Development of a Spatial Municipal Vulnerability Index

Phase 4 Final Report

May 6, 2024

List of Tables

List of Figures

Executive Summary

Background and Purpose

In September 2020, the Vermont legislature passed the Global Warming Solutions Act (GWSA), which requires the state to reduce its gross greenhouse gas emissions (GHGs) to at least 26 percent below 2005 levels by 2025, 40 percent below 1990 levels by 2030, and 80 percent below 1990 levels by 2050.[1] To help achieve these reductions, the GWSA created the Vermont Climate Council (VCC)[2] and charged them with developing a Climate Action Plan (the Plan) to provide a framework and planning process for reducing climate pollution and preparing for the impacts of climate change.[3] The GWSA also required the VCC to create subcommittees to assist in the Plan's development and carry out related duties, including the Rural Resilience and Adaptation Subcommittee.[51]

The GWSA specifically requires the VCC to develop a Municipal Vulnerability Index (MVI) that includes factors that measure "a municipality's population, average age, employment, and grand list trends; active public and civic organizations; and distance from emergency services and shelter."[4] The State, in partnership with the VCC engaged in a process to develop a tool that helps municipalities examine their vulnerability to climate change impacts across a range of factors. The resulting Municipal Vulnerability Indicator Tool (MVI) was a result of public and targeted stakeholder engagement aimed at developing a resource to help municipalities measure and identify key vulnerabilities to climate change. The MVI does not produce an index as it does not rank and compare municipality's climate vulnerabilities across the state, but the MVI is a first step in supporting municipalities in conducting climate vulnerability analyses themselves.

To advance the MVI, Eastern Research Group, Inc. (ERG), worked with representatives from the Vermont Agency of Natural Resources (ANR) Climate Action Office and the Vermont Agency of Digital Services (hereafter referred to as the VT state team), as well as members of the VCC MVI task group[5] to develop the MVI, an online geospatial tool that is being designed for use by state, regional, and municipal agencies and organizations to identify community vulnerability to climate change based on a range of social, economic, ecological, land use, built environment, and hazard factors. The MVI is intended to help identify where Vermont communities are most vulnerable to climate change, with a focus on pressures that climate change will place on Vermont's people, transportation, electric grid,

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[1] Vermont Act 153 (2020): https://aoa.vermont.gov/sites/aoa/files/Boards/VCC/ACT153%20As%20Enacted.pdf

[2] The 23 member Vermont Climate Council is comprised of state administration officials, legislative appointees, and various sector representatives: https://climatechange.vermont.gov/about

[3] Vermont Climate Action Plan: https://climatechange.vermont.gov/readtheplan; VECAN "Vermont Global Warming Solutions Act" Webpage: https://vecan.net

[4] Vermont Act 153, Page 10.

[5] The MVI task group is comprised of VCC members who are focused on the development of the MVI/ The task group helped develop the tasks and principles in the RFP for this project, including the vision for stakeholder engagement and the end product.

housing, emergency services, and communications infrastructure.[6] The purpose of the MVI is to identify where vulnerabilities occur and the factors that contribute to those vulnerabilities in order to determine the actions needed to increase climate resilience in Vermont.

MVI Development Process and Resulting Tool

The process to develop the MVI tool included three phases:

- **Phase 1.** Conducting background research and engagement to inform the factors that contribute to climate vulnerability, tool development methods, and tool use, features, and functions.
- **Phase 2.** Applying what was learned in the first phase to further refine the climate vulnerability factors to incorporate into the MVI tool and to develop a framework for the MVI, including the methods and approach for how the tool will communicate vulnerability and resilience to its users.
- **Phase 3.** Developing the geospatial tool itself, including gathering input and feedback on the draft tool, tool testing, and finalizing the tool.

The MVI developed through this process is available here. The tool consists of 48 factors of climate vulnerability across the following six domains:

- Community
- Social
- Economic and Jobs
- Infrastructure
- Built and Physical Environment
- Natural Environment

It also includes information on 13 climate hazards:

- Drought
- Extreme Precipitation
- Fluvial Erosion – River Corridors
- Hail
- Ice Storms
- Invasive Species
- Inundation Flooding
- Landslides
- Snow Storms
- High Temperature
- Low Temperature
- Wildfire
- Wind

The tool was developed to be flexible and user-guided. Geospatial data layers illustrate the various factors of climate vulnerability, and the tool generates layered geospatial information rather than a single vulnerability metric or score. This approach allows for a more user-directed analysis and evaluation, whereby users can select a location and conduct their own assessment of vulnerability for each climate hazard and/or factor of interest.

Lessons Learned

[6] According to the Vermont Statutes Annotated (VSA), 1 VSA § 126, the term "municipality" includes "a city, town, town school district, incorporated school or fire district or incorporated village, and all other governmental incorporated units." The terms "town" and "municipality" are used interchangeably throughout this report.

Key takeaways from the tool development process include:

- **Reviewing existing, relevant tools served a pivotal purpose.** Beginning the tool development process by reviewing existing geospatial tools helped provide a foundation to better understand what type of tool might be of interest (e.g., features, functions, aesthetics), the type of data or data limitations that might be a consideration, and the type of tool alignment that might be needed across state tools. This effort was also critical in helping develop a draft set of climate vulnerability factors to consider including in the tool. The overall process was key in helping gain further alignment on the vision for the final MVI.
- **Gathering input on the tool development process from potential tool users was a critical step in developing the tool and informing considerations for its use.** By engaging with tool users, ERG and the VT state team were able to better understand the factors of climate vulnerability that were of greatest interest to tool users, how the tool might be used and by whom, types of features and functions that were most important to tool users, and potential challenges or barriers to adopting the tool. The resulting information helped inform a tool that speaks to climate vulnerabilities of interest and is user-friendly. It also suggested the need for tool user training, which ANR subsequently began organizing, starting with regional planning commission trainings that will follow tool finalization and the development of this report.
- **Data availability shaped tool content.** The availability of Vermont-specific data at the appropriate scale determined what climate hazards and climate vulnerability factors could be geospatially included in the tool and how that information could be displayed.
- **Learning from other tool developers provided helpful tool considerations.** Working with the Agency of Digital Services and talking with developers of other related tools helped inform tool development considerations, such as areas of alignment across state tools, available data, and hosting and server considerations.
- **Training will help increase use of the MVI.** Since the tool will have a variety of users with varying levels of experience using geospatial tools, training will help increase user capacity and understanding of the MVI and further promote tool use. Based on this understanding, ERG will conduct a preliminary tool training with regional planning commissions, and the VT state team is planning additional tool training and follow-up after the conclusion of this project.
- **Future customization will improve user experience.** While using the standard features in Experience Builder allowed the MVI tool to be developed efficiently, additional tool customization that extends beyond these standard features could help improve the tool user's experience. For example, additional customization can help address some tool functions, features, and useability concerns raised by tool testers (described further in the section below).

Considerations and Recommendations for Future Tool Updates

Considerations for future tool updates stemming from the tool development and testing process as well as presentations on the final tool include:

- **Update tool functions and features**. Possible changes or additions include:
    - Custom legend for layers that allows users to rename sub-layers or organize information differently (e.g., ability to reorganize map layers).

- Include additional pre-packaged exercises or "quick view" combinations of preselected layers to understand how to effectively use the tool.

- **Determine the number and type of preferred data layers**. While several tool testers would like some data layers removed to simplify the tool and its use (specific data layers were not named), others recommended additional data layers to include, such as:
  - Utility outage data and statistics for various timeframes.
  - Centers for Disease Control and Prevention Social Vulnerability Index data.
  - Other health indicators, aside from adult asthma.
  - Ability to select sub-options for internet access, including fiber, cable/copper, and cellular.
  - Moderate income data.
  - Dams.
  - Drinking water source type.
- **Consider refinements to current data.** Considerations for updating or refining types of data already included in the tool include:
  - Adjust temperature threshold for high heat from 90 °F to 87 °F for greater alignment with heat warnings determined by the National Oceanic and Atmospheric Administration (NOAA).
  - Parse different types of droughts to align with drought classification from the U.S. Drought Monitor.
  - Compare NOAA and Federal Emergency Management Administration (FEMA) floodplain data and consider differences and appropriateness of each source in assessing community vulnerability to flooding hazards.
  - Include updated landslide data. The Vermont State Geologist has applied for a grant to compile a full landslide inventory for the state and then use it along with several other data sets (including the new Light Detection and Ranging (LiDAR) data) to perform a landslide susceptibility modeling exercise. If funded, the project would be finalized in 2026–2027 and could be incorporated into the MVI.
- **Continue to collect input on climate vulnerability factors.** To help ensure the climate vulnerabilities included in the MVI reflect the priorities and perspectives of tool users, it could be beneficial to gather additional input on the tool factors prior to updating the tool. Input could include another round of tool user engagement prior to updating the MVI and/or collecting tool input from users over time as the tool is implemented.

1. Introduction

1.1 Background

In September 2020, the Vermont legislature passed the Global Warming Solutions Act (GWSA) that requires the state to reduce its gross greenhouse gas emissions (GHGs) to at least 26 percent below 2005 levels by 2025, 40 percent below 1990 levels by 2030, and 80 percent below 1990 levels by 2050.[7] To help achieve these reductions, the GWSA created the Vermont Climate Council (VCC)[8] and charged them with developing a Climate Action Plan (the Plan) to provide a framework and planning process for reducing climate pollutants and preparing for the impacts of climate change.[9] The GWSA also required the VCC to create a specific set of subcommittees to assist in the Plan's development and carrying out related duties, including the Rural Resilience and Adaptation Subcommittee.[1]

The GWSA mandated the Rural Resilience and Adaptation Subcommittee to "focus on the pressures that climate change adaptation will impose on rural transportation, electricity, housing, emergency services, and communications infrastructure, and the difficulty of rural communities in meeting the needs of its citizens that sets greenhouse gas emission reduction requirements."[10] Moreover, the GWSA specifically requires that the Rural Resilience and Adaptation Subcommittee advance the development of a municipal vulnerability index that includes factors that measure the climate risks associated with "a municipality's population, average age, employment, and grand list trends; active public and civic organizations; and distance from emergency services and shelter."[11]

To advance the municipal vulnerability index, Eastern Research Group, Inc. (ERG) worked with representatives from the State of Vermont (the VT state team) and members of the VCC municipal vulnerability index (MVI) task group[12] to develop the municipal vulnerability index, an online geospatial tool that is being designed for use by state, regional, and municipal agencies and organizations to identify community vulnerability to climate change based on a range of social, economic, ecological, land use, built environment, and climate hazard factors. The MVI is intended to help identify where Vermont communities are most vulnerable to climate change, with a focus on pressures that climate change will place on Vermont's people, transportation, electric grid, housing, emergency services, and communications infrastructure.[13] The purpose of the MVI is to identify where vulnerabilities occur and

[7] Vermont Act 153 (2020): https://aoa.vermont.gov/sites/aoa/files/Boards/VCC/ACT153%20As%20Enacted.pdf

[8] The 23 member Vermont Climate Council is comprised of state administration officials, legislative appointees, and various sector representatives: https://climatechange.vermont.gov/about

[9] Vermont Climate Action Plan: https://climatechange.vermont.gov/readtheplan; VECAN "Vermont Global Warming Solutions Act" Webpage: https://vecan.net

[10] Vermont Act 153, Page 9.

[11] Vermont Act 153, Page 10.

[12] The MVI task group is comprised of VCC members who are focused on the development of the MVI/ The task group helped develop the tasks and principles in the RFP for this project, including the vision for stakeholder engagement and the end product.

[13] According to the Vermont Statutes Annotated (VSA), 1 VSA § 126, the term "municipality" includes "a city, town, town school district, incorporated school or fire district or incorporated village, and all other governmental incorporated units." The terms "town" and "municipality" are used interchangeably throughout this report.

the factors that contribute to those vulnerabilities in order to determine the actions needed to increase climate resilience in Vermont and its communities.

1.2 MVI Tool Purpose

ERG and the VT state team developed a statement of purpose for the MVI to provide a clear and stable definition of the tool's purpose, focus, and intended users. The statement of purpose is based on input and discussions with the VT state team and MVI task group as well as findings from three background research efforts conducted by ERG: 1) an evaluation of existing tools that can be used to inform the MVI, 2) document review and background research of Vermont's climate issues, and 3) engagement of key partners[14] to ensure the MVI reflects their experiences, expertise, and concerns related to climate vulnerability within their communities and organizations across Vermont. The resulting statement of purpose is as follows:

> *The Vermont Municipal Vulnerability Index (MVI) is designed for use by Vermont State agencies, regional planning commissions, municipal staff, communities, and non-governmental organizations to measure vulnerability to climate change at the municipal level for the purposes of informing climate-related planning and decision-making and supporting the professional duties of tool users (e.g., grant-writing, development of local hazard mitigation plans, identification of climate vulnerability hot spots, disaster planning and response). The MVI will measure climate vulnerability based on a range of factors related to the built/physical environment (e.g., buildings, infrastructure), economy and jobs (e.g., unemployment, per capita income), climate hazards (e.g., flooding, extreme temperatures), natural environment (e.g., forest cover, ecosystem services), and social/community (e.g., sociodemographic factors, housing, access to emergency services).*

1.2.1 MVI Tool Users

As described in the statement of purpose, the primary users of the MVI are municipalities, state agency staff, regional planning commissions (RPCs), non-governmental organizations, and community groups to better understand the climate vulnerability at a municipal scale and identify planning actions and strategies to reduce vulnerability and increase resilience.

1.2.2 MVI Tool Uses

The municipal climate vulnerability information generated by the MVI has a variety of applications, including (but not limited to):

- Developing local plans, such as local hazard mitigation, emergency preparedness and response, and climate action and adaptation plans.
- Guiding planning efforts, such as land use planning, capital planning, and infrastructure and utility planning and maintenance.

[14] Engagement under this project includes the following groups: expected MVI tool users; entities, communities, or their representatives who will potentially be affected by the tool's use; entities whose work is parallel to, or overlaps with, the MVI tool, and there is a need to align efforts; and Vermont state staff assisting with the tool's development who will be responsible for updating and maintaining the tool over time.

- Conducting vulnerability assessments and/or impact analyses that highlight vulnerabilities to and disproportionate impacts from climate change.
- Providing information needed to support grant writing/grant applications.
- Supplying key information needed for education and outreach efforts related to climate vulnerability.
- Helping direct technical support from state, regional, NGOs to communities and municipalities.

1.3 Report Layout

The process to develop the MVI tool includes three phases:

- **Phase 1.** Conducting background research and engagement to inform the factors that contribute to climate vulnerability, tool development methods, and tool use, features, and functions.
- **Phase 2.** Applying what was learned in the first phase to further refine the factors of climate vulnerability to be included in the tool and also develop a framework for the MVI, including the methods and approach for how the tool will communicate vulnerability and resilience to tool users.
- **Phase 3.** Developing the geospatial tool itself, including gathering input and feedback on the draft tool, tool testing, and finalizing the tool.

This report represents the conclusion to the third phase of MVI tool development. The purpose of this report is to describe the development, testing, and finalization of the MVI geospatial tool, including recommendations and considerations for future iterations of the tool. It also shows how the MVI can be applied to assess climate vulnerability in five Vermont municipalities through a series of community profiles.

Each of the aspects of MVI tool development are described in the sections that follow:

- **Section 2** describes the tool development and testing process.
- **Section 3** describes the first iteration of the MVI resulting from the tool development process, including its key functions, features, and limitations.
- **Section 4** includes five community profiles that provide an analysis of climate vulnerabilities using the MVI.
- **Section 5** describes the lessons learned from the development of the MVI, along with considerations and recommendations for future iterations of the tool.

2. Tool Development Process

The section describes the process used to develop the MVI (See Figure 1). The development of the MVI was conducted in three phases:

- **Phase 1.** Conducting background research and tool engagement to inform the factors that contribute to climate vulnerability, tool development methods, and tool use, features, and functions.
- **Phase 2.** Applying what was learned in the first phase to further refine the factors of climate vulnerability to be included in the tool and develop a framework for the MVI, including the methods and approach for how the tool will communicate vulnerability to tool users.
- **Phase 3.** Developing the geospatial tool, including gathering input and feedback on the draft tool, tool testing, and finalizing the tool.

The activities conducted within each of these phases are described in greater detail in the sections that follow.

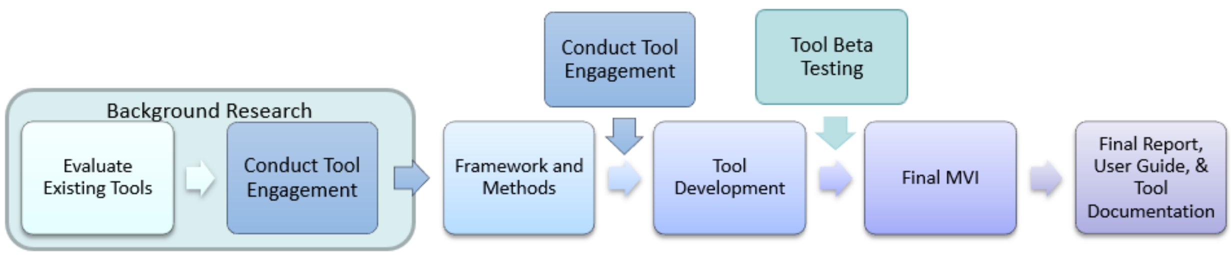

Figure 1: Overview of Tool Development Process

2.1 Evaluation of Existing Tools

To inform the development of the MVI, ERG reviewed and evaluated 21 existing web-based geospatial tools and data visualization platforms (hereafter referred to as “tools”). The primary focus of the evaluation was to review tools considered relevant to developing the MVI, along with their objectives and outputs. The secondary focus of the evaluation was to consider the data and information used in each tool and their applicability to the MVI.

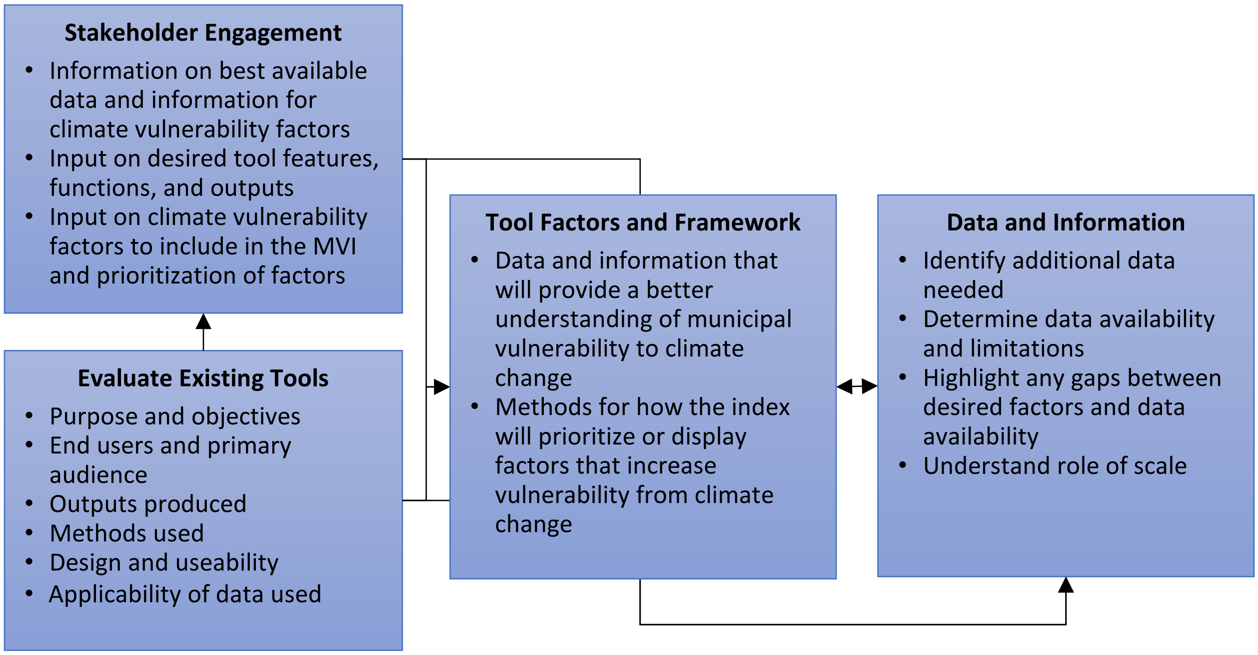

Figure 2. Flow of information and data into the MVI factors and framework.

Figure 2 shows the process steps used to support the development of the MVI framework. The information collected through evaluating existing tools was used to inform engagement, the MVI factors and framework, and the types of data and information available to support tool development. To confirm the findings from the tool evaluation step, ERG presented the draft factors and the framework and refined and revised based on the input and recommendations received by participants.

2.1.1 Tools Reviewed

The VT state team provided initial guidance on tools and methods to consider when developing the MVI factors and framework, including those from the states of California and Maine, in addition to those from Green Mountain Power, the Vermont Department of Health, and Vermont's Agency of Transportation (VTrans), Agency of Commerce and Community Development (ACCD), and Agency of Natural Resources (ANR). Using this guidance, ERG developed an initial set of key tools for review and confirmed the list with the VT state team. ERG then expanded the draft list through feedback from the MVI task group and VT state team. The list of resulting tools is presented in Table 1 below.

Table 1. List of Tools Reviewed

Tool	Geographic Area	Lead Agency/ Organization	Tool Focus
BioFinder	VT	ANR	Database and online mapping tool that identifies Vermont's lands and waters that support important ecosystems, natural communities, habitats, and species.
Department of Housing and Community Development Planning Atlas	VT	Department of Housing and Community Development	Provides town- and state-level information for use in planning (e.g., community development information, town boundaries).
Flood Ready Atlas	VT	ANR	Online mapping tool to help users identify critical flood hazard areas in a community.
Green Mountain Power 2021 Integrated Resource Plan	VT	Green Mountain Power	Highlights how Green Mountain Power will move forward to satisfy Vermont's energy needs and comply with Vermont's greenhouse gas reduction legislation.
Green Mountain Power Maps	VT	Green Mountain Power	Maps illustrating Green Mountain Power's service area, power outages, solar coverage, and distributed generation siting.
Historic Preservation Online Resource Center	VT	ACCD	Online access to the Division for Historic Preservation's documents related to historical preservation activities throughout the state since the 1960s.
Landslide Hazard Mapping	VT	ANR	Reports and maps documenting instances of landslides, rockfall, and areas of extreme erosion.
Mobile Home Park Registry	VT	ACCD	Provides list of all mobile home parks in Vermont.
Natural Resources Atlas	VT	ANR	Provides geographic information of natural features on land managed by VT ANR.
Vermont Commercial/Industrial Site Locator	VT	ACCD	Identifies optimal business locations by combing real estate listings with demographic and industry analysis.
Statewide Highway Flood Vulnerability and Risk Map	VT	VTrans	Online map of flood vulnerability and risk to support emergency preparedness, capital programming, and hazard mitigation planning.
Vermont Social Vulnerability Index	VT	Department of Health	Online mapping tool to evaluate relative social vulnerability across the state.
Vermont Transportation Flood Resilience Planning Tool	VT	VTrans	Identifies bridges, culverts, and road embankments vulnerable to damage from floods, estimates risk based on how vulnerable and critical roadway segments are, and identifies potential mitigation measures based on the factors driving the vulnerability.
California Climate Change & Health Vulnerability **Indicators**	CA	Department of Public Health	Interactive data visualization platform for the Climate Change & Health Vulnerability Indicators for California focused on climate exposure, population sensitivity, and adaptive capacity to the impacts of climate change.
Climate Vulnerability in Greater Boston	Boston, MA	Metropolitan Area Planning Council	Online tool used to gage which populations are most vulnerable to the extreme heat and flooding in the Boston metro area.
Maine Coastal Risk Explorer	ME	The Nature Conservancy	Online mapping tool that shows how rising sea levels will impact infrastructure (e.g., roads) in Maine and how these impacts relate to the overall social vulnerability of the community.
Rural Capacity Index	U.S.	Headwaters Economics	Online mapping tool and index that indicates community capacity by incorporating variables based on metrics related to local government staffing, community education and engagement, and socioeconomic trends.

Tool	Geographic Area	Lead Agency/ Organization	Tool Focus
Cooling Site Map	VT	Vermont Department of Health	Map that provides locations of indoor cooling sites open during normal hours; indoor cooling sites open during special hours; indoor cooling sites that are occasionally open; free beaches, pools, splash pads, or swimming holes; and beaches, pools, or splash pads that usually charge an entry fee.
Reducing Repeat Damage Tool	VT	VTrans	This tool depicts the VTrans analysis for reducing repeat damage from major storm events. The tool shows locations across the full Vermont Federal Aid System that have been damaged in multiple governor- or president-declared events between 2007 and 2021.
Vermont Communities Index	VT	Agency of Administration	Data-based tool designed to identify Vermont county subdivisions (i.e., municipalities) and labor market areas that may benefit from additional support to access funding from state, federal, and other sources. Using publicly available data, the Vermont Communities Index estimates each community's need for investment and administrative capacity to implement projects and pursue external support.
Vermont Heat Vulnerability Index	VT	Vermont Department of Health	The online, mapped index shows the overall vulnerability of each Vermont town to heat-related illness. This index is a composite of the following themes: Population, Socioeconomic, Environmental, Acclimatization, and Heat Emergency.

2.1.2 Evaluation Framework

ERG developed an evaluation framework in Microsoft Excel to structure the review of the tools and ensure that the initial assessment was consistent and robust. ERG designed the framework to capture relevant information about each tool or data set that could contribute to the development of the MVI. For example, the evaluation framework includes whether the tool aligned with priority topics of interest that may inform one or more aspects of climate vulnerability (e.g., climate hazards, built environment, socioeconomic information), the type of data available, outputs produced (e.g., maps, tables), design features, ease of use, and methods used in developing the tool. The VT state team and MVI task group reviewed the draft framework to provide an opportunity for input prior to ERG's evaluation of the tools. Figure 3 below shows the categories of the evaluation framework used for the review.

Tool/Dataset	Objectives	Audience	Key Users	Key Functions	Outputs	Data Sources
Name of tool/dataset	Goals of the tool/ dataset (e.g., decision-making, prioritize funding, understanding risk)	End users (e.g., emergency responders, community partners, planners)	Municipalities and internal agency users (e.g., Agency of Natural Resources)	Set of services or capabilities that the tool/dataset can provide (e.g., public user interface, zoom in/out of map, etc.)	Information produced from tool/dataset	Location of data that tool/dataset used or will process from

Data Scale	Data Type	Limitations	Maintenance	Potential Area of Alignment to VT MVI (Domains)	Vulnerability Index Design	Equity and Just Transition
Geographic scale of data (e.g., state, regional, Census-tract, town)	Qualitative, quantitative, or both types of data	Constraints of the tool/dataset	Description of any continual updates to the tool/dataset	Hazards, built environment, social/community, natural environment, governance	Description of method of weighting and scoring of vulnerability indicators	Description of any incorporation of equity and just transition aspects in tool/dataset

Figure 3. Evaluation framework

2.1.3 Key Findings

The evaluation of existing tools resulted in the following:

- Six "domains" or categories of factors that inform climate vulnerability. The six domains are listed below, followed by the types of information included within the domain:
    - **Built and Physical Environment.** Includes key structures within each town, such as critical assets, emergency services, and residential dwellings. It also includes housing age, which can help determine how vulnerable housing might be.
    - **Community.** Includes important community boundaries such as designated growth centers and downtown district boundaries. It also includes factors such as municipal staff and financial capacity.
    - **Social.** Includes social metrics of vulnerability such as vehicle access, the percentage of elderly residents and of children under five, and energy and transportation burden.
    - **Economic and Job.** Includes the percentage of each town that has outdoor and tourism workers. These professions tend to be more vulnerable to climate hazards due to their work being mainly outside.
    - **Infrastructure.** Includes important transportation, energy, and water infrastructure such as airports, powerlines, and drinking water infrastructure.

  - **Natural Environment.** Includes natural features that can help increase the resilience of a community to climate hazards, such as biodiversity and conserved and protected lands.
- Preliminary set of factors that contribute to climate vulnerability.
- Initial data sets that could be useful to include in the MVI that measure the identified set of draft factors at the municipal level in Vermont, along with identified data gaps.
- Information on the methods used by the tools reviewed and their transparency (e.g., how the tool measures vulnerability, whether the tool focuses on a single or multiple hazards).
- Types of outputs generated by the tool (e.g., climate vulnerability score, geospatial map of priority areas, vulnerability ranking).
- Design features of interest or applicability to the MVI (e.g., general aesthetics of user interface, information contained in the map legend, ability to select data of interest, ability to download or print tool data)

For further information about the review and evaluation of existing tools and the related findings, please see the Task 2 Evaluation of Existing Tools and Engagement Report.

2.2 MVI Engagement

Building upon the findings from the evaluation of existing tools (Section 2.1), ERG conducted engagement efforts to further inform the development of the MVI framework and methods. The aim of the engagement efforts was to give participants the opportunity provide input on the approach for defining the vulnerability tool, ensure tool outputs meet the needs of tool users, confirm or modify the findings from the evaluation of existing tools, and identify the types of data and information that would be most useful for them.

2.2.1 Participant Identification

ERG worked with the VT state team and MVI task group to determine the key groups for engagement prior to developing the tool's framework and methods. Through a series of conversations with the VT state team and input from the MVI task group, we identified the following groups:

- **MVI tool users.** Primary end users of the MVI tool, including municipalities, regional planning commissions (RPCs), and electric utilities.
- **Affected populations.** Populations that may experience disproportionate impacts from climate change based on characteristics such as race, ethnicity, age, income, education, and geographic location. Engagement included representatives of organizations serving or working with these populations.
- **MVI tool partners.** Entities whose work is parallel to, or overlaps with, the MVI tool where there is a need to align efforts.
- **Vermont State staff responsible for MVI tool design and maintenance.** Individuals working with the State of Vermont to assist in the tool's development and who are responsible for updating and maintaining the tool over time.

The scope of the engagement efforts across participant groups for this project included nine, one-hour interviews and two, two-hour online meetings.

