

# Planning Framework for a Climate-Resilient Economy

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[Inside front cover material]

PLACEHOLDER

Project contacts for EPA, Rhode Island, and contractors

Acknowledgments

Can list North Kingstown team members here if appropriate or can create a separate appendix about the North Kingstown pilot

# Executive Summary

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### I. Introduction

All businesses, irrespective of size, location, and products or services offered, are affected by weather and climate. While climate change is creating a more uncertain and challenging environment, it can also create opportunities to develop new products and services and build more resilient communities and economies. Businesses depend on their local communities for their workforce, customer base, supplies, and reliable transportation and utility infrastructure. Likewise, communities depend on businesses for goods and services, tax revenue, and employment. Having a climate-resilient economy—i.e., one that can withstand or recover quickly and efficiently from climate impacts in the short and long term—therefore is essential to a community’s well-being. Business and industry leaders can work with community leaders to develop resilience strategies that make them more competitive. Community leaders can use resilience strategies to design smarter and more prosperous communities that better protect human health and property and attract business and tourism.

The framework described in this document can help communities assess their economic vulnerability to climate change and explore options to become more economically resilient and take advantage of new business opportunities. Because of the breadth of expertise and information required, local government staff, particularly planning and economic development staff, are the most likely primary users. However, many private businesses, commercial property owners, and business associations are thinking about how to improve their resilience and capitalize on new opportunities as the climate changes. Business leaders could use this framework to engage other community leaders and encourage the local government to convene a team to work through the assessment. Having private-sector representatives on that team is essential to the success of this assessment. Interested

#### **Figure 1: Smart Growth Strategies and Resilience**

Where and how communities develop profoundly affects their resilience to extreme events. Smart growth strategies, which promote compact, mixed-use, walkable communities that protect ecologically and economically valuable open space and offer housing and transportation options, can help communities develop in ways that also make them better prepared for climate change. For example:

- Development in areas more vulnerable to storm surges, sea level rise, or riverine flooding puts people and property at risk. Property owners or tenants have to protect their property and sometimes evacuate. The community often has to take expensive measures to protect the area or rescue people stranded there in a disaster.
- Compact communities use water more efficiently, as they have shorter pipe networks to distribute the water and less water is lost to leaks. Water efficiency is particularly important in the face of projected increases in droughts.
- Development patterns influence transportation options, and transportation networks are vital to evacuating people before a natural disaster, rescuing them during the disaster, and rebuilding after the disaster. Businesses rely on transportation networks every day to bring employees, customers, and supplies and to send out goods. Before, during, and after a disaster, businesses want reliable access to their facilities to make sure their staff, buildings, equipment, and inventory are safe.

members of the business community can also consider the options in step 5.2 to make individual businesses and properties more resilient to climate hazards.

### Figure 2: Key Concepts and Terms

**Adapt, adaptation:** “Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effect.”\*

**Climate:** The weather averaged over a long period of time, typically 30 years or more.\*\*

**Climate change:** “A change in the state of the climate that can be identified (e.g., using statistical tests) by changes in the mean and/or the variability of its properties that persist for an extended period, typically decades or longer.”\*\*

**Hazard:** “The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources.”\*\*

**Resilience:** “A capability to anticipate, prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to social well-being, the economy, and the environment.”\*

**Risk:** “A combination of the magnitude of the potential consequence(s) of climate change impact(s) and the likelihood that the consequence(s) will occur.”\*

**Vulnerability:** “The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its ability to adapt.”\*

**Weather:** The atmospheric conditions at a particular place in terms of air temperature, pressure, humidity, wind speed, and rainfall. Weather is what is happening now or is likely to happen in the very near future.

\* National Research Council. *America's Climate Choices: Panel on Adapting to the Impacts of Climate Change*. National Academy of Sciences, 2010. p. 19. [www.nap.edu/catalog.php?record\\_id=12783](http://www.nap.edu/catalog.php?record_id=12783).

\*\* Agard, J., et al, Eds. “Annex II: Glossary”. In *IPCC, 2014: Climate Change 2014: Impacts, Adaptation, and Vulnerability*. (Field, C.B., et al Eds.). Cambridge University Press, Cambridge, UK. [www.ipcc.ch/report/ar5/wg2](http://www.ipcc.ch/report/ar5/wg2).

## A. How the Framework Was Developed

As part of the state’s effort to write a new economic development plan, the Rhode Island Division of Planning recognized the need to help communities build resilience into their economic development planning, decision-making, and implementation. The division requested help from the U.S. Environmental Protection Agency (EPA) Smart Growth Implementation Assistance Program<sup>1</sup> to develop a framework to help communities analyze major climate change impacts (both negative and positive) on local economic activity and identify actions that the local government and private businesses could undertake to build resilience. EPA hired a consultant team that included Renaissance Planning Group and Tetra Tech, Inc.

The Division of Planning selected North Kingstown, Rhode Island, as a pilot location to test and refine the process and results. North Kingstown had already done some work on climate change adaptation, including working with Rhode Island Sea Grant to map sea level rise and storm surge

<sup>1</sup> For more information on the program, see Appendix A.

scenarios and identify vulnerable transportation and real estate assets, as well as to incorporate hazard mitigation strategies into its comprehensive plan. More than 14,000 people work in North Kingstown at a variety of scales and sectors of economic activity. The Quonset Business Park, the state's largest employer, houses 164 businesses with more than 10,000 employees and has the state's most active deep-water port. In historic Wickford Village, a variety of small businesses rely on tourism. Manufacturing employs about 4,400 people. Because of this variety of industries and types of businesses, North Kingstown is a useful model for not only the rest of the state, but other communities around the country as well.

[PLACEHOLDER FOR MORE DETAILS ON NORTH KINGSTOWN PILOT TO BE ADDED AFTER PILOT IS DONE]

In developing the framework, the team examined projected climate change impacts and considered how those impacts affect local economies.

### B. Climate Change Impacts

The 2014 National Climate Assessment summarizes changes to the global climate and observed and projected impacts in the United States. For the country as a whole, temperatures are projected to continue to rise. These higher temperatures contribute to shifts in precipitation patterns, rising sea levels, and changes in extreme weather events, which vary by region. For example, in the Northeast region, the assessment notes that, "Between 1895 and 2011, temperatures in the Northeast increased by almost 2°F (0.16°F per decade), and precipitation increased by approximately five inches, or more than 10 percent (0.4 inches per decade). Coastal flooding has increased due to a rise in sea level of approximately 1 foot since 1900."<sup>2</sup> These trends are projected to continue (see Figure 3 for details).

The assessment also describes how extreme weather is likely to strain the Northeast's transportation, communications, energy, and water and waste infrastructure. Flooding and sea level rise can put infrastructure and equipment out of commission by inundating them, and repeated flooding and saltwater corrosion can cause longer-term problems by requiring more

#### Figure 3: Projected climate change impacts for the Northeast region

- By the 2080s, temperatures are projected to increase by 3°F to 6°F if global greenhouse gas emissions decrease substantially, and 4.5°F to 10°F if emissions do not drop.
- The frequency, intensity, and duration of heat waves is projected to increase, while cold air outbreaks are projected to decrease.
- Winter and spring precipitation is expected to increase, but projected changes in summer and fall precipitation and over the entire year are expected to be small. (Precipitation projections are less certain than temperature projections.)
- Heavy downpours are projected to become more frequent.
- Drought is projected to increase in summer and fall.

Melillo, J.M., Terese (T.C.) Richmond, and G. W. Yohe, Eds. *Climate Change Impacts in the United States: The Third National Climate Assessment*. Ch. 16: Northeast. U.S. Global Change Research Program, 2014.  
<http://nca2014.globalchange.gov/report/regions/northeast>.

<sup>2</sup> Melillo, J.M., Terese (T.C.) Richmond, and G. W. Yohe, Eds. *Climate Change Impacts in the United States: The Third National Climate Assessment*. Ch. 16: Northeast. U.S. Global Change Research Program, 2014. p. 373.  
<http://nca2014.globalchange.gov/report/regions/northeast>.

frequent maintenance.<sup>3</sup> These disruptions of infrastructure and services can have severe financial consequences for local businesses and economies.

### C. Climate Change Impacts on Local Economies

Communities can face many stressors, such as rapid population increases or losses, aging public infrastructure, economic fluctuations, volatile or unpredictable energy prices, and natural hazards. Climate change is likely to exacerbate many of these challenges; for example, damaging infrastructure and requiring more frequent repair and maintenance, which costs local and state governments money, or changing environmental conditions in ways that affect local industries such as fisheries or tourism. A resilient community will continue to thrive in the face of those stressors.

A resilient community will also find ways to adapt its economy to opportunities that arise from the changing climate. Opportunities could come from changing consumer preferences, consumption patterns, demands for new products and services (including those that are climate resilient), major public infrastructure engineering and construction, and alternative supply chain services. Businesses that can operate with minimal interruption during and after extreme weather events could have a competitive advantage compared to less-prepared companies. Similarly, communities that help their businesses prepare and protect their transportation, utilities, and other essential assets and services could be more attractive to businesses looking for more secure locations.

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<sup>3</sup> Ibid.



## II. Using the Framework

The framework is intended to help communities recognize their economic vulnerabilities and identify ways to be more climate resilient, with a focus on helping the business community to prepare for and adapt to projected changes and prosper in a changing climate. The framework assesses a specified area such as a town, municipality, or larger region. The framework recognizes the interdependencies of municipalities, which influence development patterns and infrastructure, and local businesses, and the role of both as critical elements to economic resilience and growth.

The framework is designed to be flexible so that communities with varying levels of expertise, time, and funds can use it. For example, if a community has a geographic information system (GIS)<sup>4</sup> that maps its infrastructure assets, it can conduct a more robust mapping exercise. If a community does not have GIS or a GIS specialist, a local college or university, state agency, or regional entity might be able to provide assistance, or the community might have the resources to hire a private firm. If a community does not have many resources to support this effort, it can take a more general, qualitative approach. A qualitative approach uses existing data and resources to make assumptions and explore the connection between climate-related impacts and a community's economic future. A qualitative approach can give a general idea of the impact to community assets (e.g., approximately 30 businesses worth \$60 million are on the shoreline and will probably be affected by coastal storms), while a quantitative GIS approach could provide detailed information on the impacts to each structure, including the magnitude (e.g., 22 businesses are projected to be in inundation areas with a water depth of at least 3 feet, exposing \$42 million of value to potential damage and losses).

The framework is designed to leverage previous community assessment efforts. For example, communities that have already conducted a climate vulnerability analysis and know which local assets are most at risk can likely spend fewer resources on the second step, which is designed to highlight exposed assets. Information from the comprehensive plan or hazard mitigation plan can also help with conducting the assessment or developing options to increase economic resilience.

This chapter walks users through applying the framework using the steps illustrated in Figure 4.

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<sup>4</sup> GIS provides a computerized assessment tool that integrates, stores, edits, analyzes, shares, and displays geographic information to inform decision-making. GIS software allows users to create searches, analyze spatial information, edit data in maps, and present results.



**Figure 4. Steps in the Framework to Plan for a Climate-Resilient Economy**

The steps are:

- Step 1: Organize
  - 1.1 Establish the assessment team.
  - 1.2 Define the community of interest.
  - 1.3 Set objectives for the assessment.
- Step 2: Evaluate Projected Climate Change Impacts and Hazards
  - 2.1 Select climate change scenarios.
  - 2.2 Assess hazards.
  - 2.3 Select a method for spatial analysis.
- Step 3: Identify Community Assets and Their Vulnerability
  - 3.1 Develop an assessment methodology.
  - 3.2 Identify community assets at risk.
  - 3.3 Define and apply a local vulnerability scale.
  - 3.4 Assess potential positive and negative impacts on economic activity.
- Step 4: Analyze Overall Economic Implications for the Community
- Step 5: Explore Options to Enhance Resilience and Pursue Opportunities
  - 5.1 Raise public awareness and garner support.
  - 5.2 Identify actions to enhance economic resilience and pursue opportunities.

### A. Step 1: Organize

Getting the right team members involved from the beginning and having clearly defined boundaries and goals will help the assessment succeed. Initial, organizational actions are:

- 1.1. Establish the assessment team.
- 1.2. Define the community of interest.
- 1.3. Set objectives for the assessment.

#### 1.1 Establish the Assessment Team

- **Sub-step objective:** Assemble a team to conduct the assessment representing all the necessary stakeholders and expertise.

The first step is to determine who will lead the assessment effort and identify the team that will work through the framework. This guide assumes that a municipal staff person, most likely from the planning or economic development department, will lead the effort. Although others in the community could take this role, they would likely need support and help from the local government to convene all the necessary stakeholders and gather the data.

