



# **Vulnerability Assessment and Resiliency Planning: The National Renewable Energy Laboratory's Process and Best Practices**

**May 23, 2014-June 5, 2015**

J. Vogel and S. Renfrow  
*Abt Environmental Research*  
*Boulder, Colorado*

NREL Technical Monitor: Lissa Myers

**NREL is a national laboratory of the U.S. Department of Energy  
Office of Energy Efficiency & Renewable Energy  
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## List of Acronyms

CCRP	Climate Change Resiliency and Preparedness
DOE	U.S. Department of Energy
IT	information technology
NREL	National Renewable Energy Laboratory
STM	South Table Mountain campus

# Table of Contents

<b>1</b>	<b>Introduction</b> .....	<b>1</b>
1.1	About the NREL Climate Change Resiliency and Preparedness Effort.....	2
1.2	Reasons for Undertaking Climate Change Resiliency Planning .....	2
<b>2</b>	<b>Develop Project Support</b> .....	<b>4</b>
<b>3</b>	<b>Assess the Vulnerabilities</b> .....	<b>6</b>
3.1	Create an Impacts Framework.....	6
3.1.1	Build an Impacts Framework .....	6
3.1.2	Use the Impacts Framework to Create a Potential Vulnerabilities Questionnaire .....	7
3.2	Convene Staff Focus Groups and Brainstorm Potential Vulnerabilities .....	9
3.2.1	Use Staff Focus Groups to Understand Potential Vulnerabilities .....	9
3.2.2	Collate and Synthesize Potential Vulnerabilities .....	10
3.3	Score Potential Vulnerabilities and Identify the Highest Risk Vulnerabilities .....	10
3.3.1	Understand Climate, Climate Change, and Associated Vulnerabilities .....	10
3.3.2	Determine Potentially Relevant Climate Variables and Their Likelihood.....	11
3.3.3	Associate Climate Variables with Potential Vulnerabilities .....	12
3.3.4	Score Potential Vulnerabilities for Magnitude of Consequence .....	13
3.3.5	Score Potential Vulnerabilities for Risk and Determine Overall Risk .....	14
3.4	Finalize the List of Highest Risk Vulnerabilities .....	15
<b>4</b>	<b>Identify Resiliency Actions</b> .....	<b>17</b>
4.1	Categorize the Vulnerabilities .....	17
4.2	Explore Potential Resiliency Actions.....	18
4.2.1	Use Staff Focus Groups to Explore Resiliency Actions.....	18
4.2.2	Synthesize Potential Actions .....	19
4.3	Evaluate and Score Resiliency Actions.....	21
4.4	Finalize the Resiliency Actions List.....	22
<b>5</b>	<b>Conclusion</b> .....	<b>25</b>
	<b>Glossary</b> .....	<b>27</b>
	<b>References</b> .....	<b>29</b>

## List of Figures

Figure 1. NREL’s risk score matrix .....	14
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## List of Tables

Table 1. Final NREL Impacts Framework .....	6
Table 2. NREL’s Climate Variables of Concern and Associated Likelihood of Changing .....	12
Table 3. Example Table to Help Check a Potential Vulnerability against Potentially Relevant Climate Variables .....	12
Table 4. Example Table Showing Vulnerability to the Workforce and its Scoring .....	15
Table 5. NREL Vulnerabilities with Highest Overall Risk Scores .....	16
Table 6. NREL Risk Categorization for Vulnerabilities with the Highest Overall Risk Scores .....	17
Table 7. Evaluation Criteria Scoring for Resiliency Actions .....	20
Table 8. Example of a Resiliency Action Plan Table for One of NREL’s Vulnerabilities, <i>Damage to Climate-Sensitive Equipment May Disrupt Research</i> .....	22
Table 9. Example of Final Resiliency Action Table with High-Level Vulnerability Information <sup>a</sup> .....	23

## List of Boxes

Box 1. Tips for Building a Steering Committee .....	4
Box 2. Do You Need External Assistance? .....	5
Box 3. Tips for Building an Impacts Framework .....	7
Box 4. Exploring Climate and How It May Change .....	8
Box 5. Tips for Identifying Potential Vulnerabilities .....	9
Box 6. When Outside Climate Expert Resources Are Not Available .....	11
Box 7. Tips for Involving Staff in Identifying Resiliency Actions .....	19
Box 8. Tips for Synthesizing Potential Actions .....	20



# 1 Introduction

The National Renewable Energy Laboratory (NREL) is a U.S. Department of Energy (DOE) research laboratory that employs more than 2,500 people. The laboratory focuses on renewable energy and energy-efficiency research and has two campuses along the Front Range of Colorado. In 2014, NREL worked with Abt Environmental Research (then called Stratus Consulting Inc.) to develop a vulnerability assessment and resiliency action plan as part of NREL's Climate Change Resiliency and Preparedness (CCRP) project.

This guide describes the process that NREL undertook during this project. NREL used a participatory approach to vulnerability assessment and resiliency planning that emphasized organizational context, building internal capacity, and the application of climate science in a practical and actionable manner. Through literature review, NREL observed that many vulnerability assessments start by emphasizing climate science and downscaling climate projections to a finer scale, however this approach creates fundamental limitations. Such assessments:

- Can be expensive
- Often do not reduce the uncertainty from climate projections
- Can introduce new uncertainties into projections
- May not address the scientific issues of greatest importance to the organization, system, or facility at hand.

The decision was also made to include resiliency planning as part of ongoing management and operations across the laboratory. NREL thus selected an approach that built on the knowledge and capabilities of internal staff by engaging them at various stages of the vulnerability assessment and resiliency planning process. Using this approach built ownership of the process, helping to ensure that staff will buy into and support the implementation of resiliency measures. Finally, NREL decided to use an approach that emphasized NREL's unique organizational structure to understand vulnerability and evaluate resiliency actions in a manner that would maximize their impact. The vulnerability assessment and resiliency planning process considered NREL as an entire organization, ranging from its physical facilities, operations, management, and planning; to its mission, people, and technical research efforts.

A similar approach may be beneficial to other DOE laboratories, other government agencies, the private sector, the nonprofit sector, or academia to pursue similar efforts within their own organizations. Throughout this document, the authors present each step from a general perspective and then offer details that pertain to NREL's specific experience; tips appear in text boxes throughout the guide.

For the findings and outcomes of NREL's vulnerability assessment and resiliency action plan, refer to *A Climate Change Vulnerability Assessment Report for the National Renewable Energy Laboratory* (hereafter Vogel et al. 2015a) and *A Resiliency Action Plan for the National Renewable Energy Laboratory* (hereafter Vogel et al. 2015b).

## 1.1 About the NREL Climate Change Resiliency and Preparedness Effort

Observations and projections indicate that the Front Range of Colorado is experiencing shifts in climate that include rising temperatures, changes in precipitation, and more-severe extreme events (for more information, see Vogel et al. 2015a, Appendices A and B). To address emerging federal requirements and support the laboratory's resiliency, NREL sought to better understand and prepare for the potential impacts these climate changes could have on fulfillment of the laboratory's mission. NREL's approach centered around proactive resiliency planning as a basis for its CCRP project.

In response to Executive Orders 13653, *Preparing the United States for the Impacts of Climate Change* (White House, Office of the Press Secretary 2013), and 13693, *Planning for Federal Sustainability in the Next Decade* (White House, Office of the Press Secretary 2015), DOE is committed to supporting ways to develop climate resiliency at its sites. The DOE Sustainability Performance Office awarded funding for NREL's CCRP pilot assessment to help inform the efforts of resiliency planning at other DOE sites.