Table 2 below shows the allocation of interview slots and online meetings across tool users and affected populations.

Table 2. Stakeholder interview and meeting slots by stakeholder group.

Engagement Slot	Stakeholder Group	Representative(s)
Interviews (9)		
1	Tool User	Brattleboro
2	Tool User	Bristol
3	Tool User	Newark
4	Tool User	Newfane
5	Tool User	South Burlington
6	Tool User	Vermont Department of Public Service and Electric Utilities (GMP, WEC, VEC)
7	Affected Population	Champlain Valley Office of Economic Opportunity and Capstone Community Action
8	Affected Population	Natural Resource Conservation Districts
9	Affected Population	Community Resilience Organizations
Online Meetings (2)		
1	Tool Users	Municipalities
2	Tool Users	RPCs

2.2.2 Engagement with Tool Users

Online Meeting with RPCs

ERG facilitated an online meeting with representatives of Vermont's 11 RPCs to gather input on the content, data, information, use, functions, and outputs of tool, as well any potential barriers to tool use. The online meeting was conducted via Zoom and lasted two hours. The meeting included a presentation that provided a brief overview of the project and the draft purpose of the MVI tool, followed by break-out group discussions facilitated by ERG staff.

Discussion topics included:

- Key components of climate and social vulnerability in Vermont.
- Data availability.
- Tool use cases (e.g., how might the tool be used).
- Tool information and data to be used in the tool.
- Tool functions, features, and outputs that would be helpful to RPCs.
- Challenges and barriers to tool use, including RPC staff and resources as well as municipal capacity.

Interviews

Similar to the discussion with RPCs, the aim of interviews was to collect information from municipalities to inform the content, data, information, use, functions, and outputs of the tool. To this end, the interviews focused on the following topics:

- Key factors that inform climate vulnerability in Vermont's towns.
- Available data.

- Tool use cases (e.g., how might the tool be used).
- Tool information and data to be used in the tool.
- Outputs that would be helpful to municipalities.
- Priority functions and features.
- Challenges and barriers to tool use, including staff or volunteer capacity.

Online Meeting with Municipalities

Following the interviews with municipalities, a broader meeting of municipal representatives was held to ensure input was collected from as many municipalities as possible to inform the MVI. The aim of this meeting was to present and confirm our findings to date, fill any information gaps identified after reviewing and summarizing the findings from the previous interviews and meetings, and broaden input on key topics addressed in the municipal interviews.

Forty-eight municipal representatives attended the two-hour online meeting conducted via Zoom. The meeting included a presentation that provided an overview of the project and the tool's draft purpose, followed by breakout group discussions facilitated by ERG staff.

2.2.3 Engagement with Affected Populations

Three small group interviews (two to four participants) were held with representatives from organizations that work closely with affected populations. The focus of these interviews was to gather input on:

- Key factors and population characteristics that inform climate and social vulnerability.
- Underlying conditions that affect the way that climate exposure is experienced.
- Sources of community support and assistance to prepare, respond to, and recover from climate hazards, climate change, and other shocks and stressors.
- Potential uses of the climate vulnerability information that will be generated by the MVI.
- Concerns or considerations when making decisions using the tool's outputs.

2.3 Key Findings

Tool engagement yielded a variety of key themes related to factors that influence a municipality's vulnerability to climate change; ways that the MVI tool can assist with municipal, regional, or state planning efforts; and desired features and information to include in the tool. Given the differences in the capacity and capabilities of the municipalities and RPCs, some participants were unsure how they might use the tool, while others were enthusiastic about the prospect of using the MVI tool to better understand climate and social vulnerabilities. The sections that follow delve deeper into the key findings that emerged from engagement efforts, including key findings by participant type (e.g., municipality, utility, RPC, affected population representative) and a discussion of findings on the ways the MVI tool can fill existing information gaps.

2.3.1 Findings by Participant Type

Municipal Representative Participants

Representatives of five municipalities of different sizes, densities, geographic locations, and staff capacity were interviewed to gather the input to further inform the development of the MVI. Key findings from these interviews are presented below by discussion topic.

Factors Influencing Climate Vulnerability

Municipal representatives who participated in the interviews were asked to share their perspectives on what makes their towns vulnerable to climate change. As part of this question, representatives were also asked to identify specific factors or indicators related to climate exposure and vulnerability, such as climate hazards (e.g., flooding, extreme temperatures), the built environment (e.g., infrastructure, the electric grid), demographic factors (e.g., race, age), and others. According to municipal representative interview participants, key themes around climate vulnerability, indicators of concern and elements that contribute to vulnerability in Vermont municipalities include the topics presented below.

Indicators of Climate Vulnerability

- **Impacts from climate hazards** that result in biodiversity and habitat loss, increased distribution of invasive species, and corresponding loss of native species have already begun to impact Vermont and will continue to do so according to current climate projections. There has been an increasing number of severe weather events, with snow, extreme precipitation, and corresponding flood events specifically mentioned. Seasonal droughts and loss of food and water security have also affected some municipalities. The issue of increased forest fire risk and air quality effects related to fires inside and outside of Vermont was raised as a concern. Wildfire risk was brought forward within the context of the severe wildfires in Canada that began in March 2023, and participants shared that they were increasingly concerned about wildfire risk across Vermont, particularly in southeastern Vermont and in heavily wooded areas.
- **Built environment** concerns included physical assets such as bridges and roads as well as energy and water infrastructure. Bridges are critical infrastructure in small and rural communities. In some areas, bridges connect two parts of a town, and if the bridge goes out, part of the community would be cut off from critical services. Additionally, some small, rural communities may lack town water systems, therefore making individuals who rely on their own wells more vulnerable during periods of seasonal drought or power outages when they're unable to pump water.
- **Demographic factors** and indicators of social vulnerability mentioned by participants included low-income populations, households without sufficient heating and cooling systems, populations that experience high energy cost burden, unhoused populations, individuals above the age of 65, and individuals without cars or accessible transportation options.

Community Characteristics Contributing to Municipal Vulnerability

- **Built environment and infrastructure,** such as a lack of town sewer and water treatment systems and corresponding reliance on wells, lack of broadband connectivity, and aging transportation and energy infrastructure.
- **Demographic factors,** such as an aging population and unhoused populations. Low population density across the majority of the state can make it difficult to reach individuals during severe

storms or power outages. Aging housing stock, lack of affordable housing, and a high percentage of renters can also contribute to community vulnerability.

- **Additional factors** mentioned included the reliance on volunteer emergency service providers (e.g., firefighters) and the scale of agriculture (e.g., loss of small farms in favor of wholesale distributors and subsequent loss of food security).

Data, Information, and Tool Use

Municipal interview participants were asked to share whether their towns currently use demographic or climate information or tools for planning purposes in their towns, what types of information and outputs would be helpful to municipalities in their planning purposes, and if they were aware of any data or information that should be included in the tool. In response, participants indicated the following:

- **Current uses of demographic or climate information or tools for municipal planning.** Most of the participants shared that they were not using demographic information or tools to inform their climate planning, and a few representatives shared that their towns were not engaged in much climate planning at all. One participant, for example, noted that their town plan includes some census data to inform future development decisions in terms of where future town development may occur, but this was the extent of their use of demographic information in planning. Participants who represented smaller towns explained that they lacked professional planners and often rely on assistance from their RPCs for town planning efforts. Some of these representatives noted that they were familiar with ANR's tool, BioFinder, but that it was not a tool they used regularly. Representatives from a large Vermont municipality explained that their planning department uses national weather service data to understand precipitation trends to inform planning, and also uses census data and Green Mountain Transit ridership data to inform planning for the creation of bike lanes and associated bike infrastructure.
- **Desired information and outputs from the tool.** Multiple representatives thought it would be helpful to include information on past and future weather-related events, such as rain and ice storms, flooding, extreme temperatures (hot and cold), and previous occurrences of natural disasters like flooding or landslides. Similarly, one participant suggested including information about the ways river and stream corridors are changing or could change in the future. Several participants noted that it would be helpful to include information on why areas are vulnerable to specific climate effects and explained that having this information would help to educate the general public and contribute to informed voting and decision-making. Regarding the scale of data to be included in the tool, participants noted that it would be helpful to have data at town, regional, and watershed scales. Some municipal participants also explained that it would be helpful to have data that is more granular than the town level to help identify where previous vulnerabilities have occurred in the past (e.g., specific bridge or road failures, flooding) and inform where they might occur in the future. They went on to say if they are unable to get a downscaled and accurate picture of vulnerabilities in their town, the tool might not be of great use to them. Participants also reinforced that having a regional understanding of vulnerabilities that extend beyond state lines is crucial, as climate hazards span across town and state boundaries.
- **Additional data sources.** Participants suggested several sources of data and information to include in the tool, such as:
    - Data from ANR's BioFinder tool.

- Information from town planning documents to provide an overview of community and zoning characteristics.
- Data on vegetation migration and information on how climate change is shifting species distribution.
- Natural disaster locations, such as those made available by FEMA.
- Information on transit corridors and transportation data.

Capacity and Potential Barriers to Use

In order to understand potential barriers to the use of the MVI tool and to potentially overcome these barriers or challenges, ERG asked participants to consider town capacity and capability to use the tool, anticipated barriers or challenges to tool use, and potential ways these barriers or challenges could be overcome. Key findings emerging from these discussion topics include:

- **Capacity and capability to use the tool.** There was mixed feedback among participants surrounding their capacity for using the MVI. Some participants indicated that their town, or an agency within their town government, has the staff capacity and capabilities to use the MVI. These participants noted that they would likely work with their planning and zoning offices to use the tool to inform planning decisions and decisions about where to prioritize capital improvement projects, or that their fire departments might use the tool to understand potential fire risk. The majority of municipal representatives indicated that their town does not have the staff capacity and/or capabilities to use the tool. They were often from smaller, rural towns that may or may not have paid staff, let alone full-time planning staff. These participants shared that they are already overwhelmed with other efforts and likely would not have the time or capacity to learn how to use the MVI tool and take on planning efforts using the tool. While these participants noted that their RPCs would likely be able to support them in using the tool, they also shared that they would prefer to have the RPCs be the primary tool users.
- **Anticipated barriers or challenges to use.** Participants mentioned a lack of staff capacity, a community's reluctance to acknowledge climate change, difficulties communicating climate change effects to residents, and a general lack of geographic information system (GIS) experience in planning or town offices. To overcome these barriers, participants suggested that tool outputs should be directly tied to planning requirements and that the level of detail in the data provided is consistent across towns both large and small. Multiple participants emphasized that it will be challenging to effectively communicate climate risk and vulnerability to a wide audience, but this barrier could be lessened if the tool presents information in a way that is straight forward and easy to understand.

Representatives of Vermont Utilities and the Vermont Public Service Department

A group discussion was held with representatives from PSD, Green Mountain Power, Vermont Electric Cooperative, and Washington Electric Co-op to better understand how both large and small utility providers in the state are thinking about climate vulnerability, how they're planning for climate change, challenges or issues they face in taking climate planning steps, suggested information or data to include in the tool, and how the MVI tool might assist them in understanding, planning for, or prioritizing actions to address climate change. Key takeaways from this conversation are presented below.

Factors Influencing Climate Vulnerability

Utility representatives shared that the greatest indicators of climate and social vulnerability of the energy grid are the remoteness and rural nature of the coverage area, type of vegetation cover, and proximity to floodplains. The greatest factor influencing power grid or energy transmission vulnerability was perceived to be the age of the infrastructure and type of power line (e.g., three-phase or single-phase lines).

- **Rural nature of coverage areas.** Representatives explained that the more rural an area is, the more vulnerable the energy infrastructure will likely be, and it will require more effort to maintain service per customer. With regard to vegetation cover and proximity to floodplains, the participants explained that after Hurricane Irene, it became apparent that energy customers living in mobile home parks near floodplains were especially vulnerable. Additionally, energy providers found that rural customers were more likely to live in areas with high vegetation cover, so in the event of a rainstorm or high winds, the energy infrastructure is more exposed to wind and downed trees. These customers are also harder to reach based on distance, single points of access, and hazard disruptions to this access (e.g., flooding, snow, downed trees or utility poles, landslides). In addition to low population density as a factor influencing vulnerability, respondents noted that rural customers who are older, have lower incomes, and who may not have neighbors or family nearby to assist them during a power outage are particularly vulnerable during outages.
- **Age and type of power line.** Some participants shared that most of the power lines under their jurisdiction were installed in the 1930s, making the lines over 90 years old. While relocating or undergrounding the lines is a priority for utilities, it is extremely difficult and expensive and is therefore not something that is taking place across the state at this time. Additionally, the participants shared that the type of wire in a power line is indicative of its age and that the older, single-phase lines experience the worst outages. These single-phase power lines are the primary type of lines in rural areas.

Ways Electrical Utilities are Planning for Climate Change

One of the primary ways electrical utilities are planning for climate change is thinking about the resilience of their systems and how quickly the systems can recover after a disaster or disruption that results in a power outage. While energy utilities in the state are trying to improve the grid’s resilience, it has been difficult for energy providers to keep up with newer technologies. Participants observed that in rural areas of Vermont, the gap is widening in terms of infrastructure preparation and resilience compared to non-rural areas. They also noted that low-income, rural communities experience a significant energy burden in the state, where energy costs can comprise a large percentage of a household’s income.

Suggested Data or Information to Include in the Tool

Suggestions for data or information to be integrated into the tool included:

- **Outage data** to help visualize areas which repeatedly experience outages. Communities that frequently experience power outages are likely to be more vulnerable during climate-related weather events and natural disasters, as basic needs and services dependent upon electricity are diminished or eliminated (e.g., daily household or business operations, internet-based communication systems).

- **Zoning information** to know if a town falls under the Act 250 zoning laws,[15] which require permits for commercial projects on more than 10 acres if the town has permanent zoning and subdivision regulations, or on more than 1 acre if the town does not, or on the subdivision of 10 lots or more in a five-year period.
- **Data on EJ communities** would help utilities support decision-making and promote equity in the Tier 3 energy programs that aim to help their customers reduce fossil fuel consumption by adopting new, affordable, and clean energy electrification technologies, thereby cutting energy costs.

Desired Tool Outputs

Suggestions for MVI tool outputs included:

- **Data layers on broadband network, cellular reliability, and electric infrastructure.**
- **Data layers illustrating locations of previous power outages.**
- **Locations of emergency backup systems and critical facilities** such as hospitals, emergency shelters, fire stations, and electric vehicle charging stations.
- **Locations of EJ communities.**
- **Locations of people who rely on electricity for health provision.** Participants acknowledged that there may be challenges obtaining and publicizing this information due to privacy concerns but noted that it could be critical information.

RPC Participants

An online meeting was held with representatives from RPCs across the state to discuss climate vulnerability factors, MVI tool use and information, and capacity and barriers to using the MVI. Key findings from this discussion are presented below.

Factors and Vulnerability

In discussing factors and vulnerabilities, meeting participants were asked to consider what populations in the communities they work with are most vulnerable. The populations that are considered most vulnerable by participants included:

- Aging populations.
- People living in floodplains.
- People who are dependent on electric medical devices.
- People who are energy burdened.
- People who are unable to reach or access heating or cooling centers during extreme temperatures.
- Unhoused populations.
- Migrant workers.
- New Vermont residents.
- People with limited English language proficiency.
- Black, Indigenous, and people of color (BIPOC) populations.

[15] Act 250 Rules: https://nrb.vermont.gov/sites/nrb/files/documents/2015%20Adopted%20Rules.pdf

Tool Use and Information

Meeting participants discussed specific data or information related to climate and social vulnerability that they would like to see included in the tool as well as the type of preferred outputs generated by the MVI.

Specific data or information that RPC meeting participants would like to see embedded in the tool include:

- Income data.
- Flooding data, including the new FEMA flood plans and also flood maps that consider future precipitation.
- Heat data and projected heat increases for the state.
- Utility data, including grid capacity, vegetation data overlaid with transmission lines, location of broadband networks, and wastewater, drinking water, and stormwater capacity for towns.
- Location of emergency services.

Outputs and information that participants would like to see generated by the MVI tool include:

- Vulnerability by climate hazard in map form.
- Housing needs and where development is most suitable based on climate hazards in different locations.
- Municipal capacity for fire suppression (e.g., wet and dry hydrants).
- Forest fire risk and data on red flag warnings.
- Climate hazard mitigation strategies by census block group and region.
- Sample policy recommendations or sample language to include in policy recommendations.

Capacity and Barriers

Meeting participants raised capacity concerns at both the RPC and municipal levels. In general, participants shared that a general lack of familiarity with GIS mapping and technology could present a barrier to tool use. At the municipal level, RPCs often provide technological support to community members and staff, and participants were unsure if municipal staff would be able to use the MVI tool without their support. Participants suggested including tutorials and “how-to” resources to help people who may not be as familiar with the technology to use the tool. Other participants noted that it was unclear to them how they might use a “big-picture” tool like the MVI and that it would be helpful for RPCs and municipalities to receive some education on how to use the tool and for what purposes. Participants also commented that in order to support the municipal use of the tool, RPCs would need additional resources that include not only additional funding, but also take into account the potential need to hire additional staff, which can be a complex issue given the additional resources needed, turnaround time for hiring, and difficulty attracting new hires in some areas due to a range of contextual factors, such as lack of housing.

When discussing capacity from a community-resilience perspective, participants shared that during events that significantly impact their communities (e.g., COVID, significant flood), they have observed that sources of community support tend to be organic, with communities and/or their members coming together in times of need.

Findings from Representatives of Affected Populations

During interviews with representatives from three organizations that work with or serve vulnerable populations, participants shared information regarding factors or indicators of climate vulnerability that are prevalent in the communities in which they work, the characteristics contributing to these vulnerabilities, the groups that people turn to during a climate-related event (e.g., flooding, snowstorm), how the MVI tool might assist municipalities and community organizations, and types of outputs or information from the tool that they would find most helpful. The findings from these discussions are presented below by discussion topic.

Factors Influencing Climate Vulnerability

Factors or indicators of climate exposure and vulnerability that are prevalent in the communities in which participants work or communities that they work with included:

- **Demographic factors** such as populations with limited or no English language proficiency, transgender people, chronically ill populations, people with low literacy levels, low-income populations, and other traditionally marginalized communities, as well as individuals with pre-existing medical conditions or individuals who may not even know they are vulnerable to particular climate hazards or pre-existing hazards such as toxic waste.
- **Industry and job sector.** Multiple participants highlighted farmers and the agricultural sector as being especially vulnerable to climate impacts, as farmers tend to have low incomes and/or limited resources and often lack capacity to apply for state or federal assistance programs.
- **Climate hazards** such as extreme weather, drought, and flooding.

Participants indicated that some characteristics of these communities that make them more vulnerable to climate impacts include demographic factors such as race, new Vermont residents, income, English proficiency, literacy, pre-existing medical conditions, energy burden, lack of access to weatherization services for renters, high population density within households and neighborhoods, high concentration of low-income residents, low population density, lack of access to transportation, lack of access to medical and health care, lack of secure and affordable housing, lack of food security, and lack of access to land.

Sources of Support for Communities During a Disaster

Participants shared a number of ways communities find support during or after a significant event, such as COVID-19 or a natural disaster. Multiple participants spoke about person-to-person connections, neighborhood support, and the strong community ties that people rely on during a significant event. Similarly, other participants spoke to the strength of grassroots mutual aid organizations throughout the state and the role those organizations played in providing direct support to people during the COVID-19 pandemic. Other participants noted that conservation districts provide support during disasters but also acknowledged that the districts are often underfunded and unable to provide all the support that people may need. The Vermont Farm Bureau and farming alliances[16] provide support to the farming community.

[16] The Connecticut River Watershed Farmers Alliance, the Champlain Valley Farmers Coalition, and the Franklin County Farmers Alliance were specifically named.

Ways the MVI Could Assist Municipalities and Desired Outputs

Community organization representatives shared that the MVI could assist municipalities in understanding the issues that community members face related to climate change; inform planning both for the purposes of development as well as disaster; and help prioritize improvement projects for underserved and vulnerable communities. Participants noted that it would be helpful if the tool could provide demographic information about land and home ownership, data illustrating food security and people's ability to access to healthy foods, data layers on social and ecological vulnerability, information on locations of mutual aid networks in different communities, and locations of emergency routes. Having this information in a centralized tool would help staff at municipal, regional, and state levels gain a better understanding of the interplay between climate and social vulnerability and how to prioritize assistance to the most vulnerable communities.

2.3.2 Findings Related to Needs, Gaps, and Opportunities for the MVI Tool to Fill

The MVI tool is intended to indicate municipal-level vulnerability to climate change based on a range of social, economic, and biophysical factors. The State of Vermont anticipates that information generated by the tool may be used to develop local hazard mitigation plans, local and regional energy plans, or other climate-related plans; inform decisions on how to prioritize climate-related projects and funding within communities and possibly across the state; and help emergency managers and members of the public prepare for and respond to likely climate hazards. In gathering input from municipal, utility, RPC, and affected population representatives, participants thought the MVI tool could fill the following needs and gaps currently facing these groups:

- Lack of comprehensive understanding of climate vulnerabilities.
- Need to prioritize allocation of resources.
- Lack of comprehensive understanding or definition of equity.
- Lack of actionable income data for energy utility customers.
- Lack of centralized information and data on EJ populations.
- Lack of maps illustrating critical facilities, including emergency shelters, hospitals, and microgrids.
- Lack of information on whether a municipality has paid staff.

By providing comprehensive data on climate hazards and social and climate vulnerability for municipalities in Vermont in a centralized tool, the MVI could fill the gaps mentioned above and assist municipalities, RPCs, and state agencies in better understanding the different social and climate vulnerabilities that Vermont communities face. The MVI could also help communities prepare to address those vulnerabilities in a way that reduces the most urgent vulnerabilities.

Desired Functions or Outputs of the MVI Tool

In both interviews and larger group meetings, participants were asked which functions and outputs would be most helpful from the MVI tool. The primary desired functions or outputs included:

- Map layers of the locations of past and future weather-related events, natural disasters, and power outages.
- Map layers of projected changes in locations of streams or river corridors and changes in water flow.

- Forest fire risk and historical data on red flag warnings.
- Map layers of broadband networks, cellular reliability, and electric infrastructure.
- Locations of emergency backup systems and critical facilities such as hospitals, emergency shelters, hospitals, fire stations, and electric vehicle charging stations.
- Map layers that provide information on municipal vulnerability to specific climate hazards.
- Map illustrating municipal capacity for fire suppression (e.g., locations of wet and dry hydrants).
- Map layers of EJ communities.
- Map layers illustrating housing needs for an area and where development is most suitable based on current and future climate hazards.
- Locations of people who rely on electricity for health provision.
- Data on current risks and projections, including details of scenarios used for projections.

Concerns Regarding Resources, Value, or Role of the MVI Tool

While some participants were enthusiastic about the data and information that the MVI tool will provide, other participants had some reservations regarding the need for and utility of the tool. One of the primary concerns from participants representing smaller towns was that the tool would result in greater burdens rather than benefits, and they noted that they would prefer if state agencies were the primary user of the tool, rather than municipalities without the necessary capabilities and capacities. Some participants also shared concerns regarding how the tool will communicate climate risk and noted that in some areas of Vermont, it is very difficult to talk about climate change and some residents are resistant to learning about or preparing for climate change. Similarly, a few participants mentioned that they hope the MVI tool does not overwhelm municipalities with too much information and data; while detailed data are important for professional planners and GIS experts, participants also thought it would be helpful to have fact sheets or summaries included so that vulnerability information could be easily communicated to towns, municipalities, and their residents. Another participant also raised the concern that even if towns or state planners are able to access information on vulnerable populations and climate vulnerabilities through this tool, vulnerable communities will continue to be left out of decision-making. Participants emphasized the need to involve vulnerable communities in the development of the tool and to educate them and the organizations representing vulnerable communities about the information included in the tool and how it will be used.

Additional detail on the tool engagement process can be found in the Task 2 Evaluation of Existing Tools and Engagement Report.

2.4 Identifying Tool Factors, Methods, and Framework

The second phase of tool development included applying what was learned through the evaluation of existing tools and MVI tool engagement to further refine the factors of climate vulnerability to be included in the tool and also develop a framework for the MVI, including the methods and approach for how the tool will communicate vulnerability and resilience to tool users. The following section summarizes the processes and information used to identify the factors of climate vulnerability that are most relevant to Vermont, the conceptual framework underpinning the tool, and the methods used to indicate climate vulnerability within the MVI tool.

2.4.1 Factors of Climate Vulnerability

A key component of phase 2 of the tool development process was the identification of a broad range of climate vulnerability factors for each of the six domains. These factors were informed by:

- **Legislation:** The development of the MVI is outlined in the GWSA. The legislation specifies certain factors that should be included in the MVI.[17]
- **Existing tools:** Our team reviewed existing tools to understand factors that were used by similar tools that were designed to identify social vulnerability, ecological assets, transportation vulnerability to flooding, and other similar tools used by Vermont and areas outside of the Commonwealth.[18]
- **MVI Tool Engagement:** Our team engaged with subject matter experts and partners through MVI task group meetings, interviews, and small group meetings.[19] This process provided information on which factors were identified most often, which factors were identified as a priority, and examples provided of how certain characteristics contribute to vulnerability or resilience to climate change.
- **Background Research and Expert Opinion:** We drew on background research of the characteristics of vulnerability and resilience that have been identified in Vermont and adjacent states, and the climate hazards most likely and consequential to the Commonwealth's communities and assets. Additionally, we also used our team's expertise in climate vulnerability to ensure we did not overlook any key vulnerability factors.

An overview of this process is presented in Figure 4 and is described in more detail below.

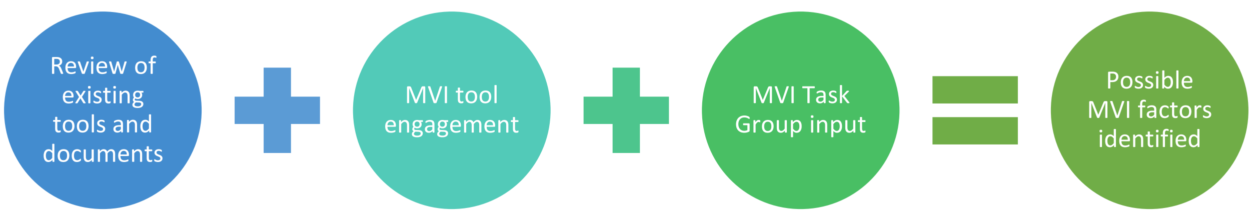

Figure 4. Process of MVI factor identification

From a broad range of over 100 factors, the team identified a focused list of factors for inclusion in the MVI based on the priorities identified during engagement, alignment with other Vermont tools, direction from the legislation, data availability, and experience with similar vulnerability tools and assessments. The process for selecting these factors is described in more detail below.

[17] The GWSA specifies that the MVI should include the following factors: municipality's population, average age, employment, grand list trends, active public and civic organizations, and distance from emergency services and shelter.

[18] Examples of tools we reviewed include: Climate Vulnerability in Greater Boston, Maine Coastal Risk Explorer, California Climate Change & Health Vulnerability Indicators, and Vermont Flood Ready Atlas.

[19] As part of the stakeholder engagement process, our team spoke with representatives from the following groups: MVI tool users, affected populations, MVI tool partners, and Vermont State staff responsible for MVI tool design and maintenance.

Process of Selecting MVI Factors

Upon compiling and reviewing a broad range of potential factors across the six domains, the team identified six key considerations to help refine the list of factors into those that most greatly influence climate vulnerability or that represent a priority for those we engaged or as described in the legislation. The key considerations are depicted in Figure 5 below and described further below.

Tool Statement of Purpose. A key component of the factor selection process was the tool's statement of purpose. We assessed the factors to ensure a focus on factors that "measure vulnerability to climate change at the municipal level for the purposes of informing climate-related planning and decision-making and supporting the professional duties of tool users", as specified in the statement of purpose.

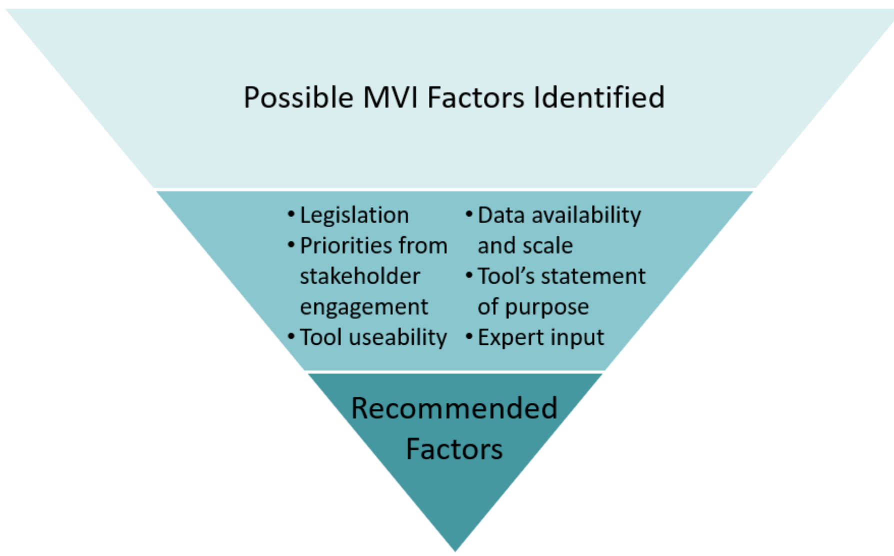

Figure 5. Overview of factor selection considerations

Legislation, Engagement, and Experience. In addition to prioritizing factors that clearly relate to the tool's statement of purpose, factors were prioritized if they were in the GWSA, were identified as a priority during the engagement process, or the team identified as high priority based on the team's expertise and experience with past tools and assessment. Prioritization also included considerations based on experiences from the July 2023 severe flooding in Vermont.[20]

Data availability. The team determined the data availability and scale for each of the priority factors identified through the process described above. For example, though "active public and civic organizations" were identified in the legislation as an important factor of resilience, there is no adequate geospatial data to support this factor. Rather than losing the important role that public and civic organizations play in supporting communities in preparing for and recovering from events due to a lack of available data, a narrative description will be included to describe the role it plays in community resilience. By including a narrative description for factors that lack adequate geospatial data, all high priority factors will be incorporated in some capacity within the tool.