The person or entity taking the lead on the tool will need to put together a team. The economic assessment will likely touch on many community assets and economic sectors. Therefore, the assessment team will probably need specialized technical expertise and sector-specific knowledge, as well as members who understand climate hazards. Planning climate-resilient economic measures will require integrated strategies with multiple sectors working together to identify gaps and opportunities to integrate climate adaptation into economic development, land use, and other community plans, programs, and policies. Appropriate team members might include:

- **Planning and emergency management department staff:** Can provide the master plan, hazard mitigation plan, land use data, community asset data, transportation data, and population data, among other things.
- **Economic development department staff:** Can provide economic development plan, economic data, understanding of the area's economic strengths and weaknesses, and knowledge of businesses and infrastructure they rely on. Staff could come from a local, county, or multijurisdictional economic development agency.
- **Geographic Information Systems (GIS) staff:** Can provide maps and data on elevation, flood plains, land use, critical facilities, demographics, and environmental assets, among other things.
- **Public works and transportation department staff:** Can provide information on utility and transportation assets and identify building vulnerability characteristics, such as foundation type and first-floor elevation.

- **Tax assessor, finance, or budget department staff:** Can provide parcel information to help identify who will be affected.
- **Elected officials:** Could become a champion for the effort and help build the political will to implement adaptation strategies developed through this assessment.
- **Business community:** Might have knowledge of potential business impacts of climate change and can provide the business perspective on the assessment. Engaging the business community, including commercial property owners, businesses owners, and associations or trade groups, helps ensure that results are relevant and useful.
- **Chamber of Commerce:** Could help facilitate contacts with businesses that might be interested in participating in the assessment and identifying new economic opportunities. The chamber could also help build awareness in the community and advocate for resilience.
- **Insurance companies:** Have the expertise to look at buildings and properties and assess risks. They can also help identify mitigation actions that can help a business make changes to its facility to better withstand and recover from hazards, as well as lower the insurance premium because risks are reduced.
- **State agency staff:** Could have experts and data on climate-related impacts, government facilities, debris management plans, historical impacts, smart growth and economic development resources, state hazard mitigation plans, and other information.
- **Federal agency staff:** Might be able to identify experts and data on smart growth strategies and climate assessment and adaptation, flood plains, surge inundation areas, elevation data, sea level rise data, hazardous materials facilities, repetitive loss facility data, historical impacts, and other information.
- **Nonprofit organizations:** Might have specialized expertise and tools to support the effort; knowledge of the community that helps assess impacts; or good relationships with businesses, populations, or interests the team needs to hear from.
- **University faculty or students:** Might be able to provide downscaled climate data and analysis, student volunteers, advanced modeling capabilities, or data collection services.

[PLACEHOLDER FOR BRIEF DESCRIPTION OF ENTITIES ON NORTH KINGSTOWN TEAM AND WHY (WE DON'T HAVE TO MENTION SPECIFIC NAMES IF THE PARTICIPANTS AREN'T COMFORTABLE WITH THAT)]

Regardless of who is on the team, the assessment team should stay in contact with the business community, local associations, elected officials, municipal staff, and the public throughout the process of applying the framework. Their input at different stages can provide crucial information for the assessment. Just as importantly, the team's process should be transparent. The team might consider creating a web page tracking progress on the assessment, providing updates at regularly scheduled meetings like Chamber of Commerce events or city council meetings, hosting public discussions, and meeting individually with particularly important people or groups.

### 1.2 Define the Community of Interest

- **Sub-step objective:** Establish the geographic area and economic sectors the team will examine.

Basic information about the community can help define the assessment's parameters.

- **Geographic area:** The geographic boundary will determine the business establishments and assets that the team will consider in the assessment. While municipal boundaries might be the simplest and most obvious choice, other considerations can help determine the assessment's geographic scale. For instance, the team might want to assess critical infrastructure (e.g., airports, utilities, or industrial complexes) or natural resources (e.g., water sources, wetlands, or flood plains) that are outside municipal boundaries. The process described here will work at local, regional, and broader scales, but it is important to determine the scale from the beginning to understand the magnitude of the undertaking. The scale will influence the goals of the assessment. [PLACEHOLDER FOR MAP OF NORTH KINGSTOWN AREA ASSESSED WITH BRIEF EXPLANATION OF WHY THESE BOUNDARIES WERE CHOSEN]
- **Primary economic activities:** The assessment needs a general economic profile of the community. The assessment team should identify the community's major economic sectors and primary economic development priorities and determine which are relevant to include in the assessment. This analysis will help identify businesses to engage in the process and help ensure the assessment aligns with the community's economic development objectives. Market sectors might include:
  - Agriculture and landscaping.
  - Defense industries and military installations.
  - Energy and utilities.
  - Engineering, planning, and design.
  - Retail, restaurants, and consumer services.
  - Fisheries and aquaculture.
  - Innovation industries such as biosciences and information technology.
  - Insurance and real estate.
  - Manufacturing.
  - Ports and marine trades and transportation.
  - Tourism.

The team might also find it helpful to categorize economic activity based on characteristics that might put businesses at particular risk or position them to build certain resilient capacities:

- Businesses with significant inventory on site.
- Businesses that design, build, and maintain the built environment.
- Businesses that rely mainly on natural resources like the ocean or land.
- Businesses that provide critical functions to other businesses (e.g., utilities or freight).
- Small and/or locally serving businesses.
- Tourism-based businesses.
- Businesses that rely on constant flow of materials and goods by truck or rail or have a significant electric or gas load. Disruptions to transportation or utilities could force businesses to close until service is restored.

The team would use whatever method works best to help the community understand its current economic base. [PLACEHOLDER FOR BRIEF EXAMPLE OF WHAT NORTH KINGSTOWN CHOSE AND WHY]

### 1.3 Set Objectives for the Assessment

- **Sub-step objective:** Establish objectives for the assessment to help ensure a clear and common purpose among team members.

The framework's intent is to help the community understand important implications of climate-related impacts on its economy. The team can clarify its purpose and provide the foundation for using the assessment by answering questions such as:

- What specific questions does the team hope to answer with the assessment?  
[PLACEHOLDER FOR EACH BULLET TO GIVE NORTH KINGSTOWN'S ANSWERS TO THESE QUESTIONS, IF APPROPRIATE]
- What level of effort (i.e., funding and time commitment) can the team put forth? Is this level of effort sufficient to answer the questions the team wants answered?
- How will the assessment help the community and its economy?
- What is the target date for finishing the assessment? Is there any forcing event such as an upcoming election or a deadline for completing a comprehensive plan update?

## B. Step 2: Evaluate Projected Climate Change Impacts and Hazards

Once the team is organized, the next step is to evaluate which climate change impacts, such as flooding, sea level rise, storm surge, drought, and excessive heat, could affect the community, and over what time period. In this step, the team will:

- 2.1. Select climate change scenarios.
- 2.2. Assess hazards.
- 2.3. Select a method for spatial analysis.

If the community has already completed a climate vulnerability analysis, the team can focus on summarizing those results in Step 2 to set the stage for economic assessment in Step 3. If the community has not yet conducted a climate vulnerability analysis, then Step 2 can help establish which parts of the community are projected to be affected by climate-related hazards and which assets in or related to those areas could affect the community's economy if hit by a hazard.

### 2.1 Select Climate Change Scenarios

- **Sub-step objective:** Establish which climate scenario projections to use for context for the economic assessment.

Climate change scenarios show how the world might look in the future depending on how global greenhouse gas emissions increase or decrease. If the community has already conducted a climate vulnerability assessment, the team can select projections from that analysis to use for economic assessment. Community economic development leaders are often interested in longer range projections to have time to plan for anticipated trends, while individual businesses might want to look 15 or 30 years into the future, depending on their product or service and lease or ownership status. The team can consider the objectives and resources that it established under Step 1 and select the most appropriate scenarios.

If the community does not have a completed climate vulnerability assessment or other related studies to draw from, the team will need to determine what it will use based on how it intends to obtain climate hazard information and what is available. At the most basic level, communities with no climate change projections for their specific geographic area can use regional scenarios developed for the National Climate Assessment and tools from federal agencies and nongovernmental groups<sup>5</sup> to get a general sense of what impacts are likely to occur in their region. Some states have more regionally specific climate change projections, and some regions have also developed finer-grained projections.

To ensure it can explain and defend the assumptions underlying the assessment, the team should document which climate change scenarios it selected and why (e.g., data availability or relationship to the community goals and objectives).

### 2.2 Assess Hazards

- **Sub-step objective:** Determine which portion(s) of the community's geographic area are projected to be affected for each climate hazard of concern.

Once the assessment team has selected the climate change scenarios, it will next assess hazards that are considered under those scenarios. This document focuses on the economic assessment methodology and assumes the team will be able to access climate hazard assessment results and use them in the economic impact analysis. The experts on the assessment team or other partners

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<sup>5</sup> See Appendix C for links to some of these resources.



can provide information such as results from web tool applications, GIS analysis results, or hard-copy maps for each hazard type. A community without immediate access to existing hazard assessments can refer to Appendix C for some ideas on obtaining assessments. Examples of climate hazard impact areas to locate include:

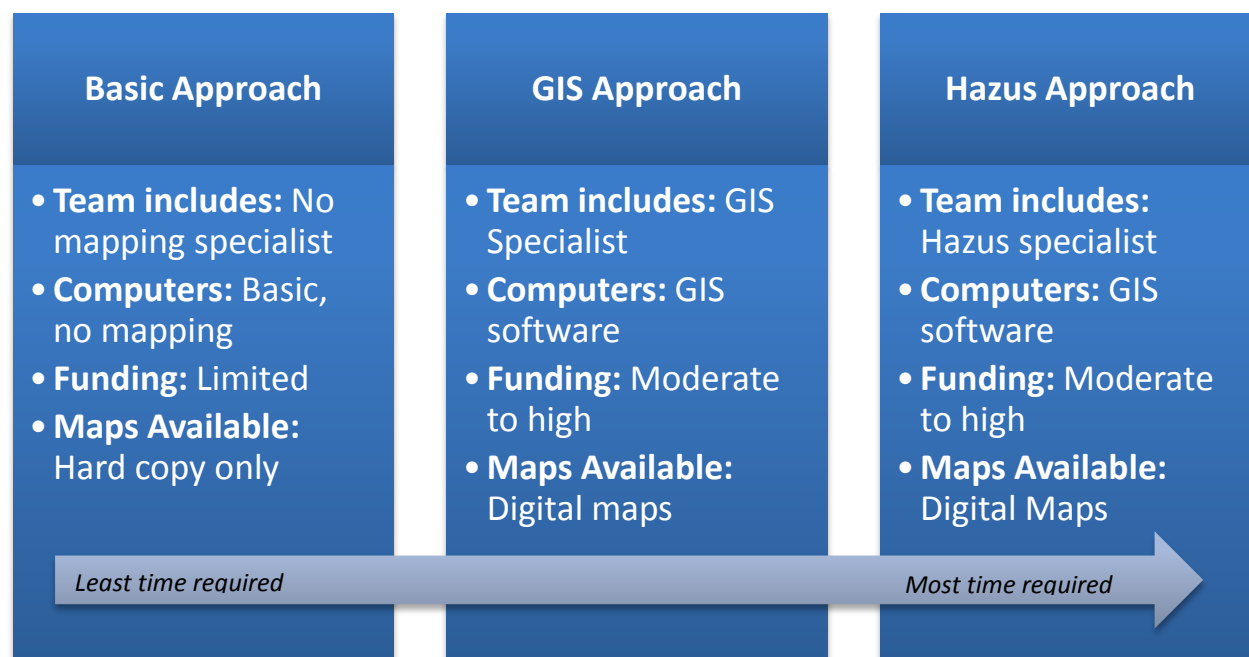
- **Sea level rise:** For coastal communities affected by sea level rise, the team can generate a map of the area expected to be inundated at high tide under the selected climate change scenarios (the team can summarize the projections of the depth of the water and the geographic boundary of the inundation area from the various tools or studies it uses for the selected scenarios).
- **Flood and storm surge:** The team can determine the boundaries of the areas where water is expected to inundate land to a specific, problematic depth, temporarily during or immediately after a storm.
- **Excessive heat and drought:** In most cases, the spatial gradient for temperature and drought conditions will be very low or unnoticeable at the local scale. Unless assessment tool results suggest otherwise, the team can assume that the entire community will have approximately the same changes in the number of excessive heat days or drought frequency under the selected climate scenarios.

### 2.3 Select a Method for Spatial Analysis

- **Sub-step objective:** Establish how the location of community assets affected by the various climate-related hazards will be identified, analyzed, and communicated.

The assessment team's objective is to identify and evaluate which of the community's businesses and assets are likely to be affected, negatively or positively, by climate change. GIS capabilities can greatly enhance the assessment by overlaying multiple layers of information for analysis. Figure 5 illustrates how the team can determine which method of spatial analysis might be appropriate. The factors include how much expertise the team has in spatial analysis, resources available (e.g., computer equipment, funding, and time), and whether the available hazard maps are digital or hard copy.