## 1.2 Reasons for Undertaking Climate Change Resiliency Planning

According to the Intergovernmental Panel on Climate Change, "Human influence on the climate system is clear and growing, with impacts observed on all continents. If left unchecked, climate change will increase the likelihood of severe, pervasive, and irreversible impacts for people and ecosystems" (IPCC 2014, p. 1). In the United States, federal government agencies, states, and local governments are undertaking climate change adaptation planning efforts to inform action in their jurisdictions by identifying infrastructure systems that are vulnerable to climate and to ascertain viable options to reduce the vulnerability. As Executive Order 13653 states, "Managing these risks requires deliberate preparation, close cooperation, and coordinated planning by the federal government, as well as by stakeholders, to facilitate federal, state, local, tribal, private-sector, and nonprofit-sector efforts to improve climate preparedness and resiliency; help safeguard our economy, infrastructure, environment, and natural resources; and provide for the continuity of executive department and agency operations, services, and programs" (White House, Office of the Press Secretary 2013, p. 1).

NREL's review of vulnerability assessments, adaptation plans, and similar efforts by other federal government agencies, states, and local communities revealed that many efforts to date focused on either whole communities or natural ecosystems. No studies were identified that investigated the impacts of climate change at a campus scale. In the course of their investigation, NREL staff identified a risk-based, natural ecosystem approach<sup>1</sup> that provided an adaptable structure for addressing resiliency. This approach was used as a guide for NREL's efforts to develop a broader understanding of the climate risks that face their organization and build support for resiliency actions.

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<sup>1</sup>NREL staff selected this approach, which was developed by the U.S. Environmental Protection Agency's Climate-Ready Estuaries Program (EPA 2013). NREL staff worked with consultants to modify this approach as detailed in this process guide.

For simplicity, NREL divided climate change adaptation planning into a two-stage effort. In the first stage, NREL identified its vulnerabilities to climate change based on a review of resources, the current state of its infrastructure systems, and potential climate impacts on its mission. In the second stage, NREL explored recommendations to reduce those vulnerabilities through resiliency actions. Both stages of NREL's climate change vulnerability and resiliency assessments are presented in this paper. The overall process took NREL over a year to conduct. The timeframe may vary depending on the size and complexity of the organization.

## 2 Develop Project Support

Project champions are key to a successful vulnerability assessment and resiliency action plan. These people can stimulate and sustain momentum to support the project's efforts, care about the success of the organization, and inspire action in others. Sometimes these champions surface from grass roots efforts and spontaneously undertake a project on behalf of their organization; in other cases, they are approached by management to lead the organization toward climate resiliency. The champions who lead the development of a vulnerability assessment and resiliency action plan typically need input from additional personnel with important knowledge, authority, and organizational reach. These people can form an advisory team, a formal steering committee, or even a mix of internal and external stakeholders.

To initiate the NREL's CCRP process, NREL management tasked with this objective identified staff from NREL's Sustainability, Infrastructure Transformation, and Engineering Operations group to serve as the CCRP project champions and lead the effort on behalf of the laboratory. These project champions then established a CCRP steering committee that comprised 22 mid- and senior-level staff members representing departments across the laboratory, including facility and business operations personnel from groups such as building maintenance, emergency preparedness, human resources, information technologies, environment, health, and safety, and others, as well as those with knowledge or a research interest in climate science (Vogel et al. 2015a). Steering committee members also included subject matter experts or managers who could provide strategic guidance, make decisions, ensure project alignment with NREL's mission, and recommend additional staff representation from within the organization. Steering committee members provided periodic input and guidance on the vulnerability assessment and resiliency action planning process. The committee also identified specific departments or staff who had implementing roles or specific technical knowledge that would benefit the project to provide management-level review of project documents. See Box 1 for tips on building a steering committee.

### Box 1. Tips for Building a Steering Committee

- **Select members with diverse expertise from across your organization.** Include staff from facilities operation and maintenance, technical or research groups, communications, information technology (IT), non-facility operations, human resources, etc. Including a broad range of stakeholders builds organizational **capacity** and buy-in, and brings a broad range of perspectives for generating creative resiliency actions.
- **When possible, include mid- to senior-level staff on your steering committee.** These staff members possess broad and deep knowledge across their departments and can understand connections and intricacies that could illuminate the benefits and drawbacks of ideas under discussion. Junior staff members with specific expertise may also offer valuable input. Consider excluding staff members who are overcommitted and unable to complete the expected duties; these individuals may be able to provide their expertise or comments when specific critical decisions need to be made.
- **Explain the expectations for each steering committee member.** Include as much information as possible about the project scope, expected time commitment (number and lengths of meetings), estimated project duration, and potential activities. Provide details, but acknowledge that some adjustments may be necessary as the project unfolds. Outline the project scope and how it aligns with the organizational mission and other efforts such as climate mitigation, business continuity, and emergency preparedness.

The NREL CCRP project champions decided to contract with an environmental consultant, Abt Environmental Research (then called Stratus Consulting) to facilitate the CCRP process. Abt is a local environmental consulting firm with demonstrated experience in climate adaptation planning. It has established relationships with communication and outreach specialists from PACE Consulting, as well as climate scientists at the Western Water Assessment. The Western Water Assessment is a consortium of climate science experts from the University of Colorado at Boulder, the National Oceanic and Atmospheric Administration Regional Integrated Sciences and Assessments program, and other regional partners. NREL project champions, along with Abt, PACE, and Western Water Assessment staff, formed the CCRP project team, which shepherded the project on a day-to-day basis, including convening the steering committee at key points to obtain feedback. See Box 2 for more information about bringing in external assistance to facilitate a CCRP process.

### **Box 2. Do You Need External Assistance?**

If you work for a large organization, or one that involves complex technology, significant infrastructure, limited internal capacity, challenging organizational dynamics, or particularly difficult climate-related challenges, consider hiring a third-party consultant group or nongovernmental organization that specializes in guiding organizations by assessing vulnerabilities and planning associated resiliency actions. When selecting and working with a consultant:

- Consider and agree upon the consultant's level of involvement. Do you want the consultant to lead the project or provide input at key points (e.g. interpreting climate science or facilitating steering committee meetings)?
- If exploring options or issuing a request for proposals, ask public- and private-sector organizations in your area or industry about consultants they have worked with on climate change adaptation. Learn about their successes and difficulties, and review reports or publications produced by the consulting group to determine if their capabilities can support your project objectives.
- Understand the expertise of potential consulting groups and nongovernmental organizations to ensure their capabilities align with the work effort and address your organization's requirements. For example:
  - Can the consultants bring the expertise you require, such as climate change impact assessment or downscaling climate change projections?
  - Do they have the industry-specific experience you need?
  - Do they offer expertise in regulations that are important to your organization?
  - Have they worked with your size and type of organization, state agency, national laboratory, small private company, etc.?
- Prepare a list of direct questions for the consulting groups and for the project references they provide. Document their responses so you can compare consulting groups and nongovernmental organizations across specific categories such as expertise, project delivery, and cost.
- Upon selection, provide your consulting group or nongovernmental organization with background information and sufficient access to key contacts. Provide high-level documents and reports, including strategic plans, organizational charts, and relevant operational and business plans to support organizational understanding and provide context for the CCRP effort. Also ensure that consultants have a designated point of contact or direct access to staff members who can help answer questions and provide insights into your organization.
- Plan for the continuous involvement of the organization's staff. NREL found that the continuous inclusion of staff expertise was vital to the success of the laboratory's climate preparedness effort.

### 3 Assess the Vulnerabilities

A vulnerability assessment identifies an organization’s highest risk<sup>2</sup> vulnerabilities to climate change based on the organization’s needs, infrastructure, and mission. The CCRP project team followed a step-by-step approach to completing its vulnerability assessment, as further detailed in Section 3.1 through Section 3.3. The general steps included:

1. Create an impacts framework to collect and organize pertinent organizational information that will be used to identify potential vulnerabilities.
2. Convene staff focus groups to brainstorm organization-specific potential vulnerabilities and relevant climate variables on specific topic areas (e.g. water, energy, etc).
3. Score and rank the potential vulnerabilities to identify the vulnerabilities that pose the highest risks to the organization.
4. Develop a list of highest risk vulnerabilities to establish priorities for addressing adaptation.