[20] For more information on the July 2023 flooding in Vermont, read more from the NOAA National Weather Service here.

Ease of Use. A key consideration of which factors to include was the need to balance the depth and breadth of data in the tool with the complexity that would be created by including too many factors. A common theme throughout the tool engagement process was that the MVI needs to be easy to use while still providing meaningful information. Additionally, those engaged raised the concern of the limited capacity for municipalities and RPCs to use the tool and the need for it to be simple, clear, and easy to use. To ensure that the tool fits these criteria, the number of factors needed to be limited to those with a clear link to climate change vulnerability or resilience. To help with this process, the team conducted an exercise to identify the direct connection between factors and climate vulnerability. Factors with limited or hard-to-identify relationships to climate vulnerability were not recommended for inclusion in the tool. This method allowed the team to balance the amount of data included in the tool with the tool's overall ease of use, simplicity, and clarity.

Data scale and data processing considerations. The scale of the data and data processing needs were important considerations when identifying data sources. Based on the team's experience with similar tools and assessments, as well as the preferences of those engaged in the process, it was clear that local data should be selected over regional or national data sets to ensure that the MVI is as specific and meaningful to each municipality as possible. Another consideration regarding data availability is the form that the current data is in and how much processing will be needed to include it in the MVI. This process is ongoing, and the team will continue to assess the level of effort to process data sets for use within the tool and balance the priority of the factor that the data represents with the level of effort needed to process the data.

Alignment with existing mapping tools. To better understand the relevant, existing tools in Vermont and ensure that the MVI is designed to align with these tools, the team met with tool partners and developers of existing Vermont tools. The discussions allowed the team to understand the opportunities for alignment across factors, methods, tool design; the data and analysis available in each tool; the challenges and lessons learned, and any recommendations for the MVI from each of the tool partners. Specifically, we engaged with partners familiar with the VT Social Vulnerability Index, Community Resilience Index, Transportation Resilience Planning Tool, and BioFinder.

The resulting final list of factors for inclusion in the tool are included in Appendix B.

2.4.2 Framework and Methods

Based on engagement with the VT state team and MVI task group, tool engagement efforts, discussions with tool partners as well as the review of documentation and existing tools review, decided upon a flexible, user-guided approach for the development of the MVI. In a flexible, user-guided approach, the various geospatial data layers will represent the various factors of climate vulnerability, and the tool outputs layered geospatial information rather than single vulnerability metric or score. Users can select a location and conduct their own assessment of vulnerability for each climate hazard.

This approach is often used in multi-hazard and multi-asset tools and allows for more self-directed analysis and evaluation. For example, a municipal user can use such a tool to identify where electric power infrastructure is located within a flood zone by using the geospatial data available. They can add social vulnerability factors to their analysis to determine where power infrastructure is at risk of flooding in neighborhoods with characteristics of social vulnerability. If they're interested in what electric power infrastructure is vulnerable to high winds, they could layer information related to above-ground infrastructure and wind speeds to determine areas of highest vulnerability to winds. In addition to representing hazard-specific vulnerabilities, this method also helps users understand specific locations of vulnerabilities within a municipality. This local level information can help municipalities with climate-related planning and decision-making, and can support grant proposal efforts, development of local hazard mitigation plans, identification of climate vulnerability hot spots, and disaster planning and response (all of which are specified in the tool's statement of purpose). An additional benefit is that this approach is often easier to update and maintain when new data is available, projects are implemented that change the risks, or conditions or priorities change within municipalities.

Although a flexible, user-guided approach can often provide a better understanding of climate vulnerability at the municipal level and allow for more user directed analysis and evaluation, the approach usually requires more effort for users to determine the analysis that should be conducted and to interpret the information provided in the tool and understand the areas of highest vulnerability. This issue can be overcome by information provided in the user guide, support provided by regional and state agencies, and often this is addressed by providing guidance on how to use and interpret the factors available in the tool and the role they play in climate vulnerability.

Additional detail on the MVI framework and methods and how they were determined can be found in the Task 3 Framework and Methods Report.

2.5 Tool Development and Testing

The third phase of the project involved developing geospatial tool, including gathering input and feedback on the draft tool, tool testing, and finalizing the tool. Each of these activities is described in further detail in the sections that follow.

2.5.1 Development of Geospatial Tool

The MVI was developed in collaboration with the Vermont Agency of Digital Services to ensure the tool aligns with Vermont systems, software, and servers upon completion. The MVI was developed in ArcGIS Experience Builder platform in order to ensure alignment with other State software, platforms, and tools. This first iteration of the MVI was developed using an off the shelf version of Experience Builder that allowed the foundational elements of tool to be built in an efficient manner and also created the opportunity to identify where customization would be most beneficial in future iterations of tool. Considerations when using the "out-of-the box", standard functions in Experience Builder include limited customization options, such as those associated with aesthetics, integrating certain types of web services, and types of functions that are possible (e.g., layers, legend, print, controller).

2.5.2 Beta Testing

Upon completion of the draft tool, ERG conducted a round of tool testing with individuals identified by the VT State team who had been previously engaged in the tool development process, such as MVI Task group members, along with municipal and state staff. The VT State team identified 29 individuals for participation in the tool testing, and of those individuals, 11 people participated (38%).

The tool testing was conducted via a questionnaire that was developed and implemented using the Qualtrics online survey software platform.[21] Participants were given two written scenario exercises to practice using the tool and were then asked a series of nine questions to elicit feedback on tool aesthetics, functions and features, ease of use, and suggested Improvements. The tool testing questionnaire is included in Appendix C.

The key themes distilled from the questionnaire results included:

- Testers generally felt the tool was visually appealing and had a lot of potentially useful information
- Themes for suggested improvement include:
  - Update/Revise color schemes
  - Control/Selection of layers is not intuitive
  - Overlay of layers and need for transparency feature can be frustrating
  - Desire for more help interpreting data and providing data references
  - A detailed user guide with clear instructions and examples could be helpful

In addition, testers suggested a number of specific changes to the tool for consideration, such as the addition of other map boundary layers (e.g., counties, regional planning commission boundaries), addition or subtraction of data layers, and other features (e.g., ability to “clear all” selected layers, exporting data in certain file formats (e.g., shapefiles).

Where possible, the MVI was updated to incorporate tester feedback. Tool updates made based on the information gathered through testing included:

- Adding new boundary layers for Counties, Regional Planning Commissions boundaries, and Distribution Utility Service Territories boundaries
- Adding data sources to the layer name, legend, and/or popups on the map
- Modifying colors schemes across different layers to make distinguishing them easier
- Adjusting spatial extents and text contrast
- Incorporating feedback into the user guide (See Appendix A)

Some feedback received from the testing process was not able to be integrated into this iteration of the MVI due to the fact that they pertained to methodological decisions that had be previously determined, data limitations, or they were not standard features in Experience Builder and would require further customization. While the core of the tool’s methodology may remain in the next iteration of the tool, other functions and features and additional sources of data, as they relate to other factors of interest or new data becomes available, could be considered in future tool updates. Suggestions for MVI updates that were not included in this iteration of the tool include:

[21] https://www.qualtrics.com/

- Having the MVI produce a single index score to aid in the comparison of municipalities
- Ability to shuffle or reorganize map layers
- Removal of some data layers to simplify the tool (specific data layers were not named)
- Addition of other data layers, including:
    - Utility outage data and statistics for various timeframes
    - CDC Social Vulnerability Index data
    - Other health indicators, aside from adult asthma
    - Ability to select sub-options for internet access including fiber, cable/copper, and cellular
    - Moderate income data
    - Dams
- Exporting geospatial map data as shapefiles rather than GeoJSON
- Additional pre-packaged exercises or "quick view" combinations of preselected layers to understand how one might effectively use the tool

2.5.3 The Final MVI

Upon finalizing the MVI with input received through tool testing, the tool and relevant documentation was provided to the VT ADS so that the tool could be transferred to the State's server, where it will be hosted and maintained. The first iteration of the MVI developed through the tool development process described in this report is available here. The final set of functions and features included in the tool can be viewed in the tool user guide available in Appendix A.

3. MVI Community Analysis

This section presents vulnerability analyses for the five communities of Barton, Barre City, Isle La Motte, Newfane, and the City of Rutland that were conducted using the MVI. The aim of the profiles is to illustrate the type of information that can be gleaned to inform climate vulnerability at the community level by using the MVI. Where possible, the profiles provide a detailed description of climate vulnerabilities specific to each community, including examples of those vulnerabilities specific to the community. Where community-specific examples of vulnerabilities cannot be identified using the MVI given the type of underlying data or how the data are geospatially represented, the profiles include a general description of these vulnerabilities to show the full range of climate vulnerabilities that a community might consider when conducting its own analysis using the MVI. The profiles are designed to be viewed on their own and can be printed as standalone documents.

Barton

Municipal Overview

Barton is a rural area with a population of 2,471 people. It is located in the northeast of Vermont (see map).

Demographic Characteristics

The MVI considers demographic characteristics and social factors as they relate to climate change. The demographic characteristics listed below are above the state average and increase Barton's vulnerability to the impacts of climate change:

- **Income:** 38.99% of residents are considered low-income
- **Elderly:** 24.12% of population
- **Disability:** 26.79% of the population have at least one disability
- **Single parent households:** 18.19% of households
- **Linguistically isolated:** 0.68% of the population
- **Race and ethnicity:** Percent of population that are:
  - Black or African American: 1.98%
  - Indigenous Americans/Alaskans: 0.97%
  - Two or more races: 4.05%

Hazard Exposure

The MVI includes analysis of 13 climate hazards. When available, climate change projections are provided for that hazard. The hazards that had reliable climate projection data at the time the MVI was completed include extreme precipitation, high, and low temperature projections. When reliable climate projection data were not available, the MVI relies on historical occurrence data. The lists below describe the past, current, and/or future likelihood of these climate hazards occurring within the town of Barton:

- **Drought.** Between the years 2000 and 2022, Barton spent approximately 16 weeks per year, on average, in severe to exceptional drought. This average falls within the state average during the same period, which ranged from approximately 10 to 18 weeks per year.
- **Extreme precipitation.** Defined as days with precipitation greater than 2 inches. Under the climate project scenario where abundant fossil fuel use continues and resource- and energy-intensive lifestyles are adopted around the world (SSP5-8.5), Barton is projected to experience an increase of 0–1 days of extreme precipitation for 2015–2044, 2045–2074, and 2075–2100.[22]
- **Fluvial erosion.** Barton River, Roaring Brook, Hogtrough Brook, Willoughby Brook, and tributaries to these waterways run through Barton, which could present a fluvial erosion hazard. This hazard is further considered in the natural environment domain.
- **Hail.** Between 1955 and 2022, Barton experienced an average of less than one hail event per year.
- **Ice storms.** Between 1996 and 2022, Barton experienced an average of less than one ice storm per year.
- **Invasive species.** According to the Vermont Agency of Natural Resources, which maps invasive species on ANR - owned land in the state, Japanese knotweed and Japanese honeysuckle are present near Orleans Village in the northern region of Barton.

[22] This projection is based on the Fossil-fueled Development projection (SSP5-8.5). For additional information, see MVI User Guide Section 3.1 regarding climate projections.

Barton

- **Flooding.** No areas in Barton are within the FEMA-designated AE flood zone (1% annual chance floodplains with elevations).
- **Landslides.** According to the Vermont Agency of Natural Resources, eight mass failure landslides have occurred in Barton at various points along the Barton River.[23]
- **Snow storms.** On average, Barton experienced 10 snow storms per year between 1996 and 2022. Overall, the season in which Vermont experiences snow events is expected to shorten by two weeks to a month between 2050 and 2070.
- **High temperature projections.** If abundant fossil fuel use continues and resource- and energy-intensive lifestyles are adopted around the world, Barton is projected to experience 0–20 days above 90 °F per year for 2015–2044, 20–40 days for 2045–2075, and 60–80 days for 2075–2100.
- **Low temperature projections.** If abundant fossil fuel use continues and resource- and energy-intensive lifestyles are adopted around the world, the majority of Barton is projected to experience 160–180 days below 32 °F per year for 2015–2044, with the southern portion projected to experience 180–200 days. For 2045–2074, the majority Barton is projected to experience 140–160 days below 32 °F per year, again with the southern portion projected to experience 160–180 days. For 2075–2100, all of Barton is projected to experience 140–160 days below 32 °F per year.
- **Wildfire.** Barton has very low to low wildfire risk.
- **Wind risk.** On average, Barton experienced six high-wind events per year between 1996 and 2022.

Vulnerability and Resilience Factors

Barton has several factors flagged[24] in the MVI in addition to the demographic characteristics noted above that increase its climate vulnerability, including:

- **Aging housing stock.** 16% of homes were built after the year 2000 (above state average), which may reduce their vulnerability. The vulnerability of housing to climate change can vary greatly based on housing materials, construction methods, and maintenance. Older homes are often more at risk of damage or loss.
- **Housing cost burden (owned).** 17% of the population is experiencing cost burden associated with owning a home, meaning their mortgage is 50% or more of household income (above state average), which increases the vulnerability of these homeowners. Housing affordability is an important determinant of health and well-being and can put families at an increased risk to climate change impacts because families that spend a significant portion of their income on housing costs have fewer financial resources to prepare for or recover from a climate hazard event.
- **Housing cost burden (renting).** 24% of the population is experiencing cost burden associated with rentership, meaning their rent is 50% or more of household income (above state average), which increases the vulnerability of these renters.
- **Energy and transportation burden.** On average, 14% of median household income is spent on energy and transportation costs (above state average), which increases the vulnerability of these households. Families that spend a significant portion of their income on energy and transportation costs have fewer financial resources to prepare for or recover from a climate hazard event.
- **Toxic and hazardous sites.** Over 30 toxic and hazardous sites are located within Barton, with many clustered around both the Barton and Orleans Village centers. Flooding and extreme precipitation events can cause toxic and

[23] This data set does not indicate the period of years that it covers.

[24] Flagged factors included in the MVI were selected based on those that are not represented geospatially in the MVI tool and that contribute to climate vulnerability. The MVI User Guide provides additional information, including an explanation of how each flagged factor increases or decreases vulnerability to climate change hazards.

hazardous materials to enter soils and nearby water sources, and result in risks to sensitive receptors such as nearby schools, playgrounds, and housing, increasing the risks associated with these hazards.

- **Outdoor workers.** 17% of the population is employed in farming, fishing, forestry, construction, extraction, or maintenance occupations (above state average), which can increase the risks to these workers. Outdoor workers are particularly vulnerable to the effects of extreme temperature and poor air quality due to the amount of time they spend outdoors.
- **Vehicle access.** 7% of households do not have access to a vehicle (below state average). Access to a vehicle can be critical to evacuate or access resources before, during, or after a climate hazard event. While vehicle access below the state average reduces the overall risk to Barton, there is an increased risk to these households.
- **Internet access.** 18% of households do not have internet access (above state average). Access to the internet can be critical to receive information before, during, or after a climate hazard event. Internet disruptions can increase climate vulnerability by preventing people from accessing important information that can help them safely manage a climate hazard event.
- **Emergency Relief and Assistance Fund (ERAF).** ERAF rate of 7.5%, indicating that fewer than four hazard mitigation actions[25] have been adopted that could result in risk reduction to Barton's assets and communities. Adopting hazard mitigation actions can help make a community more resilient and manage their vulnerability to climate hazard events such as flooding by ensuring measures are in place to help mitigate flooding and recover after experiencing flood damage.
- **Limited municipal financial capacity:** The equalized municipal grand list value is $2,051,259 (below state average), which increases Barton's vulnerability. Municipalities with less financial capacity may face greater challenges when recovering from climate hazard events, such as when repairing damaged public infrastructure.

Vulnerability Analysis

Built and Physical Environment Domain

Barton's built and physical environment is exposed to several climate hazards, resulting in vulnerabilities to these assets and services. If abundant fossil fuel use continues and resource- and energy-intensive lifestyles are adopted around the world, Barton is projected to experience an increase of one day of extreme precipitation per year (defined as days with greater than 2 inches of precipitation) for year ranges 2015–2044, 2045–2074, and 2075–2100. This projection relates to the entirety of the city. Extreme precipitation can cause flash floods and riverine flooding, resulting in damage and disruption to the built and physical environment.

Extreme precipitation, snowmelt, and ice jams can also increase the likelihood of fluvial erosion, or streambed and streambank erosion associated with physical adjustment of stream channel dimensions (i.e., width and depth). Fluvial erosion can damage critical assets, emergency services, mobile parks, and residential dwellings sited in or near the river corridor. In urban areas, creeks and waterways are more likely to be channelized, which can increase the speed of river

[25] According to Flood Ready VT, "the ERAF provides State funding to match Federal Public Assistance after federally-declared disasters. Eligible public costs are reimbursed by federal taxpayers at 75%. For disasters after October 13, 2014, the State of Vermont will contribute an additional 7.5% towards the costs." Learn more at Flood Ready VT.

flows and result in bank erosion and increased flood risk downstream. In Barton, critical assets such as schools, utilities, wastewater treatment plants, health clinics, and town offices are located within river corridors, which could flood during extreme precipitation events or be impacted from fluvial erosion and river channel migration. For example, the wastewater treatment plant north of Orleans Village off Maple Street and the town office in Orleans Village are located within the river corridor of Barton River. A fire station is also located within the river corridor in Barton Village. Many commercial buildings are located within river corridors in Barton and Orleans villages. Other at-risk and sensitive assets include mobile homes and commercial buildings, which are located along the Barton River north and south of May Farm Road and are within the Barton River corridor.

Figure 1 (left) and Figure 2 (below). Town offices (pink), residential buildings (red and blue), and commercial buildings (purple) located in and near the river corridor (light green).

Barton currently experiences high temperatures and drought, both of which are expected to increase with climate change. If abundant fossil fuel use continues and resource- and energy-intensive lifestyles are adopted around the world, Barton is projected to experience 0–20 days above 90 °F per year for 2015–2044, 20–40 days for 2045–2075, and 60–80 days for 2075–2100. Critical assets such as schools and health clinics, emergency services such as fire stations, senior care facilities, pre-manufactured buildings, mobile home parks, and residential dwellings can be sensitive to high heat due to factors such as the use of lightweight building materials, less insulation, lack of high-heat-mitigating design features (such as ventilation), and being located in areas with higher temperatures, such as in areas that experience urban heat island effect. Older and inconsistently maintained buildings, historic buildings, buildings without access to air conditioning, and buildings in parts of Barton without vegetation or tree cover are most vulnerable to extreme heat.

Figure 3. Impervious surface cover near Orleans Village in the town of Barton. Impervious surfaces include buildings (red), roads (black), other paved surfaces (gray), railroads (purple), and compacted bare soil (tan).

Areas within Barton may experience high heat differently based on land uses and land cover, with areas that are predominantly covered by impervious surfaces and little vegetation being most exposed to what is known as the urban heat island effect.[26] The downtown areas of Barton Village and Orleans Village are likely to experience increased urban heat island effects due to high impervious surface coverage (see Figure 3) compared to the outer-lying areas (i.e., areas further away from main roadways), where the land cover is predominantly trees and pasture. High temperatures can also increase risks associated with drought and increase wildfire risk. Localized and seasonal drought can increase

[26] Urban areas often have concentrated areas of roads, buildings, and other structures that absorb and re-emit heat from the sun more than natural landscapes such as forests. These urban areas become "islands" where temperatures are higher relative to other areas; these areas of concentrated higher heat are referred to as "heat islands". Source: https://www.epa.gov/heatislands/learn-about-heat-islands

the risk of wells drying up. Given that Barton spent an average of approximately 16 weeks per year under severe to exceptional drought conditions between 2000 and 2022, households and others in Barton who rely on wells as their primary water source are vulnerable to overdraft, subsidence, and decreased water quality, as well as general water scarcity issues.

Community Domain

Barton's two villages (Barton Village and Orleans Village) are exposed to drought, extreme precipitation and fluvial erosion, hail, ice storms, flooding, snowstorms, and high and low temperatures. Barton has adopted some ERAF mitigation actions that reduce community risk to hazards. Barton has also adopted three ERAF mitigation actions, including participating in the National Flood Insurance Program, having a Local Emergency Management Plan, and adopting Road and Bridge Standards. Barton's Local Hazard Mitigation Plan is currently expired. The ERAF provides state funding to match Federal Public Assistance after federally-declared disasters. If a municipality adopts over four mitigation actions, they are eligible for a higher percentage of reimbursement from the State. Because Barton has adopted less than four ERAF mitigation measures, the state of Vermont will contribute 7.5% of the total cost of disaster recovery. Barton's resilience and ability to navigate climate vulnerability are improved by the fact that the city has municipal capacity in the form of at least two paid municipal staff, along with a confirmed planning process. Barton does not, however, have local land use regulations designed to reduce risk. The lack of local land use regulations that shift development away from areas likely to be exposed to hazards may lead to development projects that could put people at increased risk of experiencing climate hazard events.

Social Domain

Some of Barton's demographic characteristics can increase the population's vulnerability to the impacts of climate change. Populations will be impacted differently by climate hazards depending on their location within Barton, the characteristics of their communities, individual factors, and the resilience and preparedness of their communities. Characteristics such as housing cost burden, single-parent households, income, linguistic isolation, age, and pre-existing disabilities can make it difficult for individuals and households to prepare for, withstand, and recover from climate change–related impacts. For example, elderly populations are more susceptible to the effects of heat stress, which can exacerbate pre-existing cardiac conditions (nearly one-quarter of Barton's population is aged 65 or older) (see Figure 4). Black or African American (1.98% of the population), Indigenous Americans/Alaskans (0.97% of the population), and populations that are two or more races (4.05% of the population) are known to experience disparate access to health care (including physical and mental healthcare), and therefore are more at risk from the health impacts of extreme heat or flooding. Additionally, low-income populations in the United States and Canada have broadly been found to experience higher rates of high-temperature-related mortality, which could be due to factors such as residential location (e.g., in a heat island rather

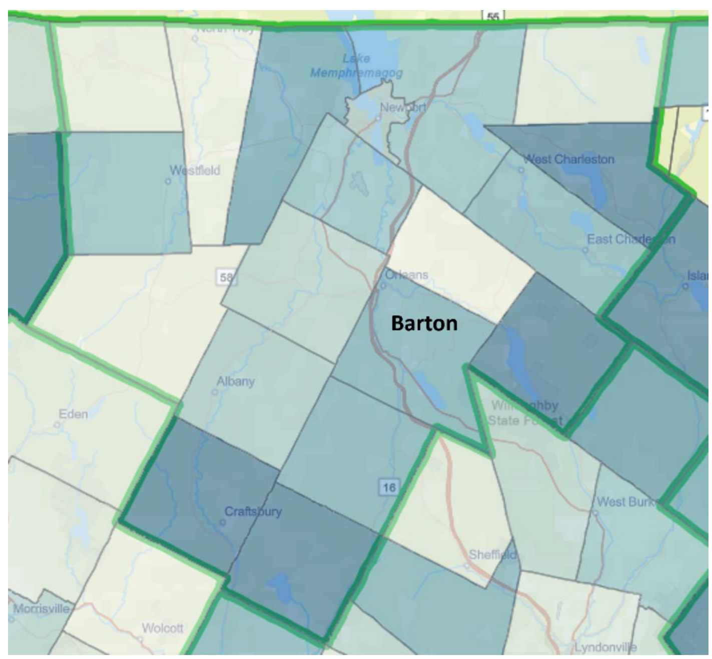

Figure 4. The percentage of Barton's population considered elderly is 24.12%. Other towns in the county of Orleans (outlined by the green line) have elderly populations ranging from 8.81% (Brownington) to 41.33% (Morgan).

than surrounded by trees) or a lack of air conditioning, resources to maintain housing, and health insurance. Nearly 40% of Barton's residents are considered low-income.

Populations that are linguistically isolated (0.68% of the Barton's population) are vulnerable to climate change impacts as they may have limited access to hazard warnings or information on how to prepare for or recover from a disaster. People with disabilities (over one-quarter of Barton's population) can be more vulnerable to climate change impacts if hazard preparations are not inclusive and accessible, and they may need ongoing medical care that can be difficult or impossible to access during some extreme events (such as power outages or flooding).

Economic and Job Domain

The MVI maps include a percentage of outdoor workers and the tourism industry to create a picture of economic sectors and jobs that may be vulnerable to climate change impacts. According to the U.S. Census Bureau, about 17% of the employed civilian population aged 16 years or older in Barton is employed in an outdoor occupation (e.g., farming, fishing, forestry, construction, extraction, and maintenance). The outdoor worker population is most vulnerable to the effects of high and low temperatures and extreme precipitation. These climate hazards could impact this population's ability to access or perform their jobs and increase their risk of health impacts such as heat stroke or exhaustion if they are working outside during extreme heat. In addition, the projected overall changes in the climate (e.g., increased extreme precipitation and temperatures) may impact the success of these industries in the future. For example, the farming industry may shrink due to decreased profits, which would in turn effect the people employed in this industry.

Flooding that disrupts access to workplaces, commercial areas, or small businesses—or a climate hazard event that damages or results in the loss of businesses—could have significant economic impacts on Barton and its residents. Barton has commercial and accessory buildings located in river corridors, mostly near the village centers of Orleans Village and Barton Village. Workers without access to leave, day workers, and gig workers are at risk of losing their pay and their jobs depending on the extent of this disruption, damage, or loss.

Infrastructure Domain

Roads, railroads, drinking water infrastructure, electric substations, power lines, and wastewater infrastructure in Barton are vulnerable to high temperatures. Asphalt softens under high temperatures, which can damage the integrity of roads and cause them to buckle, shortening the service life of the roadways and requiring more maintenance work. Conversely, freeze-thaw cycles deteriorate concrete and pavement and shorten their lifecycles. With climate change, freeze-thaw cycles are happening earlier in the spring, putting a strain on municipal resources for road maintenance and damaging roads. Roads and paved surfaces contribute to urban heat island effects. Railroad tracks can buckle and bend under extreme heat, which could impact the Vermont Rail System railroad tracks that run through Barton.

Barton

Barton's infrastructure, particularly Barton Orleans Road (US-5), the major road between Orleans and Barton villages, the railroad tracks, and Willoughby Avenue (VT-58) may be vulnerable to impacts from extreme precipitation, which could cause landslides (see Figure 5). There have been five mass failure landslides reported in these areas. Future landslides could impact these critical roads and railroads, which could significantly impact the community. Additionally, Barton has over 30 toxic and hazardous sites, many of which are located near Barton River or other rivers in the town. Flooding from these rivers can cause toxins and contaminants to enter soils or downstream water bodies.

Figure 5. The map area in the figure could experience an additional day of extreme precipitation under the Fossil-fueled Development (SSP5-8.5) projection for 2015–2044. The green dots on the map indicate culverts that could be at risk from the impacts of extreme precipitation events.

Drought impacts to drinking water supplies include loss of pressure in the supply system, general lack of water, increased water temperatures, and decreased water quality. Reduced public water supply could increase reliance on groundwater, reduce the quality of the remaining groundwater, and possibly affect future water supplies.

During periods of extreme precipitation, bridges and roads located near or above rivers and waterways are vulnerable to flooding. Culverts are at risk of being overtopped or blocked by woody debris, leading to culvert failure and an increased risk of flood exposure and depth, as well as bank erosion in the area above the blockage. There are nearly 100 culverts located throughout Barton, including eight culverts located under Interstate 91, which is a major interstate running north–south through all of Vermont. If culverts under this interstate fail or are blocked, the resulting flooding or damage to the road in this area could impact north–south travel for this region of the state. There are also many culverts under VT-16 (Glover Road and Willoughby Lake Road) and US-5 (Barton Orleans Road), which can impact local travel. For example, if a culvert failure or blockage under VT-16 east of US-5 causes flooding or damage to the road in this area, then residents in the eastern part of Barton may be blocked from accessing key services near Barton Village such as schools and health clinics. Extreme precipitation can also lead to fluvial erosion, which would damage the roads, bridges, culverts, and electric substations located in river corridors in Barton.[27]

Though generally rural, Barton has two areas, Barton Village and Orleans Village, with a high number of impervious surfaces (e.g., buildings, paved areas, railroads, roads, compacted soils). Impervious surfaces are unable to absorb precipitation, leading to increased runoff that overwhelms storm drain systems and allows pollutants from roads, lawns, and fields to enter waterways.

Natural Environment Domain

Maintaining functioning natural environments can be one of the most effective climate mitigation measures. However, when natural environments are degraded, their ability to provide climate mitigation benefits for the surrounding area decreases, and as a result, the surrounding area can experience increased vulnerability.

[27] The Transportation Resilience Planning Tool data (developed by the Vermont Agency of Transportation and available directly in the MVI) provides additional analysis that can further inform a transportation sector vulnerability analysis to flooding.

Barton

The natural environment in Barton could be degraded due to direct changes (e.g., land-use changes) as well as changes caused by exposure to climate hazards such as drought, extreme precipitation, flooding, and high temperatures. These hazards increase risks to the ecosystems surrounding rivers and creeks in Barton. Maintaining healthy and functioning natural environments can provide important resilience benefits. For example, the southeast region of Barton contains a highest priority interior forest block and highest priority connectivity block at the landscape scale, meaning this area provides a foundation for interior forest habitat and associated ecological functions, as well as landscape and habitat connectivity. This area, which includes Willoughby State Forest, is vulnerable to high temperatures and drought conditions. These hazards could negatively impact ecosystem function in this area and increase the risk of invasive species, habitat shifts, and wildfires. Given the ecological importance of the southeast region of Barton, the town and state should prioritize maintaining the health and functioning of this natural environment.