**Figure 5. Guide to Help the Team Select a Spatial Analysis Approach.**

**The basic approach** gives the team a general sense of the impacts the community might experience using online tools and hard-copy maps. Although a community might use this approach as a starting point to raise awareness of potential impacts and vulnerabilities, the basic approach is not sufficient for developing land use regulations or making infrastructure siting or other engineering decisions. For team planning purposes, a community the size of North Kingstown analysis of each climate-induced hazard (e.g., storm, flood, drought) could take approximately eight to 24 hours. The team can approximate affected areas and identify the assets to create a general consequence assessment that estimates what gets affected and how might that affect the community.

**The GIS approach** gives the team a better sense of the location and magnitude of potential impacts. The team would use digital data and GIS tools for this approach. This analysis could take more time and resources, depending on the availability of GIS data, but it can provide a more accurate depiction of the assets exposed to climate-related hazards and help the community identify appropriate adaptation strategies. For a community the size of North Kingstown, each climate-induced hazard analysis could take as little as four hours to as much as 80 hours, depending on the level of data available and analysis required. The team can map affected assets and areas and create a more detailed consequence assessment that maps community impacts. The team could also conduct an exposure estimate using the value of the assets in the affected areas.

**The Hazus approach** allows the team to estimate detailed potential economic losses in a GIS format. This approach gives the community a better sense of the magnitude of the impacts and could help justify any adaptation strategies the community eventually identifies. However, it requires access to Hazus modeling expertise and sufficient resources to conduct the more

detailed analysis. Hazus is a free, nationally applicable standardized methodology that contains models for estimating potential losses from earthquakes, floods, and hurricanes.<sup>6</sup> Hazus uses GIS technology to estimate physical, economic, and social impacts of disasters. It graphically illustrates the boundaries of locations at high risk from earthquakes, hurricanes, and floods. For a community the size of North Kingstown, each climate-induced hazard analysis could take as little as eight hours to as much as 80 hours, depending on the level of data available and analysis required. The team can map affected assets and areas, including direct and business interruption losses. This methodology produces a loss estimate based on the severity of the climate-induced hazard along with the exposure estimate. The team can also conduct a functionality assessment to determine which critical assets and lifelines will be functional, which can lead to a very detailed consequence assessment.

[PLACEHOLDER TO EXPLAIN HOW NORTH KINGSTOWN DID THIS]

### C. Step 3: Identify Community Assets and Their Vulnerability

In this step, the team identifies critical local economic assets that might be at risk from climate change impacts and how vulnerable they are. The actions are:

- 3.1. Develop an assessment methodology.
- 3.2. Identify community assets at risk.
- 3.3. Define and apply a local vulnerability scale.
- 3.4. Assess potential positive and negative impacts on economic activity.

#### 3.1 Develop an Assessment Methodology

- **Sub-step objective:** Create, select, and/or adapt a methodology for conducting the assessment that best fits the community's context, needs, and capacity.

The components of a local economy that might be most affected by climate change, and to what extent, will depend on multiple factors such as the amount of each type of local asset at risk, the characteristics of each asset, the type of hazard, and the overall nature of the community's economy. Users can modify the methodology presented in this document to reflect local realities, capture the significance of specific economic assets, and determine their relative climate-related vulnerability for the purposes of this assessment.

Many options exist for evaluating and organizing information during this process. Table 1 provides a sample assessment form that users can adapt as needed; steps 3.2 through 3.4 walk through filling out this form. The assessment form inventories locally important economic assets and creates a starting point for the team to assess the vulnerability of each asset to better understand the potential collective threat of climate-related hazards to the local economy and

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<sup>6</sup> Hazus can be downloaded from FEMA's Map Service Center at <http://msc.fema.gov/portal/resources/hazus>. This web page includes links to Hazus training and user groups.

begin to identify opportunities and activities that could mitigate the impacts and make the community more resilient. For teams using Hazus, potential relevant output from the model is listed in Table 1.

Examining all the elements of a community related to its economy can be an overwhelming task. The team will likely need to prioritize which assets to examine in depth. The assets that are most critical to the community's economy—meaning that their failure would severely affect the local economy—are probably the most important to assess. Formal assessment tools exist,<sup>7</sup> but the team could informally determine assets that are critical to the community's economy by reviewing economic data and talking to key stakeholders. Some critical components might be obvious, like a road that is essential for getting goods in and out, a company that is the largest employer in the community, or utilities that supply power and water. Others might be less evident, like a supplier that other companies rely on for raw materials.

As the changes and risks become clearer, the assessment team can work to identify how those changes open up new economic opportunities. By focusing on the ways in which climate-related hazards might affect the essential drivers of a local economy, the team can begin to pinpoint where the most severe threats or best opportunities might exist.

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<sup>7</sup> For example, see Federal Highway Administration. "Assessing Criticality in Transportation Adaptation Planning." 2014. [http://www.fhwa.dot.gov/environment/climate\\_change/adaptation/adaptation\\_framework/modules/criticality\\_guidance/](http://www.fhwa.dot.gov/environment/climate_change/adaptation/adaptation_framework/modules/criticality_guidance/). This guidance was developed for transportation assets, but the basic concepts are relevant to economic considerations as well.

**Table 1. Sample Form to Assess Economic Impacts of Climate Hazards**

Community Assets (see step 3.2)	Vulnerability Rating as Defined by the Team (see step 3.3)—for example, High (H), Moderate (M), Low (L), or None (N).					Description of Potential Impacts on Economic Activity (see step 3.4)
	Sea Level Rise	Flood	Storm Surge	Drought	Excessive Heat	
<b>Transportation</b>						
Describe transportation infrastructure affected: names and locations of street segments, bridges, transit facilities, bike and pedestrian facilities, etc. Level of detail depends on scale of community being assessed						E.g., estimated number of users affected and how they are affected, such as employees being unable to get to work or customers to businesses or an inability to receive supplies or ship goods out. (Hazus outputs: bridge damage, loss, and functionality)
<b>Utilities and Emergency Response Operations</b>						
Describe types and locations of affected utility infrastructure and critical emergency response functions						E.g., estimated number or percentage of customers affected by utility outages and how they are likely to be affected, such as an inability for a business to operate without power, communications, water, or sewer service; facilities for fire, police, medical, and other critical services that need to operate in an emergency (Hazus outputs: potable water, wastewater, electric, gas, and oil facility damage and functionality)
<b>Industrial Operations</b>						
Names and locations of affected industrial areas or facilities						To extent possible, describe types or percentage of industries affected (e.g., 10 percent of manufacturing facilities in the community) and how they are likely to be affected, such as an inability to open because of damage to the facility or inaccessibility to employees, suppliers, and customers; impacts to employees and customers; loss of inventory; interruptions in supply chain.

## Planning Framework for a Climate-Resilient Economy

Community Assets (see step 3.2)	Vulnerability Rating as Defined by the Team (see step 3.3)—for example, High (H), Moderate (M), Low (L), or None (N).					Description of Potential Impacts on Economic Activity (see step 3.4)
	Sea Level Rise	Flood	Storm Surge	Drought	Excessive Heat	
						(Hazard outputs: industrial facility damage and loss including business interruption losses)
<b>Commercial Operations</b>						
Names and locations of affected areas						To extent possible, describe types or percentage of commercial businesses affected and how they are likely to be affected, such as inability to open because of damage to the facility or inaccessibility to employees, suppliers, and customers; impacts to workers, and customers; loss of inventory; interruptions in supply chain. (Hazard outputs: commercial facility damage and loss, including business interruption losses)
<b>Agricultural Operations</b>						
Names and locations of affected areas						To extent possible, describe types or percentage of agricultural operations affected and how they are likely to be affected, such as damage to fields or equipment, lack of access; loss of inventory; and impacts to workers, suppliers, and customers. (Hazard outputs: agricultural facility damage and loss, including business interruption losses and crop loss)
<b>Natural Resources</b>						
Names, descriptions, and locations of affected areas						To extent possible, describe types of resources affected and how impacts to them might affect the local economy, such as loss of tourism or damage to harvestable natural resources such as fish
<b>Other</b>						
Describe						Describe

### 3.2 Identify Community Assets at Risk

- **Sub-step objective:** Identify asset categories to examine and assets in each category that are critical to the local economy.

To determine the community's economic vulnerability to climate change, the team first needs to identify which assets are significant contributors to the local economy. In the sample assessment form in Table 1, this information would go in the "Community Assets" column.

The team's local knowledge and information gathered in previous steps can help them determine which asset categories to include in the assessment form. For example, priorities might include basic community operations (e.g., infrastructure and utilities) that support all economic activity, as well as sectors that are particularly important to the community (e.g., large employers, tourist attractions, or natural assets).

To make sure they are getting a complete picture of the community's assets, the assessment team should try to contact important stakeholders and community representatives who are not on the team. The team could hold public discussions, solicit input online, or go door to door to make sure they are reaching key commercial property owners, business owners and operators, and others.

Asset categories that are likely to be in every community include:

- Transportation
- Utilities and emergency response operations
- Industrial operations
- Commercial operations
- Agricultural operations
- Natural resources

The assessment team could include additional asset categories, as appropriate, that are important to their community's local economy, such as:

- Historic areas and assets
- Natural and cultural assets
- Specific business sectors
- Health and social services
- Residential areas

Below is guidance on the asset categories in the sample assessment form.

- **Transportation:** The transportation network throughout a community and its region is important not only for moving residents locally but also for moving goods, services, and commodities. The assessment team can identify the most critical components of the

transportation network that support the local economy, breaking the network down to individual street segments, bridges, transit facilities, and bicycle and pedestrian facilities, as appropriate. The level of detail the team applies would reflect the scale at which the team is assessing—relatively small, specific segments could be important to list for a small town or village, whereas larger segments and areas could be appropriate for a regional assessment.

- **Utilities and emergency response operations:** The assessment team can identify the most critical public and private utilities that serve the affected areas of the community. These utilities might include the electrical system, sanitary sewer collection and treatment systems, water supply, stormwater management, natural gas, telecommunications, cable television, mobile and landline telephone service, and internet service. Whether the utility is publicly or privately owned will not necessarily increase or decrease its risk, but its ownership will be important to know when the team discusses potential actions to improve resilience. Reliable utilities are essential to a strong, functioning economy, and interrupting their operations can have a dramatic impact on the community's economy, affecting both consumers and suppliers. If utility representatives are not already on the assessment team, the team might want to make a particular effort to consult with local utilities when filling out the assessment form.

Although it might be obvious that effective emergency management operations are essential in natural or manmade disasters, critical facilities and equipment have been flooded or rendered inaccessible or inoperable during disasters. The assessment team, in consultation with local emergency operations officials, can evaluate whether any changes should be considered in terms of the location of emergency operation facilities such as police, fire, and emergency medical services to ensure that they will be operational and accessible during flooding.<sup>8</sup>

- **Industrial operations:** Industrial operations are often important to a community's economy for many reasons, including their potential to create jobs and inject money into the community. The assessment team can identify key information for each industrial operation, including the name of the operation, the types of goods and/or services it manufactures and/or provides, and how many people it employs, using resources such as the community's land use map, local tax records, and walking or windshield surveys.<sup>9</sup> The team could also reach out to the local Chamber of Commerce, business association, business district, or county or regional economic development organization to obtain

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<sup>8</sup> A FEMA study of critical facilities that were affected by Hurricane Sandy provides useful information about impacts in New York and New Jersey: FEMA. "Performance of Critical Facilities and Key Assets." Chapter 5 of *Mitigation Assessment Team Report: Hurricane Sandy in New Jersey and New York*. 2013. [http://www.fema.gov/media-library-data/1385587199555-ebd60a9506168b4fd5a79ee519520c1e/Sandy\\_MAT\\_Ch5\\_508post.pdf](http://www.fema.gov/media-library-data/1385587199555-ebd60a9506168b4fd5a79ee519520c1e/Sandy_MAT_Ch5_508post.pdf).

<sup>9</sup> Walking and windshield surveys let someone gather information about a community by walking or driving around.

relevant information. Industrial operations might also be important contributors to local and regional supply chains by providing essential goods and services to other businesses. Understanding the nuances of one facility's impact on other businesses will be an important component to evaluating the local economy's true economic vulnerability to climate change.