#### 3.1 Create an Impacts Framework

An impacts framework helps project teams understand and outline an organization’s potential vulnerabilities. The framework should identify the aspects of an organization that answer the question, “What are the critical functions and corresponding needs of the organization to achieve its mission?” NREL’s Impacts Framework used two categories of information: key resources and key objectives, further described in Section 3.1.1 and Section 3.1.2. The final NREL Impacts Framework appears in Table 1.

**Table 1. Final NREL Impacts Framework**

Key Objectives	Key Resources					
	Water	Energy	Physical Space	Site Access	Workforce	Research and Mission
1. Execute research, analysis, and deployment						
2. Deliver facility stewardship						
3. Sustain laboratory operations						

##### 3.1.1 Build an Impacts Framework

Table 1 shows NREL’s Impacts Framework—a simple two-dimensional tool that cross-referenced the organization’s critical functions with the organization’s critical needs—as a way to ascertain potential vulnerabilities. This simple framework helped to scope all subsequent work on the vulnerability assessment and was consciously designed to align the climate preparedness effort within NREL’s existing organizational and management structures.

<sup>2</sup>See the glossary for a definition of *risk*.

Along the x-axis, the framework categorized the key resources that are critical for the laboratory to conduct its mission. Because NREL's strategy and operational documents had not previously considered this subject matter, the CCRP project team and steering committee had to brainstorm and then qualify the possible resources that were critical for NREL to conduct its mission.

NREL's key objectives, which formed the y-axis of the framework, highlighted the main facets of NREL's mission. These key objectives originated in NREL's *2014 Annual Plan and Performance Evaluation and Measurement Plan* (NREL 2014), a document that outlined NREL's strategic performance goals, to which DOE holds the laboratory accountable. Organizations may look to their high-level strategic planning documents, outlining mission, vision, and goals to inform their framework. See Box 3 for tips on building an impacts framework.

### Box 3. Tips for Building an Impacts Framework

- **Build your organization's impacts framework using input from key stakeholders.** The greater the commitment from management early on, the more likely your organization will be to adopt the resiliency actions you propose in the final stage.
- **Rely as much as possible on existing, vetted, and accepted materials.** This will save you time, facilitate ownership and support, and ensure the direction you take is one your organization can continuously endorse, implement, and integrate. The NREL CCRP project team's use of the Performance Evaluation and Measurement Plan meant that the impacts framework was based on material with which management and staff were familiar and that aligned with the laboratory's official performance metrics.
- **Plan to expend a great deal of time and energy building the framework.** Even if you can rely on available materials as criteria to build your framework, expect the process to take time and involve many iterations and discussions. NREL's framework took shape during multiple discussions between the CCRP project team and the CCRP steering committee. The CCRP project team explored various ways to create the framework, including basing it on NREL's organizational structure, research areas, and other NREL functional areas before selecting the final criteria.
- **Tailor your organization's impacts framework to reflect its unique internal processes and goals.** Each organization needs to build its own impacts framework. Each organization is complex and unique, so no generic impacts framework can be applied to every organization.
- **Redefine your impacts framework if necessary.** Some of NREL's initial framework categories became less useful or appropriate as the vulnerability assessment stage moved into the resiliency action plan stage. Instead of staying with a difficult impacts framework category, the CCRP project team allowed the framework to evolve.

### 3.1.2 Use the Impacts Framework to Create a Potential Vulnerabilities Questionnaire

The impacts framework is a useful tool to help project teams develop specific questions that can be used to identify potential vulnerabilities across the organization. For example, in NREL's framework, the following questions were developed to understand the impacts of "water" on "executing research, analysis, and deployment":

- What are the water needs for executing research, analysis, and deployment?
- How do NREL research staff and systems use water?
- Do some areas of research depend on ionized or distilled water?

Questions like these guided assessment participants and enabled them to engage in the discussion with a broad perspective and brainstorm potential climate vulnerabilities in each cell of the impacts framework matrix. NREL’s CCRP project team developed a list of 38 questions for the NREL Potential Vulnerabilities Questionnaire (Vogel 2015a, Appendix D). The questions sparked wide-ranging discussions with participants about the laboratory and its potential vulnerabilities to climate. See Box 4 for information about introducing climate change into the discussion.

#### **Box 4. Exploring Climate and How It May Change**

To successfully conduct a vulnerability assessment, the participating staff members need to be provided with a basic understanding about climate change. A common, broad understanding of climate change science is essential so they can identify the different ways certain aspects of climate change (e.g., higher temperatures and increased fires) might make your organization vulnerable. For example, participants might need to know that your organization’s location near the ocean will likely expose facilities to sea level rise or increasingly intense coastal storms. After your organization’s potential vulnerabilities have been identified, project teams will lead a more robust effort to analyze, score, and identify vulnerabilities (Section 3.3).

The level of effort for this initial exploration depends on your organization’s resources. A low-level effort could entail a literature review or online research through science-based websites, such as the U.S. National Assessment, that provides basic information on local climate change—historical climate trends, recent observations, and projected changes (see Box 5 for more ideas). A more robust analysis could include detailed climate-related analysis as described in Section 3.3, or working with local climate scientists, such as those at nearby universities, the National Oceanic and Atmospheric Administration Regional Integrated Sciences and Assessments program, or the U.S. Department of the Interior Climate Science Centers. Local climate science experts can be identified online through The U.S. Climate Resilience Toolkit.<sup>3</sup>

For NREL’s effort, climate scientists from the consulting group summarized the latest climate change science as it pertained to NREL, including a high-level overview of observations and projections for the Front Range of Colorado (Vogel et al. 2015a, Appendix B). These same climate change experts also provided more detailed climate change analysis later in the process, during the scoring of potential vulnerabilities. See Section 3.3.1 for more information.

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<sup>3</sup> “U.S. Climate Resilience Toolkit.” *Climate.Gov*. National Oceanic and Atmospheric Administration, Web 10 Feb 2016.



### Box 5. Tips for Identifying Potential Vulnerabilities

- **Select focus group participants for their diverse perspectives, interests, and backgrounds.** Place a priority on people who implement activities in their groups and who can identify day-to-day facets of their work that climate change might affect.
- **Be prepared for categorization challenges.** Successful brainstorming relies on an individual's capacity to think in an interdisciplinary and broad manner; synthesizing the resulting information into logical material for scoring purposes can be complex. In NREL's process, the CCRP project team found that the focus groups identified the same potential vulnerabilities but placed them under different key resources. To address this conflict, the project team had to corral the wide-ranging focus group discussions back to fit into the framework that would facilitate a uniform analysis across focus areas.
- **Depending on the size of your organization, you may need to reconvene your focus groups so they can synthesize the information they helped generate.** Engaging internal staff on multiple occasions can help build internal capacity and understanding of resiliency and help ensure a more critical and consistent assessment of vulnerabilities.
- **Facilitation can improve the efficiency and impact of focus group discussions.** This enables the full participation of project team members who are also part of the organization, helps ensure all attendees fully participate in the discussion, and keeps the discussion on track. Facilitators can also help with timekeeping and note-taking. Project team members from NREL's consulting group facilitated the focus groups, took notes, and wrote summaries, where a facilitator was relied on more heavily for steering committee meetings (Vogel et al. 2015a).