The rivers and streams running through Barton are highest priority surface water and riparian habitats meaning that they provide habitat for aquatic species in addition to other ecological functions. They have also been the focus of riparian wetland restoration and conservation, which has reduced the vulnerability of the surrounding communities. Drought and flooding could damage these in-stream and riparian habitats, but restoration can minimize that impact. Drought could increase water temperatures, lower water quality, damage soil and vegetation, increase the risk of contaminants entering the system, and increase vulnerability to invasive species, leading to habitat and species loss. Extreme precipitation could cause flooding, leading to severe erosion that could damage in-stream and riparian habitats. Extreme precipitation could also generate impacts related to the toxic and hazardous sites located in Barton. For example, if a site has contaminated soils or is storing toxic or contaminated material, an extreme precipitation event could cause these toxics and contaminants to enter soils, vegetation, and waterways.

Barre City

Municipal Overview

Barre City is an urban area with a population of 8,491 people. It is in the northern part of central Vermont, southeast of Montpelier.

Demographic Characteristics

The MVI considers demographic characteristics and social factors as they relate to climate change. The demographic characteristics listed below are above the state average and increase Barre's vulnerability to the impacts of climate change:

- **Income:** 43.84% of residents are considered low-income
- **Disability:** 31.91% of the population has at least one disability
- **Single-parent households:** 23.63% of households
- **Linguistically isolated[28]:** 0.34% of the population
- **Race and ethnicity**: Percent of population that are:
  - Black or African Americans: 1.77%
  - Hispanic/Latino: 2.07%
  - Two or more races: 3.91%
  - Some other race: 1.09%
- **Adult asthma:** 11% of population

Hazard Exposure

The MVI includes analysis of 13 climate hazards. When available, climate change projections were incorporated into the MVI. Reliable climate data were available for extreme precipitation, high temperatures, and low temperatures, climate change projections. When reliable climate change data were unavailable, the MVI relies on historical occurrence data. The list below describes the current, and where available, future potential climate hazard exposure for Barre City:

- **Drought.** Between the years 2000 and 2022, Barre spent approximately 16.5 weeks per year, on average, in severe to exceptional drought. This average falls within the state average during the same period that ranged from approximately 10 weeks to approximately 18 weeks per year.
- **Extreme precipitation.** Defined as days with precipitation greater than 2 inches. Under the climate project scenario where abundant fossil fuel use continues and resource- and energy-intensive lifestyles are adopted around the world (SSP5-8.5), Barre City is projected to experience an increase of 0—1 days of extreme precipitation for 2015—2044, 2045—2074, and 2075—2100.[29]
- **Fluvial erosion.** Stevens Branch, Gunners Brook, and Jail Branch rivers run through Barre City, presenting a fluvial erosion hazard.
- **Hail.** Between 1955 and 2022, Barre experienced an average of less than one hail event per year.
- **Ice storms.** There is no ice storm data for Barre.
- **Invasive species.** Goutweed is present near the Mcfarland State Office Building in Barre.

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[28] Linguistic isolation is a term used by the U.S. Census Bureau for limited English speaking households: https://www.census.gov/library/working-papers/2007/adrm/ssm2007-02.html.

[29] This is based on the Fossil-fueled Development projection (SSP5-8.5). For additional information, see MVI user guide section 3.1 regarding climate projections.

Barre City

- **Flooding.** Areas of the city near the Stevens Branch and Jail Branch of the Winooski River as well as Gunners Brook are located within flood zones including the Lake Champlain Basin Flood inundation mapping 2-year flood zone (50% annual exceedance) to the 500-year flood zone (0.02% annual exceedance). Areas around Stevens Branch are also within the FEMA-designated AE flood zone (1-percent annual chance floodplains with elevations).
- **Landslides.** Eight gully landslides and seven landslides have been recorded in various locations throughout Barre according to the Vermont Agency of Natural Resources.[30]
- **Snow storms.** On average, Barre experienced 10 snow storms per year between 1996 and 2022. Overall, the season in which Vermont experiences snow events is expected to decline by at least to two weeks and up to a month between 2050 and 2070.
- **High temperature:** If abundant fossil fuel use continues and resource-and energy-intensive lifestyles are adopted around the world, Barre is projected to experience 0—20 days above 90 °F per year for 2015—2044, 20—60 days per year for 2045-2075, and 100—120 days per year for 2075—2100.
- **Low temperature projections.** If abundant fossil fuel use continues and resource-and energy-intensive lifestyles are adopted around the world, Barre is expected to experience 120—140 days below 32 °F per year for 2015—2044, and 0—120 days per year for 2045—2074 and 2075—2100.
- **Wildfire.** Barre has very low to low wildfire risk.
- **Wind risk.** On average, Barre experienced eight high-wind events per year between 1996 and 2022.

Vulnerability and Resilience Factors

Barre has several factors flagged[31] in the MVI in addition to the demographic characteristics noted above that influence its climate vulnerability, including:

- **Aging housing stock.** Approximately 8% of homes were built after the year 2000 (above state average) which can indicate less vulnerability for that housing stock. The vulnerability of housing to climate change can vary greatly based on housing materials, construction methods, and maintenance. Older homes are often more at risk of damage or loss.
- **Housing cost burden (renting).** 22% of Barre's population is experiencing cost burden associated with rentership, meaning their rent is 50% or more of household income (above state average), which increases vulnerability for those renters. Housing affordability is an important determinant of health and well-being and can put families at an increased risk to climate change impacts because families that spend a significant portion of their income on housing costs have fewer financial resources to prepare for or recover from a climate hazard event.
- **Energy and transportation burden.** Over 12% of the median household income for Barre is spent on energy and transportation costs (above state average), which increases vulnerability for those households. Families that spend a significant portion of their income on energy and transportation costs have fewer financial resources to prepare for or recover from a climate hazard event.
- **Toxic and hazardous sites.** There are over 80 toxic and hazardous sites in Barre, with many clustered around Washington Street. Flooding and extreme precipitation events can cause toxic and hazardous materials to enter soils, nearby water sources and sensitive receptors such as nearby schools, playgrounds, and housing, increasing the risks from climate hazards in Barre.

[30] This data set does not indicate the period of years that it covers.

[31] Flagged factors included in the MVI were selected based on those that are not represented geospatially in the tool and that contribute to climate vulnerability. For additional information see the MVI User Guide.

Barre City

- **Vehicle access.** 24% of households do not have access to a vehicle (above state average) increasing vulnerability to those households. Access to a vehicle can be critical to evacuate or access resources before, during, or after a climate hazard event.
- **Internet access.** 17% of households do not have internet access (below state average), increasing vulnerability to those households. Access to the internet can be critical to receive information before, during, or after a climate hazard event. Internet disruptions can increase climate vulnerability by preventing people from accessing important information that can help them safely manage a climate hazard event.
- **Emergency Relief and Assistance Fund (ERAF).** ERAF rate of 7.5%, indicating that fewer than four of the hazard mitigation actions required for increased State contributions to eligible public costs following federally-declared disasters have been adopted. [32] The adoption of additional mitigation measures could result in risk reduction to Barre's assets and communities.

Vulnerability Analysis

Built and Physical Environment Domain

Barre City's built and physical environment is susceptible to a range of vulnerabilities from climate hazards. According to the Fossil-fueled Development (SSP5-8.5) projection for year ranges 2015—2044, 2045—2074, and 2075—2100, Barre is expected to experience an increase of 1 day of extreme precipitation per year; this projection relates to all of Barre. Extreme precipitation is defined as days with over two inches of precipitation. Extreme precipitation can cause flash floods and inundation flooding (the rise in riverine or lake water levels), causing damage to the built and physical environment. In July 2023, communities in central Vermont along the spine of the Green Mountains received 4 to 8 inches of rain in 48 hours.[33] The city of Barre sustained significant damage as a result of this extreme precipitation event and associated flash flooding, especially in downtown areas located along the river and within the floodplain. An increase in extreme precipitation events in Barre City could cause flood exposure to critical assets located in or near the floodplain or in areas that areas that are at lower elevations (see Figure 1). For example, the city's wastewater treatment plant is located near the Stevens Branch of the Winooski River and portions of the treatment plant are located within the 100-year flood zone (1% annual exceedance) and the 500-year flood

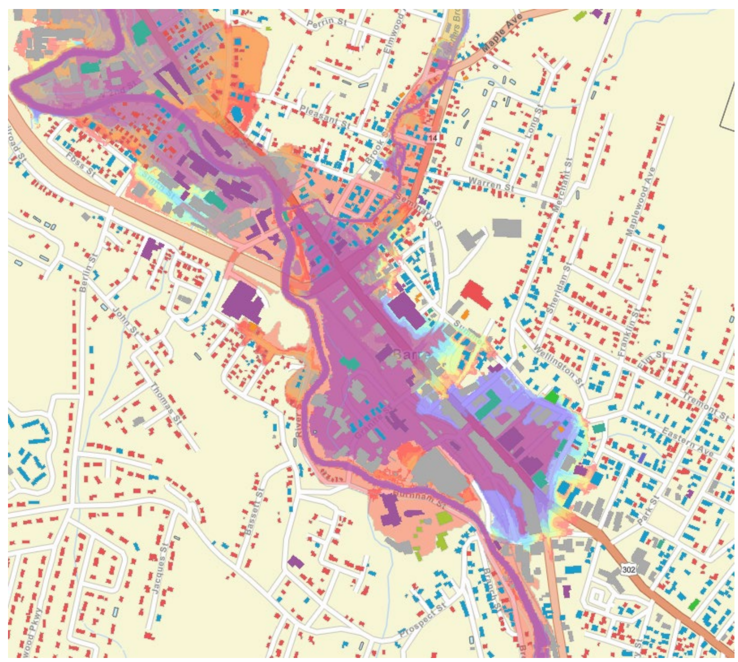

Figure 1. Critical assets, emergency services, mobile homes, commercial buildings, and residential dwellings in downtown Barre within the FEMA National Flood Hazard and Lake Champlain Basin Flood Inundation floodplains.

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[32] According to Flood Ready VT, "the ERAF provides State funding to match Federal Public Assistance after federally-declared disasters". The four mitigation measures that a community is required to take in order to receive an increased cost contribution from the State (12% of eligible costs) include: Participation or application to the National Flood Insurance Program, Adoption of Town Road and Bridge Standards that meet or exceed the 2013 template in the current: VTrans Orange Book: Handbook for Local Officials, Adoption of a Local Emergency Management Plan, and adoption of a FEMA-approved Local Hazard Mitigation Plan (or have submitted a plan for to FEMA Region 1 for review). Learn more at Flood Ready VT.

[33] https://www.weather.gov/btv/The-Great-Vermont-Flood-of-10-11-July-2023-Preliminary-Meteorological-Summary

zone (0.02% annual exceedance) according to the Lake Champlain Basin Flood data, and within the FEMA National Flood Hazard AE flood zone (1% annual chance floodplains with elevations). Other critical assets such as schools, health clinics, libraries and town services are also located in the floodplain, southeast of Maple Ave and on the north side of North Main Street. The closest hospital is the Central Vermont Medical Center located north of Barre off Route 62, just south of Montpelier. Flooding could prevent residents located in the southern, central, and northwest parts of Barre from accessing the Medical Center because North Main Street (running from 6th Street down to Church Street) is at risk of flooding and located within the FEMA National Flood Hazard AE flood zone (1% annual chance floodplains with elevations) and the Lake Champlain Basin Flood 2-year flood zone (50% annual exceedance and the 500-year flood zone (0.02% annual exceedance). Mobile homes located in the downtown area and further south along the Jail Branch of the Winooski River are also at risk from flooding. The highest concentration of buildings in the floodplain is in downtown Barre along the north bank of the Stevens Branch and along North Main Street.

Extreme precipitation, snowmelt, and ice jams can also increase the likelihood of fluvial erosion, or streambed and streambank erosion associated with physical adjustment of stream channel dimensions (width and depth). Fluvial erosion can damage the critical assets, emergency services, mobile parks, and residential dwellings sited in or near the river corridor. In urban areas, creeks and waterways are more likely to be channelized, which can increase the speed of river flows and result in bank erosion and increased flood risk downstream. There are schools, commercial buildings, residential buildings (single and multi-family dwellings), and mobile homes located within areas of Barre designated as river corridors, putting them at risk to impacts from fluvial erosion and river channel migration.

Barre currently experiences high temperatures and drought, both of which are expected to increase with climate change. Under the Fossil-fueled Development (SSP5-8.5) projection for 2015--2044, Barre is expected to experience 0—20 days above 90 °F per year; for 2045—2075 Barre is expected to experience between 20—60 days above 90 °F per year; in 2075—2100 it is expected to experience 100—120 days above 90 °F per year. Critical assets such as schools and health clinics, emergency services such as fire stations, senior care facilities, pre-manufactured buildings, mobile home parks and residential dwellings are all sensitive to high heat due to factors such as the use of lightweight building materials, less insulation, lack of high heat mitigating design features (such as ventilation), and being located in areas with higher temperatures such as in areas that experience urban heat island effect.[34] Older and inconsistently maintained

Figure 2. Impervious surface cover in downtown Barre. Impervious surfaces include buildings (red), roads (black), other paved surfaces (gray), railroads (purple), and compacted bare soil (tan).

[34] Urban areas often have concentrated areas of roads, buildings, and other structures that absorb and re-emit heat from the sun more than natural landscapes such as forests. These urban areas become "islands" where temperatures are higher relative to other areas; these areas of concentrated higher heat are referred to as "heat islands". Source: https://www.epa.gov/heatislands/learn-about-heat-islands

buildings, historic buildings, buildings without access to air conditioning, and buildings in parts of Barre without vegetation or tree cover are most vulnerable to extreme heat. Areas within Barre may experience high heat differently based on land uses and land cover, with areas that are predominantly covered by impervious surfaces (see Figure 2) and little vegetation being most exposed to what is known as the urban heat island effect. The downtown area of Barre is likely to experience increased urban heat island effects due to a high percentage of impervious surface coverage compared to the outer lying areas (i.e., areas further away from main roadways) where the land cover is trees and pasture. High temperatures can also increase risks and impacts of drought. Localized and seasonal drought can increase the risk of wells drying up. Given that Barre spent an average of approximately 16.5 weeks per year under severe to exceptional drought conditions between 2000 and 2022, households and others in Barre who rely on wells for their primary water source are vulnerable to overdraft, subsidence, and decreased water quality as well as general water scarcity issues.

Community Domain

Barre's designated downtown area and historic district are exposed to drought, extreme precipitation and fluvial erosion, hail, ice storms, flooding, snowstorms, and high and low temperatures. The City of Barre has adopted two ERAF mitigation actions. The ERAF provides State funding to match Federal Public Assistance after federally-declared disasters. If a municipality adopts over four ERAF mitigation actions, they are eligible for a higher percentage of reimbursement from the State. Barre has a Local Emergency Management Plan and participates in the National Flood Insurance Program but has not undertaken other actions such as adopting 2013 Road and Bridge Standards, and the City's Local Hazard Mitigation Plan is expired. Because Barre has adopted less than four ERAF mitigation actions, the State of Vermont will contribute 7.5% of the total cost of disaster recovery. Barre's resilience, and ability to navigate climate vulnerability are improved by the fact that the city has municipal capacity in the form of two paid municipal staff, along with a confirmed planning process or land use regulation.

Social Domain

Some of Barre's demographic characteristics can increase the population's vulnerability to the impacts of climate change. Populations will be affected differently by different climate hazards depending on their location within Barre, the characteristics of their communities, individual factors, and the resilience and preparedness of their communities. Characteristics such as the cost burden for rental properties, single parent household, income, linguistic isolation, age, and pre-existing health and disability can make it difficult for individuals and households to prepare for, withstand, and recover from climate-change-related impacts. For example, exposure to extreme temperatures exacerbates existing health conditions such as asthma or other respiratory conditions, and 11% of adults in Washington County (in which Barre is located) have adult asthma. Elderly populations are more susceptible to the effects of heat stress, which can exacerbate pre-existing cardiac conditions, and 13.15% of Barre's population is aged 65 or older. Black or African American (1.77% of Barre's population), and Hispanic or Latino populations (2% of Barre's population), and populations that are two or more races (3.91% of Barre's population) are known to experience disparate access to health care (including physical and mental healthcare), and therefore are more vulnerable to the health impacts of extreme heat or flooding or other disasters. Additionally, low-income

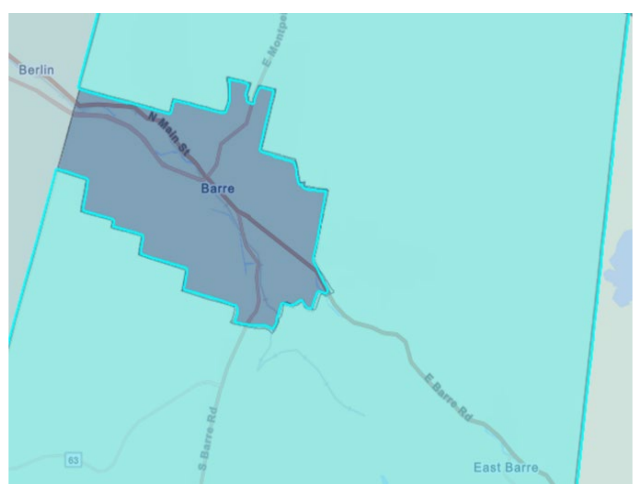

Figure 3. The percentage of Barre's population which is considered low-income is 43.84% (dark blue), which is higher than the surrounding Barre town (turquoise) where the population that is considered low-income is 19.4%.

populations in the U.S. and Canada have, broadly, been found to experience higher rates of high temperature-related mortality—this could be due to factors such as residential location (e.g., in a heat island rather than surrounded by trees), lack of air conditioning, inability to maintain condition of housing, and lack of health insurance. Over 43% of the population in Barre is considered low-income (Figure 3), which is above the state average, increasing Barre's vulnerability to climate change. Populations that are linguistically isolated (0.34% of Barre's population) are vulnerable to climate change impacts as they may have limited access to hazard warnings or to access information on how to prepare or recover for a disaster. People with disabilities (23.91% of Barre's population) are more vulnerable to climate change impacts as hazard preparations may not have been designed to be inclusive and accessible, and they may need ongoing medical care which can be difficult or impossible to access during some extreme events (such as power outages or flooding).

Economic and Job Domain

The MVI maps the percentage of outdoor workers and tourism industry to create a picture of economic sectors and jobs that may be vulnerable to climate change impacts. According to the U.S. Census Bureau, approximately nine percent of the employed civilian population aged 16 years or older in Barre is employed in an outdoor occupation (e.g., farming, fishing, forestry, construction, extraction, and maintenance). The outdoor worker population is most vulnerable to the effects of high and low temperatures, and extreme precipitation. These climate hazards could impact this population's ability to access or perform their jobs and increase their risk of health impacts such as heat stroke or exhaustion if they are working outside during extreme heat. In addition, the projected overall changes in the climate (e.g., increased extreme precipitation and temperatures) may impact the success of these industries in the future. For example, the farming industry may shrink due to decreased profits, which would, in turn, effect the people employed in this industry.

Flooding that disrupts access to workplaces, commercial areas, or small businesses—or a climate hazard event that damages or results in the loss of businesses—can have significant economic impacts on Barre and its residents. Barre has commercial and accessory buildings located in the floodplain, with the highest concentration of these building located along Steven's Branch, and areas between North Main Street and State Route 62, and on both sides of North Main Street, south of State Route 62. Workers without access to leave, day workers, and gig workers are at risk of losing their pay and their jobs depending on the extent of this disruption, damage or loss.

Infrastructure Domain

Roads, railroads, drinking water infrastructure, electric substations, power lines, and wastewater infrastructure in Barre are vulnerable to impacts from high temperatures. Asphalt softens under high temperatures, which can damage the integrity of roads and cause them to buckle, shortening the service life of the roadways and requiring more maintenance work. Conversely, freeze-thaw cycles deteriorate concrete and pavement and shorten their lifecycles. With climate change, freeze-thaw cycles are happening earlier in the spring, putting a strain on municipal resources for road maintenance and damaging roads. Roads and paved surfaces contribute to urban heat island effects. The majority of Barre's downtown area is covered with impervious surfaces—either buildings, roads, or other paved surfaces. Railroad tracks can buckle and bend under extreme heat, which could impact the railroad line that runs through the city.

Drought impacts to drinking water supplies include loss of pressure in the supply system, general lack of water, increased water temperatures, and decreased water quality. Reduced public water supply could increase reliance on groundwater, reduce the quality of the remaining groundwater, and possibly affect future water supplies.

Barre City

During periods of extreme precipitation, culverts could be overtopped or blocked by woody debris, leading to culvert failure and an increased risk of flood exposure and depth, as well as bank erosion in the area above the blockage. There are nearly 40 culverts in Barre, located on Gunners Brook, Jail Branch, and other smaller tributaries. Some culverts are located under State Route 62, and North Main Street which are the two major roadways running through the city. If culverts under these roads fail or are blocked, the resulting flooding or damage to the road could block access to the health clinic on Summer Street (near downtown) for residents who live south of these culverts.

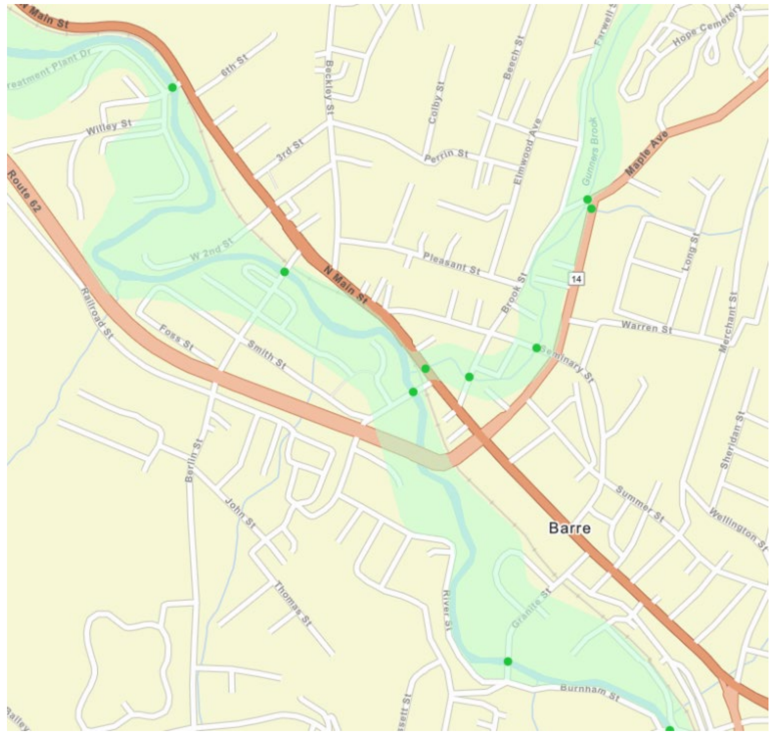

Figure 4. Bridges (green dots) in Barre that are within the river corridor (light green highlight) and therefore at risk to damage from fluvial erosion.

Extreme precipitation can also lead to fluvial erosion, which would damage the roads, bridges, culverts, drinking water infrastructure, electric substations, and powerlines located in the river corridor. Additionally, there are at least 20 toxic and hazardous sites located in the river corridor. Damage to toxic and hazardous sites as a result of fluvial erosion could cause release of toxins or hazardous substances into nearby waterways, soils, and the surrounding environment. In downtown Barre, North Main Street bridge passes over Gunners Brook where it branches from Steven's Branch; if this bridge were to be damaged due to fluvial erosion, access to the downtown area via North Main Street could be blocked north of the bridge (see Figure 4).

Barre has a high number of impervious surfaces (e.g., buildings, paved areas, railroads, roads, and compacted soils). These are highly concentrated in the center of the city where there are many buildings and paved roads. Impervious surfaces are unable to absorb precipitation, leading to increased runoff, which overwhelms storm drain systems and allows pollutants from roads, lawns, and fields to enter waterways. There are roads, bridges, culverts, drinking water infrastructure, electric substations, powerlines, and wastewater infrastructure located in Barre's floodplains.[35] The wastewater treatment plant in Barre is located in the river corridor and floodplain (FEMA 1-percent chance annual floodplain with elevation, and the Lake Champlain Basin Flood inundation mapping 500-year flood zone [.02% annual exceedance]).

Natural Environment Domain

A healthy natural environment is one of the best resilience measures that a community can take to reduce risks from climate change. Healthy forests, wetlands, urban green spaces, parks, and trees provide urban cooling against extreme heat and urban heat island effect; flood risk reduction by slowing and storing water during extreme precipitation events; reduce risks from wildfires and invasive species and provide clean air and clean water, including better resilience from drought events, particularly seasonal and localized droughts. Connectivity between natural areas and larger stands of healthy natural areas that include protected, natural wetlands are the best at providing climate risk reduction. While

[35] The Transportation Resilience Planning Tool data (developed by the Vermont Agency of Transportation and available directly in the MVI) provides additional analysis that can further inform a transportation sector vulnerability analysis to flooding.

Barre City

Barre is considered urban and has an urbanized downtown area, the southwest portion of the city is comprised of forested areas and open fields or farmland. Additionally, there is a 67-acre open space preserve—Barre City Cow Pasture—in the northwest corner of the city. The forested areas of Barre, located south of State Route 62, consist of highest priority and priority interior forest blocks, meaning that this area provides a foundation for interior forest habitat and associated ecological functions and climate benefits. These areas should be reviewed to consider how these forest blocks currently mitigate the impact of climate hazards on the built environment, and where that can be enhanced. In addition, given that Barre experiences extreme heat and drought, these forest areas both mitigate the impact to the city but also could be damaged due to these climate hazards over time. Drought and heat often result in increased stress to forests, increasing the risk of wildfire, invasive specifies, and diminishing the health of the forest. Given that the entirety of Barre is exposed to drought and high heat, forested areas will reduce drought and heat impacts to adjacent areas of Barre. Incorporating green areas (by building parks and increasing tree cover) in the more urban areas of Barre could enhance these benefits, as well as increase biodiversity and habitat connectivity. The rivers and streams running through Barre provide important in-stream and riparian habitat. These areas are classified as highest priority surface water and riparian habitats according to the Vermont Agency of Natural Resources because they provide habitat for aquatic species and other ecological functions. They also pose risks to the city from flooding. Drought and flooding alike could damage these in-stream and riparian habitats and should be considered as the rivers are enhanced to maximize floodplain habitats to minimize flooding damage to infrastructure and maximize ecological benefits. Preserving and enhancing these rivers and streams, increasing tree cover and native vegetation in the buffers where/if needed will reduce Rutland's risks from drought, heat, flooding, and wildfire. Extreme precipitation could also generate impacts related to the toxic and hazardous sites located in Barre. For example, if a site has contaminated soils or is storing toxic or contaminated material, an extreme precipitation event could mobilize these toxins and contaminants, and distribute them to soils, vegetation, and waterways. Drought could increase water temperatures, lower water quality, damage soil and vegetation, increase risk of contaminants entering the system, and increase vulnerability to invasive species, leading to habitat and species loss.

While healthy natural environments increase the resilience of cities and towns in Vermont, it is also important to note that natural areas can be damaged and degraded from climate change, making management and restoration important tools for ensuring that the benefits from healthy natural areas are not lost, but protected and enhanced. Designing management and restoration efforts to reduce risks from erosion associated with extreme precipitation, drought effects, contamination from flood events, and habitat loss and shift from extreme heat and invasive species will be critical to Barre City's overall resilience in the future.

Isle La Motte

Municipal Overview

Isle La Motte is the northernmost island within Lake Champlain in the northwest region of Vermont. Isle La Motte is connected to the rest of Vermont via one bridge (VT-129). Isle La Motte has a year-round population of 450 people. During the summer, many vacationers, boaters, fishers, and part-time residents travel to the island to enjoy its natural beauty.

Demographic Characteristics

The MVI considers demographic characteristics and social factors as they relate to climate change. The demographic characteristics listed below are above the state average and increase Isle La Motte's vulnerability to the impacts of climate change:

- **Income:** 28.41% of residents are considered low-income
- **Elderly:** 29.56% of the population
- **Disability:** 16.22% of the population has at least one disability
- **Single-parent households:** 12.37% of households

Hazard Exposure

The MVI includes analysis of 13 climate hazards. When available, climate change projections are provided for that hazard. The hazards that had reliable climate projection data at the time the MVI was completed included extreme precipitation, high, and low temperature projections. When reliable climate projection data were not available, the MVI uses historical occurrence data. The list below describes the past, current, and/or future likelihood of these climate hazards occurring within Isle La Motte:

- **Drought.** Between the years 2000 and 2022, Isla La Motte spent approximately 11 weeks per year, on average, in severe to exceptional drought. This average falls within the state average during the same period, which ranged from approximately 10 to 18 weeks per year.
- **Extreme precipitation.** Defined as days with precipitation greater than 2 inches. If abundant fossil fuel use continues and resource- and energy-intensive lifestyles are adopted around the world, Isle La Motte is projected to experience an increase of 0—1 days of extreme precipitation for 2015--2044, 2045—2074, and 2075—2100.[36]
- **Fluvial erosion.** Based on the River Corridors data from the Vermont Department of Environmental Conservation, there are no areas in Isle La Motte that present a fluvial erosion hazard.
- **Hail.** Between 1955 and 2022, Isle La Motte experienced an average of less than one hail event per year.
- **Ice storms.** Between 1996 and 2022, Isle La Motte experienced, on average, less than one ice storm per year.
- **Invasive species**. According to the Vermont Agency of Natural Resources (ANR), no invasive species are present in Isle La Motte. ANR maps invasive species on ANR-owned land in the state. There is no ANR-owned land in Isle La Motte and, therefore, no invasive species are mapped in the area.
- **Flooding.** There are no areas in Isla La Motte that are within the FEMA-designated AE flood zone (1% annual chance floodplains with elevations) or that are identified by the Lake Champlain Basin inundation flooding map. However,

[36] This is based on the Fossil-fueled Development projection (SSP5-8.5). For additional information, see MVI user guide section 3.1 regarding climate projections.

flooding is a hazard that should be carefully considered as exemplified by past events such as the May 2011 flooding on Isle La Motte.