- **Commercial operations:** Commercial operations include retail, restaurants, and professional offices. As with industrial assets, commercial operations create jobs, pay taxes, and could be important links in local and regional supply chains. Commercial assets might also contribute to unique aspects of a local economy such as tourism or synergies with other local businesses. The assessment team can identify key information for each commercial operation, including the types of goods and/or services it provides, its relationship to other local businesses, and how many people it employs, using resources such as the community's local tax records, walking or windshield surveys, and other resources. The team could also reach out to the local Chamber of Commerce, business association, business district, or county or regional economic development organization to help identify and get relevant information about these businesses.
- **Agricultural operations:** Agricultural operations (e.g., livestock, crops, and landscaping nurseries) are usually directly affected by the climate. Temperature and precipitation patterns are typically primary factors when these operations choose a location. Any change in the climate could dramatically affect agricultural operations. For example, too much rain and resulting floods could wash away a farm's soil or oversaturate and spoil the crop. Not enough rain or excessive heat or cold could kill off or prevent crops from growing, which could mean less feed for animals or reduce the quality and amount of the harvest. The assessment team can gather information for each operation including what they produce, the climate conditions that make the community a favorable location, and the operation's relationship to local businesses as well as those outside the community. The team could work with agricultural extension staff or the agricultural operations' managers and owners to get necessary information.
- **Natural resources:** Because natural resources support all of the sectors discussed above, climate impacts can have profound economic implications. For example, communities depend on streams, lakes, and aquifers for drinking water, agriculture, energy, navigation, manufacturing, and recreation. Climate change can increase demand—and competition—for shrinking water supplies. Coastal activities that are vital to a local economy, from fishing to offshore drilling, can be disrupted by climate change impacts. Streams, lakes, and coastlines are vulnerable to erosion, flooding, increased water pollution, and acidification. Green spaces, including wetlands, flood plains, meadows, and woods, are nature's natural filter and storage for rainwater runoff. Communities' tree canopies provide shade, cool ambient air temperatures, store carbon, and can increase property values and commercial activity. With climate change, trees and working forests are more



at risk from fire, drought, and pest infestation. Climate change can shift the range of where certain animal and plant species can live, in turn affecting local fishing, hunting, tourism, and agriculture.

### 3.3 Define and Apply a Local Vulnerability Scale

- **Sub-step objective:** Determine the comparative vulnerability of each asset to each climate stressor.

A vulnerability scale lets the team distill diverse factors for each asset into a representative vulnerability designation where possible. It is not necessary to spend a great deal of time refining this scale. The important thing is to have a consistent basis for distinguishing where climate-related hazards pose the greatest risk to the local economy. The sample assessment form uses *high, moderate, low, and none* as a scale to help estimate and compare assets' vulnerability to various climate impacts. The team could establish ranges for each level; for example, a low level of risk might be that 1 to 5 percent of the asset category could be affected by the climate hazard, moderate could be 5 to 20 percent, and high could be more than 20 percent. The team could consider factors such as value of the assets, potential for collateral impact (i.e., dependence of other economic activities on those assets), or similar concerns in bracketing the ranges. Ultimately, the team can use whatever scale it wants based on the community's context and identified threats.

Once the team has defined a scale, it would apply it to each identified asset for each climate change-related hazard. Some hazards (e.g., sea level rise, flood, and storm surge) affect specific areas of the community, while others such as drought and excessive heat might affect the entire community. The team can rely on information and resources gathered during earlier steps of this process to determine which assets are vulnerable to which threats.

An asset's vulnerability depends on its exposure to the threat, the effect the threat would have on its operations, and its ability to adapt to or protect against the threat. For example, a business might be in a flood plain and therefore exposed to flooding that could damage its HVAC equipment, but if it moves the HVAC equipment to the roof, it will have a lower vulnerability rating than a business next door that has its HVAC equipment in the basement. A monument that attracts tourists might be exposed to drought but might not suffer any ill effects, giving it a rating of "none" on the scale.

### 3.4. Assess Potential Positive and Negative Impacts on Economic Activity

- **Sub-step objective:** Determine how potential climate change impacts could affect each asset's economic impact on the community, both positively and negatively.

Once each asset has a vulnerability designation for each hazard, the team can describe the collective potential impacts of all threats for each asset in the "Description of Potential Impacts" column of the assessment form. This step distills all previous information and findings into a

clear connection between threat and economic impact for each asset and the community as a whole. Based on local conditions and the identified hazards from step 2, the team will determine which factors it will consider when evaluating economic impacts. Particularly if it has limited time and resources, the team might want to focus on vulnerabilities and potential economic impacts on critical local economic drivers.

The team would explore how each category and/or individual asset affects the local economy. For example, a community with a manufacturing and distribution-based economy might consider how impacts to roads might affect supply chains, shipping, and other elements important to creating and moving goods. How might road closures, traffic, or other inconveniences affect key businesses? What might be the additional induced economic impacts (e.g., job loss, tax loss, future vacancy, loss of the community's role as a manufacturing center)? Perhaps many workers at a major manufacturing facility rely on public transit to get to and from work, and flooding from a storm surge is likely to shut down the transit system. The team could assess how losing this transportation option might affect the local economy during the storm, immediately after it, and in the long term. Would workers still be able to get to the facility in other ways? If not, how would that affect the manufacturer's business and the workers' paychecks? Would impacts be particularly severe on lower-income workers who cannot afford to miss a paycheck and might not have any other way to get to work? In the longer term, would having a public transit system less vulnerable to flooding encourage more businesses to locate in the community because it offers more reliable transportation? Including this information in the assessment form helps illustrate the interconnection of potential economic vulnerabilities among asset categories.

Some assets might be indirectly affected by the hazard. For example, a bakery employs 25 people full time and makes all of the bread products for the restaurants that are in the impact area. If the hazard requires the restaurants to close, it will indirectly affect the bakery, which will lose revenue and might need to reduce employees' hours or even lay them off. To find these indirect impacts, the team might need to conduct extensive interviews with local businesspeople, who might not be aware themselves of these potential effects.

To get a complete picture of potential effects on the economy, the assessment team should try to identify both negative and positive impacts. Sample negative impacts might include:

- For all assets, identify where there is risk of complete loss (i.e., inability to access or use the asset) and what this means for businesses, residents, workers, visitors, and the economy.
- For businesses, note where production capacity could be reduced or disrupted, efficiency in doing business reduced, capital or operations and maintenance costs might increase, demand for goods and services might drop, workers or jobs might be lost, or climate change might lead to changes in consumer preferences, consumption patterns, and the length of prime consumption periods for seasonal businesses.

- For jobs, identify where jobs might be disrupted temporarily or where permanent layoffs could occur, describe the workers most likely to be affected by work interruptions or layoffs, identify potential problems for commuting to work, and identify where work might take longer or cost more because outdoor workers have to work shorter hours in extreme heat.
- For natural resources, note how climate impacts could harm natural flood protection, ecosystem services such as protecting water quality, wildlife habitats, and tourist attractions, and how these impacts might affect specific business sectors.

Sample positive impacts or potential opportunities might include:

- Explore how climate change impacts might affect spending patterns, economic drivers, and consumer preferences in ways that could create new local business sectors or synergies. For example, might rainier weather or hotter days make people want more indoor activities?
- Businesses and residents might need climate-resilient products and services such as drought- and salinity-resistant crops, technologies that use water more efficiently, or storm-resistant building materials. Which of these new products and services could the local business community provide? How might the local government support businesses that want to experiment with climate-resilient goods and services?
- Assess whether any local businesses currently provide goods and services that might be in greater demand after a natural disaster (e.g., building materials or landscaping that might be needed to rebuild after a storm).

Appendix D provides some sample questions for the common asset categories to help the team estimate the relative magnitude of potential economic impacts, negative and positive.

### **D. Step 4: Analyze Overall Economic Implications for the Community**

To comprehensively understand climate-related economic vulnerability and opportunity, the team should analyze each asset not only individually but also as a component of an interconnected economy. The goal of this step is to develop a comprehensive picture of the local economic risks and opportunities associated with climate change.

Damage to transportation or utility assets, for example, could have far-reaching impacts on all sectors of the economy, including businesses, homes, and tourist attractions. Exploring these connections provides a picture of the potential communitywide economic impacts, positive and negative, of climate change.

The information gathered in prior steps, along with local knowledge, can help the team make connections between various asset categories, climate-related risks, and the local economy. Areas to look at with this overarching economic perspective might include:

- **Business stability:** How will the community's major economic drivers (i.e., core businesses and business sectors) likely fare if no mitigation or adaptation measures are taken? For example, in the short term, would businesses be able to survive an event like Hurricane Sandy, or would that kind of severe, one-time event drive them out of business? Consider how strong the businesses or sectors might be over the long term (e.g., if the community's economy relies on shellfish, which are getting scarcer because of ocean acidification and shifting habitat, what is going to happen to the local economy over time?).
- **Residential areas and socioeconomic conditions:** Threats to residential areas can have profound impacts on overall economic health because a community without a healthy residential population will not support a functioning economy. What overall repercussions, such as reduced services, amenities, tax revenue, might projected climate change impacts bring, and might those repercussions drive residents and businesses to leave the community? On the other hand, might climate change create significant economic opportunities (and if so, how)? What types of residences (e.g., single-family homes, multifamily buildings, and vacation rental or second homes) does the community have? What are the community's overall population demographics, and which populations are most vulnerable to climate change impacts, either because of their location, income level, age, health, or other factor? If vacation rental or second-home properties are in particularly vulnerable areas or depend on weather (e.g., snow for skiing or pleasant weather for beaches), how might that affect the community's tourism? Where do employees of various sectors live, and how do they commute to and from work? What might be the impacts on the economy of a severe weather event that mainly affects a residential area? For example, if a flood hits a low-lying residential neighborhood where many local workers live, the workers might not be able to come to work, which could affect businesses.
- **Finance (public and private):** How might climate change and its impact on the community affect public and private financing sources that have traditionally supported development? How might climate change impacts affect the nature and amount of financing that industries or businesses need? Does the community rely on financing sources that might experience financial stress due to climate change? Would any of the community's existing finance sources be reluctant about continuing to invest in high-hazard areas? What kind of public financing would be available if a major, sudden-onset weather event (e.g., flood, storm, or wildfire) occurred? Is public financing available for upgrades to individual businesses or to public infrastructure to make them more resilient? Could the community's current financial resources support efforts to build community level resilience over time?
- **Real estate:** Are particular parcels or neighborhoods at much higher risk due to climate change? Which businesses and industries rely on them? Are there less risky or

problematic locations that would be viable for those businesses or industries? If relocation becomes necessary, would an individual business-by-business approach work, or would the community need a comprehensive strategy to relocate? Could changes to building codes make new development less risky for businesses or industry? How much of a financial burden might these changes be for developers or buyers? What kinds of upgrades might be required to make existing development less risky or to decrease the impact of climate change? Are rising maintenance costs as a result of climate change going to increase the cost of development? Does vulnerable real estate play a major role in generating public revenue?

- **Insurance cost and availability:** How do residents and business owners perceive the burden of insurance cost (e.g., high or low) for the relevant climatic factors (e.g., fire, flood, or storm damage)? Is the cost of insurance likely to increase in the community due to climate change? Will insurance increases significantly raise the cost of doing business? Could the public sector help to decrease or maintain insurance rates, e.g. through the National Flood Insurance Program Community Rating System? Is it possible that insurance will no longer be available for some climate hazards, and if so, what would be the consequences?
- **Post-disaster rebuilding:** If the community has recently experienced a disaster, is rebuilding occurring with an awareness of current and future climate-related hazards? Are there opportunities to rebuild in a more resilient way than previously? Are local or regional businesses supporting the rebuilding? Have major contracts for rebuilding gone to local businesses?
- **Business and economic development support:** What actors and systems support businesses currently, and how might those actors or systems change under the identified climate change impacts? Have leaders in industries that could help advance resilience in economic development, either through products, services, or leadership, recognized those opportunities? In the case of a natural hazard, are the public and private sectors aware of who can assist with emergency management, response, and rebuilding? In the public sector, are there major economic development priorities that might compete with increasing resilience? Are there ways in which those priorities and resilience could complement one another?
- **Competitive advantage:** What competitive advantage does the community already enjoy (e.g., a distinctive character or a location close to major transportation routes), and how might the potential economic impacts, negative or positive, affect that advantage? Is the community already well positioned to encourage climate-resilient businesses? Could the community market itself as more prepared for climate change and thus safer for long-term investment? Would businesses that offer climate-resilient products or services or

that meet changing consumer demands be more competitive? Would the gains from climate-resilient offerings be enough to offset expected economic losses?

[PLACEHOLDER: COULD INCLUDE EXAMPLES OF HOW NORTH KINGSTOWN ANSWERED RELEVANT QUESTIONS]

### E. Step 5: Explore Options to Enhance Resilience and Pursue Opportunities

The final step of the framework is to help the community explore options for improving its resilience based on the results of the assessment. Actions include:

- 5.1 Raise public awareness and garner support.
- 5.2 Identify actions to enhance economic resilience and pursue opportunities.

#### 5.1 Raise Public Awareness and Garner Support

- **Sub-step objective:** Present the assessment results to the broader community and solicit ongoing input as a foundation for taking action to become more economically resilient.

The results of the assessment, including the climate projections and implications, are key messages to convey to stakeholders and the public. Public outreach and buy-in will be critical, as the community will ultimately be responsible for implementing or approving funding for public actions to enhance economic resilience. Stakeholder and community engagement conducted during the assessment phases can suggest the values and priorities that frame community perspectives on climate change and economic prosperity. These values and priorities will play a major role in continuing to build public awareness after the assessment is complete. To communicate effectively, the team should create a consistent message emphasizing opportunities to improve resilience. The team should support an ongoing exchange of information and feedback between the team, key stakeholders, and the public about the assessment and subsequent strategies.