## 3.2 Convene Staff Focus Groups and Brainstorm Potential Vulnerabilities

In this step of the vulnerability assessment, project teams use the impacts framework as a springboard to brainstorm potential vulnerabilities to climate change. NREL's CCRP project team did this by convening focus group participants who could help explore ways the laboratory might be vulnerable and research the climate variables—for example, maximum temperature and intense precipitation—that were most likely to affect NREL.

### 3.2.1 Use Staff Focus Groups to Understand Potential Vulnerabilities

Identifying the ways that an organization is potentially vulnerable to climate is perhaps the most crucial and complex activity in the first stage of a climate preparedness project. The potential vulnerabilities questionnaire discussed in Section 3.1.2 is a useful tool for completing this step. Ultimately, the project team used the information discovered during the staff focus groups to determine how staff members rely on each key resource to accomplish their work and to identify any underlying potential climate vulnerabilities.

Because NREL is a large laboratory, the CCRP project team began by identifying small focus groups (approximately 3-7 staff) of NREL subject matter experts, roughly organized around the key resources identified in the impacts framework, to discuss categories of potential impacts. These focus groups mostly involved staff that were not participating in the steering committee, which could provide representation across NREL organizational disciplines. The CCRP project team worked with steering committee members to select diverse focus group participants who worked at a technical level and who could identify aspects of their work that are affected by climate. Hour-long discussions were held with each group covering a brief project overview, a review of high-level climate changes for the Front Range of Colorado, and a discussion based on the potential vulnerabilities questionnaire (Section 3.1.2).

The key to eliciting potential vulnerabilities from the group is the participants' consideration of each question in the potential vulnerabilities questionnaire, as well as how they use the key resources in their work every day. This balance of pointed and open-ended questions helped the participants contribute broadly to the focus groups to ensure the "leading questions" did not inadvertently suppress or influence potential discussions. For example, during discussions about water, participants—whether they were researchers, support staff, or operations personnel—repeatedly identified their reliance on water to perform their work. This finding helped the CCRP project team identify that NREL's reliance on a single water supplier for each campus was a key vulnerability in NREL's ability to fulfill its mission.

### **3.2.2 Collate and Synthesize Potential Vulnerabilities**

The next step is to assess the potential vulnerabilities—to group similar concerns, remove redundancy, call out unclear or unfinished discussions, and begin to generally organize potential vulnerabilities for further analysis.

After the focus group meetings, NREL's CCRP project team categorized and discussed the potential vulnerabilities by key resource, as identified in the framework. This step took significant time to complete because conversations in the focus groups were intentionally free form and information had to be clarified or reconciled through some back and forth dialogue. However, structuring it in this way resulted in a comprehensive list of potential vulnerabilities for the laboratory. To view the final analysis and discussion of NREL's potential vulnerabilities, see Vogel et al. (2015a); for tips on identifying and collating potential vulnerabilities, see Box 5.

## **3.3 Score Potential Vulnerabilities and Identify the Highest Risk Vulnerabilities**

Once the project team members have a broad understanding of the ways in which your organization may be vulnerable to climate change, they can conduct a focused exploration of potential climate changes that might affect your organization, along with the associated risks. Climate variables that are specific to your region should be identified, such as precipitation, extreme events, temperature, wind, and sea level rise. This effort should:

- Be specific to the organization's geographic area
- Include the direction and severity of potential changes
- Determine how those changes might interact with the organization's potential vulnerabilities.

Next, project teams should complete a risk analysis about the potential vulnerabilities, taking into account the magnitude of consequences should a vulnerability occur, and understanding the likelihood of the associated climate variable to change. Once this risk analysis has been completed, identified vulnerabilities can be categorized into highest risk vulnerabilities and lower tier vulnerabilities. The team may decide that some low-risk vulnerabilities may not be worth further consideration.

### **3.3.1 Understand Climate, Climate Change, and Associated Vulnerabilities**

In this step, project teams develop a greater understanding of:

- Historical climate in their area

- How the area’s climate is already changing, based on records of observed changes; this is called *observational climate data*
- How the area’s climate is projected to change in the future, based on climate model output; this is called *projected climate data*
- How likely these changes are on a variable-by-variable basis (e.g., an increase in temperature may be virtually certain; whereas the likelihood that precipitation will increase or decrease is typically far less certain).

Frequently, project teams enlist climate change scientists who have experience working in an applied setting; for example, NREL hired a consulting group with strong connections to local climate scientists. If the organization’s project team does not plan to bring an adaptation consultant onboard, local climate scientists can be contacted in other ways. For example, government agencies, academic institutions, research organizations, and nonprofit organizations are all good places to turn for advice about finding local climate scientists with experience in an applied setting. Organizations that cannot work with outside climate experts should refer to Box 6.

**Box 6. When Outside Climate Expert Resources Are Not Available**

If your organization does not have sufficient resources to hire a climate scientist and you cannot find someone who can offer services without a fee, you can also research the information you need from published sources through a literature review. A great deal of information is available on a global or national scale—for example, you might start with publications by the Intergovernmental Panel on Climate Change or the U.S. National Assessment. However, finding sound regional and local resources can be more difficult. A good place to start is the local university or municipality environmental resources, water resources, or sustainability division; some cities have begun to prepare for climate change and may have local summary information available. If local resources are lacking, look for state-level planning departments; many states have written climate change preparedness, adaptation, or resiliency action plans that may help you begin. Regional efforts are also becoming more common. However, many of these resources may not be able to provide one key piece of information you will need: the likelihood of particular climate variables changing.

**3.3.2 Determine Potentially Relevant Climate Variables and Their Likelihood**

Next, the organization’s project team or outside climate experts determine which relevant climate variables are changing or are projected to change and how likely those changes are to occur.

Table 2 shows a list of potential climate variables for NREL as identified by the CCRP project team. Climate experts from the consulting group assigned a score for the likelihood that specific climate variables will change along the Front Range of Colorado; this likelihood score appears in the final column of Table 2 (note that the likelihood scores are regionally specific). If published literature and climate models generally demonstrated strong agreement about the direction and degree of change for a variable, the climate experts gave it a higher likelihood of occurrence. If the models and literature showed less agreement about the direction and degree of change for a variable, it received a lower likelihood of occurrence. In addition to the typical scores of low, medium, and high, the climate experts included low-to-medium and medium-to-high because this nuance was necessary to accurately reflect the state of the science. Based on NREL’s experience with this process, limiting the number of likelihood categories would be recommended for a more simplified analysis.

**Table 2. NREL’s Climate Variables of Concern and Associated Likelihood of Changing**

Colors indicate the likelihood of change, from red (high likelihood) through yellow (low likelihood).

Climate Variable	Likelihood
Increased annual average temperatures Increased extreme heat events Earlier peak stream flows Increased likelihood of fire and longer fire season Increased minimum nighttime temperatures	High
Increased intensity of summer rainfall Increased intensity of winter storms Increased drought intensity Increased evapotranspiration Changes in lightning patterns and longer lightning seasons Reduction in late summer stream flow Reduction in raw water quality Higher particulate loading Increased intensity of storm events	Medium-to-high
Increased pollen count Landslides	Medium
Increased likelihood of ice storms	Low-to-medium
Shifts in annual and seasonal precipitation amounts Changes in total annual stream flows Changes in wind patterns	Low

### 3.3.3 Associate Climate Variables with Potential Vulnerabilities

In this step, the project team developed a table for each potential vulnerability to methodically examine every climate variable. See Table 3 for an example. The key to undertaking this analysis is to look at every potential vulnerability from a broad perspective. Some associations between climate variables and potential vulnerabilities will have become clear during the staff focus group discussions, but some are more elusive. For example, a change to lightning patterns in the area might not immediately seem that it would affect NREL’s energy supply. However, if changing lightning patterns leads to more lightning strikes and downed power lines, NREL’s single energy supplier could experience power disruptions that would be problematic for laboratory operations.