- **Landslides.** There have been no landslides in Isle La Motte according to the Vermont Agency of Natural Resources.[37]
- **Snow storms**. On average, Isle La Motte experienced six snow storms per year between 1996 and 2022. Overall, the season in which Vermont experiences snow events is expected to decline by at least to two weeks and up to a month between 2050 and 2070.
- **High temperature projections.** If abundant fossil fuel use continues and resource- and energy-intensive lifestyles are adopted around the world, Isle La Motte is projected to experience 0—20 days above 90 °F per year for 2015—2044, 40—60 days per year for 2045—2075, and 100—120 days per year for 2075—2100.
- **Low temperature projections.** If abundant fossil fuel use continues and resource- and energy-intensive lifestyles are adopted around the world, Isle La Motte is projected to experience 120—140 days below 32 °F per year for 2015—2044 and 2045-2074, and 0—120 days for 2075—2100.
- **Wildfire.** Isle La Motte has very low to medium wildfire risk.
- **Wind risk.** On average, Isle La Motte experienced 3.5 high wind events per year between 1996 and 2022.

Vulnerability and Resilience Factors

Isle La Motte has several factors in addition to the demographic characteristics noted above that influence its climate vulnerability, including:

- **Housing cost burden (owned).** 15% of Isle La Motte’s population is experiencing cost burden associated with home ownership, meaning their mortgage is 50% or more of household income (above state average), increasing the vulnerability of those homeowners. Housing affordability is an important determinant of health and well-being and can put families at an increased risk to climate change impacts because families that spend a significant portion of their income on housing costs have fewer financial resources to prepare for or recover from a climate hazard event.
- **Housing cost burden (renting).** 73% of Isle La Motte’s population is experiencing cost burden associated with rentership, meaning their rent is 50% or more of household income (above state average), which increases vulnerability for those renters, increasing the vulnerability of those renters.
- **Energy and transportation burden**. On average, 12% of median household income is spent on energy and transportation costs (above state average), increasing the vulnerability of those households. Families that spend a significant portion of their income on energy and transportation costs have fewer financial resources to prepare for or recover from a climate hazard event.
- **Outdoor workers.** 19% of the population is employed in the farming, fishing, forestry, construction, extraction, or maintenance occupations (above state average), increasing the vulnerability of these workers and the Isle La Motte economy. Outdoor workers are particularly vulnerable to the effects of extreme temperature and poor air quality due to the amount of time they spend outdoors.

[37] This data set does not indicate the period of years that it covers.

Isle La Motte

Vulnerability Analysis

Built and Physical Environment Domain

Figure 1. Critical assets and emergency services are concentrated in the central area of Isle la Motte. On the island, there is one fire station (red square on Main St.), one town office (pink), one library (blue), and one school (red square north of School St.). There are no other critical services on the island (including law enforcement, ambulance services, and hospital/medical centers).

Isle La Motte faces a unique set of challenges and vulnerabilities since it is a small island with very limited resources. The Isle La Motte Volunteer Fire Company is the island's only emergency service. There are no other emergency services on the island (including law enforcement, ambulance services, and hospital/medical centers). The closest hospitals are each about a 45-minute drive from the island (Northwest Medical Center in Street Albans City, VT and Champlain Valley Physicians Hospital in Plattsburgh, NY). Critical assets on the island consist of one town office, one library, and one school (see Figure 1). The fire station and these critical assets are all located in the central part of the island. If a climate hazard event such as flooding, extreme heat, or wildfire were to impact Isle La Motte, residents could be severely vulnerable due to the difficulty of accessing emergency services. If abundant fossil fuel use continues and resource- and energy-intensive lifestyles are adopted around the world, Isle La Motte is expected to experience an increase of 1 day of extreme precipitation per year (defined as days with greater than 2 inches of precipitation) for the year ranges 2015—2044, 2045—2074, and 2075—2100. Extreme precipitation can cause flash floods and inundation flooding, causing damage to the built and physical environment and isolating residents due to damage and disruption to access to emergency services and other critical resources. Additionally, the general increasing trend in extreme precipitation across the region can lead to increased water levels in Lake Champlain, which increases flood risk on Isle La Motte.

In May 2011, Isle La Motte experienced flooding as a result of record high water levels in Lake Champlain due to snowmelt and heavy rainfall throughout the watershed. The flooding on Isle La Motte effectively split the island into two along the wetlands that are located in the center of the island. This event caused multi-day school closures. Fire and Rescue squads from Isle La Motte and surrounding areas visited affected residents to ensure they had critical resources and to the ability to evacuate if they wanted or needed to. This event demonstrates the vulnerability to being cut off from critical resources and emergency services on Isle La Motte.

The majority of homes in Isle La Motte are along the water, though there are also homes along the main central roadway (Main Street). The categories of residential dwellings include primarily single-family homes and camps or seasonal homes. There are also manufactured homes scattered throughout Isle La Motte. Homes on the Lake Champlain waterfront and near the central wetland that spans the island may be particularly vulnerable to direct damages from flooding.

Isle La Motte currently experiences high temperatures and drought, both of which are expected to increase with climate change. If abundant fossil fuel use continues and resource- and energy-intensive lifestyles are adopted around the world, Isle La Motte is projected to experience 0-20 days above 90 °F per year for 2015—2044, 40—60 days per year for 2045—2075, and 100—120 days per year for 2075—2100. Critical assets such as the school, emergency services such as the fire station, and other buildings on the island such as mobile homes and residential dwellings are all sensitive to high heat. Older and inconsistently maintained buildings, historic buildings, buildings without access to air conditioning, and buildings in parts of Isle La Motte without vegetation or tree cover are most vulnerable to extreme heat. High temperatures can also increase risks and impacts of drought. Localized and seasonal drought can increase the risk of wells drying up. There is no public water system on Isle La Motte – water sources include both well water and water drawn directly from Lake Champlain. Given that Isle La Motte spent an average of approximately 11 weeks per year under severe to exceptional drought conditions between 2000 and 2022, households and others in Isle La Motte who rely on wells for their primary water source are vulnerable to overdraft, subsidence, and decreased water quality as well as general water scarcity issues.

Community Domain

Isle La Motte has taken actions to increase its resilience to climate change, including by adopting five Emergency Relief and Assistance Fund (ERAF) mitigation actions. The ERAF provides State funding to match Federal Public Assistance after federally-declared disasters. If a municipality adopts over four mitigation actions, they are eligible for a higher percentage of reimbursement from the State. Isle La Motte has a Local Hazard Mitigation Plan, Local Emergency Management Plan, road and bridge standards, participates in the National Flood Insurance Program, and has protected river corridors. Because Isle La Motte has adopted five ERAF mitigation measures, the State of Vermont will contribute 17.5% of the total cost of disaster recovery, the highest reimbursement rate possible. Isle La Motte does not, however, have a confirmed planning process nor does it have any local land use regulations. There are two state registered historic districts in Isle La Motte (see Figure 2) which could be vulnerable to climate hazard impacts such as flooding, extreme precipitation, and high heat. Additionally, Isle La Motte has only one paid municipal staff, which makes it difficult for the town to continue to adopt and implement climate mitigation actions. As demonstrated from past disaster events such as the May 2011 flooding on the island, Isle La Motte can increase their capacity to prepare for, respond to, and recover from events by coordinating with nearby communities such as Alburgh, North Hero, and Grand Isle.

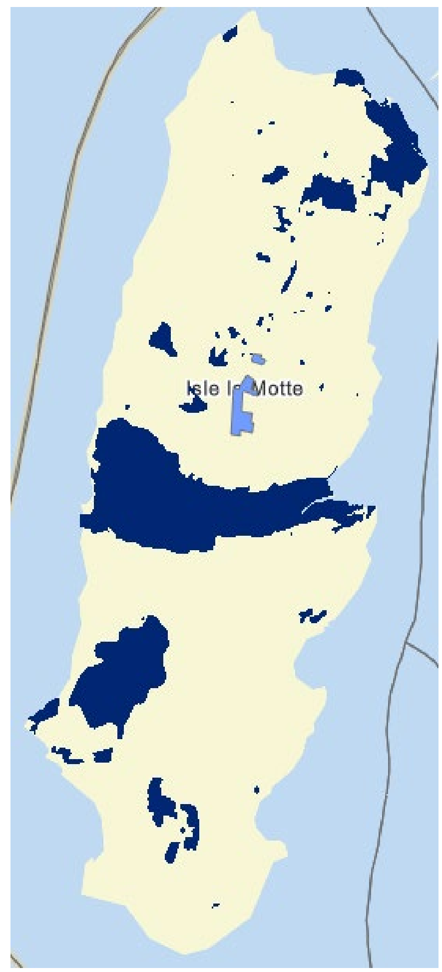

Figure 2. Isle La Motte has two state registered historic districts, both of which are in the central part of the island (light blue). These historic districts could be vulnerable to impacts from flooding, particularly due to the many wetlands surrounding the area (dark blue).

Social Domain

Some of Isle la Motte's demographic characteristics can increase the population's vulnerability to the impacts of climate change. Populations will be affected differently by climate hazards depending on their community's location within Isle La Motte, the characteristics of their communities, individual factors, and the resilience and preparedness of their communities. Characteristics such as housing and energy cost burden, single parent households, income, age, disabilities, and internet access can make it difficult for individuals and households to prepare for, withstand, and recover from climate-change—related impacts. For example, elderly populations are more susceptible to the effects of heat stress, which can exacerbate pre-existing cardiac conditions; about 30% of Isle La Motte's population is aged 65 or older. Low-income populations in the United States and Canada have, broadly, been found to experience higher rates of high-temperature-related mortality, which could be due to factors such as residential location (e.g., in a heat island rather than surrounded by trees) or a lack of air conditioning, inability to maintain condition of housing, and lack of health insurance. Over 28% of the population in Isle La Motte is considered low-income, which is above the state average, increasing the population of Isle La Motte's vulnerability to climate change. People with disabilities (16.22% of Isle La Motte's population) are more vulnerable to climate change impacts as hazard preparations may not have been designed to be inclusive and accessible, and they may need ongoing medical care which can be difficult or impossible to access during some extreme events (such as power outages or flooding). Given the one road (VT-129) that connects Isle La Motte to the rest of Vermont, these vulnerabilities may be exacerbated due to the difficulty of accessing resources before, during, or after an event.

Economic and Job Domain

The MVI includes data on the percentage of outdoor workers and tourism industry to create a picture of the economic sectors and jobs that may be vulnerable to climate change impacts. According to the U.S. Census Bureau, about 19% of the employed civilian population aged 16 years or older in Isle La Motte is employed in an outdoor occupation (e.g., farming, fishing, forestry, construction, extraction, and maintenance). The outdoor worker population is most vulnerable to the effects of high and low temperatures, and extreme precipitation. These climate hazards could impact this population's ability to access or perform their jobs and increase their risk of health impacts such as heat stroke or exhaustion if they are working outside during extreme heat. Extreme participation could also cause flooding, which could disrupt access to workplaces, commercial areas, small businesses, or a climate hazard event that damages or results in loss of businesses can have significant economic impacts on Isle La Motte and its residents. Workers without access to leave and day and gig workers are at risk of losing their pay and their jobs depending on the extent of the damage or loss. Due to the remote nature of Isle La Motte's, it can be difficult to get necessary resources to the island to help businesses recover from climate hazard events.

The rivers and streams running through Isle La Motte, as well as large areas in the northern, central and southern regions of the island, are classified as highest priority surface water and riparian habitats according to the Vermont Agency of Natural Resources as they provide habitat for aquatic species and other ecological functions. Isle La Motte also has wetlands, vernal pools, and species that are classified as highest priority, and there are areas classified with rare physical landscape diversity by Vermont Agency of Natural Resources. Drought and wildfire could damage these sensitive habitats. Drought could increase water temperatures, lower water quality, damage soil and vegetation, increase risk of contaminants entering the system, and increase vulnerability to invasive species, leading to habitat and species loss. Wildfires can lead to soil erosion because without vegetation cover the soil becomes less stable and more susceptible to erosion. Wildfires can also introduce areas for invasive species to outcompete native species and increase risks of drought and heat, as well reduce water, air, and soil quality.

Infrastructure Domain

Given that Isle La Motte is connected to Alburgh, VT via one bridge (VT-129), maintaining this bridge is critical to the ability for resources and people to move safely and effectively on and off the island. Roads, bridges, and culverts are vulnerable to impacts from flooding and storm events. [38] Flooding can cause erosion, which can undermine a road or bridge's structural integrity. Culverts are at risk from being overtopped or blocked by woody debris, leading to culvert failure and increased risk of flood exposure and depth, as well as bank erosion in the area above the blockage. There are

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[38] The Transportation Resilience Planning Tool data (developed by the Vermont Agency of Transportation and available directly in the MVI) provides additional analysis that can further inform a transportation sector vulnerability analysis to flooding.

over 20 culverts located throughout Isle La Motte. If culverts fail or are blocked, the resulting flooding or damage to the road could impact travel throughout the island. Whether by structural integrity impairments or by floodwaters directly over roadways, these issues could put residents of Isle La Motte at significant risk because of the limited number of roadways on the island and the single roadway off of the island. Roads are also vulnerable to high temperatures. Asphalt softens under high temperatures, which can damage the integrity of roads and cause them to buckle and shorten the service life of the roadways requiring more maintenance work. Conversely, freeze-thaw cycles deteriorate concrete and pavement and shorten their lifecycles. With climate change, freeze-thaw cycles are happening earlier in the spring, putting a strain on municipal resources for road maintenance and damaging roads.

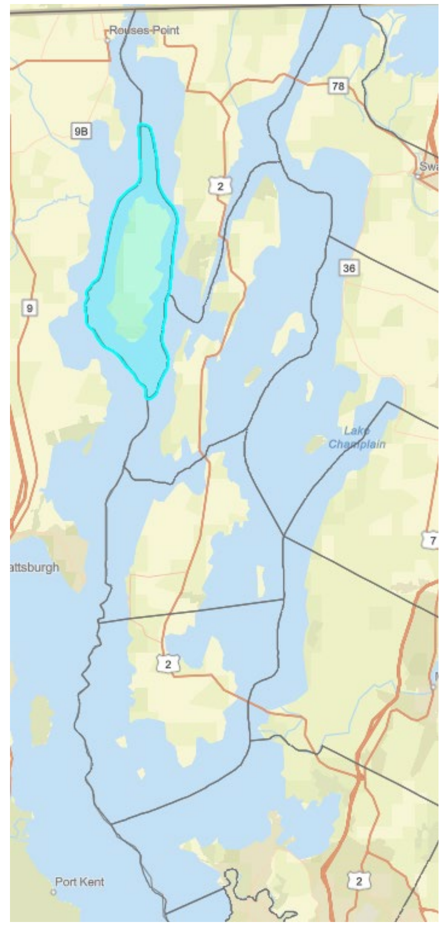


Figure 3. Isle La Motte is the northernmost island within Lake Chaplain (light blue highlighted island). Isle La Motte is connected to the rest of Vermont via one bridge off the northeast corner of the island (VT-129).

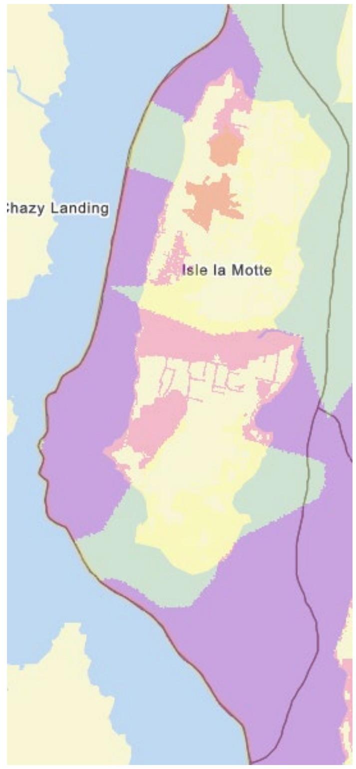
There is no public water supply system or centralized wastewater treatment plant on Isle La Motte. Properties on Isle La Motte get their water either from wells or by drawing water directly from Lake Champlain. Wastewater is treated directly on properties by septic systems. Drinking water infrastructure is vulnerable to impacts from erosion, flooding, and drought. Erosion, which can be caused by extreme precipitation events, can damage wells. Additionally, if floodwaters enter a drinking water source, chemicals and toxins in the floodwater could pollute the drinking water source. Drought impacts to drinking water supplies include loss of pressure in the supply system, general lack of water, increased water temperatures, and reduced water quality. Wastewater infrastructure such as septic systems is vulnerable to impacts from fluvial erosion and flooding, both of which can be caused by extreme precipitation events. Damaged septic systems can pose human and environmental health risks if the wastewater leaches improperly into the environment. Additionally, there are four toxic and hazardous sites located Isle La Motte. Flooding of toxic and hazardous sites could cause release of toxins or hazardous substances into nearby waterways, soils, and the surrounding environment.

Natural Environment Domain

Maintaining functioning natural environments can be one of the most effective climate mitigation measures. When natural environments are degraded, their ability to provide climate mitigation benefits for the surrounding area decreases, and as a result, the surrounding area can experience increased vulnerability.

Isle La Motte

The natural environment in Isle La Motte could be degraded due to direct changes (e.g., land-use changes), as well as changes caused by exposure to climate hazards such as flooding, extreme heat, and drought. These hazards increase risks to the important ecosystems found on Isle La Motte. Isle La Motte has many high priority ecosystems and species that many other regions of VT do not have, making it important to protect these natural environments from negative impacts of climate hazards and to preserve the important resilience benefits that these ecosystems provide. Isle La Motte has priority interior forest blocks, meaning that this area provides a foundation for interior forest habitat and associated ecological functions. Given that Isle La Motte experiences extreme heat and drought has regions with medium wildfire risk, these forest areas could be damaged or lost due to these climate hazards. Drought and heat often result increased stress to forests, increasing the risk of wildfire, invasive specifies, and diminishing the health of the forest.



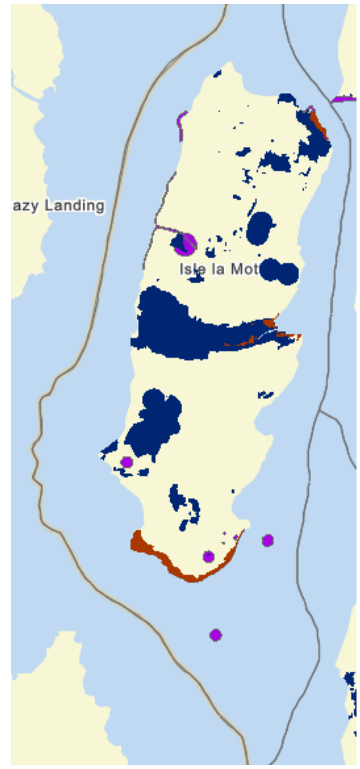


Figure 4 (left). The physical landscape diversity includes rare (orange) and representative (pink) areas.

Figure 5 (right). High priority natural communities (dark red), species (purple), and wetlands and vernal pools (dark blue).

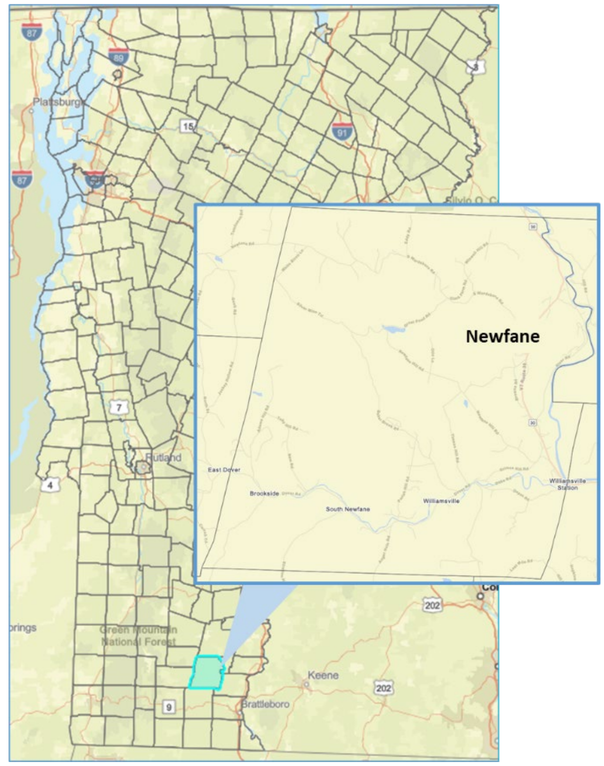
The unique geologic features found on Isle La Motte have made it an important and significant place for geological research. Fossilized rocks and other geologic features on Isle La Motte provide evidence that the region was a tropical ocean 450 million years ago and was home to the Chazy Reef Formation, which is considered to be the earliest biologically diverse coral reef on the planet. Given this unique history, a significant portion of Isle La Motte is classified as the highest priority for geologic diversity by Vermont Agency of Natural Resources. Ensuring these historic geologic features are preserved through climate hazard events is critical.

The rivers and streams running through Isle La Motte, as well as large areas in the northern, central and southern regions of the island, are classified as highest priority surface water and riparian habitats according to the Vermont Agency of Natural Resources as they provide habitat for aquatic species and other ecological functions. Isle La Motte also has wetlands, vernal pools, and species that are classified as highest priority, and there are areas classified with rare physical landscape diversity by Vermont Agency of Natural Resources. These areas can provide flood reduction benefits for Isle La Motte and therefore maintaining the health and functioning of these natural ecosystems should be prioritized. Drought and wildfire could damage these sensitive habitats. Drought could increase water temperatures, lower water quality, damage soil and vegetation, increase risk of contaminants entering the system, and increase vulnerability to invasive species, leading to habitat and species loss. Wildfires can lead to soil erosion because without vegetation cover the soil becomes less stable and more susceptible to erosion. Wildfires can also introduce areas for invasive species to outcompete native species and increase risks of drought and heat, as well reduce water, air, and soil quality. Additionally, wildfires can impact these ecosystems because animals rely on the vegetation for shelter, food, and breeding. On a small island like Isle La Motte that has rare and high priority species, these climate hazards could have significant long-term impacts on the habitats.

Newfane

Municipal Overview

Newfane is a rural area in Windham County with a population of 1,645 people. The town of Newfane includes the villages of Newfane, Williamsville, and South Newfane. It is located in the southeast part of Vermont.



Demographic Characteristics

The MVI considers demographic characteristics and social factors as they relate to climate change. The demographic characteristics listed below are above the state average and increase Newfane's vulnerability to the impacts of climate change:

- **Income.** 30% of residents are considered low-income
- **Elderly.** 22% of the population is aged 65 or older
- **Young residents.** 5% of the population are aged 5 and younger
- **Single-parent households.** 12% of households
- **Adult asthma.** 11% of population

Hazard Exposure

The MVI includes analysis of 13 climate hazards. When available, climate change projections were incorporated into the MVI. Reliable climate data were available for extreme precipitation, high temperatures, and low temperatures. When reliable climate change data were unavailable, the MVI relies on historical occurrence data. The list below describes the current, and where available, future potential climate hazard exposure for Newfane:

- **Drought.** Between the years 2000 and 2022, Newfane spent approximately 15.5 weeks per year, on average, in severe to exceptional drought. This average falls within the state average during the same period that ranged from approximately 10 weeks to approximately 18 weeks per year.
- **Extreme precipitation.** Defined as days with precipitation greater than 2 inches. Under the climate project scenario where abundant fossil fuel use continues and resource- and energy-intensive lifestyles are adopted around the world (SSP5-8.5), Newfane is projected to experience an increase of 0-2 days of extreme precipitation for 2015—2044, 1—3 days for 2045—2074, and 3—4 days for 2075—2100.[39]
- **Fluvial erosion.** The following rivers and brooks running through Newfane present a fluvial erosion hazard: Rock River, West River, Smith Brook, Wardsboro Brook, Adams Brook, Hunter Brook Baker Brook, and Marlboro Branch.
- **Hail.** Between 1955 and 2022, Newfane experienced an average of less than one hail event per year.
- **Ice storms.** Between 1996 and 2022, Newfane experienced an average of less than one ice storm event per year.
- **Invasive species.** Hemlock Woolly Adelgid is present on Wiswall Hill Road, River Road, Grout Road, and Newfane Hill Road, according to the Vermont Agency of Natural Resources.
- **Flooding.** Areas of Newfane along the Marlboro Branch, Rock River, West River, and Smith Brook are located within the FEMA-designated AE (1-percent annual chance floodplains with elevation) and A (1-percent annual chance floodplains without elevations) floodplains.

[39] This is based on the Fossil-fueled Development projection (SSP5-8.5). For additional information, see MVI user guide section 3.1 regarding climate projections.

- **Landslides.** According to the Vermont Agency of Natural Resources, four gully landslides, 10 landslides, and one landslide-gully complex landslides have occurred in Newfane.[40]
- **Snow storms.** On average, Newfane experienced 13 snow storms per year between 1996 and 2022. Overall, the season in which Vermont experiences snow events is expected to decline by at least to two weeks and up to a month between 2050 and 2070.
- **High temperature projections.** Under the Fossil-fueled Development (SSP5-8.5) projection for 2015-2044, Newfane is expected to experience 0-40 days above 90 °F per year, 20—60 days per year for 2045—2075, and 80—120 days per year for 2075—2100.
- **Low temperature projections.** Under the Fossil-fueled Development (SSP5-8.5) projection, Newfane is expected to experience 160—180 days below 32 °F per year for 2015-2044 and 2045-2074, and 120—140 days per year for 2075-2100.
- **Wildfire.** Newfane has very low to medium wildfire risk.
- **Wind risk.** On average, Newfane experienced 10 high wind events per year between 1996 and 2022.

Vulnerability and Resilience Factors

Newfane has several flagged factors[41] in the MVI in addition to the demographic characteristics noted above that influence its climate vulnerability, including:

- **Energy and transportation burden.** Approximately 12% of the median household income for Newfane is spent on energy and transportation costs (above state average), which increases vulnerability for those households. Families that spend a significant portion of their income on energy and transportation costs have fewer financial resources to prepare for or recover from a climate hazard event.
- **Toxic and hazardous sites.** There are 11 toxic and hazardous sites located within Newfane, with the most in the village of Newfane along VT Route 30. If toxins at these sites are released into the surrounding environment, toxins and contaminants could be mobilized due to storage and site closure issues. This mobilization could result in toxins and contaminants being sent to soils, nearby water sources and sensitive receptors such as nearby schools, playgrounds, and housing, increasing the risks from climate vulnerabilities in Newfane.
- **Emergency Relief and Assistance Fund (ERAF).** ERAF rate of 12.5%, indicating that four mitigation actions[42] have been adopted that could result in risk reduction to Newfane's assets and communities.

Vulnerability Analysis

Built and Physical Environment Domain

Newfane's built and physical environment is susceptible to a range of vulnerabilities from climate hazards. Under the climate project scenario where abundant fossil fuel use continues and resource- and energy-intensive lifestyles are adopted around the world (SSP5-8.5), Newfane is projected to experience an increase of 0-2 days of extreme

[40] This data set does not indicate the period of years that it covers.

[41] Flagged factors included in the MVI were selected based on factors that are not represented geospatially in the tool and that contribute to climate vulnerability. For additional information, see the MVI user guide.

[42] According to Flood Ready VT, "the ERAF provides State funding to match Federal Public Assistance after federally-declared disasters". The four mitigation measures that a community is required to take in order to receive an increased cost contribution from the State (12% of eligible costs) include: Participation or application to the National **Flood Insurance Program,** Adoption of **Town Road and Bridge Standards** that meet or exceed the 2013 template in the current: VTrans Orange Book: Handbook for Local Officials, **Adoption of a Local Emergency Management Plan**, and adoption of a FEMA-approved **Local Hazard Mitigation Plan (or have submitted a plan for** to FEMA Region 1 for review). Learn more at Flood Ready VT.

precipitation for 2015—2044, 1—3 days for 2045—2074, and 3—4 days for 2075—2100. Extreme precipitation is defined as days with over two inches of precipitation. An increase in extreme precipitation events in Newfane could cause flood exposure to critical assets located in or near the floodplain or in areas that areas that are at lower elevations. In the village of Newfane, there are residential dwellings (single- and multi-family homes), commercial buildings, a library, and mobile homes located in the FEMA AE (1-percent annual chance floodplains with elevation) and A (1-percent annual chance floodplains without elevation) floodplain (Figure 1). In the village of Williamsville, there are town-owned buildings, residential dwellings (single- and multi-family homes), commercial buildings, and a church located in the FEMA AE floodplain. South Newfane is also at risk to flooding due to the Rock River and Marlboro Branch running through it. There are a few structures in the FEMA AE floodplain, primarily residential homes. There are no hospitals or medical centers in Newfane; the closest medical center or health clinics are north of the village of Newfane in Townshend, or southwest of South Newfane, in Wilmington, VT. Residents of the village of Newfane might be unable to access the hospital in Townshend if State Route 30 (which runs north/south through the village of Newfane) is blocked due to flooding. Smith Brook runs through the village of Newfane and under Route 30 at two points and could block residents' access to medical services if flooded. The main road in Williamsville and South Newfane—Dover Road—is also vulnerable to inundation flooding as Rock River flows under it in at least two places. Extreme precipitation, snowmelt, and ice jams can also increase the likelihood of fluvial erosion, or streambed and streambank erosion associated with physical adjustment of stream channel dimensions (width and depth). The same areas that are vulnerable to flooding are also vulnerable to impacts from fluvial erosion. Impacts from fluvial erosion to Newfane's built and physical environment include damage to residential dwellings, critical assets, mobile homes, and town-owned buildings that are located in the river corridor.

Figure 1. Critical assets, mobile homes, commercial buildings, and residential dwellings in the village of Newfane within the FEMA National Flood Hazard floodplain.

Newfane currently experiences high temperatures and drought, both of which are expected to increase with climate change. Under the Fossil-fueled Development (SSP5-8.5) projection for 2015-2044, Newfane is expected to experience 0-40 days above 90 °F per year, 20—60 days per year for 2045—2075, and 80—120 days per year for 2075—2100.Critical assets such as schools and health clinics, emergency services such as fire stations, senior care facilities, pre-manufactured buildings, mobile home parks, and residential dwellings are all sensitive to high heat due to factors such as the use of lightweight building materials, less insulation, lack of high-heat-mitigating design features (such as ventilation), and being located in areas with higher temperatures such as in areas that experience urban heat island effect[43]. However, due to the fact that Newfane has high tree cover, and a low percentage of impervious surfaces, Newfane is not likely to experience significant impacts from urban heat island effect.