- **Create a consistent, positive message:** Messages that steer away from “doom and gloom” and emphasize opportunities, such as “building a resilient economy,” are generally more effective. The team can share its assessment of what could help maintain business stability, attract customers and investments, and improve the community’s reputation for supporting a healthy, climate-resilient economy. If the community has recently suffered a severe weather event, referencing this event as a sign of a long-term trend, not a once-in-a-lifetime occurrence, can help stakeholders make the connection between climate and their economic well-being. Memories of a severe weather event could trigger strong or emotional responses from the community, so the team would want to be sensitive to people’s reactions. While it can be important to show the negative consequences of inaction, placing greater emphasis on the benefits of taking action can



galvanize the community to take advantage of opportunities. The team can share its assessment of what will help maintain business stability, increase competitive advantage, and improve the community's reputation of supporting a healthy, climate-resilient economy.

- **Inform and get input from the community:** To inform the broader community and begin developing ideas for actions to enhance resilience and pursue opportunities, the team will need to reach out to key stakeholders and the public. The team can build on engagement and communication that happened in previous steps of the assessment to explore ideas for putting the assessment results to use. The team could host an interactive public event on climate change and economic resilience to educate the community and explore solutions and opportunities. Partnering with neighborhood groups can be an effective way to bring new faces into a community engagement event.

Key stakeholders to reach include the people or groups who are affected by projected climate impacts, those who have influence or power over implementing policy changes, and those who contribute to the community's economic development vision (e.g., trade organizations, the Chamber of Commerce, or prominent firms). Outreach efforts could be incorporated into existing community forums and activities, or the assessment team could hold strategic small group or one-on-one meetings. For example, the team could meet with businesses that led or helped recovery after past severe events to share the assessment findings, discuss their experiences, and solicit their ideas about next steps for the public and private sectors. The team could also ask these stakeholders and other businesses that returned after the severe event if they would consider using their experience to mentor other businesses. The team might also want to reach out to neighboring jurisdictions and other governmental entities in the region that might be interested in the assessment results.

### 5.2 Identify Actions to Enhance Economic Resilience and Pursue Opportunities

[NOTE: The options below are still very rough. We will refine them more after the site visit but wanted to have some ideas as a basis for discussion. The final version of the potential actions will have fewer options, but each one will have much more information about what to do, how other places have done it, and the pros and cons of the action.]

- **Sub-step objective:** Develop public- and private-sector actions that can help the community make its economy more resilient to climate-related threats and help businesses take advantage of climate-related opportunities.

The assessment results and the public engagement should help start discussions, publicly and privately, about how the community and individual properties and businesses can become more resilient. These discussions can also explore how to take advantage of potential opportunities and position the community and its businesses to thrive even as the climate changes.

### **PUBLIC SECTOR**

Public-sector actions could include convening, making regulatory or policy changes, strengthening infrastructure, and helping businesses plan and invest for climate hazards and opportunities.

#### **Convene partners to build capacity and share effective practices.**

- Convene businesses that have assisted or taken leadership during past natural disasters to share findings of the team's assessment, discuss their experiences and solicit recommendations about next steps for the public and private sectors. Discuss the potential for establishing a business-to-business mentoring program on resilience.
- Encourage networking opportunities for businesses in the community and the region interested in enhancing resilience. For example, establish a business-to-business mentoring program on resilience, develop a listserv, or host regular workshops for area businesses that wish to integrate resilience into business practices. Reach out to natural business networks such as industry groups and Chambers of Commerce to play a role in convening businesses. Through these channels, seek to understand the ongoing needs and challenges of businesses in the community with regard to climate hazards.
- Contact organizations that focus on climate resilience, economic development, and/or hazard mitigation, and explore ways for them to bring their expertise to the community and local businesses.
- Explore opportunities for local and regional collaboration on resilience.
- Work with business and economic development groups that are poised to take advantage of new market opportunities. Inquire about the challenges or limitations facing emerging climate-related market opportunities, such as space needs, workforce needs, permitting constraints. Bring these concerns to leaders and decision-makers.
- Convene local businesses to help identify the town's particular assets that could become the basis for economic growth and potential changes (e.g., seasonal, annual, long-term), and consider integrating these assets into the local economic development plan.

**Incorporate projected climate impacts into policies and regulations**, such as land use, hazard mitigation, and economic development plans and related ordinances such as building and zoning codes.

- Adopt zoning that promotes the safety and longevity of development and that also supports place-based economies. For example, use zoning to encourage downtown development to grow in directions away from a potential climate hazard while continuing to support the existing downtown.
- Use economic development and land use planning to support diversification in communities that rely heavily on a single, climate-vulnerable industry. Ensure that plans



and codes allow economic growth in new directions while supporting the traditional base of the area's economy.

- Use economic development planning and funding to support resilience innovation in the area's most competitive sectors.
- Incorporate measures in hazard mitigation or other plans to rebuild in stronger and more resilient ways should a sudden-onset weather event occur. Identify in plan documents infrastructure upgrades that are needed to promote resilience, so if funding opportunities arise, the community already has documentation of need.

**Strengthen the resilience of infrastructure that businesses rely on** (e.g., stormwater, wastewater, drinking water, utilities, transportation). Reducing climate change impacts to communities and businesses might require investing in infrastructure and services, but some actions have no additional cost beyond business as usual. Many can even save the local government, businesses, and residents money over the long term and benefit the community every day as well as in emergencies. Upgrading and improving transportation, water, and energy infrastructure to better withstand climate-related hazards generates jobs, better prepares communities for disasters, and improves regular service to residents and businesses.

- Incorporate backup electricity generation and resilience in the grid—for example, through on-site renewable energy or a micro-grid.
- Implement green infrastructure techniques, which use soils, vegetation, and natural processes to reduce polluted stormwater, to reduce flooding and protect water quality. Green infrastructure can save local governments money by allowing them to spend less on conventional “gray” infrastructure such as storm sewers. In addition, it can bring multiple community benefits, including beautifying streets, parking lots, and other paved areas; reducing ambient air temperatures; and even increasing property values.<sup>10,11</sup>
- Explore new or alternative water supply sources or establish interconnectedness with other supplies in event of emergency.
- Work with utility providers to create incentives for commercial water conservation in drought-prone areas.
- Develop transportation networks with multimodal options that improve everyday transportation but also can operate in emergencies (redundant transportation options so that if one mode is compromised, the community can maintain access). A well-connected transportation network that makes it safe and convenient to walk, bike, take public transit, or drive shorter distances gives people more choices in how to get around and lets them find alternate routes if their usual path is blocked. Making it easy for people to choose not

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<sup>10</sup> EPA. “Green Infrastructure.” <http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm>.

<sup>11</sup> EPA. *Enhancing Sustainable Communities with Green Infrastructure*. 2014. <http://www.epa.gov/smartgrowth/green-infrastructure.html>.

to drive reduces traffic congestion and air pollution, including greenhouse gases emissions.

- In general, provide for some redundancy in systems. Systems that always operate at maximum capacity or maximum efficiency have less flexibility to manage or absorb any kind of hazard or shock.
- Relocate or demolish at-risk facilities that cannot be made resilient. Consider establishing an acquisition or buy-out plan for at-risk commercial properties.

### **Help businesses plan and invest for climate hazards and opportunities.**

- Build internal capacity to help businesses develop continuity-of-operations plans, or bring in an outside expert to run a workshop for businesses.
- Fund a revolving loan program to help businesses improve the resilience of their infrastructure and operations (e.g., upgrade flood-proofing or switch to more resilient machinery or materials). State and local programs that have financed energy efficiency upgrades may provide helpful examples.
- Design a financing program that would help business owners recover or rebuild in a more resilient manner or location after a storm, flood, or other hazard, or help businesses identify funding sources.
- If the community or region uses marketing to attract and retain employers, incorporate a climate resilience component into the marketing campaign that highlights public-sector commitments to resilience and private-sector leaders that are preparing for climate change. Communities that are better prepared for disasters than neighboring communities could have a competitive edge in attracting business investment.
- Community leaders can also help by promoting development patterns that make it easier for businesses to be flexible and experiment with new ideas. For example, allowing a mix of uses and building sizes in a single district creates smaller, more affordable spaces for an entrepreneur to test a new business idea or an existing business to try a new venture.

### **PRIVATE SECTOR**

Businesses that can operate with minimal interruption during and after storms and climate stressors will have a competitive advantage. In addition, some industries are positioned to provide services and products that will enhance the resilience of clients' assets and operations. Individual business or property owners could consider taking these actions to improve their (and their community's) resilience and explore opportunities that could arise as the climate changes.

#### **Improve resilience.**

- Build **human resources capacity** to manage climate hazards.

- Share the results or key findings of the assessment with firm leadership to gain insight into how company leaders think about risk and resilience and to start or continue a conversation about improving resilience to climate hazards.
- Share results or key findings of the assessment with operational managers as well as with employees. Skilled, semi-skilled, unskilled, and managerial employees each have distinct and keen understandings of a firm’s processes, current constraints, and current opportunities. Many industries use small groups of “factory floor” employees to innovate on processes or products; a working group of employees who work in day-to-day operations will have a strong knowledge base to propose strategies that improve the firm’s climate resilience.
- Train managers and employees in emergency response. Provide guidance on how your workers can prepare their households for an emergency as well.
- Depending on the size of your firm, incorporate climate hazard management into the role of an existing employee or create a position to take this role. If this human resource investment is a difficult sell, keep in mind that the cost of inaction might be much higher than the cost of action.
- Building on capacity-building efforts, **plan for the vulnerabilities and opportunities** that accompany climate change hazards.
  - Incorporate relevant findings from the assessment and the needs of the firm into your strategic planning.
  - Create or update a continuity-of-operations plan.
  - Identify areas where additional products, processes, and relationships are needed to enhance the resilience of the firm. Identify the sources of these assets and build them into short- or long-term plans for the firm.
  - Incorporate the concept of resilience—focused on flexibility, strength, and learning—into strategic planning and values statements.
  - Share key findings of the assessment with the Chamber of Commerce, trade organizations, or other groups, and strategize about opportunities to improve resilience while supporting and enhancing profitability. Networks with common interests can promote improved outcomes for all, even if individual firms or organizations are competing with one another. This strategy could be particularly relevant if a climate hazard poses a special and common concern for the area.
- Make **structural investments**.
  - Implement flood-proofing measures (e.g., install watertight shields over doors, windows and other openings; raise elevation of electrical boxes, heating and

ventilation systems, generators, and other utilities above projected flood elevations; and anchor the foundation).

- Implement green infrastructure practices such as porous paving in parking lots and sidewalks; green roofs; bioswales; and rain gardens to manage stormwater runoff on site.
- Consider where it makes sense to locate or expand your business, taking into account projected climate change impacts, connections to public transit and walking and biking facilities as well as roads, and proximity to customers and workers.
- **Make operational investments.**
  - Share assessment results and/or planning efforts with supply and/or distribution networks. Discuss common interests in building secure and flexible networks, and explore or strategize about products, processes, and relationships that would provide mutual benefits given climate hazards.
  - Explore alternative supply and distribution channels from diverse geographies. The firm might want to learn more about how alternative suppliers and distributors are preparing for climate change and look for opportunities to diversify geographically.
  - Incorporate climate-readiness into your brand.
  - If your business relies on natural resource or utility inputs, add climate resilience to the list of reasons to pursue greater efficiency in use of those resources, particularly those that may fluctuate in the future, such as rainfall. Also identify potential alternative sources if needed.

**Pursue opportunities** to move into climate-related and/or climate-resilient markets. Examples of climate markets include engineering services, climate projection development, weather-related insurance, flood-resistant home development, material innovations such as saltwater-resistant materials, water conservation technology and practices, and drought-resistant crop development. Climate-resilient markets are markets that are relatively less dependent on a particular climate outcome.

- If your company might be able to move into a climate-related market, conduct formal market research that considers not just past demand but growth projections. Identify areas where your firm could compete in this market. Analyze local markets, or markets in which the firm already works, for entry opportunities.
- If your firm does not work in a sector that serves a climate market, discuss with leadership the soft returns on leadership in resilience, such as community or national recognition.

- Identify regional or research and development innovation hubs working on vulnerabilities in your industry (e.g., materials or shipping solutions), and explore opportunities to partner or pilot technologies or practices. These collaborations could be occurring in universities, private incubators and accelerators, and state-run small business technology initiatives.
- Build relationships with firms doing complementary work in climate-related markets to build a base for partnership opportunities. Support networking among organizations and partners working in this area through hosting events. A regional cluster in a field of interest provides agglomeration benefits, like innovation opportunities and workforce availability, that can help firms become competitive, particularly those firms that are poised to be “first to market.”
- Build relationships with institutions that provide workforce training, such as community colleges, four-year colleges, and vocational high schools, to develop your talent pipeline and to advance the overall talent pool for the climate-related market you are entering.
- If your business is oriented toward tourism, consider what amenities might make it possible to sustain—or change—your business given anticipated changes in weather patterns. For example, beachside businesses that are likely to see hotter days might want to invest in shaded patios, while ski areas might want to expand to offer summer or indoor activities. Also consider new opportunities that changing weather patterns might bring, such as a longer beach season.