**Table 3. Example Table to Help Check a Potential Vulnerability against Potentially Relevant Climate Variables**

Potentially Relevant Climate Variable	Potential vulnerability: NREL has only one electricity supplier and depends on electricity to support mission-critical activities (e.g. power to buildings, IT connectivity).
Increased annual average temperatures	✓
Increased extreme heat events	✓
Earlier peak stream flows	
Increased likelihood of fire and longer fire season	✓

Potentially Relevant Climate Variable	Potential vulnerability: NREL has only one electricity supplier and depends on electricity to support mission-critical activities (e.g. power to buildings, IT connectivity).
Increased minimum nighttime temperatures	
Increased intensity of summer rainfall	✓
Increased intensity of winter storms	✓
Increased drought intensity	
Increased evapotranspiration	
Changes in lightning patterns and longer lightning seasons	✓
Reduction in late summer stream flow	
Reduction in raw water quality	
Higher particulate loading	
Increased intensity of storm events	
Increased pollen count	
Landslides	
Increased likelihood of ice storms	✓
Shifts in annual and seasonal precipitation amounts	
Changes in total annual stream flows	
Changes in wind patterns	✓

### 3.3.4 Score Potential Vulnerabilities for Magnitude of Consequence

Next, organizations score the potential vulnerabilities by the magnitude of their consequences. NREL’s CCRP project team defined *consequence* as the impact on the key resource in question, should the potential vulnerability occur—specifically the potential vulnerability’s effects on:

- Internal research and operations, including the scope and duration of service interruptions, NREL’s reputation in the community, and the potential to encounter regulatory problems
- Capital and operating costs, including all capital and operating costs and revenue implications caused by the climate change impact
- NREL staff (including total number of staff)
- Health of NREL staff, including worker safety
- The environment, including the release of toxic materials, biodiversity, changes to the area’s ecosystem, and impacts on adjacent historic sites.

The CCRP project team modeled these categories on a vulnerability assessment process that was performed for infrastructure in New York City (Major and O’Grady 2010). Based on the understanding of the consequence of each potential vulnerability, the CCRP project team considered the consequences for these five categories and assigned a high, medium, or low consequence score to the potential vulnerabilities:

- A **high magnitude of consequence** score meant that if the potential vulnerability occurred, NREL’s key objectives would be significantly impacted. For example, NREL depends on water across the organization, but it relies on a single water provider to supply both sites. Service interruptions would hinder the ability for the majority of NREL’s staff to perform their work and would have serious implications for NREL’s ability to achieve its Key Objectives 1 and 3 in the framework; hence, water supply was assigned a high consequence score.
- A **medium magnitude of consequence** score meant that if the potential vulnerability occurred, NREL’s three key objectives would be moderately impacted.
- A **low magnitude of consequence** score meant that if the potential vulnerability occurred, NREL’s three key objectives would suffer no major effect, or an in-place backup system could cover the failure.

Each organization may define and approach the analysis of consequence differently, according to its unique operating conditions and impacts framework.

### 3.3.5 Score Potential Vulnerabilities for Risk and Determine Overall Risk

The final step in scoring each potential vulnerability is to assess it for risk. This requires project teams to combine the climate variable likelihood score (Section 3.3.2) and the consequence score (Section 3.3.4). NREL’s CCRP project team used the risk score matrix shown in Figure 1.

Consequence	High	Medium	Medium-to-high	Medium-to-high	High	High
	Medium	Low-to-medium	Medium	Medium	Medium-to-high	Medium-to-high
	Low	Low	Low-to-medium	Low-to-medium	Medium	Medium
		Low	Low-to-medium	Medium	Medium-to-high	High
		Likelihood				

Figure 1. NREL’s risk score matrix

NREL’s CCRP project team first assigned a risk score to each potential vulnerability/climate variable combination and then used those risk scores to determine an overall risk score for each vulnerability. Most potential vulnerabilities at NREL were associated with more than one climate variable. At this point the vulnerability is no longer referred to as “potential” because the risk score or overall risk score can be used to categorize vulnerabilities into highest risk vulnerabilities and lower tier vulnerabilities. Some low-risk vulnerabilities may not be worth further consideration.

Because NREL’s CCRP project team did not want to weight particular climate impacts,<sup>4</sup> it assigned overall risk based on the highest risk score associated with any relevant climate variable. A

<sup>4</sup>The NREL CCRP project team did not do this weighting because it had no basis to prioritize one potential climate change over another. However, an organization that is concerned with particular climate impacts may want to consider weighting or eliminating certain potential vulnerability/climate variable combinations.

relatively simple example appears in Table 4. In this example, the single workforce vulnerability, *Staff may not be able to conduct outdoor research and other outdoor work activities*, was associated with two climate variables: lightning and heat events. These two variables received individual risk scores, which in turn informed the overall risk score associated with the vulnerability:

- **Risk score.** To establish a risk score for each potential vulnerability/climate variable combination, the CCRP project team used the risk matrix in Figure 1 to average the consequence and likelihood scores. When a score fell between two possible categories, the team chose the higher of the two to determine a risk score. For example, if a potential vulnerability received a *high consequence* and a *low-to-medium likelihood* score, the team gave it a *medium-to-high risk* score.
- **Overall risk score.** To determine an overall risk score for each vulnerability, the CCRP project team compared the risk scores associated with each potential vulnerability/climate variable combination and then used the highest risk score for the vulnerability. This means the project team did not prioritize amongst climate variables. For example, if a vulnerability was associated with three climate variables, and the risk score associated with two ranked as *low-to-medium risk* and with one as *medium-to-high risk*, the team ranked the overall risk as *medium-to-high overall risk*.

**Table 4. Example Table Showing Vulnerability to the Workforce and its Scoring**

Vulnerability	Consequence	Climate Variable	Likelihood	Risk Score	Overall Risk Score
Staff may not be able to conduct outdoor research and other outdoor work activities	Medium	Increased lightning patterns and longer lightning season	Medium-to-high	Medium-to-high	Medium-to-high
		Increased extreme heat events	High	Medium-to-high	

In addition to the risk scores, NREL’s CCRP project team also wrote a narrative that described the vulnerabilities under each key resource, the climate variables associated with those vulnerabilities, and how changes to particular climate variables might prompt the vulnerability. For example, NREL’s key resource of its *workforce* had one vulnerability: *Staff may not be able to conduct outdoor research and other outdoor work activities*. The CCRP project team found that increased lightning patterns, a longer lightning season, and increased extreme heat events would pose a vulnerability because workers would seek shelter from lightning and extreme heat and would therefore be unable to complete their work. To review the complete narrative for each vulnerability, see Vogel et al (2015a).

### 3.4 Finalize the List of Highest Risk Vulnerabilities

Once an organization’s vulnerabilities are scored, the project team can synthesize the information and identify the highest risk vulnerabilities to carry into the next stage of the project—the resiliency action plan.

The NREL CCRP project team decided that vulnerabilities with a *medium-to-high* or *high overall risk* score would continue to the next phase, vulnerabilities that received a *medium overall risk* score would be good candidates to consider in a future round of resiliency planning, and

vulnerabilities that received a *low* or *low-to-medium overall risk* score should be monitored over time without immediate action. Each organization will have different thresholds for which vulnerabilities require immediate action versus those that can be postponed for future efforts.

NREL’s CCRP project team concluded the vulnerability assessment stage of the project with the nine vulnerabilities shown in Table 5. The team then carried these risks into the resiliency action planning phase.