[43] Urban areas often have concentrated areas of roads, buildings, and other structures that absorb and re-emit heat from the sun more than natural landscapes such as forests. These urban areas become "islands" where temperatures are higher relative to other

Newfane

Newfane spent an average of approximately 15.5 weeks per year under severe to exceptional drought conditions between 2000 and 2022, households and others in Newfane who rely on wells for their primary water source are vulnerable to overdraft, subsidence, and decreased water quality as well as general water scarcity issues. Localized and seasonal drought can increase the risk of wells drying up.

Community Domain

Newfane is exposed to drought, extreme precipitation and fluvial erosion, hail, ice storms, flooding, snowstorms, and high and low temperatures. Newfane has adopted four ERAF mitigation actions. The ERAF provides state funding to match Federal Public Assistance after federally-declared disasters. If a municipality adopts over four mitigation actions, they are eligible for a higher percentage of reimbursement from the State. Newfane has adopted updated road and bridge standards, has a current Local Emergency Management Plan, participates in the National Flood Insurance Program, has a Local Hazard Mitigation Plan, and has implemented river corridor protection. Newfane also has a confirmed planning process and adopted land use regulations. While Newfane has taken some steps through ERAF mitigation actions and planning processes to improve overall resilience, Newfane has limited municipal staff and financial capacity and has one paid municipal staff.

Social Domain

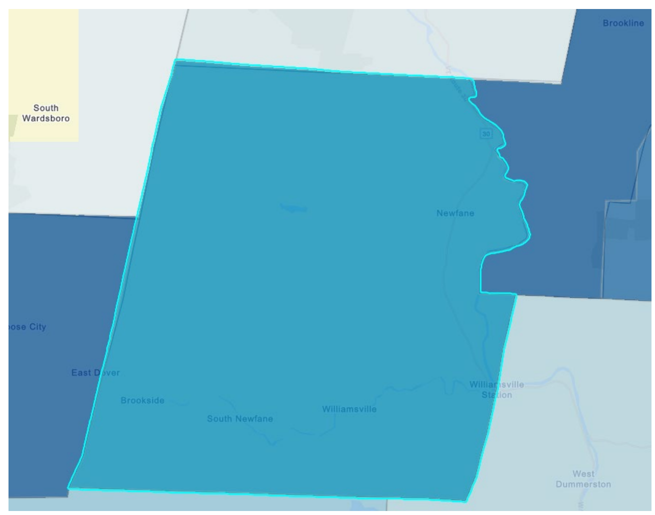


Figure 2. The percentage of Newfane's population which is considered low-income is 30.64% (turquoise), which is lower than some adjacent towns, but still above the state average.

Some of Newfane's demographic characteristics will likely increase the population's vulnerability to the impacts of climate change. Populations will be affected differently by climate hazards depending on their location within the town, the characteristics of their communities, individual factors, and the resilience and preparedness of their communities. Characteristics such as the cost burden for rental properties, single parent household, income, age, and pre-existing health conditions can make it difficult for individuals and households to prepare for, withstand, and recover from climate-change—related impacts. For example, exposure to extreme temperatures exacerbates existing health conditions such as asthma or other respiratory conditions, and 11% of adults in Windham County (in which Newfane is located) have adult asthma. Elderly populations are more susceptible to the effects of heat stress, which can exacerbate pre-existing cardiac conditions, and 22% of Newfane's population is aged 65 or older. Additionally, low-income populations in the United States and Canada have, broadly, been found to experience higher rates of high-temperature-related mortality, which could be due to factors such as residential location (e.g., in a heat island rather than surrounded by trees), lack of air conditioning, inability to maintain condition of housing, and lack of health insurance. Over 30% of the population in Newfane is considered low-income (Figure 2), which is above the state average, increasing Newfane's vulnerability to climate change. Over 12% of Newfane's households are considered single parent households, which is above the state average. Single parent households are more vulnerable to climate

areas; these areas of concentrated higher heat are referred to as "heat islands". Source: https://www.epa.gov/heatislands/learn-about-heat-islands change due to factors including access to safe and reliable housing, cost burden, income, and the difficultly such households have in preparing and responding to disasters.

Economic and Job Domain

The MVI includes data about the percentage of outdoor workers and tourism industry to create a picture of economic sectors and jobs that may be vulnerable to climate change impacts. According to the U.S. Census Bureau, approximately nine percent of the employed civilian population aged 16 years or older in Newfane is employed in an outdoor occupation (e.g., farming; fishing and forestry; or construction, extraction, and maintenance). The outdoor worker population is most vulnerable to the effects of high and low temperatures, and extreme precipitation. These climate hazards could impact this population's ability to access or perform their jobs and increase their risk of health impacts such as heat stroke or exhaustion if they are working outside during extreme heat. In addition, the projected overall changes in the climate (e.g., increased extreme precipitation and temperatures) may impact the success of these industries in the future. Flooding that disrupts access to workplaces, commercial areas or small businesses—or a climate hazard event that damages or results in loss of businesses can have significant economic impacts on Newfane and its residents. Workers without access to leave, day workers and gig workers are at risk of losing their pay and their jobs depending on the extent of the damage or loss. There are multiple small farms in Newfane which could be impacted by prolonged drought conditions and periods of extreme heat. These conditions could have a negative impact on crops and livestock that farmers are raising. Changing growing periods due to variability in frost events and the timing of regular seasons could also impact a farm's productivity, therefore having negative impacts on farmers' livelihoods.

Infrastructure Domain

Roads, electric substations, and power lines in Newfane are vulnerable to impacts from high temperatures. Asphalt softens under high temperatures, which can damage the integrity of roads and cause them to buckle and shorten the service life of the roadways requiring more maintenance work. Conversely, freeze-thaw cycles deteriorate concrete and pavement and shorten their lifecycles. With climate change, freeze-thaw cycles are happening earlier in the spring, putting a strain on municipal resources for road maintenance and damaging roads. Roads, bridges, and culverts are vulnerable to flooding and fluvial erosion. There are 9 bridges in Newfane that are within the FEMA designated AE (1-percent annual chance floodplain with elevations) floodplain (Figure 3). These bridges are also located in the river corridor, making them vulnerable to flooding and fluvial erosion. Additionally, if these bridges are damaged or blocked due to floodwaters, it could limit or eliminate residents' access to emergency services such as hospitals.[44] There is an electric substation just south of the village of Newfane. While the substation

Figure 3. Bridges (green dots) in Williamsville and South Newfane villages located within the FEMA designated AE (1-percent annual chance floodplain with elevations) floodplain.

[44] The Transportation Resilience Planning Tool data (developed by the Vermont Agency of Transportation and available directly in the MVI) provides additional analysis that can further inform a transportation sector vulnerability analysis to flooding.

is not located in the floodplain, there are bridges and roads on either side of substation that are vulnerable to flooding. If utility workers needed to access the substation during or after an extreme weather event, they might be unable to if these roads and bridges are flooded or washed out.

There is no public water supply system or centralized wastewater treatment plants in Newfane. Residents and businesses get their water from wells. For wastewater management, people rely on septic systems to hold and treat their wastewater. Wells are vulnerable to impacts from flooding and drought. If floodwaters enter a drinking water source, toxins and chemicals that are often mobilized by floodwaters could enter the well. Conversely, drought impacts to wells include loss of pressure, general lack of water, increased water temperature, and reduced water quality. Septic systems are vulnerable to impacts from fluvial erosion and flooding, both of which can be caused by extreme precipitation events. Damaged septic systems can pose human and environmental health risks if wastewater is released into the environment. There are 11 toxic and hazardous sites located within Newfane, with the most of them located in the village of Newfane along VT Route 30. If toxins and contaminants at these sites are released into the surrounding environment, these substances could be mobilized due to storage and site closure issues. This mobilization could result in toxins and contaminants being sent to soils, nearby water sources and sensitive receptors such as nearby schools, playgrounds, and housing, increasing the risks from climate vulnerabilities in Newfane.

Natural Environment Domain

A healthy natural environment is one of the best resilience measures that a community can take to reduce risks from climate change. Healthy forests, wetlands, urban green spaces, parks, and trees provide urban cooling against extreme heat and urban heat island effect; flood risk reduction by slowing and storing water during extreme precipitation events; reduce risks from wildfires and invasive species and provide clean air and clean water, including better resilience from drought events, particularly seasonal and localized droughts. Connectivity between natural areas and larger stands of healthy natural areas that include protected, natural wetlands are the best at providing climate risk reduction. Newfane is considered a rural area and has multiple protected areas ranging from state land trust easement areas to town forests and conservation areas. The majority of Newfane is forested and covered by priority and highest priority interior forest blocks (Figure 4). These are important areas for habitat connectivity, biodiversity, and ecological functions and climate benefits. Given that the entirety of Newfane is exposed to high heat and drought, this forested land cover will provide the adjacent areas of Newfane with reduced head and drought. However, extreme heat and drought could also have significant impacts on these important habitat areas as drought and heat can increase wildlife risk, make forest ecosystems more susceptible to invasive species, and diminish forest health overall. Newfane also has a high

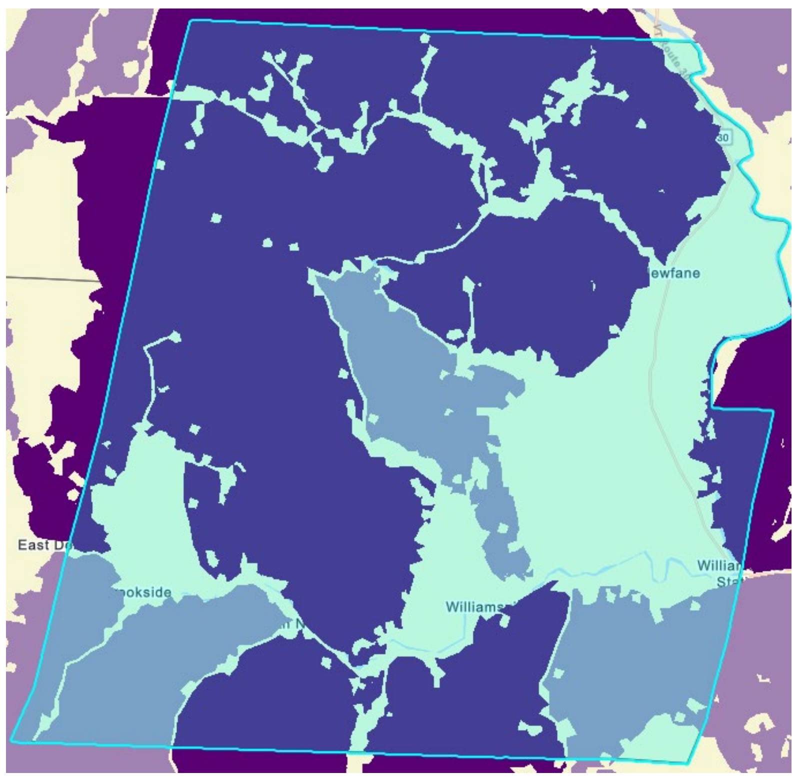


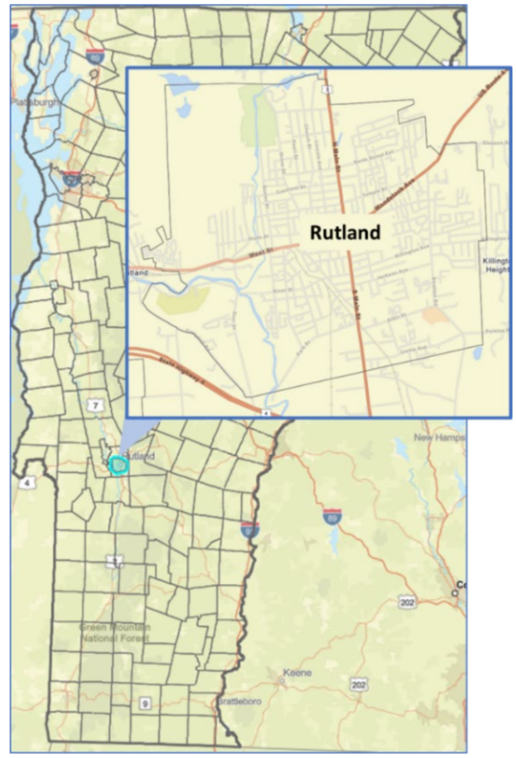
Figure 4. Much of Newfane's land cover is classified as highest priority (dark purple) or priority (light purple) interior forest block. The blue highlight covers the outline of the town.

number of highest priority riparian habitats. These habitats are also vulnerable to impacts from extreme heat and drought as a lack of water and high heat could reduce ecosystem function and diminish habitat quality in these areas. Flooding, fluvial erosion, and extreme precipitation could also cause damage to riparian habitats by physically altering the habitats if a significant erosion or flooding event were to occur. Preserving and enhancing these rivers and streams, increasing tree cover and native vegetation in the buffers where/if needed will reduce Newfane's risks from drought, heat, flooding, and wildfire. There are at least five toxic or hazardous sites located in the floodplain in Newfane. If these sites were to be exposed during a flood event, these substances could mobilize and enter soils, vegetation, and waterways damaging the ecosystems and habitats and potentially public health and safety.

While the healthy natural environments increase resilience of cities and towns in Vermont, it is also important to note that natural areas can be damaged and degraded from climate change, making management and restoration important tools for ensuring that Newfane's benefits from healthy natural areas are not lost, but protected and enhanced. Designing management and restoration to reduce risks from erosion from extreme precipitation, drought effects, contamination from flood events, and habitat loss and shift from extreme heat and invasive species will be critical to Newfane's overall resilience in the future.

Rutland City

Municipal Overview



The City of Rutland is an urban area with a population of 15,207 people. It is in the southern part of central Vermont, just west of the Green Mountain National Forest.

Demographic Characteristics

The MVI considers demographic characteristics and social factors as they relate to climate change. The demographic characteristics listed below are above the state average for the stated characteristic and increase the community of Rutland's vulnerability to the impacts of climate change:

- **Income:** 26.83% of residents are considered low-income
- **Elderly:** 21.46% of population
- **Disability:** 19.89% of the population has at least one disability
- **Single-parent households:** 11.72% of households
- **Linguistically isolated[45]:** 0.54% of the population
- **Race and ethnicity**: Percent of population that are:
  - Black or African American: 1.28%
  - Hispanic or Latino: 1.93%
  - Two or more races: 2.56%
- **Adult asthma:** 12% of population

Hazard Exposure

The MVI includes analysis of 13 climate hazards. When available, climate change projections were incorporated into the MVI. Reliable climate data were available for extreme precipitation, high temperatures, and low temperatures, climate change projections. When reliable climate change data were unavailable, the MVI relies on historical occurrence data. The list below describes the current, and where available, future potential climate hazard exposure for Rutland:

- **Drought.** Between the years 2000 and 2022, Rutland spent approximately 18 weeks per year, on average, in severe to exceptional drought. This falls at the top end of the state average during the same period that ranged from approximately 10 weeks to approximately 18 weeks per year.
- **Extreme precipitation.** Extreme precipitation is defined as days with precipitation greater than 2 inches. Under the climate project scenario where abundant fossil fuel use continues and resource- and energy-intensive lifestyles are adopted around the world (SSP5-8.5), Rutland is expected to experience an increase of 0-1 days of extreme precipitation for 2015-2044, and 1—2 days for 2045—2074 and 2075—2100. [46]
- **Fluvial erosion.** Otter Creek, East Creek, and Tenny Brook run through the city of Rutland, which could present a fluvial erosion hazard.
- **Hail.** Between 1955 and 2022, Rutland experienced an average of 2 hail events per year. Climate projections for how hail will change are not available in this iteration of the MVI.
- **Ice storms.** Between 1996 and 2022, Rutland experienced, on average, less than one ice storm per year.

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[45] Linguistic isolation is a term used by the U.S. Census Bureau for limited English speaking households: https://www.census.gov/library/working-papers/2007/adrm/ssm2007-02.html.

[46] This is based on the Fossil-fueled Development projection (SSP5-8.5). For additional information, see MVI user guide section 3.1 regarding climate projections.

- **Invasive species.** The Agency of Natural Resources maps invasive species on ANR-owned land in the State. There is no ANR-owned land in Rutland City and therefore no invasive species are mapped in the area.
- **Flooding.** Areas of the city near Otter Creek, East Creek, and Tenny Brook are located within flood zones ranging from the Lake Champlain Basin Flood inundation flood mapping 2-year flood zone (50% annual exceedance) to the 500-year flood zone (0.02% annual exceedance). Areas around Otter and East Creeks are also within the FEMA-designated AE flood zone (1% annual chance floodplains with elevations).
- **Landslides.** No landslides have been recorded in Rutland.
- **Snow storms:** On average, Rutland experienced 13 snow storms per year between 1996 and 2022. Overall, the season in which Vermont experiences snow events is expected to shorten by two weeks to a month between 2050 and 2070.
- **High temperature projections.** Under the Fossil-fueled Development (SSP5-8.5),Rutland is expected to experience 0—20 days above 90 °F per year for 2015—2044, ; 40—60 days for 2045—2075, and 80—100 days for 2075—2100.
- **Low temperature projections.** Under the Fossil-fueled Development (SSP5-8.5) projection, Rutland is expected to experience 210—1240 days below 32 °F per year for 2015—2044 and 2045—2074, and 0—120 days for2075—2100.
- **Wildfire.** Rutland has very low to low wildfire risk.
- **Wind risk.** On average, Rutland experienced 13 high wind events per year between 1996 and 2022.

Vulnerability Factors

Rutland has several factors flagged[47] in the MVI in addition to the demographic characteristics noted above that increase its climate vulnerability, including:

- **Aging housing stock.** Less than 6% of homes were built after the year 2000 (above state average). The vulnerability of housing to climate change can vary greatly based on housing materials, construction methods, and maintenance. Older homes are often more at risk of damage or loss.
- **Housing cost burden (renting)**. 23% of Rutland's population is experiencing cost burden associated with rentership, meaning their rent is 50% or more of household income (above state average). Housing affordability is an important determinant of health and well-being and can put families at an increased risk to climate change impacts because families that spend a significant portion of their income on housing costs have fewer financial resources to prepare for or recover from a climate hazard event.
- **Toxic and hazardous sites.** 191 toxic and hazardous sites located within Rutland, with many clustered around South Main Street, West Street, Woodstock Avenue, and surrounding streets. If exposed to flooding and not properly stored or closed, these toxic and hazardous sites can result in the mobilization of materials to soils, water sources and sensitive receptors such as nearby schools, playgrounds, and housing.
- **Vehicle access.** 13% of households do not have access to a vehicle (below state average). Access to a vehicle can be critical to evacuate or access resources before, during, or after a climate hazard event. While vehicle access below the state average reduces the overall risk to Barton, there is an increased risk to these households.
- **Internet access.** 18% of households do not have internet access (below state average). Access to the internet can be critical to receive information before, during, or after a climate hazard event. Internet disruptions can increase climate vulnerability by preventing people from accessing important information that can help them safely manage a climate hazard event.
- **Emergency Relief and Assistance Fund (ERAF).** ERAF rate of 7.5%, indicating that fewer than four of the hazard mitigation actions required for increased State contributions to eligible public costs following federally-declared

[47] Flagged factors included in the MVI were selected based on those that are not represented geospatially in the tool and that contribute to climate vulnerability. For additional information see the MVI User Guide.

disasters have been adopted. [48] The adoption of additional mitigation measures could result in risk reduction to Rutland's assets and communities.

Vulnerability Analysis

Built and Physical Environment Domain

Rutland's built and physical environment is susceptible to a range of vulnerabilities from critical climate hazards. On one end of the spectrum, the city could receive extreme precipitation—Rutland is predicted to experience an increase of approximately one day of extreme precipitation per year according to the SSP5-8.5 projection for 2015-2044. Extreme precipitation events over multiple days is the cause of much of Vermont's recent flooding and an additional day could significantly increase the depth, duration, and areas of affected by flooding. Extreme precipitation can overwhelm stormwater systems and culverts, increase the mobilization of contaminants and toxics, and increase damage and disruption to critical assets due to deterioration, mold, leaks, and other common impacts. Older buildings inconsistently maintained buildings, pre-manufactured buildings, and historic buildings are often more at risk to these vulnerabilities. Extreme precipitation could also lead to inundation flooding.

Figure 1. Health clinics (green), schools (red), commercial buildings (purple), residential buildings (red), and mobile homes (light blue) located in the river corridor (light green).

Inundation flooding results in damage, disruption, and loss of critical assets, including emergency services, homes—including mobile homes—schools, and other assets that support public health, safety, and well-being. Based on the likelihood of exposure in Rutland, inundation flooding could prevent residents located on the west side of Rutland from accessing the Rutland Medical Center located on the east side if South Main Street (State Route 7). The southwest corner of Rutland (which encompasses Otter and East Creeks and Moon and Mussey Brooks) holds the highest risk for inundation flooding in Rutland (Figure 1). Flooding in this area would be of high consequence to assets in the built and physical environment as mobile homes (Figure 2), multi-family, and single family dwellings, commercial buildings, a community center, and schools are in the FEMA-designated AE (1-percent annual chance floodplain with elevations) flood zone, as well as the

[48] According to Flood Ready VT, "the ERAF provides State funding to match Federal Public Assistance after federally-declared disasters". The four mitigation measures that a community is required to take in order to receive an increased cost contribution from the State (12% of eligible costs) include: Participation or application to the National Flood Insurance Program, Adoption of Town Road and Bridge Standards that meet or exceed the 2013 template in the current: VTrans Orange Book: Handbook for Local Officials, Adoption of a Local Emergency Management Plan, and adoption of a FEMA-approved Local Hazard Mitigation Plan (or have submitted a plan for to FEMA Region 1 for review). Learn more at Flood Ready VT.

Rutland City

Lake Champlain Basin Flood zones ranging from the 2-year flood zone (50% annual exceedance) to the 200-year flood zone (.05% annual exceedance).

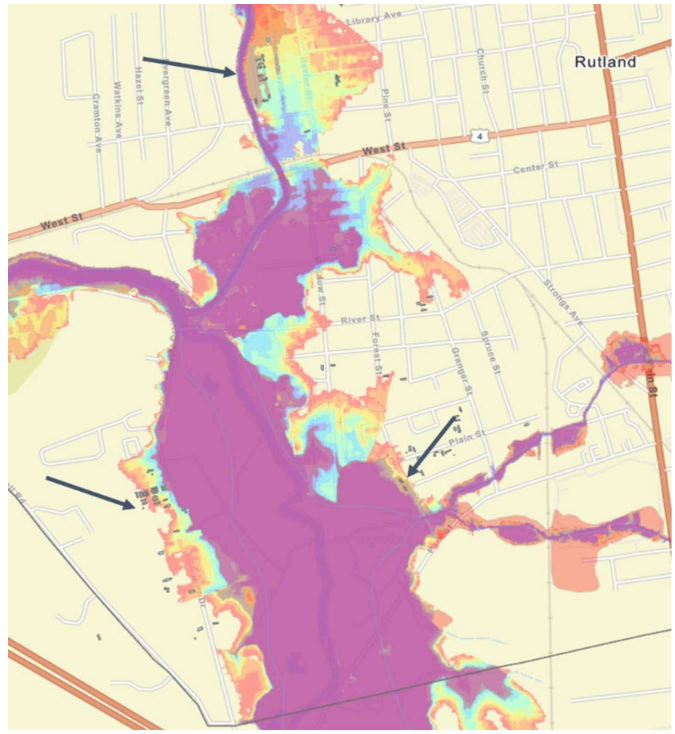

Figure 2. Mobile homes in southwest Rutland within the FEMA National Flood Hazard and Lake Champlain Basin Flood Inundation floodplains.

Extreme precipitation, snowmelt, and ice jams can also increase the likelihood of fluvial erosion, or streambed and streambank erosion associated with physical adjustment of stream channel dimensions (width and depth). Fluvial erosion can damage critical assets, emergency services, mobile parks, and residential dwellings sited in or near the river corridor. In urban areas, creeks and waterways are more likely to be channelized, which can increase the speed of river flows and result in bank erosion and increased flood risk downstream. In Rutland, there are health clinics, schools, commercial buildings, residential buildings (single and multi-family dwellings), and mobile homes located in river corridors, putting them at risk to impacts from fluvial erosion and river channel migration.

Rutland currently experiences high temperatures and drought, which will likely increase with climate change. Given that the entire city of Rutland is projected to be exposed to the same level of high heat (40-60 days above 90° per year, based on the Fossil-fuel Development [SSP5-8.5] projection), with a tipping point around 2045, critical assets such as schools and health clinics, emergency services such as fire stations, law enforcement buildings and ambulance services, senior care facilities, warehouses, pre-manufactured buildings, and mobile home parks and residential dwellings will be exposed to high heat. Older and inconsistently maintained buildings, historic buildings, buildings without access to air conditioning, and buildings in parts of Rutland without vegetation or tree cover are most vulnerable to extreme heat. Areas within Rutland may experience high heat differently based on land uses and land cover, with areas that are predominantly covered by impervious surfaces and little vegetation being most exposed to what is known as the urban heat island effect.[49]

High temperatures can also lead to drought. Localized and seasonal drought can increase the risk of wells drying up. Given that Rutland spent an average of approximately 17 weeks per year under severe to exceptional drought conditions between 2000 and 2022, households and others in Rutland who rely on wells for their primary water source are vulnerable to overdraft, subsidence, and decreased water quality as well as general water scarcity issues.

Community Domain

Rutland's designated downtown and neighborhood development areas are vulnerable to each of the high consequence climate hazards described in this profile. The City of Rutland has adopted fewer than four ERAF mitigation actions. The ERAF provides State funding to match Federal Public Assistance after federally-declared disasters. If a city adopts over

[49] Urban areas often have concentrated areas of roads, buildings, and other structures that absorb and re-emit heat from the sun more than natural landscapes such as forests. These urban areas become "islands" where temperatures are higher relative to other areas; these areas of concentrated higher heat are referred to as "heat islands". Source: https://www.epa.gov/heatislands/learn-about-heat-islands

four mitigation actions, they are eligible for a higher percentage of reimbursement from the State. Rutland has a Local Emergency Management Plan and participates in the National Flood Insurance Program but has not undertaken other actions such as adopting 2013 Road and Bridge Standards, and the City's Local Hazard Mitigation Plan is expired. Because Rutland has adopted less than four ERAF mitigation measures, the State of Vermont will contribute 7.5% of the total cost of disaster recovery. Rutland's resilience, and ability to navigate climate vulnerability are improved by the fact that the city has municipal capacity in the form of at least one paid municipal staff person, along with a confirmed planning process or land use regulation.

Social Domain

Some of Rutland's demographic characteristics can increase the population's vulnerability to the impacts of climate change. Populations will be affected differently by the climate hazards depending on their location within Rutland, the characteristics of their communities, individual factors, and the resilience and preparedness of their communities. Characteristics such as the cost burden for rental properties, single parent household, income, linguistic isolation, age, and pre-existing health and disability can make it difficult for individuals and households to prepare for, withstand, and recover from climate-change—related impacts. For example, exposure to extreme temperatures exacerbates existing health conditions such as asthma or other respiratory conditions. Elderly populations (Figure 3) are more susceptible to the effects of heat stress, which can exacerbate pre-existing cardiac conditions. African American, Hispanic and Latino, and Multiracial populations are known to experience disparate access to health care (including physical and mental healthcare), and therefore are more vulnerable to the health impacts of extreme heat or flooding. Additionally, low-income populations in the United States and Canada have, broadly, been found to experience higher rates of high-temperature—related mortality—this could be due to factors such as residential location (e.g., in a heat island rather than surrounded by trees), lack of air conditioning, and lack of health insurance.

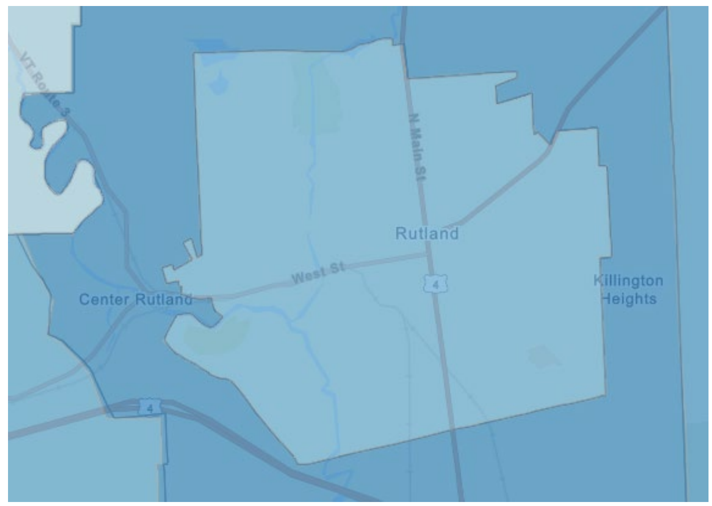

Figure 3. The percentage of Rutland City's population considered elderly is 21.46% (light blue) which is lower than the surrounding Rutland Town's percentage of 24.77% (darker blue surrounding Rutland City; covering areas such as Center Rutland and Killington Heights).

Populations that are linguistically isolated are vulnerable to climate change impacts as they may have limited access to hazard warnings or to access information on how to prepare for or recover from a disaster. People with disabilities are more vulnerable to climate change impacts if hazard preparations are not designed to be inclusive and accessible, and they may need ongoing medical care that can be difficult or impossible to access during some extreme events (such as power outages or flooding), in addition to other factors.