### III. Conclusion

[PLACEHOLDER – will include information about how to adapt this framework to other geographies and scales and any other information that can help communities, states, and regions figure out ways to apply and improve the framework]

## Appendix A: EPA Smart Growth Implementation Assistance Program

Communities around the country are looking to get the most from new development and to maximize their investments. Frustrated by development that gives residents no choice but to drive long distances between jobs and housing, many communities are bringing workplaces, homes, and services closer together. Communities are examining and changing zoning codes that make it impossible to build neighborhoods with a variety of housing types. They are questioning the fiscal wisdom of neglecting existing infrastructure while expanding new sewers, roads, and services into the fringe. Many places that have been successful in ensuring that development improves their community, economy, and environment have used smart growth principles to do so (see box). Smart growth describes development patterns that create attractive, distinctive, and walkable communities that give people of varying age, wealth, and physical ability a range of safe, convenient choices in where they live and how they get around. Growing smart also means that we use our existing resources efficiently and preserve the lands, buildings, and environmental features that shape our neighborhoods, towns, and cities.

However, communities often need additional tools, resources, or information to achieve these goals. In response to this need, the Environmental Protection Agency (EPA) launched the Smart Growth Implementation Assistance (SGIA) program to provide technical assistance—through contractor services—to selected communities.

The goals of this assistance are to improve the overall climate for infill, brownfields redevelopment, and the revitalization of non-brownfield sites—as well as to promote development that meets economic, community, public health, and environmental goals. EPA and its contractor assemble teams whose members have expertise that meets community needs. While engaging community participants on their aspirations for development, the team can bring their experiences from working in other parts of the country to provide best practices for the community to consider.

Since 2009, EPA has engaged staff from the U.S. Department of Transportation (DOT) and the U.S. Department of Housing and Urban Development (HUD) in SGIA projects. This collaboration is part of the HUD-DOT-EPA Partnership for Sustainable Communities,

### Smart Growth Principles

Based on the experience of communities around the nation, the Smart Growth Network developed a set of ten basic principles:

- Mix land uses.
- Take advantage of compact building design.
- Create a range of housing opportunities and choices.
- Create walkable neighborhoods.
- Foster distinctive, attractive communities with a strong sense of place.
- Preserve open space, farmland, natural beauty, and critical environmental areas.
- Strengthen and direct development towards existing communities.
- Provide a variety of transportation choices.
- Make development decisions predictable, fair, and cost effective.
- Encourage community and stakeholder collaboration in development decisions.

Source: Smart Growth Network. "Why Smart Growth?" <http://www.smartgrowth.org/why.php>.

under which the three agencies work together to help improve access to affordable housing, more transportation options, and lower transportation costs while protecting the environment in communities nationwide. Using a set of guiding livability principles and a partnership agreement, this partnership coordinates federal housing, transportation, and other infrastructure investments to protect the environment, promote equitable development, and help to address the challenges of climate change.

For more information on the SGIA program, including reports from communities that have received assistance, see [www.epa.gov/smartgrowth/sgia.htm](http://www.epa.gov/smartgrowth/sgia.htm).

For more information on the Partnership for Sustainable Communities, see [www.sustainablecommunities.gov](http://www.sustainablecommunities.gov).



## Appendix B: Resources on Climate Change, Smart Growth, and Economic Resilience

Amado, Jean-Christophe, and Peter Adams. *PREP Value Chain Climate Resilience: A Guide to Managing Climate Impacts in Companies and Communities*. Partnership for Resilience and Environmental Preparedness (PREP). 2012. <http://www.oxfamamerica.org/explore/research-publications/prep-value-chain-climate-resilience>.

American Planning Association. *Policy Guide on Planning & Climate Change*. Adopted 2008, updated 2011. <https://www.planning.org/policy/guides/pdf/climatechange.pdf>.

British Standards Institution and Climate Ready. *Adapting to Climate Change using your Business Continuity Management System*. 2014. <http://www.bsigroup.com/en-GB/forms/Adapting-to-Climate-Change-using-your-Business-Continuity-Management-System>.

Crawford, Meg, and Stephen Seidel. *Weathering the Storm: Building Business Resilience to Climate Change*. Center for Climate and Energy Solutions. 2013. <http://www.c2es.org/publications/weathering-storm-building-business-resilience-climate-change>.

EPA. “Smart Growth.” <http://www.epa.gov/smartgrowth>. Resources on a variety of smart growth topics. See particularly:

- *Using Smart Growth Strategies to Create More Resilient Communities in the Washington, D.C., Region*. 2013. [http://www.epa.gov/smartgrowth/sgia\\_communities.htm#dc](http://www.epa.gov/smartgrowth/sgia_communities.htm#dc). Guidebook of policy options for local governments that help prepare for climate risks while also meeting other environmental, economic, and social goals.
- Smart Growth and Economic Success series. 2012-2014. [http://www.epa.gov/smartgrowth/economic\\_success.htm](http://www.epa.gov/smartgrowth/economic_success.htm). A series of reports exploring the economic advantages of smart growth for businesses, real estate developers and investors, and local governments.

Federal Highway Administration. *Virtual Framework for Vulnerability Assessment*. Undated. [http://www.fhwa.dot.gov/environment/climate\\_change/adaptation/adaptation\\_framework](http://www.fhwa.dot.gov/environment/climate_change/adaptation/adaptation_framework). Tool to help assess the vulnerability of transportation assets to climate change and extreme weather.

National Oceanic and Atmospheric Administration (NOAA). “Climate.” <http://www.noaa.gov/climate.html>. Links to NOAA resources on climate change impacts and projections.

NOAA Sea Grant. National Sea Grant Resilience Toolkit. <http://seagrant.noaa.gov/WhatWeDo/ResilienceToolkit.aspx>. A compilation of tools and resources that the Sea Grant Network has developed to help communities become more resilient.

Reynolds, Lea. *Climate Change Preparedness and the Small Business Sector*. Small Business Majority and the American Sustainable Business Council. 2013.

<http://www.smallbusinessmajority.org/small-business-research/clean-energy/climate-change-preparedness-and-small-business.php>.

Rhode Island Commerce Corporation. *Understanding the Economic Development Opportunity & Impact of Climate Change*. April 2014 (draft).

<http://www.commerceri.com/documents/reports/CommerceRI%20EDandClimate.pdf>.

U.S. Climate Resilience Toolkit. <http://toolkit.climate.gov>. Brings together climate resilience resources from across the federal government. As of 2014, the site focuses on federal tools and data for coastal flood risk and food resilience, but resources on other topics and from other sources will be added.

Vermont Small Business Development Center. *Disaster Recovery Guide for Business*. Undated.

<http://www.vtsbdc.org/programs/irene-business-recovery-business-owner>. Guide with worksheets and checklists to help businesses figure out how to proceed after a disaster.

## Appendix C: Supplemental Information on Hazard Exposure Assessment

This appendix provides additional information on conducting climate-related hazard exposure assessments for communities that might not have completed an assessment or that want to build on their current assessment. This information focuses on some of the primary sources of data and tools to support assessment and is not meant to be a detailed, step-by-step guide. It is organized by the three levels outlined in step 2.3:

1. Basic approach.
2. Advanced GIS-based approach.
3. Hazus modeling approach.

### 1. Basic Approach

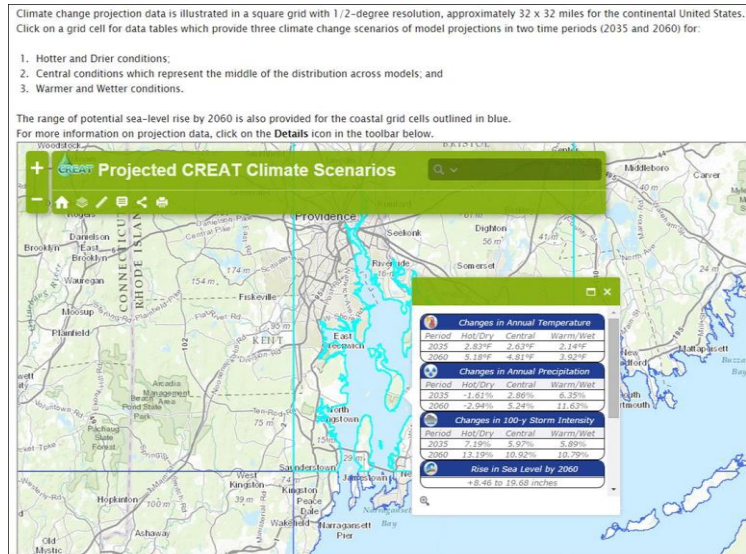
A basic climate hazard exposure assessment can give the team a general sense of the potential impacts the community might experience. The team can use online tools and maps discussing regional climate changes as a reasonable starting point to help raise awareness and for general planning purposes. This section provides information for flooding, sea level rise, storm surge, drought, and excessive heat.

Many communities in the United States have hazard mitigation plans, and if the local community does not have one, the region or state might have one that would be useful. Flooding, storm surges, drought, and excessive heat are all likely to be included in hazard mitigation plans. Many of these plans have a chapter on climate change but currently this is not required at the Federal level.

Several resources can help identify potential climate hazards:

- The 2014 National Climate Assessment Report includes observed changes and projected impacts on regions and sectors: <http://nca2014.globalchange.gov>.
- Regional climate scenarios developed for the National Climate Assessment are available at <http://scenarios.globalchange.gov>.

- EPA's Scenario-Based Projected Changes Map, an easy-to-use mapping tool, provides local projected changes in annual total precipitation, precipitation intensity, annual average temperature, 100-year storm events, and sea level rise at



**Figure C-1:** Screenshot of a sample map and projections generated by EPA's Scenario-Based Projected Changes

<http://water.epa.gov/infrastructure/watersecurity/climate/scenario.cfm>.

- NOAA's Regional Integrated Sciences and Assessment program provides detailed climate change scenarios and project impacts at <http://cpo.noaa.gov/ClimatePrograms/ClimateandSocietalInteractions/RISAProgram.aspx>.
- The U.S. Climate Resilience Toolkit links to resources from across the federal government at <http://toolkit.climate.gov>.

### Flooding

Low-lying areas can be at risk from flooding, and where climate change is projected to bring more intense rainfall events, flood plain boundaries could expand. The Federal Emergency Management Agency (FEMA) has mapped the flood risk throughout much of the United States. These maps are available at the Flood Map Service Center at <http://msc.fema.gov>. These flood plains have been developed using historical data and do not consider climate change. Therefore, many communities have decided to add a factor of safety expressed in feet above the base flood often called freeboard.

If the community lies in an unmapped part of the United States, the community's hazard mitigation plan should include flood maps. If the plan is not available, the community's emergency management department or town planner might be able to provide useful materials.

### Sea Level Rise

As sea levels rise, a community's low-lying areas might flood more frequently during high tides, and some areas will become permanently submerged. The National Oceanic and Atmospheric Administration (NOAA) has a sea level rise viewer, which shows how coastal areas could be affected by various rates of sea level rise, at <http://coast.noaa.gov/digitalcoast/tools/slr>.

Several states have climate change reports with sea level rise estimates. These estimates can be combined with the NOAA sea level rise viewer information to see the most likely projections for inundation areas in the community or region for different climate change scenarios. Ensure the projections incorporate climate change and do not simply use historical trends.

### Storm Surge

In addition to the heavy precipitation from strong coastal storms such as hurricanes and nor'easters that causes flooding, the winds can generate a storm surge that temporarily inundates low-lying areas. Mapping these surge zones lets the team better understand which community assets are at risk.

EPA's Storm Surge Inundation and Hurricane Strike Frequency Map, at <http://water.epa.gov/infrastructure/watersecurity/climate/stormsurge.cfm>, is an easy-to-use mapping tool that illustrates coastal storm surge and inundation scenarios based on NOAA's Sea, Lake, and Overland Surge from Hurricanes (SLOSH) models, FEMA's 100- and 500-year flood plains, and the National Hurricane Center's hurricane strike dataset.