**Table 5. NREL Vulnerabilities with Highest Overall Risk Scores**

<b>Key Resource</b>	<b>Vulnerability</b>	<b>Overall Risk Score</b>
Water	NREL has only one water supplier for each campus and no backup options	High
	NREL may not be able to continue to rely on evaporative cooling and chillers	Medium-to-high
Energy	NREL has only one electricity supplier and depends on electricity to support mission-critical activities, including IT connectivity	High
Physical space	Landslides may occur because the STM buildings are close to the mesa slope	High
	Site flooding may occur because the STM has poor drainage	Medium-to-high
	Damage to climate-sensitive equipment may disrupt research	Medium-to-high
Site access	Key staff may not be able to access NREL’s sites to respond to emergencies and conduct research; some situations may require staff redundancy	Medium-to-high
Workforce	Staff may not be able to conduct outdoor research and other outdoor work activities	Medium-to-high
Research and mission	NREL’s reputation as a sustainable campus may be damaged	Medium-to-high

STM: South Table Mountain campus



## 4 Identify Resiliency Actions

The goal of a resiliency action plan is to explore resiliency actions that an organization can implement to address the highest risk vulnerabilities. NREL’s CCRP project team followed a step-by-step approach to completing the resiliency action plan, as further detailed in Section 4.1 through Section 4.5. The general steps included:

1. Categorize the organization’s vulnerabilities to determine the best path forward for each.
2. Use staff focus groups to explore potential resiliency actions, then collate and synthesize the resulting actions.
3. Evaluate and score the resiliency actions and recommend next steps for each.
4. Finalize a list of resiliency action plans for decision makers to explore.

### 4.1 Categorize the Vulnerabilities

One way to identify next steps for addressing an organization’s highest risk vulnerabilities is to categorize them according to an action. NREL’s CCRP project team assigned one of the following four path categories to each vulnerability:

- *Transfer* the risk of the vulnerability to another party
- *Avoid* the risk by removing the root cause of the vulnerability
- *Accept* the risk associated with the vulnerability and purposefully choose to do nothing
- *Mitigate* the risk by taking steps to reduce the consequence of the vulnerability.

Table 6 presents the risk categorization for each of the nine vulnerabilities that progressed from NREL’s vulnerability assessment stage.

**Table 6. NREL Risk Categorization for Vulnerabilities with the Highest Overall Risk Scores**

Vulnerability	Overall Risk Score	Risk Categorization
NREL has only one water supplier for each campus and no backup options	High	Mitigate
NREL may not be able to continue to rely on evaporative cooling and chillers	Medium-to-high	Mitigate
NREL has only one electricity supplier and depends on electricity to support mission-critical activities, including IT connectivity	High	Mitigate
Landslides may occur because the STM buildings are close to the mesa slope	High	Mitigate
Site flooding may occur because the STM has poor drainage	Medium-to-high	Mitigate
Damage to climate-sensitive equipment may disrupt research	Medium-to-high	Mitigate
Key staff may not be able to access NREL’s sites to respond to emergencies and conduct research; some situations may require staff redundancy	Medium-to-high	Mitigate

Vulnerability	Overall Risk Score	Risk Categorization
Staff may not be able to conduct outdoor research and other outdoor work activities	Medium-to-high	Mitigate
NREL's reputation as a sustainable campus may be damaged	Medium-to-high	Accept

Eight of the nine vulnerabilities were assigned to the *mitigate* category, and one vulnerability, *NREL's reputation as a sustainable campus may be damaged*, was assigned to the *accept* category, with no action needed.<sup>5</sup> Organizations may wish to quickly review their identified vulnerabilities against the four potential path categories but not spend extensive time on this step, as in NREL's experience the majority of its vulnerabilities were assigned to be mitigated.

## 4.2 Explore Potential Resiliency Actions

In this step, organizations (1) identify potential resiliency actions by convening staff focus groups to brainstorm and explore ideas, and (2) evaluate the resulting information through a process of synthesis and analysis.

### 4.2.1 Use Staff Focus Groups to Explore Resiliency Actions

In this step, organizations should turn to their internal technical experts to determine potential resiliency actions that can be used in response to their organization's vulnerabilities. Staff generally have the best handle on the problems that systems and resources face, as well as potential solutions. One effective way to reach out to staff and get their ideas is through staff focus groups. Section 3.2.1 recommends that these groups be a representative cross section of an organization's personnel.

NREL's CCRP project team held six small focus groups with high-level technical participants. Almost half the staff who participated in the resiliency phase also took part in the vulnerability assessment. Additional personnel were also included in the resiliency exercise because participants had specific areas of implementation expertise. Each focus group was based around a particular vulnerability or two related vulnerabilities. For example, one focus group examined two vulnerabilities, water supply and reliance on evaporative cooling, because of their common focus on water.

Each one-hour focus group meeting took place in person and had a designated facilitator and a designated note taker. The CCRP project team began the resiliency focus group discussions with a quick overview of the project, its status, and the vulnerability in question. The focus groups then discussed the potential resiliency actions through the lens of three evaluation criteria: effectiveness, feasibility, and cost.

- **Effectiveness** was the resiliency action's capacity to reduce the vulnerability's overall risk (see Section 3.3.5 for information about overall risk).
- **Feasibility** was a measure of whether the resiliency action could be implemented, both technically and organizationally.

<sup>5</sup>NREL's CCRP project team determined that some resiliency actions that may be considered less sustainable, such as the use of traditional air conditioners in lieu of evaporative coolers to reduce water demands, may be unavoidable and the associated damage to NREL's reputation would be slight. Thus, the risk to NREL's reputation was the one vulnerability that the team assigned to the *accept* category.

- **Cost** was the monetary outlay that a particular action would require.

The CCRP project team later used these discussions as a springboard to score the resiliency actions against each of the three evaluation criteria (Section 4.2.2). A project team that undertakes a resiliency action plan should thoughtfully determine the most important evaluation criteria; additional or alternative criteria could include unintended costs, additional benefits, implementation timing, flexibility, and robustness against a variety of potential climate conditions. See Box 7 for tips to involve staff in identifying resiliency actions.

#### **Box 7. Tips for Involving Staff in Identifying Resiliency Actions**

- **Provide resiliency focus group participants with descriptions of each vulnerability, the associated climate variables, the likelihood, consequence, risk, and overall risk scores for each vulnerability ahead of time.** The NREL CCRP project team implemented two stages—the vulnerability assessment and the resiliency action plan—as distinct, sequential steps and waited to convene the resiliency focus groups until after the results of the vulnerability assessment were complete. This enabled the project team to provide detailed information before the staff focus groups convened, which helped participants to understand the context and brainstorm applicable questions and solutions prior to the meetings.
- **Focus group leaders should prepare a script in advance of each focus group meeting.** A script helps facilitators and project team members offer helpful background information at the start of the meeting, including any material concerning current or future climate change and links to the vulnerability being discussed. A script also helps facilitators direct the participants' energy to specific questions or aspects of resiliency and can become documentation that project teams can later use to ensure consistency and reproducibility.
- **Separating the roles of facilitator and note taker helps ensure a more time-efficient, focused, and well-captured discussion.** The NREL CCRP project team felt that the note taker was crucial to ensuring that all the essential information was captured and could be processed effectively at a later time. This step also reduced the need to go back to focus group participants for clarification.

### **4.2.2 Synthesize Potential Actions**

After developing a list of potential resiliency actions, the project team will then synthesize and analyze all the information.

To do this, NREL's CCRP project team used the focus group discussion notes to build a series of tables and narratives that discussed each potential resiliency action, together with a summary of each adaptation's effectiveness, feasibility, and cost. The CCRP project team and the focus group participants then reviewed all the information and made changes based on their collective understanding of each resiliency action. They assigned one of three scores—*good*, *fair*, or *poor*—to each evaluation criterion for the resiliency action under discussion. NREL defined these three scores as shown in Table 7. The CCRP project team intended its scores to be used as preliminary scores of the resiliency plans. Although focus group participants engaged in an iterative process for refining and validating these scores, additional research and assessment may be necessary before NREL implemented specific actions.

