes until it is too late to embark upon effective adaptation. Our climate change adaptation efforts must start before the effects are fully felt. Making these efforts now will help us cope with decades (and even centuries) of unsafe development in river floodplains and low coastal areas. Acting now can mitigate future natural disasters regardless of climate change, but in addition will advance our ability to cope with climate change.

Adaptation regarding water resources and agriculture can also improve our ability to cope with “normal” weather extremes, in addition to potential effects of climate change. It is important to note that our “drought of record” in the 1960’s happened long enough ago that most current residents are unfamiliar with how devastating its effects were. New Jersey is much better prepared for extreme drought in some ways, but also has a much larger population, making the consequences of failure that much more profound.

It the natural tendencies of people to act admirably in the face of emergency conditions and clear damages, but to delay action when needs aren’t so clear. New Jersey needs to recognize that our current efforts are insufficient to cope with potential damages from events similar to those that have occurred in our past, much less any worse conditions to come from climate change.

Table 1: Preliminary Climate Change Adaptation and Natural Hazards Sustainability Indicators and Targets

Component	Preliminary Sustainability Indicators	Preliminary Target	Scale of Analysis	Availability and Period of Data
Natural Hazards	•Flood and storm surge areas delineated using LiDAR-based topography, modern models, and V zone boundary "based on a 1.5-foot breaking wave rather than the present 3-foot wave." (NRC, 2009)	•Hazard areas are defined, delineated and regulated to minimize the potential for inadequate mitigation, and incorporate hydrologic changes related to climate change	•River reaches or watersheds (fluvial flooding); coastal reach (storm flooding and surge damage); used in FEMA Flood Insurance Rate Maps (FIRMs) as developed	•Variable (e.g., LiDAR topography and models are not yet available for all areas). Regulations are available but not all reflect modern standards
	•Infrastructure-specific targets (e.g., potential for electrical line damage). Development location and value in hazard areas.	•Disaster risk from flooding, wind and storm damage to infrastructure, improved properties and community resilience declines to levels allowing for rapid restoration of critical functions	•Infrastructure system and municipality through Multiple Hazard Mitigation Plans	•Variable by municipality and infrastructure system. Property improvements tracked by municipality and by insurance companies. Risk assessment variable by hazard mitigation plan
	•Health statistics; emergency preparation, response and health care system capacity	•Mortality, injury, and mental health effects decline, and appropriate acute health care increases, relative to event severity	•Municipality, county and state	•Health department (local and state) tracking systems (in place)
	•Cost of risk insurance (all categories of natural hazards), property improvement and potential uninsured damage costs relative to household income and wealth	•Potential disaster damages are proportional to owner capacity for response and restoration	•Economic cohort by municipality, county and state	•Unknown

Component	Preliminary Sustainability Indicators	Preliminary Target	Scale of Analysis	Availability and Period of Data
Water Resources (see also briefing papers on Water Availability, Water Quality, and Water Infrastructure)	•Percentage of reservoirs and watersheds/subwatersheds with modified calculations	•Safe yields and available capacity for reservoir systems and Net Water Availability from surficial aquifers incorporate hydrologic changes related to climate change	•Reservoirs and watersheds/subwatersheds	•Safe yield models exist for all major reservoirs; New Water Availability exists and public for Highlands, exist and no public for full state
	•Consumptive use rates (currently estimated at 29%)	•Reduction of growing season consumptive water use as a percentage of total water use	•Public community water supply system and watershed/subwatershed	•NJDEP's NJWaTR annual tracking system available 1990- 2009, updated
	•Percentage of stormwater managed using "green infrastructure" techniques	•Increase Net Water Availability through restoration of ground water recharge using "green infrastructure" techniques	•Municipality and subwatershed	•Unknown but very limited for development prior to 2003 regulations
Agriculture (see also briefing paper on Agriculture and Food Security)	•Peak month demands per acre, growing season	•Estimated peak irrigation demands incorporate soil moisture deficits reflecting effects of climate change	•Farm unit, aggregated by watershed/subwatershed	•Agricultural water use certifications, NJDEP
	•Net Water Availability with seasonal agricultural demands	•Agricultural water demands during drought periods do not exceed Net Water Availability for atersheds/subwatersheds	•Watershed/subwatershed	•NJDEP water use data, NJWaTR tracking system by watershed
	•On-site water availability relative to estimated peak month demand	•On-farm water storage or supply availability to offset loss or constraints on ground or surface water supplies	•Farm unit, aggregated by watershed/subwatershed	•Unknown – county agricultural agent?
	• Peak month demands per acre by crop type, growing season	•Farm crop choices reflect temperature, soil moisture and rainfall effects of climate change	•Farm unit	•Unknown – county agricultural agent?
	•Agricultural acres in IPM by crop type	•Monitoring and integrated pest management regarding pest migration with climate change	•Farm unit, county and state	•Unknown – county agricultural agent?

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Printing of conference material underwritten by:
The Master's Program in Sustainability Studies at Ramapo College

RAMAPO COLLEGE OF NEW JERSEY