Economic and Job Domain

The MVI maps percentage of outdoor workers and tourism industry to create a picture of economic sectors and jobs that may be vulnerable to climate change impacts. According to the U.S. Census Bureau, over six percent of the employed civilian population aged 16 years or older in Rutland is employed in an outdoor occupation (e.g., farming, fishing and forestry, or construction, extraction and maintenance). The outdoor worker population is most vulnerable to the effects of high and low temperatures, and extreme precipitation. These climate hazards could impact this population's ability to access or perform their jobs and increase their risk of health impacts such as heat stroke or exhaustion if they are working outside during extreme heat. In addition, the projected overall changes in the climate (e.g., increased extreme precipitation and temperatures) may impact the success of these industries in the future. Flooding that disrupts access to workplaces, commercial areas, or small businesses—or a climate hazard event that damages or results in the loss of businesses—can have significant economic impacts on Rutland and its residents. Rutland has commercial and accessory buildings located in the floodplain, with the highest concentration of these building located just south of West Street (State Route 4) where Otter Creek branches off to East Creek. Workers without access to leave and day workers and gig workers are at risk of losing their pay and their jobs depending on the extent of the damage or loss.

Infrastructure Domain

Roads, railroads, drinking water infrastructure, electric substations, power lines, and wastewater infrastructure in Rutland are vulnerable to high temperatures. Asphalt softens under high temperatures, which can damage the integrity of roads and cause them to buckle, shortening the service life of the roadways requiring more maintenance work. Conversely, freeze-thaw cycles deteriorate concrete and pavement and shorten their lifecycles. With climate change, freeze-thaw cycles are happening earlier in the spring, putting a strain on municipal resources for road maintenance and also damaging roads. Roads and paved surfaces contribute to urban heat island effects. Railroad tracks can buckle and bend under extreme heat, which could impact the Amtrack line that runs through the city.

Drought impacts to drinking water supplies include loss of pressure in the supply system, general lack of water, increased water temperatures, and decreased water quality. Reduced public water supply could increase reliance on groundwater, reduce the quality of the remaining groundwater, and possibly affect future water supplies.

During periods of extreme precipitation, bridges and roads located near or above rivers and waterways are vulnerable to flooding. Culverts are at risk of being overtopped or blocked by woody debris, leading to culvert failure and an increased risk of flood exposure and depth, as well as bank erosion in the area above the blockage. There are nearly 30 culverts in Rutland, located on Tenney Brook, Moon Brook, and other smaller tributaries. Some culverts are located under South Main St (US Route 7), which is a major roadway running north/south in Rutland. If culverts under this road fail or are blocked, the resulting flooding or damage to the road in this area could block residents of the western part of Rutland from accessing key services in the east side of Rutland such as the Regional Medical Center, other health clinics, and schools.[50]

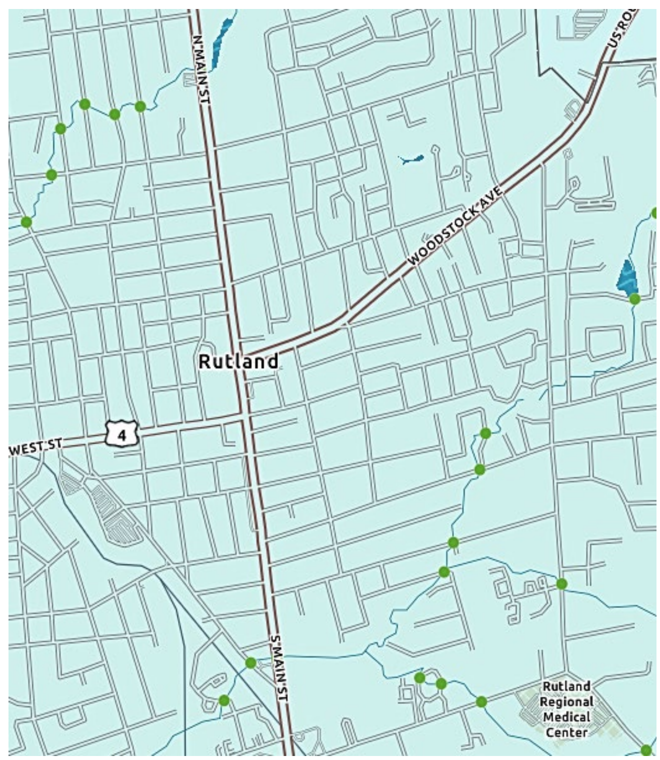

Figure 4. The map area represents the area could experience an additional day of extreme precipitation under the Fossil-fueled Development (SSP5-8.5) projection for 2015-2044. The green dots on the map indicate culverts that could be at risk from the impacts of extreme precipitation events.

Extreme precipitation can also lead to fluvial erosion, which would damage to the roads, bridges, culverts, drinking water

[50] The Transportation Resilience Planning Tool data (developed by the Vermont Agency of Transportation and available directly in the MVI) provides additional analysis that can further inform a transportation sector vulnerability analysis to flooding.

infrastructure, electric substations, and powerlines located in the river corridor (Figure 4). For example, West Street (Business Route 4) passes over East Creek; if the creek were to experience a significant erosion event at this area, the road could washout. Rutland has a high number of impervious surfaces (e.g., buildings, paved areas, railroads, roads, and compacted soils). Impervious surfaces are unable to absorb precipitation, leading to increased runoff that overwhelms storm drain systems and allows pollutants from roads, lawns, and fields to enter waterways. There are roads, bridges, culverts, drinking water infrastructure, electric substations, powerlines, and wastewater infrastructure located in Rutland's floodplains. One wastewater facility in Rutland is located in the floodplain (FEMA 1-percent chance annual floodplain with elevation, and the Lake Champlain Basin Flood mapping 500-year flood zone [.02% annual exceedance]).

Natural Environment Domain

A healthy natural environment is one of the best resilience measures that a community can take to reduce risks from climate change. Healthy forests, wetlands, urban green spaces, parks, and trees provide urban cooling against extreme heat and urban heat island effect; flood risk reduction by slowing and storing water during extreme precipitation events; reduce risks from wildfires and invasive species and provide clean air and clean water, including better resilience from drought events, particularly seasonal and localized droughts. Connectivity between natural areas and larger stands of healthy natural areas that include protected, natural wetlands are the best at providing climate risk reduction. Given the urban nature of Rutland, the natural environment itself in Rutland has a limited set of vulnerabilities but should be viewed as a way to mitigate impacts to the city itself. Climate hazards such as drought, extreme precipitation, flooding, and high temperatures could, increase risks to the city itself and the natural areas surrounding Rutland. The northwest corner of Rutland contains a highest priority interior forest block, meaning that this area provides a foundation for interior forest habitat and associated ecological functions and climate benefits. Pine Hill Park is included in portions of this forest block area. Given that the entirety of Rutland is exposed to drought and high heat, this forested land cover will provide the adjacent areas of Rutland with reduced heat and drought. Building off of this area and building greening into the more urban areas of Rutland could enhance these benefits, as well as increase biodiversity and habitat connectivity. The southeast corner of Rutland contains a portion of a highest priority landscape-scale connectivity block, which contributes to landscape and habitat connectivity and the protection of this area should be coordinated with neighboring towns. The rivers and streams running through Rutland are highest priority surface water and riparian habitats as they provide habitat for aquatic species in addition to other ecological functions. Otter Creek has been the focus of restoration efforts resulting in the mitigation of flooding impacts on downstream communities. Preserving and enhancing these rivers and streams, increasing tree cover and native vegetation in the buffer where/if needed will reduce Rutland's risks from drought, heat, flooding, and wildfire. Drought and flooding alike could also damage these in-stream and riparian habitats. Drought could increase water temperatures, lower water quality, damage soil and vegetation, increase risk of contaminants entering the system, and increase vulnerability to invasive species, leading to habitat and species loss. Extreme precipitation could cause flooding that could lead to severe erosion, which could also damage in-stream and riparian habitats. Extreme precipitation could also generate impacts related to the toxic and hazardous sites located in Rutland. For example, if a site has contaminated soils or is storing toxic or contaminated material, an extreme precipitation event could mobilize these toxics and contaminants, and distribute them to soils, vegetation, and waterways.

While the importance of a healthy natural environment to Rutland's resilience is the primary purpose of this slide, it is also important to note that natural areas can be damaged and degraded from climate change, making management and restoration important tools for ensuring that Rutland's benefits from healthy natural areas are not lost, but protected and enhanced. Designing management and restoration efforts to reduce risks from erosion from extreme precipitation, drought effects, contamination from flood events, and habitat loss and shift from extreme heat and invasive species will be critical to Rutland's overall resilience in the future.

4. Lessons Learned and Recommendations for Future Iterations of the MVI

4.1 Lessons Learned

The process to develop the MVI yielded a number of lessons learned that can be applied to development of similar tools in the future as well as updates to the next iteration of the tool. Key takeaways from the tool development process include:

- **Reviewing existing, relevant tools served a pivotal purpose.** Beginning the tool development process by reviewing existing geospatial tools helped provide a foundation to better understand what type of tool might be of interest (e.g., features, functions, aesthetics), the type of data or data limitations that might be a consideration, and the type of tool alignment that might be needed across state tools. This effort was also critical in helping develop a draft set of climate vulnerability factors to consider including in the tool. The overall process was key in helping gain further alignment on the vision for the final MVI.
- **Gathering input on the tool development process from potential tool users was a critical step in developing the tool and informing considerations for its use.** By engaging with tool users, ERG and the VT state team were able to better understand the factors of climate vulnerability that were of greatest interest to tool users, how the tool might be used and by whom, types of features and functions that were most important to tool users, and potential challenges or barriers to adopting the tool. The resulting information helped inform a tool that speaks to climate vulnerabilities of interest and is user-friendly. It also suggested the need for tool user training, which ANR subsequently began organizing, starting with regional planning commission trainings that will follow tool finalization and the development of this report.
- **Data availability shaped tool content.** The availability of Vermont-specific data at the appropriate scale determined what climate hazards and climate vulnerability factors could be geospatially included in the tool and how that information could be displayed.
- **Learning from other tool developers provided helpful tool considerations.** Working with the Agency of Digital Services and talking with developers of other related tools helped inform tool development considerations, such as areas of alignment across state tools, available data, and hosting and server considerations.
- **Training will help increase use of the MVI.** Since the tool will have a variety of users with varying levels of experience using geospatial tools, training will help increase user capacity and understanding of the MVI and further promote tool use. Based on this understanding, ERG will conduct a preliminary tool training with regional planning commissions, and the VT state team is planning additional tool training and follow-up after the conclusion of this project.
- **Future customization will improve user experience.** While using the standard features in Experience Builder allowed the MVI tool to be developed efficiently, additional tool customization that extends beyond these standard features could help improve the tool user’s experience. For example, additional customization can help address some tool functions, features, and useability concerns raised by tool testers (described further in the section below).

4.2 Considerations and Recommendations for Future Tool Updates

Considerations for future tool updates stemming from the tool development and testing process as well as presentations on the final tool include:

- **Update tool functions and features**. Possible changes or additions include:
  - Custom legend for layers that allows users to rename sub-layers or organize information differently (e.g., ability to reorganize map layers).
  - Include additional pre-packaged exercises or "quick view" combinations of preselected layers to understand how to effectively use the tool.
- **Determine the number and type of preferred data layers**. While several tool testers would like some data layers removed to simplify the tool and its use (specific data layers were not named), others recommended additional data layers to include, such as:
  - Utility outage data and statistics for various timeframes.
  - Centers for Disease Control and Prevention Social Vulnerability Index data.
  - Other health indicators, aside from adult asthma.
  - Ability to select sub-options for internet access, including fiber, cable/copper, and cellular.
  - Moderate income data.
  - Dams.
  - Drinking water source type.
- **Consider refinements to current data.** Considerations for updating or refining types of data already included in the tool include:
  - Adjust temperature threshold for high heat from 90 °F to 87 °F for greater alignment with heat warnings determined by the National Oceanic and Atmospheric Administration (NOAA).
  - Parse different types of droughts to align with drought classification from the U.S. Drought Monitor.
  - Compare NOAA and Federal Emergency Management Administration (FEMA) floodplain data and consider differences and appropriateness of each source in assessing community vulnerability to flooding hazards.
  - Include updated landslide data. The Vermont State Geologist has applied for a grant to compile a full landslide inventory for the state and then use it along with several other data sets (including the new Light Detection and Ranging (LiDAR) data) to perform a landslide susceptibility modeling exercise. If funded, the project would be finalized in 2026–2027 and could be incorporated into the MVI.
- **Continue to collect input on climate vulnerability factors.** To help ensure the climate vulnerabilities included in the MVI reflect the priorities and perspectives of tool users, it could be beneficial to gather additional input on the tool factors prior to updating the tool. Input could

include another round of tool user engagement prior to updating the MVI and/or collecting tool input from users over time as the tool is implemented.

Appendix A: MVI User Guide

Vermont Municipal Vulnerability Index Tool User's Guide

May 6, 2024

Table of Contents

Definitions and Acronyms

Definitions

Term	Definition
Climate exposure	Assets or communities that are exposure to climate hazards. For example, critical assets in the FEMA flood hazard zone are exposed to flooding.
Climate hazard	Climatic or environmental hazards that could cause harm to people, the environment, and physical and non-physical assets and services, including public and private property. Climate hazards may also be referred to as "hazards" in the user guide or MVI for brevity.
Climate resilience	The capacity of a community, business, or natural environment to prevent, withstand, respond to, and recover from a disruption.[b]
Climate scenarios	Different pathways scientists use to project future climate change outcomes. Each pathway has a different narrative about how global security, demographics, and economics might change over time.
Climate 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.[a]
Domain	Categories of assets and services, often known as sectors, including built and physical environment, economy and jobs, natural environment, and society and community.
Factor	Characteristics within domains that influence vulnerability to climate change. For example, people over 65 or under 5 are more vulnerable to most hazards, including extreme heat and flooding, two hazards that are projected to increase in Vermont. Another example is that tree cover and pervious surfaces can decrease risks from extreme precipitation, flooding, and extreme heat.
Flagged Factor	Flagged factors are those factors that are not represented geospatially in the tool and contribute to climate vulnerability or resilience.
Hazard / Climate hazard	Climatic or environmental hazards that could cause harm to people, the environment, and physical and non-physical assets and services, including public and private property. The term "climate hazard" I al
Layer	Geospatial data displaying each factor on the map.
MVI Users	The primary users of the MVI are municipalities, state agency staff, regional planning commissions (RPCs), non-governmental organizations, and community groups
Written Narratives	Short summaries of the vulnerabilities that do not currently have data that can be mapped in the MVI.

[a] Brooks, 2003. https://www.ipcc.ch/apps/njlite/srex/njlite_download.php?id=5463
[b] IPCC, 2022.
https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_SummaryForPolicymakers.pdf

Acronyms

Acronym	Definition
ERAF	Emergency Relief and Assistance Fund
GWSA	Global Warming Solutions Act
MVI	Municipal Vulnerability Index
SSPs	Shared Socioeconomic Pathways
TRPT	Transportation Resilience and Planning Tool
WHP	Wildfire Hazard Potential

1. Introduction

In September 2020, the Vermont legislature passed the Global Warming Solutions Act (GWSA), which requires the state to reduce its gross greenhouse gas emissions (GHGs) to at least 26 percent below 2005 levels by 2025, 40 percent below 1990 levels by 2030, and 80 percent below 1990 levels by 2050.[51] To help achieve these reductions, the GWSA created the Vermont Climate Council (VCC)[52] and charged them with developing a Climate Action Plan (the Plan) to provide a framework and planning process for reducing climate pollutants and preparing for the impacts of climate change.[53] The GWSA also required the VCC to create a specific set of subcommittees to assist in the Plan's development and carry out related duties, including the Rural Resilience and Adaptation Subcommittee.[51]

The GWSA specifically requires the state to develop a municipal vulnerability index (MVI) that includes factors that measure "a municipality's population, average age, employment, and grand list trends; active public and civic organizations; and distance from emergency services and shelter."[54]

The MVI tool is intended to help identify where Vermont communities may be most vulnerable to climate change, with a focus on pressures that climate change will place on Vermont's people, transportation, electric grid, housing, emergency services, and communications infrastructure. The aim of the MVI is to help its users understand where climate hazard exposure is likely to occur and the factors that influence climate hazard vulnerability to help design the actions needed to increase climate resilience in Vermont and its communities. The user groups that the MVI was designed for include municipalities, regional planning commissions, and state agencies. The MVI can also be used by community and other groups but was not designed specifically for these audiences.

About this User Guide

The remainder of this user guide is laid out as follows:

- Section 2 describes how to access and use the MVI.
- Section 3 describes the methods underlying the MVI.
- Section 4 provides information on who to contact if you have additional questions about the MVI tool and its use.

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[51] Vermont Act 153 (2020): https://aoa.vermont.gov/sites/aoa/files/Boards/VCC/ACT153%20As%20Enacted.pdf

[52] The 23 member Vermont Climate Council is comprised of state administration officials, legislative appointees, and various sector representatives: https://climatechange.vermont.gov/about

[53] Vermont Climate Action Plan: https://climatechange.vermont.gov/readtheplan; VECAN "Vermont Global Warming Solutions Act" Webpage: https://vecan.net

[54] Vermont Act 153, Page 10.

2. Tool Access and Use

This section provides information about how to use the MVI, including how to access the tool; descriptions of tool buttons, legends, and map layers; and other helpful tips to improve tool use.

2.1 Tool Access

The MVI can be accessed here. The MVI is accessible by all web browsers.

2.2 Tool Buttons

After loading the tool, the screen defaults to a map of Vermont and its town boundaries, as shown in .

Figure 1: MVI Default Setup: MVI Default Setup

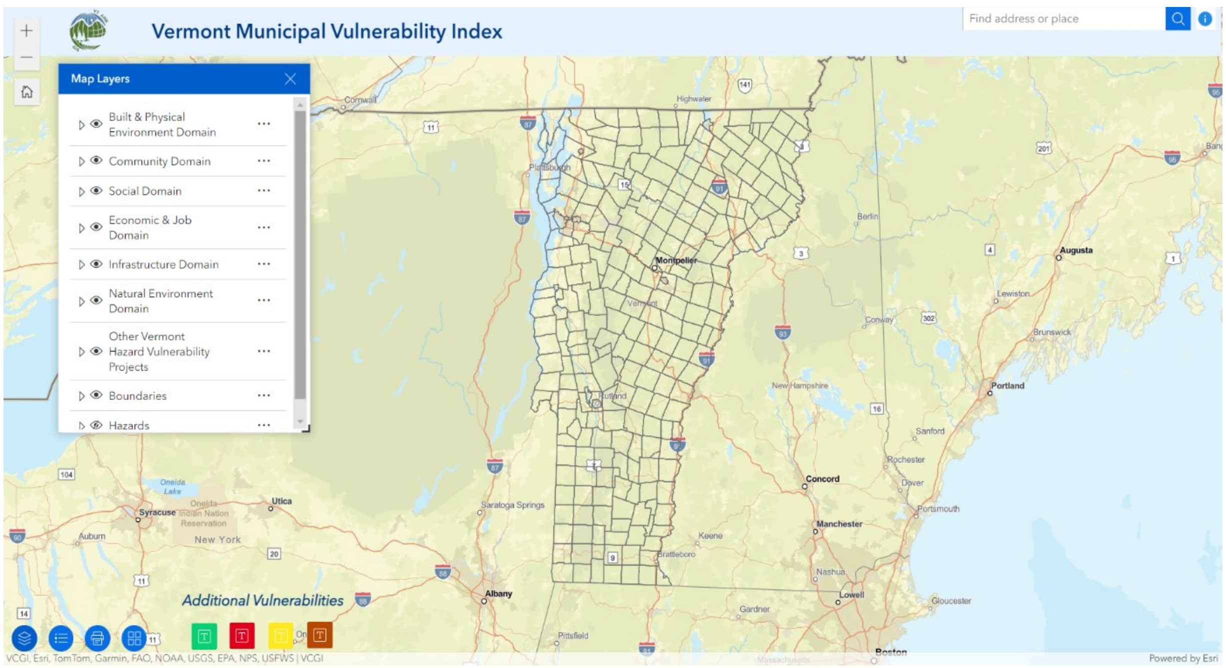
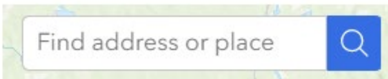
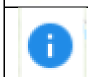
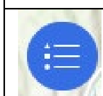
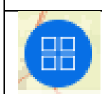
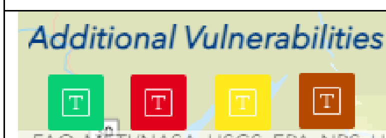


Table 1 below describes what each button on the tool's user interface does.

Table 1: Tool Buttons and Their Functionality

Icon/Button	Functionality Description
	Zoom in and out on the map by clicking on the plus or minus or return to the default view by clicking the home button located at the top left.
	Search and zoom into a specific town, city, or address.
	Access information about what the tool was intended for by clicking the information button in the top right corner.
	Open a list of available climate vulnerability factor and climate hazard layers to be toggled on and off by selecting the button near the bottom left. The layers feature loads automatically.
	Open the legend to see the symbols and information for the layers displayed on the map by selecting the button near the bottom left.
	Print the current extent of the map and displayed layers by selecting the button near the bottom left. By expanding the “Advanced” option, users can include things like a legend, north arrow, and scale bar. The final maps are generated in the “Print result” tab.
	Change the basemap that is displayed from the default map. Other available basemaps include a satellite view, a topographic map, and a terrain map.
	Click the text buttons to learn more about climate vulnerabilities that are not represented on the map due to a lack of reliable data or ability to map the data. There is a separate button for narratives associated with each of the different domains, or categories of factors, that shape climate vulnerability.

2.3 Map Layers

Default

By default, the MVI loads the Vermont State and town boundary layers. The user will need to select individual map layers of interest, as described below. The basemap for the tool defaults to the “Streets” basemap. Users can also choose from almost 30 other basemaps, including satellite view and terrain view, to further inform their analysis.

Boundaries

The MVI allows the user to select and view state, county, town, regional planning commission, and distribution utility service territory boundaries.

Domains

Domains are the six categories of factors that inform climate vulnerability:

- **Built and Physical Environment.** Includes key structures within each town, such as critical assets, emergency services, and residential dwellings. It also includes housing age, which can help determine how vulnerable housing might be.

- **Community.** Includes important community boundaries such as designated growth centers and downtown district boundaries. It also includes factors such as municipal staff and financial capacity.
- **Social.** Includes social metrics of vulnerability such as vehicle access, the percentage of elderly residents and of children under five, and energy and transportation burden.
- E**conomic and Job.** Includes the percentage of each town that has outdoor and tourism workers. These professions tend to be more vulnerable to climate hazards due to their work being mainly outside.
- **Infrastructure.** Includes important transportation, energy, and water infrastructure such as airports, powerlines, and drinking water infrastructure.
- **Natural Environment.** Includes natural features that can help increase the resilience of a community to climate hazards, such as biodiversity and conserved and protected lands.

By selecting one of the domains, the factors of climate vulnerability included in the MVI's map layers will appear below the domain so the user can select the factors of interest. For example, in Figure 2, "Community" represents the domain, and the layers underneath it are the factors that influence climate vulnerability associated with that domain. The top-level eye icon for the domain must be "open" for the lower-level layers to show and be selected by the user.

Table 2 presents the factors of climate vulnerability included in the MVI categorized by domain (see Section 3.2 for additional information on developing factors). Table 2 also shows how each factor is measured (i.e., metric), thresholds for flagged factors that are not represented geospatially in the tool and that influence climate vulnerability (See Section 3.3 for more information), and corresponding data sources.

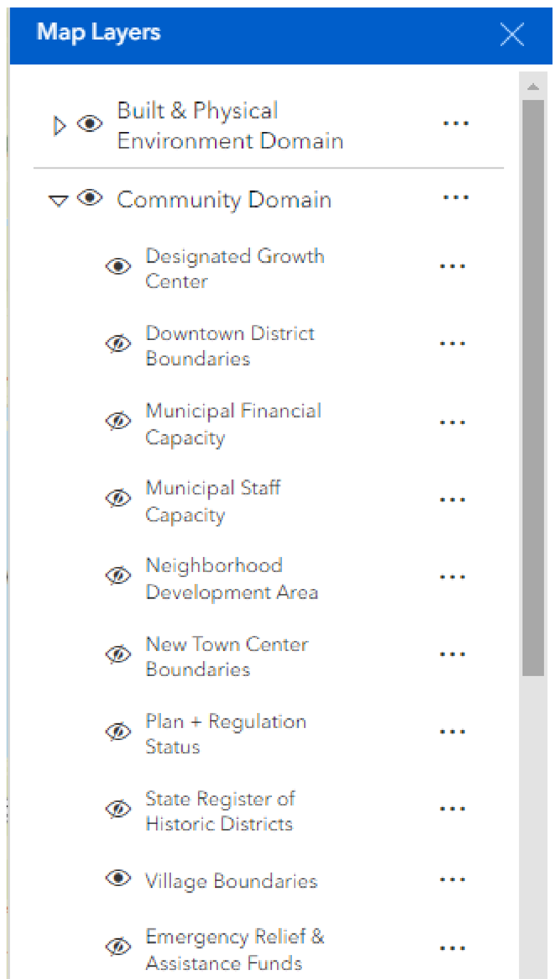


Figure 2: Map Layers Showing the Community Domain and Related Factors

Table 2. Factors of Climate Vulnerability Included in the MVI by Domain

Layer	Metric	Threshold for Flagged Factors [a]	Data Source
Social Domain			
Adult Asthma	Percent (%) of adults with asthma	Above state average (10.92%)	Vermont Behavioral Risk Factor Surveillance System (Vermont Department of Health, 2021)
Population	Population size (number of people)	Above state average (2,448 people)	American Community Survey (U.S. Census Bureau, 2020)
Low Income	Percent (%) of households with an annual household income less than 2x the federal poverty rate	Above state average (22.99%)	American Community Survey (U.S. Census Bureau, 2020)
Elderly residents	Percent (%) of people aged 65 and older	Above state average (21.34%)	American Community Survey (U.S. Census Bureau, 2020)
Children	Percent (%) of people aged 5 and younger	Above state average (4.59%)	American Community Survey (U.S. Census Bureau, 2020)
People with Disabilities	Percent (%) of population with a disability	Above state average (14.40%)	American Community Survey (U.S. Census Bureau, 2020)
Single Parent Households	Percent (%) of households that are single parent households	Above state average (11.58%)	American Community Survey (U.S. Census Bureau, 2020)
Linguistic Isolation	Percent (%) of households with limited English-speaking proficiency	Above state average (0.33%)	American Community Survey (U.S. Census Bureau, 2020)
Vehicle Access	Percent (%) of households without access to a vehicle	Above state average (4.06%)	American Community Survey (U.S. Census Bureau, 2020)
Internet Access	Percent (%) of households with no internet	Above state average (12.36%)	American Community Survey (U.S. Census Bureau, 2020)
Rentership	Percent (%) of housing units that are renter-occupied	Above state average (14.19%)	American Community Survey (U.S. Census Bureau, 2020)
Asian	Percent (%) of population that is Asian alone	NA	American Community Survey (U.S. Census Bureau, 2020)
Black or African Americans	Percent (%) of population that is Black or African American alone	Above state average (0.60%)	American Community Survey (U.S. Census Bureau, 2020)
Hispanic or Latino	Percent (%) of population that is Hispanic or Latino	Above state average (1.83%)	American Community Survey (U.S. Census Bureau, 2020)
American Indian and Alaska Native	Percent (%) of population that is American Indian or Alaska Native alone	Above state average (0.4%)	American Community Survey (U.S. Census Bureau, 2020)
Native Hawaiian and Other Pacific Islander	Percent (%) of population that is Native Hawaiian or Other Pacific Islander alone	Above state average (0.04%)	American Community Survey (U.S. Census Bureau, 2020)
Two or More Races	Percent (%) of population that is two or more races	Above state average (2.49%)	American Community Survey (U.S. Census Bureau, 2020)

Layer	Metric	Threshold for Flagged Factors [a]	Data Source
White, Not Hispanic or Latino	Percent (%) of population that is White alone	NA	American Community Survey (U.S. Census Bureau, 2020)
Some Other Race	Percent (%) of population that is some other race alone	Above state average (0.3%)	American Community Survey (U.S. Census Bureau, 2020)
Housing cost burden	Owner-occupied housing units - Percent (%) of owner-occupied housing units where mortgage is 50% or more of household income Renter-occupied housing units - Percent (%) of renter-occupied housing units where rent is 50% or more of household income	Above state average - Owner occupied (13.3%) - Renter (16.25%)	American Community Survey (U.S. Census Bureau, 2020)
Energy and transportation burden	Average percent (%) of median household income spent on energy and transportation costs	Above state average (10.58)	Energy Burden by Town (Efficiency Vermont, 2023)
Access to healthy foods	At least 500 people or 33% of the population live farther than 1 mile (urban areas) or 10 miles (rural areas) from the nearest supermarket - Yes - No	NA	Food Access Research Atlas (USDA, 2019)
Community Domain			
Designated Growth Center	NA	NA	Vermont Planning Atlas (VT Agency of Commerce and Community Development, 2020)
Downtown District Boundaries	NA	NA	Vermont Planning Atlas (VT Agency of Commerce and Community Development, 2020)
Municipal Financial Capacity	Equalized municipal grand list value ($)	Below state average ($4,254,119)	State of Vermont Equalized Grand List (VT Department of Taxes, 2023)
Municipal Staff Capacity	Number of paid staff - 1 - 2 - 3 - 4 or more	If town does not have at least one paid manager or administrator	VT League of Cities and Towns (2023)

Layer	Metric	Threshold for Flagged Factors [a]	Data Source
Neighborhood Development Area	NA	NA	Vermont Planning Atlas (VT Agency of Commerce and Community Development, 2020)
New Town Center Boundaries	NA	NA	Vermont Planning Atlas (Undated)
Plan and Regulation Status	- Unconfirmed planning process and local land use regulation - Unconfirmed planning process and no local land use regulation - Confirmed planning process and local land use regulation - Confirmed planning process and no local land use regulation	If municipality has unconfirmed planning process and/or no local land use regulation *[Rationale: not having either a planning process or local land use regulations indicates higher vulnerability since adopting local land use regulations and town plans are important measures that communities can take to increase their resilience and decrease their climate vulnerability. These regulations and plans can help to limit development in areas of increased climate vulnerability, reduce urban sprawl, preserve natural areas, promote use of green infrastructure, and encourage energy-efficient development. Less than 50% of all VT municipalities do not have at least one of these.]*	Vermont Planning Atlas (Undated)
State Register of Historic Districts	State registered historic districts	NA	VT Agency of Commerce and Community Development, 2020
Village Boundaries	NA	NA	Vermont Planning Atlas (VT Center for Geographic Information, 2023)