Table 8 (Section 4.3) provides an example of the final table for the resiliency actions that NREL could pursue to address an example vulnerability, *damage to climate-sensitive equipment may disrupt research*, along with the resiliency actions' scores against the three evaluation criteria. To see the detailed explanation for each vulnerability, including the narrative that explains scores and assignments see Vogel (2015b). For tips about synthesizing potential actions, see Box 8.

**Table 7. Evaluation Criteria Scoring for Resiliency Actions**

Evaluation Criterion	Score: Description		
	Good	Fair	Poor
Effectiveness	Would completely or nearly eliminate the vulnerability's risk	Would significantly reduce part or all of the vulnerability's risk	Would not significantly reduce the vulnerability's risk
Feasibility	Could be implemented technically and organizationally	Could be implemented technically and organizationally, with some reservations, or only a part of the action could be implemented	Could not be implemented technically or organizationally
Cost	Would have low monetary costs relative to other types of projects evaluated; this score was primarily applied to desk-style projects, often with no or few infrastructure components	Would have moderate monetary costs relative to other types of projects evaluated; actions that were assigned this score often included a modest infrastructure component	Would have high monetary costs relative to other types of projects evaluated; actions that were assigned this score often included significant infrastructure components

**Box 8. Tips for Synthesizing Potential Actions**

- **Look for cross-cutting actions that could apply across all your organization's vulnerabilities.** NREL's CCRP project team discovered a number of cross-cutting actions as they analyzed the resiliency actions. These actions have the potential to provide strong economies of scale across an organization because they address multiple vulnerabilities across multiple key resources. NREL's cross-cutting actions included integrating climate considerations into current operations and practices, creating and implementing a climate monitoring communications system for indoor and outdoor conditions, and allocating a part of facilities funding toward issues that address climate change.
- **Build time into your schedule for the focus group participants to review your preliminary "capture" of the information.** Sharing meeting notes or draft summaries for review with participants will ensure you have represented the group's thoughts accurately and thoroughly.
- **"Calibrate" your scores to meet the unique needs of your organization.** NREL's CCRP project team used to broad language to describe costs: low, moderate, or high. Some organizations might be able to put actual dollar ranges into each category.
- **Be prepared for the project team and focus group participants to discover new ideas for resiliency actions that the focus groups did not initially examine.** Depending on where you are in developing your final resiliency action plan, the introduction of new ideas too late in the process may create logistical challenges. NREL's CCRP project team chose to handle such ideas by explicitly calling them out in the resiliency action plan as late-breaking additions rather than attempting to analyze and refine them for detailed explanation. For an example of this approach, see Vogel (2015b), Section 3.2.
- **Set resources aside to validate and elaborate on resiliency actions and their scores.** The first step in developing a resiliency action is to identify possible actions. Before resources are applied to implement resiliency actions, specific actions may need more detailed evaluation and their scores may need to be adjusted as more information is made available. This can occur either alongside the synthesis and analysis of the resiliency actions or as a distinct pre-implementation stage in your organization's climate readiness project.

### 4.3 Evaluate and Score Resiliency Actions

The final step in identifying resiliency actions is to make a recommendation to your organization's leadership on the approach for each action. NREL's CCRP project team used the following evaluation criteria scores to make one of three recommendations for each resiliency action:

- ***Do now*** was reserved for no- or low-regrets resiliency actions that NREL should reasonably pursue. No-regrets strategies provide benefits under current and potential future climate conditions. When an organization spends money on a no-regrets strategy, it will reduce a facility's risk to current climate stressors and make it more resilient to future climate change. This will ensure the investment is worthwhile regardless of which climate future unfolds. A low-regrets strategy may involve some cost that is not fully justified under current climate conditions, but the costs are generally low and are not a significant factor in the decision.
- ***Continue evaluating*** was reserved for resiliency actions that needed further information before they could either be endorsed as *do now* actions or be completely removed from consideration.
- ***Remove from consideration*** was reserved for actions that were untenable for one or more reasons.

Table 8 shows an example of a resiliency action plan for one of NREL's vulnerabilities. The table shows the evaluation criteria scores and the recommended approach scores. This particular table did not have any "poor" or "remove from consideration" scores.

NREL's CCRP project team was careful to emphasize the limitations in these recommended approach scores. The team wanted to ensure that:

- The laboratory's decision makers understood that scores for resiliency actions were determined based on preliminary information
- The team relied heavily on the input of a number of non-NREL team members from the consulting group
- The team did not attempt to prioritize across the vulnerabilities.

The recommendations were intended as a guide and additional investigation would be required. Depending on NREL decision makers' priorities amongst the three evaluation criteria of effectiveness, feasibility, and cost, they could assign each resiliency action a different recommended approach than the CCRP project team had done. NREL management could also choose to change the weighting of the criteria or how the results were combined to determine their recommended approach.

**Table 8. Example of a Resiliency Action Plan Table for One of NREL’s Vulnerabilities, *Damage to Climate-Sensitive Equipment May Disrupt Research***

Evaluation scores are *good* (dark blue), *fair* (medium blue), and *poor* (light blue). Recommended action scores are *do now* (green), *continue evaluating* (orange), and *remove from consideration* (red).

Action	Description	Evaluation Criteria and Score			Recommended Approach
		Effectiveness	Feasibility	Cost	
Integrate climate considerations into current operations and practices	Provide a framework to integrate climate considerations into current operations and practices, including facility management plans, laboratory operating procedures, and equipment purchases	Good	Good	Fair	Do now
Retrofit climate-sensitive equipment	Redesign HVAC or laboratory layouts to minimize potential hazards associated with climate change	Fair	Fair	Fair	Continue evaluating

HVAC: heating, ventilating, and air conditioning

The aforementioned caveats may not be necessary if:

- A project team consists entirely of internal staff
- The focus group discussion and later analysis include robust research to inform the evaluation scoring
- The organization is less complex or smaller than NREL.

For complete information about all the caveats that the CCRP project team included, see Vogel et al. (2015b), Box 2.

#### 4.4 Finalize the Resiliency Actions List

Depending on the needs of the organization and the preferences of its decision makers—including their level of involvement in the process thus far—the project team may wish to present all the adaptation actions in a single collated table. The table can be sorted by recommended action, vulnerability, or recommended approach.

Table 9 is NREL’s final resiliency action table. The CCRP project team chose to remove all the actions that received *remove from consideration* scores and to sort the table by key resource. By including the key resource, vulnerability, and overall risk score, the team could reflect the vulnerability assessment and resiliency action planning processes for decision makers. Smaller organizations, or ones in which top decision makers have played an integral role throughout the process, may prefer to present their final resiliency action tables differently.

**Table 9. Example of Final Resiliency Action Table with High-Level Vulnerability Information<sup>a</sup>**

Key Resource	Vulnerability	Overall Risk Score	Resiliency Actions	Recommended Approach
Multiple	Cross-cutting solutions identified to mitigate across multiple vulnerabilities	Not applicable	Integrate climate considerations into current operations and practices	Do now
			Create and implement a climate monitoring and communication system	Do now
Water	NREL has only one water supplier for each campus and no backup options	High	Develop a water-shortage contingency plan	Do now
			Connect the National Wind Technology Center to a public water system	Continue evaluating
	NREL may not be able to continue to rely on evaporative cooling and chillers	Medium-to-high	Create and implement a climate monitoring and communication system	Do now
			Add conventional backup air conditioning	Continue evaluating
Energy	NREL has only one electricity supplier and depends on electricity to support mission-critical activities, including IT connectivity	High	Improve demand management	Do now
			Install a battery supply	Do now
			Establish a microgrid	Continue evaluating
Physical space	Site flooding and landslides may occur at the STM	High/medium-to-high <sup>b</sup>	Evaluate and redesign the site to improve drainage and slope stability	Do now
	Damage to climate-sensitive equipment may disrupt research	Medium-to-high	Integrate climate considerations into current operations and practices	Do now
			Retrofit climate-sensitive equipment	Continue evaluating

Key Resource	Vulnerability	Overall Risk Score	Resiliency Actions	Recommended Approach
Site access	Key staff may not be able to access NREL's sites to respond to emergencies and conduct research; some situations may require staff redundancy	Medium-to-high	No resiliency action proposed because NREL is already addressing this issue	No recommended approach beyond current NREL efforts
Workforce	Staff may not be able to conduct outdoor research and other outdoor work activities	Medium-to-high	Integrate climate considerations into current operations and practices	Do now
			Create and implement a climate monitoring and communication system	Do now

<sup>a</sup> This table presents only medium-to-high and high risk vulnerabilities that fell in the mitigate category and received a *do now* or *continue evaluating* recommendations.