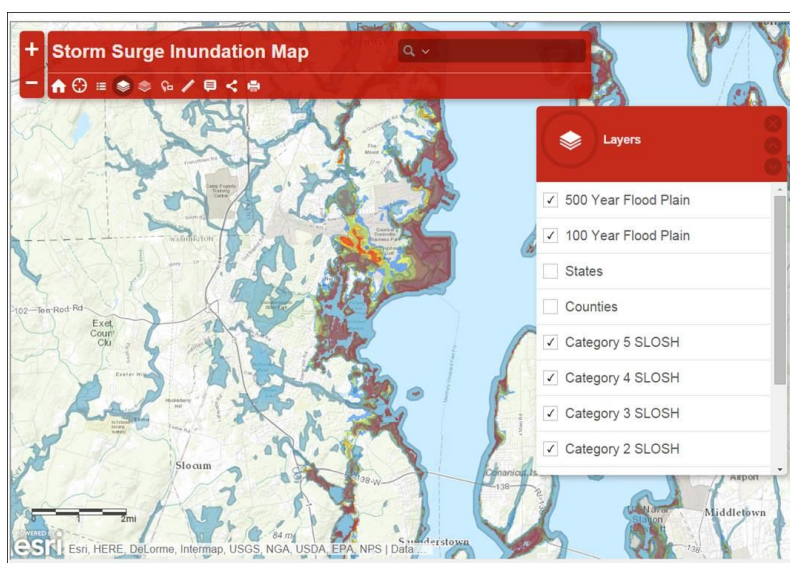
A community can see how many coastal storms have occurred in the area by viewing historical storm tracks and characteristics at the National Hurricane Center's archives at

[www.nhc.noaa.gov/data/#tracks\\_us](http://www.nhc.noaa.gov/data/#tracks_us). The storm reports on this site include more information than the EPA mapping tool, including wind speeds, pressures, surge, total losses, and locations.

Another source of information is the Applied Technology Council's wind speed website at <http://windspeed.atcouncil.org>. A community can identify its 10-, 25-, 50-, and 100-year wind speed. Wind speeds have been developed using historical data including hurricane information. Users might need to type in addresses across the community to better understand the range of current 100-year wind speeds.

### Drought

The Drought Risk Atlas, at <http://droughtatlas.unl.edu>, can help identify drought risk based on historical events. To help determine if the community might experience drought conditions in the



**Figure C-2:** Screenshot of a sample map from EPA's Storm Surge Inundation and Hurricane Strike Frequency Map.

future, the team can see information about projected future precipitation and temperature at the Climate Wizard website at [www.climatewizard.org](http://www.climatewizard.org).

### Excessive Heat

To help determine if the community might experience excessive heat conditions in the future, the team can see information about projected future temperatures at the Climate Wizard website.

## 2. Advanced GIS-Based Approach

The advanced GIS-based approach can give the community a better sense of the likelihood and magnitude of potential impacts. The team will need to identify online data and GIS tools for this approach. This analysis typically takes considerably more time and resources but could more accurately depict the impacts, which might help the community more forcefully justify adaptation strategies. See the list of resources in the Basic Approach section for sites that can provide regional climate change projections. The resources identified in the Basic Approach also have GIS data that can be downloaded and analyzed. This section provides information for flooding, sea level rise, storm surge, drought, and excessive heat.

### Flooding

The advanced approach involves identifying and using flood data in GIS or modeling future flood conditions using hydrologic and hydraulic modeling for river flooding or a hydrodynamic model for coastal flooding.

The team can download the National Flood Hazard Layer from FEMA's Flood Map Service Center at <http://msc.fema.gov>. This layer includes existing flood plains developed using historical data. To model flooding in the mid- and late-century scenarios, the team can use U.S. Geological Survey (USGS) regression equations that calculate a river's flow based on watershed and climatic characteristics and are provided by state at <http://water.usgs.gov/osw/programs/nss/pubs.html>. If the user knows the mid- and late-

### Figure C-4: Resources for Projected Climate Characteristics

Communities can find projected future climate characteristics at:

- The Bias-Correction Spatial Disaggregation (BCSD) climate and hydrology downscaled data for the Coupled Model Intercomparison Project phase 5 (CMIP5): [http://gdo-dcp.ucllnl.org/downscaled\\_cmip\\_projects](http://gdo-dcp.ucllnl.org/downscaled_cmip_projects).
- North American Regional Climate Change Assessment Program (NARCCAP) dynamically downscaled Coupled Model Intercomparison Project phase 3 (CMIP3): [www.narccap.ucar.edu](http://www.narccap.ucar.edu).
- The USGS national climate change viewer: [www.usgs.gov/climate\\_landuse/clu\\_rd/nex-dcp30.asp](http://www.usgs.gov/climate_landuse/clu_rd/nex-dcp30.asp).
- The Climate Change, Agriculture and Food Security global downscaled data (see the MarkSim spatial downscaling for finer resolution): [www.ccafs-climate.org](http://www.ccafs-climate.org).



century watershed and climatic characteristics, he or she can calculate the river's flow for these scenarios. To understand these characteristics, the team can look at the peak-flow annual exceedance probabilities at the USGS national climate change viewer website (see Figure C-4). The site provides an equation that relates the peak flow to the watershed and climatic characteristics. If the user knows the future characteristics, he or she can calculate the future peak flow. See Figure C-4 for other sources for future climate characteristics.

### Sea Level Rise

To help determine sea level rise in the community, the team can find local sea level trends on NOAA's Tides and Currents website at <http://tidesandcurrents.noaa.gov/sltrends/sltrends.html>. For guidance on using and mapping the sea level rise data, see: NOAA. *Technical Considerations for Use of Geospatial Data in Sea Level Change Mapping and Assessment*. NOAA Technical Report NOS 2010-01. 2010. [www.ngs.noaa.gov/PUBS\\_LIB/Technical\\_Use\\_of\\_Geospatial\\_Data\\_2010\\_TM\\_NOS\\_01.pdf](http://www.ngs.noaa.gov/PUBS_LIB/Technical_Use_of_Geospatial_Data_2010_TM_NOS_01.pdf).

To quantify the sea level rise, the team can use the global projections in conjunction with the local trends from the Tides and Currents website.

Once the team identifies sea level rise estimate(s), it can get a digital elevation model from the community or state, from NOAA's Digital Coast website at <http://coast.noaa.gov/digitalcoast/dataregistry/?redirect=301ocm#/> if it is a coastal area, or from the USGS National Map Viewer at <http://viewer.nationalmap.gov/viewer>. For guidance on creating inundation models in GIS software, see: NOAA. *Detailed Methodology for Mapping Sea Level Rise Inundation*. 2012. [www.coast.noaa.gov/slr/assets/pdfs/Inundation\\_Methods.pdf](http://www.coast.noaa.gov/slr/assets/pdfs/Inundation_Methods.pdf).

### Storm Surge

If the team can better understand and quantify the storm surge risk, it will have a more accurate picture of potential impacts to the community. The effect of climate change on the frequency and strength of coastal storms is somewhat dependent on regional location, but the team should keep in mind that sea level rise will add to the extent of storm surges.

Along with the resources identified in the storm surge section of the Basic Approach, the National Hurricane Center provides several storm surge products for response, readiness, or planning and mitigation at [www.nhc.noaa.gov/surge](http://www.nhc.noaa.gov/surge). The team can download the Maximum of MEOWs (MOMs), where MEOWs are Maximum Envelopes of Water, at [www.nhc.noaa.gov/surge/momOverview.php](http://www.nhc.noaa.gov/surge/momOverview.php). The team would use these data in conjunction with the historical storm tracks to help determine which category storm the community should prepare for and where the inundation would occur. If most of the storms in the region are category 3 or below, consider looking at a category 4 inundation area for the late-century climate scenario.

### **Drought**

The team can download downscaled climate precipitation and temperature data and analyze the trends. Consider reviewing consecutive dry days, number of days with temperatures over a critical value, and change in precipitation. Downscaled data for mid- and late-century climate scenarios are available at the Climate Wizard website (see Figure C-3) and at the websites in Figure C-4.

### **Excessive Heat**

For the advanced approach, the team can download downscaled climate temperature data and analyze the trends. Consider reviewing number of days with temperatures over a critical value, average temperatures shown seasonally, and change in maximum temperatures. Downscaled data for the mid- and late-century climate scenarios are available at the Climate Wizard website (see Figure C-3) and at the websites in Figure C-4.

## **3. Hazus Modeling Approach**

Hazus is a free, nationally applicable standardized methodology that contains models for estimating potential losses from earthquakes, floods, and hurricanes.<sup>12</sup> Hazus uses GIS technology to estimate physical, economic, and social impacts of disasters. It graphically illustrates the boundaries of locations at high risk from earthquakes, hurricanes, and floods. Two steps are presented for those considering Hazus modeling to support vulnerability analysis:

1. Identify exposure
2. Determine sensitivity.

### **Step 1: Identify Exposure**

#### **Riverine Flooding**

The team can use Hazus to model mid- and late-century riverine flood conditions using the USGS regression equations described in the Advanced GIS-Based section to estimate the future hydrology and the Hazus hydraulic model to delineate the flood plain.

Run the Hazus model with the mid- and late-century 100- and 500-year peak flows to produce the corresponding flood plains. To do this, do not run the hydrology step in Hazus, but instead skip to “delineate flood plain” and enter the peak flow values. Hazus will create the flood depth grid for this event, which can be used in Step 1.4. Alternatively, run another hydraulic model with the results of the hydrologic model, and bring the results into Hazus.

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<sup>12</sup> Hazus can be downloaded from FEMA’s Map Service Center at <http://msc.fema.gov/portal/resources/hazus>. This web page includes links to Hazus training and user groups.



### Coastal Flooding

To use Hazus to assess future coastal flooding, the team would consider modeled precipitation, future storm events, sea level rise, and long-term erosion. All of these factors can help produce flood plains for mid- and late-century climate scenarios. To use Hazus for the analysis, the team can use the sea level rise analysis results from the Advanced GIS-Based Approach sea-level rise section; a long-term erosion model; and the Hazus coastal flood model.

The digital elevation model (DEM) used in the Hazus coastal model will need to incorporate rates of erosion if long-term shoreline erosion is an issue. Local erosion data are usually available from the state emergency management or coastal resources management agency. The team can use local erosion rates, with a focus on recent trends and corresponding sea level rise, to model future erosion rates for mid- and late-century climate scenarios. If these data do not exist, this article describes different ways to model erosion due to sea level rise: Leatherman, Stephen P., Keqi Zhang, and Bruce C. Douglas. "Sea Level Rise Shown to Drive Coastal Erosion." *Eos*. Vol. 81, No. 6. 2000:55-57.

<http://onlinelibrary.wiley.com/doi/10.1029/00EO00034/pdf>. A DEM that has undergone erosion could be added to the Hazus model in the user data and DEM tabs.

Another requirement to run the Hazus coastal model is the Flood Insurance Study (FIS) which can be downloaded at FEMA's Flood Map Service Center at <http://msc.fema.gov>. The FIS provides the still water elevation (SWEL) for current return period events (such as the 100- and 500-year events). The current SWEL should be added to the sea level rise estimate for the mid- and late-century climate scenarios to get the future SWEL. If hurricanes, nor'easters, and other storms are expected to increase in the area, the sea level rise estimate can be added to the 500-year SWEL, which might better represent a late-century 100-year event.

Run the Hazus model with the mid- and late-century SWELs and eroded DEM to get the flood depth grid for this event.

### Storm Surge

To use Hazus to assess future storm surge, the team can consider future storm events, sea level rise, and long-term erosion. All of these factors can help produce inundation areas for mid- and late-century climate scenarios. To use Hazus to model future storm surge conditions, the team will need: the sea level rise analysis results from Advanced GIS-Based Approach sea-level rise section for the mid- and late-century climate scenarios, a long-term erosion model, and the Hazus surge model which includes NOAA's Sea, Lake, and Overland Surge from Hurricanes (SLOSH) and Delft University of Technology's Simulating WAVes Nearshore (SWAN) models.

The digital elevation model (DEM) used in the Hazus storm surge model could incorporate rates of erosion if long-term shoreline erosion is an issue. Local erosion data are usually available from the state emergency management or coastal resources management agency. The team can use local erosion rates, with a focus on recent trends and corresponding sea level rise, to model

future erosion rates for storm surge for mid- and late-century climate scenarios. If these data do not exist, this article describes different ways to model erosion due to sea level rise: Leatherman, Stephen P., Keqi Zhang, and Bruce C. Douglas. “Sea Level Rise Shown to Drive Coastal Erosion.” *Eos*. Vol. 81, No. 6. 2000:55-57.

<http://onlinelibrary.wiley.com/doi/10.1029/00EO00034/pdf>. A DEM that has undergone erosion could be added to the Hazus model in the user data and DEM tabs.

The sea level rise for the mid- and late-century climate scenarios could be added to the water level boundary conditions at the beginning of the analysis. Historical events, “hurricane” events (a hurricane decision support tool administered by FEMA, the U.S. Army Corps of Engineers, and NOAA, available at [www.hurrevac.com](http://www.hurrevac.com)), and manual events can be modeled in Hazus. If the community is expecting more intense storms in the late-century climate scenario, increase the wind speeds of historical events or create a customized storm to reflect this change. The result of the analysis will be a storm surge inundation zone.

### Step 2 Determine Sensitivity

Hazus can help support the potential impact analysis by producing a detailed loss estimate for future riverine and coastal flooding and storm surge. Because Hazus was created in a GIS-based environment, all of the outputs can be mapped to identify areas of higher risk. Once the team has set up the climate hazard as described in Step 1 of this section (Identify Exposure), the team can simply run the analysis.