<sup>b</sup> This vulnerability has two rankings because two vulnerabilities were combined into one discussion due to strong overlap in the associated resiliency actions.



## 5 Conclusion

Based on NREL's experience and other bodies of work, the following best practices have been developed for climate change adaptation and resiliency planning:

- ***Establish an ongoing process to institutionalize climate change planning.*** Beyond exploring and implementing adaptation actions, each organization needs to find ways to internalize and institutionalize the process of vulnerability assessment and resiliency action planning. Conditions will change over time as the understanding of climate variability and change improves and as policy preferences, each organization's mission and objectives, and local climate conditions change. Periodic reviews and updates will ensure that organizations continuously practice adaptive management as they pursue resiliency and integrate changing information and conditions into their preparedness efforts.
- ***Mainstream resiliency into current decision-making processes.*** Integrating resiliency planning into current processes is generally both more efficient and more effective than isolating adaptation in a separate top-down initiative. As part of this effort, understand that each organization may have policies and cultural nuances that could undermine efforts to mainstream climate considerations into its operations and decision making; be aware of that possibility and be ready to pursue updates and provide education as needed.
- ***Learn from within.*** Remember to look within the organization for departments or groups that are already considering climate in their work. For example, the operations group may already have policies that relate to extreme climate events. Furthermore, the steering committee that assisted in the planning process could provide expertise in climate change impacts and adaptation and should be viewed as an ongoing resource. Bring these internal stakeholders into ongoing efforts in vulnerability assessment and resiliency planning.
- ***Develop a process to remain up-to-date on developments in climate science that can affect your organization.*** Climate science is continuously evolving; some areas of vulnerability for an organization may involve climate variables about which the science is uncertain, such as changes in average precipitation. Treat the likelihood scoring in the vulnerability assessment as subject to revision as the science evolves. This could change the highest risk vulnerabilities in future rounds of resiliency planning. Routine consultations with local climate experts will help your organization's staff stay abreast of the latest developments in climate science. Seek out and establish relationships with university-, government-, and nonprofit-based scientists in your area.
- ***Ask the "climate question."*** Whenever organizational leadership is considering long-term investments, particularly infrastructure improvements, ask how climate variability and change could affect your organization's near- and long-term decisions.
- ***Prepare for uncertain futures.*** As part of ongoing resiliency action planning, strive to avoid the appeal of planning around a single-scenario climate future. Understanding and preparing for an array of possible "climate futures" will ensure that the organization selects resiliency actions that will be the most beneficial, even when observational climate trends are unclear or projections conflict.

- ***Look for resiliency actions that are no- or low-regrets strategies.*** As described in Section 4.3, these measures will provide immediate benefit to the organization and even greater benefit as climate changes with little to no additional cost.
- ***Look for and take advantage of opportunities that climate change provides.*** Do not assume that all change is bad for your organization; look for ways to use changes in climate as a “plus” for the organization.
- ***Continue to identify near- and long-term actions.*** Adaptation to a changing climate may not require that all resiliency actions be instituted now; some actions may need more study. Some resiliency actions may not be needed now but may be needed in the future as conditions change. Contingency plans may be put in place and implementation may depend on results from monitoring or analysis of climate variables.
- ***Cooperate with government entities and organizations in your area.*** Differentiate between decisions the organization can make internally and those that will require cooperation with external entities. Leaders will want to consider these realities as they determine priorities amongst resiliency actions.
- ***Learn from others.*** Look to outside organizations to find discover how others are building on current best practices and how they are following up on their own vulnerability assessments and resiliency action planning. Find out if your organization’s state or city has addressed adaptation planning and ask about other organizations in your area who have initiated efforts. Two examples appear in the References section that follows: the *Colorado Climate Change Vulnerability Study* (Colorado Energy Office 2015) and the *Boulder County Climate Change Preparedness Plan* (Boulder County 2012). For further detail on NREL’s CCRP process, reference Vogel et al. (2015a) and Vogel et al. (2015b).
- ***Collaborate with other organizations and entities as they adapt to climate change.*** Neighboring communities and organizations can network, learn from, and leverage each other’s efforts, and collaborate when possible. For example, utilities are beginning to reach out to climate scientists to better understand climate change through the Water Utility Climate Alliance; local entities could similarly collaborate as a group to leverage resources and knowledge.

In conclusion, the CCRP project team would like to share an overarching key lesson from its own experiences during the CCRP project: Understanding vulnerabilities and planning resiliency actions to mitigate their risk is not a linear process. And maintaining resiliency is an iterative and dynamic process. No single, standalone resiliency action will entirely eliminate a vulnerability, and even a comprehensive planning effort will not stand the test of time—and the test of climate change—if it does not become part of a larger, ongoing process. Adapting to change will require organizations to pay continued attention to vulnerabilities and resiliency. With support from stakeholders, organizations will be able to adopt a proactive stance and lead the way toward strong organizational resiliency in the face of climate change.

## Glossary

Adaptation	Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects (U.S. Global Climate Change Research Program (2015)).
Climate	The average of weather over some period of time (which can be hundreds to thousands of years). The World Meteorological Organization standard uses 30 years of weather observations to measure climate. A climate can be thought of as the mean and variance of weather over 30 years (WMO 2015).
Climate change	Typically denotes a significant change in average conditions but can also be the result of a change in variance of weather or in extreme weather conditions.
Climate change impacts	Negative or positive effects that changes in climate variables may have on human systems. Examples include damage to equipment, changes in maintenance cycles, and increased asthma rates.
Climate preparedness	Efforts to adapt (prepare) for climate-related effects. Also see <i>adaptation</i> and <i>resiliency</i> .
Climate variables	Measurable aspects of climate. Examples include temperature, precipitation, wind, humidity, extreme events, drought, and flooding.
Consequence	A measure of the impact of a vulnerability on a key resource, as measured against key objectives.
Likelihood	A measure of the possibility that a climate variable will change.
Resiliency	A capability to anticipate, prepare for, respond to, and recover from significant multihazard threats with minimum damage to social well-being, the economy, and the environment (U.S. Global Climate Change Research Program (2015)).
Risk	Threats to life, health and safety, the environment, economic well-being, etc. Typically evaluated in terms of how likely an event is (probability) and the damages that would result (consequences) (U.S. Global Climate Change Research Program 2015).

Vulnerability	The degree to which an affected unit (a person, facility, community, etc.) faces risk from climate. It considers whether the unit is exposed to a climate driver and the extent to which the driver can affect the unit. A key factor in determining vulnerability is the resiliency of the unit. Greater likelihood and consequence increase vulnerability; greater resiliency decreases vulnerability.
Weather	Typically the climate conditions experienced at a particular point in time. It may be the temperature range over a day or a short period, precipitation, wind, etc. Thirty years of weather is used to statistically define climate.

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