Hazus provides a set of community inventory data that can be updated using local GIS data. Demographic data, community assets, commercial and industrial values, utilities, bridges, agricultural products, building elevation values, and economic modeling parameters can all be updated in Hazus’ Inventory. Once the hazard and inventory models have been set up, users can model and map the following in Hazus:

- Economic loss including direct building loss and business interruption loss for each occupancy type, which provides losses at the census block level in flood plains and surge inundation areas.
- Utilities and bridges damage, loss, and functionality, which provides damage, loss, and a yes/no functionality assessment at the site level.
- Community asset damage and loss, which estimates damage and loss at the site level.
- Debris estimates and costs to remove debris, which estimates building debris in different categories for floods and hurricanes and provides tree debris estimates for hurricanes.
- The number of displaced households, which provides the number of displaced households for floods and hurricanes.
- Shelter requirements, which provides short-term shelter requirements based on displaced households and demographic information.

## Appendix D: Sample Economic Vulnerability Assessment Questions

This appendix offers examples of questions a community assessment team could consider when examining the vulnerability of certain economic assets and their potential impact on the community. The team could select which questions are most relevant and add to or modify the questions to reflect the size of the community, its major economic sectors (for example, agricultural operations are likely to be more important to rural communities than to cities), level of detail desired (for example, a smaller village might examine impacts for individual parcels, whereas a regional assessment might focus on neighborhoods, corridors, or districts), and the goals the team selected for the economic assessment. The assets discussed here are:

1. Transportation
2. Utilities and Emergency Response Operations
3. Industrial Operations
4. Commercial Operations
5. Agricultural Operations
6. Natural Resources

### 1. Transportation

- a. What are the major transportation network components in the community (e.g., roads; public transit such as buses, trains, subways, or streetcars; airport; bicycle and pedestrian trails, paths, and lanes; water-based transportation such as ferries and water taxis; or freight)?
- b. Who owns, operates, and maintains the transportation network components (e.g., the community, a transit authority, the state, or the federal government)? What is the geographic scale of each component? How many people does each component serve? Are there peak times of year for each component? How many people are employed by each component?
- c. What are the impacts of a changing climate on critical transportation network components? Consider incremental changes in climatic conditions (e.g., rising temperatures or changing rainfall patterns), increased extreme weather (e.g., heat waves, droughts, heavy downpours, floods, or storms), more permanent changes (e.g., sea level rise), and indirect implications (e.g., increased exposure to water or saltwater, soil erosion, or fires). Approximately what proportion of the transportation network components described in response to question 1.a are vulnerable to these changes? Approximately what proportion of people using the transportation components could be affected by temporary shutdowns of the networks in these vulnerable areas? Have there

already been extreme weather events that give some indication of potential economic consequences? Some specific examples:

- i. Could disruption in the electrical grid due to high temperatures result in train delays or even a system shutdown?
  - ii. Could damage from natural hazards or other climate-related impacts to train tracks, bridges, or the road system disrupt or shut down the entire network or significant portions of it? If so, are there alternative routes or transportation modes that could continue to provide access to key places?
  - iii. Could weather-related damage to bicycle and pedestrian paths and trails and bicycle lanes prevent them from being used? Alternatively, could these paths continue to provide access if other routes or modes are blocked?
- d. Do residents rely on the public transit system to access employment outside of the community, and do businesses rely on it to bring their workers in?
  - e. Does the public transit system serve multiple places in the community (to estimate the potential number of people and spatial area affected)?
  - f. Of the transportation components in particularly vulnerable areas, which corridors or components are considered more important to the community's economy? Consider connectivity to economic assets and areas that could be cut off, amount of traffic, portion of community residents, residents' characteristics (e.g., income level, age, disability, or other factor that could make residents more vulnerable) and businesses affected (e.g., customers, employees, or distributors rely on the transportation component to reach the business).
  - g. What opportunities might there be to mitigate the various types of impacts from the climate change scenarios that were evaluated to the transportation components? Would these opportunities translate to new types of business for the community?
  - h. Are there opportunities to make the transportation components more resilient to projected climate change impacts, or to offer new transportation options that are more resilient? What economic opportunities (e.g., new businesses, products, services) might be associated with these changes?

## 2. Utilities and Emergency Response Operations

- a. What utilities serve the community (e.g., sewer, water, electricity, natural gas, telephone and cellphone, internet or Wi-Fi, or cable TV)? Who owns them? What percentage of the community consumes these utility services?
- b. What are the potential impacts of a changing climate on the utilities? Consider incremental changes in climatic conditions (e.g., rising temperatures and changing rainfall patterns), increased extreme weather (e.g., heat waves, droughts, heavy downpours, floods, and storms), more permanent changes (e.g., sea level rise), and indirect implications (e.g., increased exposure to water or saltwater, wind damage, soil

- erosion, or fires). Approximately what proportion of the customers for the various utilities are predicted to be affected in vulnerable areas? Have there already been extreme weather events that give some indication of potential economic consequences?
- c. Do any of the utilities need cooling to function and would loss of cooling result in damage to other systems and potentially inability to operate?
  - d. Does each utility have redundant power sources? Does the need for a redundant power source create economic opportunities?
  - e. How do these utilities relate to other major assets in the community?
    - i. Are there operations that use a significant amount of electricity?
    - ii. Are there operations that use a significant amount of potable water for drinking, cleaning, swimming, or other uses?
    - iii. Are there operations that use a significant amount of natural gas?
    - iv. Are there commercial or industrial operations that use large amounts of certain utilities (e.g., water or electricity)?
    - v. Are there critical community assets (e.g., hospitals) that require an uninterrupted supply of electricity, natural gas, and/or potable water?
  - f. Have any of the utilities implemented any mitigation or resilience measures to eliminate or reduce harm from climate change impacts? What business opportunities might these strategies create?
  - g. Where are critical fire, police, medical, and other emergency response facilities located? How much area does each facility cover?
  - h. In the event of an emergency, can emergency response personnel get to and from the critical facilities?

### 3. Industrial Operations

- a. What industrial operations are located in the community? Are they locally, regionally, nationally, or internationally owned, and what is the scale of their operations? What is the estimated number of employees? Approximately what proportion of the local tax base do industrial operations comprise?
- b. What are the potential impacts of a changing climate on industrial operations? Consider incremental changes in climatic conditions (e.g., rising temperatures and changing rainfall patterns), increased extreme weather (e.g., heat waves, droughts, heavy downpours, floods, and storms), more permanent changes (e.g., sea level rise), and indirect implications (e.g., increased exposure to water or saltwater, wind damage, soil erosion, or fires). Approximately what proportion of the total industrial employees or tax base could be affected by impacts to industries in these vulnerable areas? Have there already been extreme weather events that give some indication of potential economic consequences?

- c. What are the potential impacts of a changing climate on the transport and logistics of industrial products? What connected businesses might be affected (e.g., transporters, warehouses, retailers, or end users)?
- d. Do the industrial operations depend on water supplies for their operations?
  - i. If significant, what is the risk of a reduction in available water?
  - ii. Are the industrial operations served by public or private water supplies?
  - iii. What opportunities might there be to improve water efficiency or use alternative water sources? Is there an opportunity for new businesses to meet this need?
- e. What is the approximate (rough order of magnitude) potential value of the industrial products that are produced or stored on site that could be lost due to projected climate impacts for the scenarios evaluated?
- f. Do any parts of the operation take place outside and therefore might be directly affected by weather? Could excessive heat or severe storms negatively affect the operation's products or supplies stored outside? What alternative types of operations might be economically successful under the changed conditions (i.e., reflecting changes in preferences and material needs)?
- g. Do industrial operations' employees work outside? Will excessive heat negatively affect employees and prevent them from effectively and efficiently completing their work?
- h. Are there strategies to reduce or eliminate the impacts of climate change? What business opportunities might these strategies create?

### 4. Commercial Operations

- a. What primary types of commercial operations are located in the community? Are the commercial operations locally, regionally, nationally, or internationally owned, and how does their scale relate to the community's economy? Approximately what proportion of the local tax base do commercial operations comprise?
- b. What are the potential impacts of a changing climate on preparation, transportation, and/or delivery of the products produced at these operations? Consider incremental changes in climatic conditions (e.g., rising temperatures and changing rainfall patterns), increased extreme weather (e.g., heat waves, droughts, heavy downpours, floods, and storms), more permanent changes (e.g., sea level rise), and indirect implications (e.g., increased exposure to water or saltwater, wind damage, soil erosion, or fires). Approximately what proportion of the total employees work for commercial operations in these vulnerable areas, and what is the approximate collective local tax base for those vulnerable operations? Have there already been extreme weather events that give some indication of potential economic consequences?
- c. Do the commercial operations depend on water supplies for their operations?
  - i. If significant, what is the risk of a reduction in available water?

- ii. Are the commercial operations served by public or private water supplies?
- iii. What opportunities might there be to improve water efficiency or use alternative water sources? Is there an opportunity for new businesses to meet this need?
- d. Do the commercial operations depend on cooling systems to function effectively or at all, for example, to make, store, or preserve their product or for operations (e.g., ice rink, restaurants, offices, retail)? If the need for cooling is significant, do the operations need it for customers or the production of goods and products, and what is the approximate potential for cost of repairing damages and lost revenue?
- e. What are the potential impacts of a changing climate on the transportation and logistics of commercial products produced on site? What connected businesses might be affected (e.g., transporters, warehouses, retailers, or end users)?
- f. What is the approximate (rough order of magnitude) potential value of the commercial products that are either produced or stored on site that could be lost due to projected climate impacts?
- g. Are there strategies to reduce or eliminate the climate change impacts? What business opportunities might these strategies bring?
- h. Do the commercial operations involve activities outside? Would the projected climate change impacts affect these outside activities? Could excessive heat negatively affect the operation? What alternative types of operations might be economically successful under the changed conditions (i.e., reflecting changes in preferences or consumer product or service needs)?
- i. Do the commercial operations' employees work outside? Will excessive heat negatively affect employees and prevent them from effectively and efficiently completing their work?

## 5. Agricultural Operations

- a. In an effort to understand the impact to the economy, what is the total number of these operations in the community? What is the estimated number of employees for each? Consider breaking down the total numbers by the type of operation (e.g., livestock, crops, or nurseries), as each type might be affected differently by climate-related impacts.
- b. What are the impacts of a changing climate on primary types of livestock, crops, or nurseries in the community? Consider incremental changes in climatic conditions (e.g., rising temperatures or changing rainfall patterns), increased extreme weather (e.g., heat waves, droughts, heavy downpours, flooding, or storms), more permanent changes (e.g., sea level rise), and indirect implications (e.g., increased exposure to water or saltwater, wind damage, soil erosion, or fires). Approximately what proportion of agricultural operations are located in the vulnerable areas? Do agricultural extension experts have insight as to how these changes could potentially affect agricultural economic factors such as yield reliability, quality, and price? Have there already been extreme weather events that give some indication of potential economic consequences?



- c. How dependent are the community's agricultural and landscaping operations on a reliable freshwater supply? What is the risk of a reduction in available water? What opportunities might there be to improve water efficiency or use alternative water sources?
- d. What is the approximate (rough order of magnitude) potential value of agricultural or landscaping products that could be lost due to projected climate impacts?
- e. What are the potential impacts of a changing climate on transportation and logistics of agricultural and nursery products? What connected businesses might be affected (e.g., transporters, warehouses, or retailers)?
- f. What opportunities might there be to test new strains of crops or animals in the most vulnerable product lines or regions of agricultural and landscaping operations in the community?

### 6. Natural Resources

- a. What are the major natural resource network components in the community (e.g., streams, rivers, flood plains, lakes, coastal areas, parks, street trees, greenways, and forests and silviculture areas)?
- b. What are the potential impacts of a changing climate on these natural resources? Consider incremental changes in climatic conditions (e.g., rising temperatures and changing rainfall patterns), increased extreme weather (e.g., heat waves, droughts, heavy downpours, floods, and storms), more permanent changes (e.g., sea level rise), and indirect implications (e.g., increased exposure to water or saltwater, wind damage, soil erosion, or fires).
- c. Do industrial or agricultural operations depend on these resources as water supplies for their operations (e.g., direct withdrawals of water), particularly meeting certain water quantity or quality requirements?
  - i. If significant, what is the risk of a reduction in available water or reduced water quality?
  - ii. What opportunities might there be to improve water efficiency or use alternative water sources?
- d. What connected local businesses might be affected by impacts on these natural resources (other than water supply)? What is the approximate (rough order of magnitude) potential loss to these businesses? Businesses outside the community?
- e. What is the approximate (rough order of magnitude) potential value of the natural resource ecosystem functions (e.g., floodwater storage, carbon sequestration, cooling, or water supply) that could be lost due to projected climate impacts?
- f. Are there strategies to reduce or eliminate the climate change impacts? What business opportunities might these strategies bring? Consider breaking this down by different natural resource elements, then considering the elements as a whole.