Layer	Metric	Threshold for Flagged Factors [a]	Data Source
Emergency Relief and Assistance Funds	Emergency Relief and Assistance Fund (ERAF) rates - 7.5%: Less than four mitigation actions adopted - 12.5%: Four mitigation actions adopted[b] - 17.5%: Five or more mitigation actions adopted[c]	ERAF rate = 7.5% [Rationale: ERAF rates greater than 7.5% indicate that the community has adopted at least four mitigation measures]	State of Vermont Agency of Natural Resources (Flood Ready Vermont, 2024)
		Economic and Job Domain	
Outdoor Worker	Percent (%) employed civilian population aged 16 years and older in farming, fishing and forestry occupations and construction, extraction, and maintenance occupations	Above state average (13.21%)	U.S. Census Bureau Decennial Census (PCT086) (2020)
Tourism	Percent (%) employed civilian population aged 16 years and older in tourism industry (transportation, tourism, and lodging attendants)	Above state average (0.13%)	U.S. Census Bureau Decennial Census (PCT086) (2020)
		Built and Physical Environment Domain	
Critical Assets	- School K/12 - Library - Health Clinic - Town Garage - Wastewater Treatment Plant - Communication Tower - Substation - Town Office - Utility - Nursing Home / Long Term Care - Hydroelectric Facility - City/Town Hall - Public Water Supply Well	NA	Vermont Open Geodata Portal E911 Data (Libraries, Schools, other buildings and houses) (VT Center for Geographic Information, 2024)

Layer	Metric	Threshold for Flagged Factors [a]	Data Source
Emergency Services	- Fire station - Law enforcement - Hospital / medical center - Ambulance service	NA	Vermont Open Geodata Portal E911 Data (VT Center for Geographic Information, 2024)
Mobile homes	Mobile homes	NA	Vermont Open Geodata Portal E911 Data (VT Center for Geographic Information, 2024)
Other Site Types	- Accessory Building - Commercial - Commercial Farm - Other Commercial - Accessory Barn - Other	NA	Vermont Open Geodata Portal E911 Data (VT Center for Geographic Information, 2024)
Residential Dwellings	- Single family - Multifamily - Camp - Condominium - Other residential - Seasonal home	NA	Vermont Open Geodata Portal E911 Data (Libraries, Schools, other buildings and houses) (VT Center for Geographic Information, 2024)
Housing age	Percent (%) of houses built: - 1939 and earlier - 1940 to 1959 - 1960 to 1979 - 1980 to 1999 - 2000 and later	Above state average for houses built before 2000 (83.95%)	American Community Survey (U.S. Census Bureau, 2020)
Infrastructure Domain			
Toxic and Hazardous Sites	Hazardous sites	NA	Vermont Agency of Natural Resources (Undated)
Roads, bridges, and culverts	- Roads - Bridges - Culverts	NA	VT transportation Flood Resilience Planning Tool (TRPT) (Vermont Agency of Transportation, 2022)
Airports	Airports	NA	Vermont Open Geodata Portal (2020)

Layer	Metric	Threshold for Flagged Factors [a]	Data Source
Drinking water infrastructure	Drinking water infrastructure - Existing - Abandoned - Potential - Proposed	NA	Vermont Open Geodata Portal (Vermont Agency of Natural Resources, 2020)
Electric Substations	Electric utility substations	NA	Vermont Open Geodata Portal (Vermont Department of Public Service, 2021)
Impervious Surfaces	Impervious surfaces	NA	Vermont Open Geodata Portal (2016)
Power Lines (Green Mountain Power)	Green Mountain Power lines - Underground structure data - Pole data - Line data	NA	Vermont Open Geodata Portal (VT Center for Geographic Information, 2022)
Power Lines (VEC "spans" data	VEC power lines	NA	VEC "spans" data (2023)
Power Lines (WEC Utility Lines)	WEC utility lines	NA	Vermont Open Geodata Portal (Vermont Department of Public Service, 2022)
Power Plants and Neighboring Communities	- Operating - Retired or plan to retire	NA	Power Plants and Neighboring Communities Mapping Tool (EPA, 2021)
Public Transit Routes	Public transit routes	NA	Vermont Open Geodata Portal (VT Center for Geographic Information, 2024)
Wastewater Infrastructure	Wastewater treatment facilities	NA	Vermont Open Geodata Portal
Natural Environment Domain			
Biodiversity	Areas of high biological significance or diversity	NA	Vermont Open Geodata Portal (Vermont Agency of Natural Resources, 2022)
Conserved and protected lands	Protected lands	NA	Vermont Open Geodata Portal (VT Center for Geographic Information, 2021)
Geological Diversity	Places with a diverse mix of topography, bedrock and surficial geology and aspect	NA	BioFinder (Vermont Agency of Natural Resources, 2023)
Landscape Scale	- Interior Forest Blocks - Connectivity Blocks - Surface Water and Riparian - HP Riparian Wildlife Connectivity - HP Physical Landscape Diversity - HP Physical Landscape Blocks	NA	BioFinder (Vermont Agency of Natural Resources, 2023)

Layer	Metric	Threshold for Flagged Factors [a]	Data Source
Location of Community and Species Scale Priorities	- Natural Communities - Aquatic Habitats - Wetlands - Vernal Pools - Terrestrial Wildlife Crossings - Riparian Wildlife Crossings - Species	NA	BioFinder (Vermont Agency of Natural Resources, 2023)
Municipal Tree Inventory	- Good condition - Fair condition - Poor condition - Dead - Vacant - Unknown	NA	VT Agency of Natural Resources (2023)

[a] Flagged factors are those factors that are not represented geospatially in the tool and contribute to climate vulnerability or resilience. The thresholds for flagging were determined based on the type of data associated with each factor. Whenever appropriate, the flagging threshold for the factor is based on the average of the state data (either above or below this average, whichever indicates greater vulnerability). When this threshold is not appropriate (e.g., ERAF rate), a threshold specific to that factor was defined.

[b] The four mitigations measures include: National Flood Insurance Program (participate or have applied); Town Road and Bridge Standards (adopt standards that meet or exceed the 2013 template in the current: VTrans Orange Book: Handbook for Local Officials); Local Emergency Management Plan (adopt annually after town meeting and before May 1); Local Hazard Mitigation Plan – Adopt a FEMA – approved local plan (valid for five years), or a draft plan has been submitted to FEMA Region 1 for review. **Flood Ready VT**.

[c] Include four mitigation action included in [a] in addition to: Protect River Corridors from new encroachment, or protect their flood hazard areas from new encroachments and participate in the FEMA Community Rating System. **Flood Ready VT**.

Other Vermont Hazard Vulnerability Projects

The MVI includes data and information from the Vermont Agency of Transportation's Transportation Resilience Planning Tool (TRPT) as well as data on manufactured homes in flood plains as separate projects included within the MVI. These two projects have important analysis and data available for Vermont and were included to make it easier for users to access these data within the MVI tool. It is important to note that these data are still hosted and managed by each project sponsor. Users can find and select the data and layers available within the MVI under the Other Vermont Hazard Vulnerability Projects layer.

Hazards

The MVI is designed to allow the user to assess vulnerability to each included climate hazard by selecting one hazard at a time in combination with the factors that shape climate vulnerability, as described under the Domain section below. Note that some of the hazard layers, like Extreme Precipitation featured in Table 3, include more than one layer due to different climate scenarios. In these cases, users must expand the hazard layer and select among the climate scenarios. To learn more about the individual hazard layers, see Table 3 below. Further information about projected climate hazard data can be found in Section 3.1

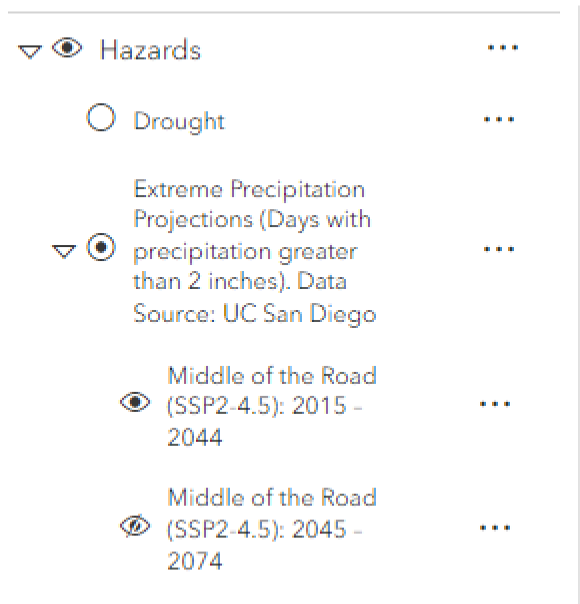


Figure 3: Hazard Layers

Table 3. Hazard layer information.

Hazard	Definition	Metric	Years of Available Data Analyzed	Data Source
Drought	Drought classifications explained.	Average weeks per year county was in a severe drought (D2) status or higher	2000–2022	U.S. Drought Monitor
Extreme Precipitation	>2 inches of precipitation in a day.	Average number of days per year with >2 inches of precipitation	2015–2044, 2045–2074, 2075–2100	UC San Diego
Fluvial Erosion – River Corridors	River corridors encompass an area around and adjacent to the present channel where fluvial erosion, channel evolution, and down-valley meander migration are most likely to occur.	River corridor locations	N/A	VT DEC

Hazard	Definition	Metric	Years of Available Data Analyzed	Data Source
Hail	Hail events that have sufficient intensity to cause loss of life, injuries, significant property damage, and/or disruption to commerce.	Average number of events per year	1955–2022	NOAA NCEI Storm Events Database
Ice Storms	Ice storms that have sufficient intensity to cause loss of life, injuries, significant property damage, and/or disruption to commerce.	Average number of storms per year	1996–2022	NOAA NCEI Storm Events Database
Invasive Species	Invasive species are nonindigenous plants, animals, algae, fungi, or pathogens—disease causing organisms like viruses and bacteria—that threaten the diversity and survival of native species or the ecological stability of infested ecosystems, or commercial, agricultural, or recreational activities dependent on these natural resources.	Location of invasive species on Agency of Natural Resource lands	NA	VT Agency of Natural Resources
Inundation Flooding: FEMA	Flood hazard areas are those areas of the floodplain that may be inundated by a range of flood frequencies up to and including the 1% annual chance flood.	AE (1% annual chance floodplains with elevations) A (1% annual chance floodplains without elevations) AO (1% annual chance zone of shallow flooding 1-3 feet) 0.2% annual chance flood hazard zone	NA	FEMA
Inundation Flooding: Lake Champlain	Flood inundation layer for the Vermont portion of the Lake Champlain Basin. Depicts the lateral extent of flooding at eight modeled storm sizes of recurrence intervals ranging from 2 to 500 years for rivers that drain more than 2 square miles.	Location of potential flooding	NA	Vermont Center for Geographic Information

Hazard	Definition	Metric	Years of Available Data Analyzed	Data Source
Landslides	A compilation of landslide locations from the Vermont Geological Survey's preliminary landslide inventory, verified landslides from the public Geoform, and other technical reports.	Landslide locations	NA	VT Agency of Natural Resources
Snow Storms	Winter storm, heavy snow, winter weather, and blizzards that have sufficient intensity to cause loss of life, injuries, significant property damage, and/or disruption to commerce.	Average number of storms per year	1996–2022	NOAA NCEI Storm Events Database
High Temperature	Days with high temperature >90 °F.	Average number of days with temperatures > 90 °F per year	2015–2044, 2045–2074, 2075–2100	UC San Diego
Low Temperature	Days with low temperature <32 °F.	Average number of days with temperatures < 32 °F per year	2015–2044, 2045–2074, 2075–2100	UC San Diego
Wildfire	The wildfire hazard potential (WHP) data set represents an index that quantifies the relative potential for wildfire that may be difficult to control. WHP can be used as a measure to help prioritize where fuel treatments may be needed.	Wildfire Hazard Potential	Not given	Northeast-Midwest State Foresters Alliance
Wind	High wind, strong wind, and thunderstorm wind that have sufficient intensity to cause loss of life, injuries, significant property damage, and/or disruption to commerce.	Average number of events per year	1996–2022	NOAA NCEI Storm Events Database

Layer Functions: Map Transparency, Data, and Exporting Information

Users can click on the three dots to the right of any layer to view additional options for that layer (see Figure 4). By clicking on the three dots, users may:

- **Increase or decrease the transparency of the layer to more easily view it in combination with other layers.** Transparency is an important feature when using the MVI to analyze relationships among hazards and factors. Increasing the transparency of data layers can provide a better view of the other factors and the relationship between a hazard and multiple factors. For this reason, if the user selected multiple layers but can only see one layer, it could be helpful to select one layer at a time to see if there are data in the specific area the user is viewing, and/or check the transparency of the top layer shown and consider making it more transparent to see if other layers show through, allowing the user to view multiple layers of data at one time.

- **View details of the data** source**.** Clicking the "details" icon will take the user to an ArcGIS REST Services Directory that describes the layers and data.
- **Export the data.** Click on the "Export" icon to export data in JSON, GeoJSON, or CSV formats. This feature allows the user to analyze the data on their own.

Figure 4: Layer Options by Selecting Ellipsis

To learn more about the specific data for a certain town or asset, users may click on any feature on the map and view a popup window with relevant information. This popup window displays information specific to the area clicked for the selected layer. Users can also use the popup to zoom to the location of interest and export the data. If multiple layers are selected on the map, users can navigate between the layer information in the popup window using the arrows at the top left, as seen in Figure 5.

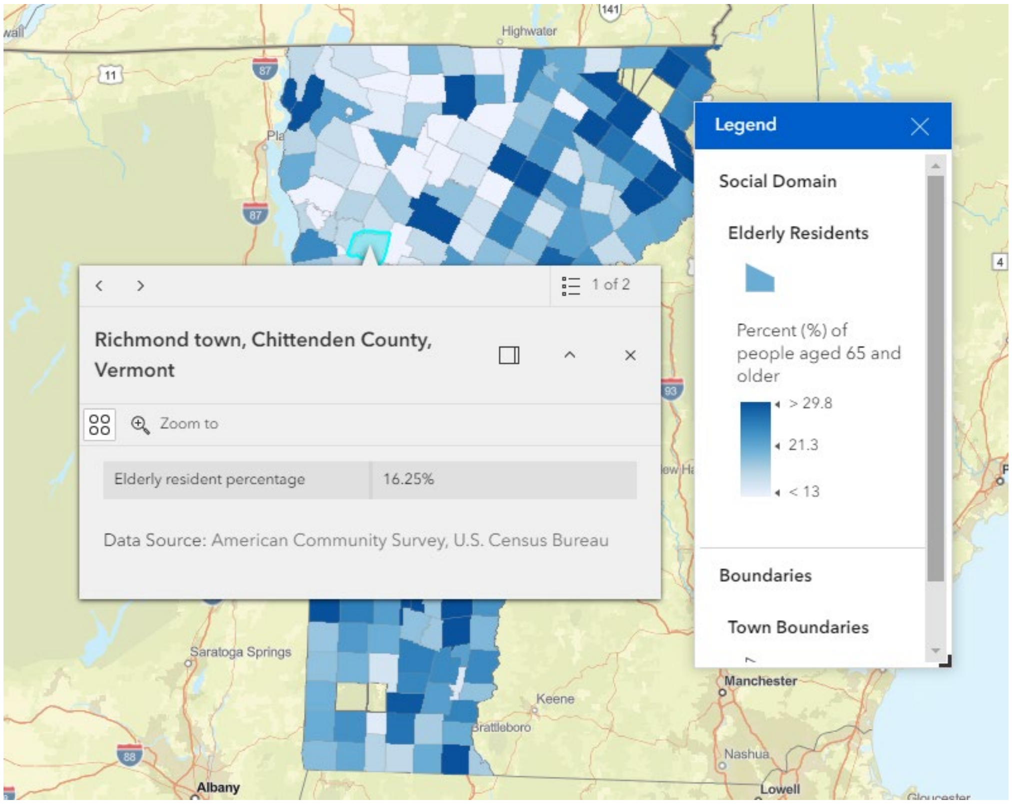
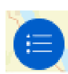


Figure 5. Example Popup Display

2.4 Map Legend

By selecting the legend button , a popup screen will appear that shows the information for the selected layers. For example, the legend in Figure 6 shows the colors in the legend are used to identify the different built and physical assets, with each critical asset being assigned a different color in the legend and that color matching the color in the map wherever that asset is located within the municipality.

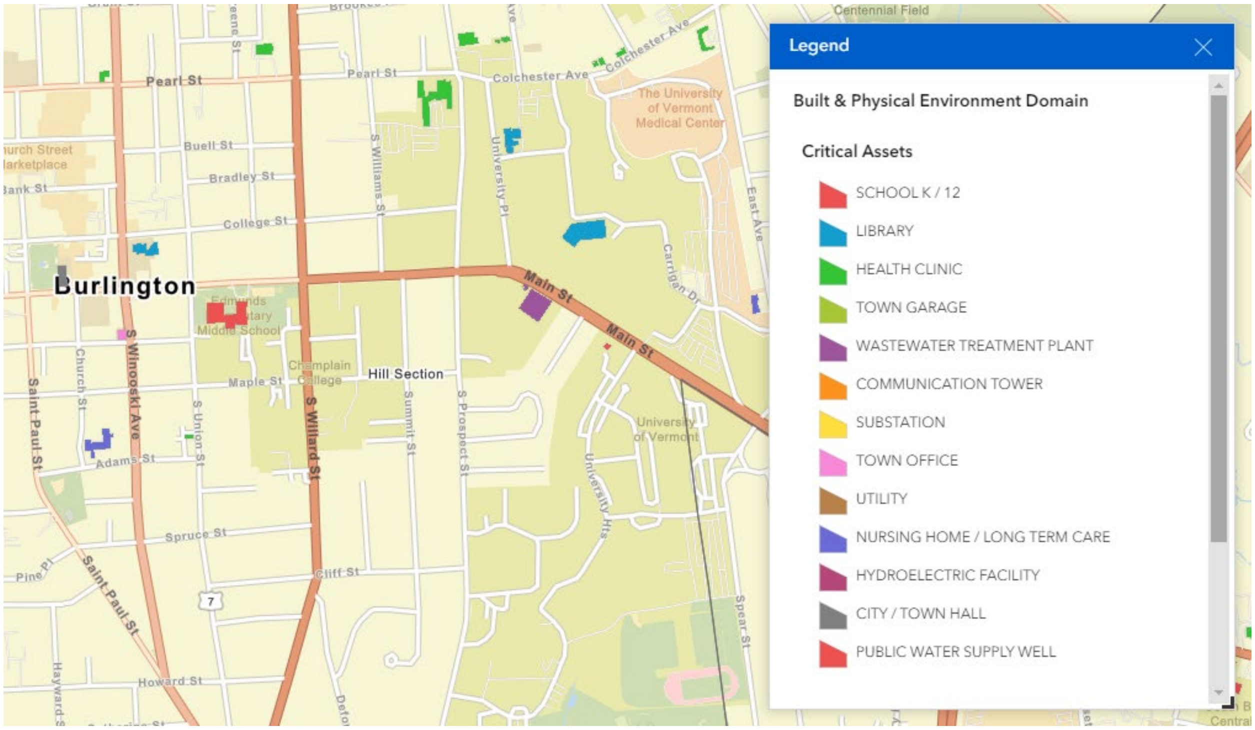


Figure 6: Example Legend Information Symbology

2.5 Additional Vulnerabilities

The additional vulnerabilities are accessible through text boxes (as shown in the image to the right) that provide brief explanations of how the nonspatial factors can contribute to climate vulnerability. As mentioned under the Tool Buttons section above, the Additional Vulnerabilities text buttons appear at the bottom of the map, and there is a separate button for each domain. Additional vulnerabilities included in the tool are presented below by domain.

Community

- **Public and civic organizations.** Many past disasters and research studies have found that public and civic organizations increase social cohesion and community capacity, which reduces vulnerabilities from climate change. Public and civic organizations provide community members with ways to get to know one another, increase opportunities to get involved in climate mitigation and adaptation, and can serve an important role in hazard preparedness, response, and recovery.[55]

- **Cultural resources.** Many cultural and tribal resources cannot be replaced once they are damaged or lost. Working with community and technical experts to identify these critical

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[55] Social cohesion; Wildfire preparedness, community cohesion and social–ecological systems; Building community resilience; Climate Preparedness Planning

resources and map their locations will help municipalities reduce risks to resources that contribute meaning and a sense of history and place to the people of Vermont.[56]

Economic and Jobs

- **Natural resource industries.** Vermont's economy and employment includes several industries that rely on the health of the environment and natural resources, including timber, maple syrup, skiing, and outdoor recreation. These industries are important to Vermont's economy and culture, and climate change poses a risk to all of them due to increased risks from flooding, heat, drought, wildfire, invasive species and pests, and habitat and species shifts. See below for more detail on each of these industries:
  - **Timber Industry.** All aspects of the supply chain for the timber industry are affected by climate change, including changes in the harvesting season; tree health degradation from heat, drought, and pests; damage and disrupted access to roads; and warmer and wetter winters with inconsistent and unreliable conditions, creating challenges for industry planning.[57]
  - **Maple syrup.** Increasing heat, extreme precipitation events, drought, and other climate impacts have changed where maple trees can grow and when maple syrup can be harvested during the season. Climate change has shifted the season to begin and end earlier, is projected to shift the maple habitat range northward, increase the likelihood of damage to soil moisture and chemistry, and increase the variability of year-to-year yields. To produce maple syrup, the trees must go through a cycle of freezing and thawing, and snow cover is important to protect soil health. Climate change is projected to reduce snowpack and freezing, increasing risk to syrup production, tree health, and soil health.[58]
  - **Skiing.** Climate change is projected to reduce the ski season in Vermont by two weeks under the low-emissions scenario to one month under the high-emissions scenario due to warming temperatures and more precipitation falling as rain rather than snow. Beginning in 2050, snowfall is projected to decline, and by 2080, current projections suggest the Vermont ski season will be shortened by between two weeks (low-emissions scenario) and one month (high-emissions scenario).[59]
- **Outdoor recreation.** Flooding, extreme heat, warming surface waters, drought, wildfires, and secondary impacts such as landslides, air and water quality degradation, and habitat and vegetation damage are already disrupting outdoor recreation areas across the country. Outdoor recreation is critical to the economy and culture of Vermont. Whether algal blooms impact

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[56] Safeguarding cultural property; Cultural heritage resources in climate action; Climate adaptation and resilience

[57] Climate Adaptations in the Northeast's Forest Products Supply Chain, Northeastern Forest Products Supply Chain Climate Adaptation Toolkit, A warm start to winter adds to challenges for Vermont's logging industry

[58] Rapp, Joshua M., et al. "Finding the sweet spot: Shifting optimal climate for maple syrup production in North America." Forest Ecology and Management 448 (2019): 187-197. Climate change is already impacting the maple sugaring industry, Climate Change Resource Center - Maple Syrup .

[59] Vermont Climate Assessment Tourism chapter

beaches or a lack of snow impacts ice fishing, sledding, or skiing, recreation is an important climate change consideration for Vermont, especially for towns that rely heavily on recreation.[60]

- **Small businesses.** The damage and disruption caused by climate change can affect multinational corporations, large companies, and small businesses. However, small businesses tend to be more vulnerable than larger companies and corporations since they less access to capital to prepare for or recover from climate change impacts. Small businesses report lacking the time, financial resources, and expertise to reduce their risks from climate change or rebuild after a disaster.[61]

Built and Physical Environment

- **Wildfire mitigation.** While large-scale wildfires are not a risk for Vermont, the risk of wildfire has increased in the Northeast due to droughts, higher heat, and changes in the timing and amount of precipitation. Wildland fire mitigation actions such as open burning permits, forest restoration and management actions at the landscape scale, vegetation management, and home hardening at the building scale, as well as developing plans such as Community Wildfire Protection Plans, can reduce wildfire risk to Vermont's communities even as climate change increases the risks.[62]
- **Wells at risk of drying up.** Communities that rely on wells for water supply are more at risk from drying up from even localized and seasonal droughts. Communities and households that rely on well water often lack redundant sources of water, leaving them much more vulnerable to overdraft, subsidence, and decreased water quality, as well as water scarcity issues. With 60 percent of Vermont residents receiving their water from groundwater supplies, climate change influences on drought and wells could have a widespread impact across the state.[63]
- **Heating and cooling centers.** The presence of accessible and well-advertised heating and cooling centers in a community reduces life safety risks and health risks from extreme heat and cold. It is important to consider location, accessibility, familiarity, and hours of operation when determining the value of heating and cooling centers to a community. Locating these centers in areas that are familiar to the community, having longer hours of operation, and including other benefits such as internet connections, games, clean water, and other necessities will increase their value and use.[64]
- **Housing materials, construction methods, and maintenance.** The vulnerability of housing, schools, or other buildings to climate change can vary greatly based on housing materials, construction methods, and maintenance. Older homes, modular homes and buildings, homes and buildings with belowground living or usable spaces, and homes and buildings that are not tied to their foundations are often more at risk of damage or loss. Residents and occupants

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[60] Vermont Climate Assessment and the NOAA 2022 State Climate Summary

[61] Small Business Climate Action: Barriers & Bridges, Climate Change Preparedness and the Small Business Sector

[62] Why Should My Community Plan for a Wildfire?; Firewise Resources for Residents

[63] Vermont Climate Assessment

[64] The Role of Cooling Centers in Protecting Vulnerable Individuals from Extreme Heat; Five Ways To Increase Use Of Cooling Centers

without the resources to maintain and upgrade their dwelling units to reduce risks from climate change are also more at risk of damage or loss.[65]

Natural Environment

- **Air quality.** Extreme heat, wildfires, and flooding can all contribute to degraded indoor and outdoor air quality. Extreme heat increases ground level ozone, wildfires increase particulate matter, and flooding can increase algae and mold. Degraded air quality has health and safety impacts on residents and workers, with greater risks for those over 65 or under 5 years old, people with pre-existing health conditions, and people with prior or ongoing exposure to other pollutants.[66]

2.6 Printing

To print a map, users should select the print button . As shown in Figure 7, users can set the title for the map, select from various templates, and select advanced printing options. The advanced options allow users to modify the map's extent and scale, include additional metadata, add a legend, and select helpful items as seen in the figure. The created map is then saved in the "Print result" tab.

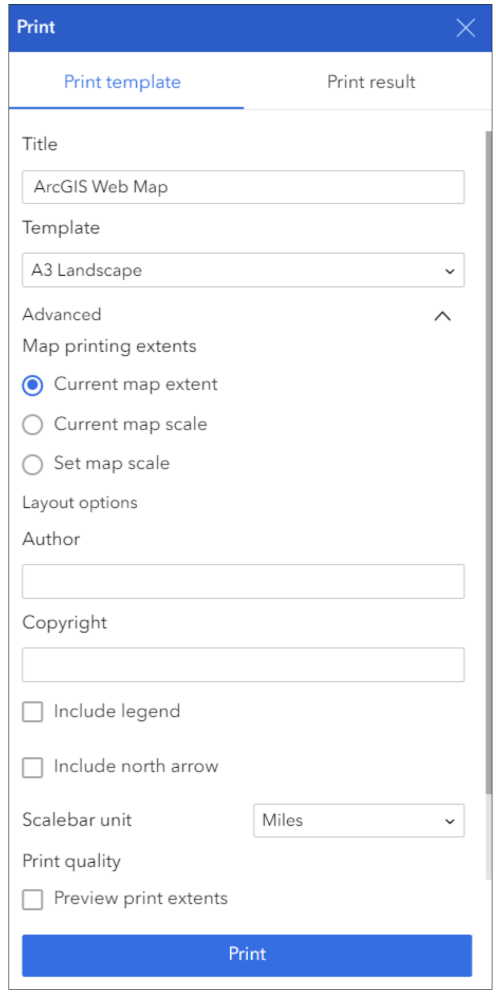

Figure 7: Print Options by Selecting Print Button

[65] The Role of Housing in Climate Change Mitigation and Adaptation Opportunities To Reduce Climate Risks Through Land Use Regulations Resiliency at Work; Durability and Climate Change—Implications for Service Life Prediction and the Maintainability of Buildings

[66] Vermont Department of Health, Climate and Health Air Quality Page

3. Methods

The MVI tool is intended to support climate-related planning and decision-making in Vermont, as outlined in more detail below in the tool's statement of purpose:

> ***MVI Tool's Statement of Purpose.*** *The Vermont Municipal Vulnerability Index (MVI) is designed for use by Vermont State agencies, regional planning commissions, municipal staff, communities, and non-governmental organizations to measure vulnerability to climate change at the municipal level for the purposes of informing climate-related planning and decision-making and supporting the professional duties of tool users (e.g., grant-writing, development of local hazard mitigation plans, identification of climate vulnerability hot spots, disaster planning and response). The MVI will measure climate vulnerability based on a range of factors related to the built/physical environment (e.g., buildings, infrastructure), economy and jobs (e.g., unemployment, per capita income), hazards (e.g., flooding, extreme temperatures), natural environment (e.g., forest cover, ecosystem services), and social/community (e.g., sociodemographic factors, housing, access to emergency services).*

The MVI is a geospatial tool that includes data layers relating to factors of climate vulnerability, resilience, and climate hazards (e.g., drought).

The factors and climate hazards included in the MVI tool were identified and selected through a series of steps. First, an extensive list of possible factors to include in the tool were identified. This list of factors was developed by reviewing existing tools and documents (particularly the GWSA, which identified certain factors that should be included in the tool). Next, the list of factors was expanded based on engagement and input from subject matter experts and the MVI task group. Figure 8 shows an overview of the process to identify possible factors for inclusion in the tool.

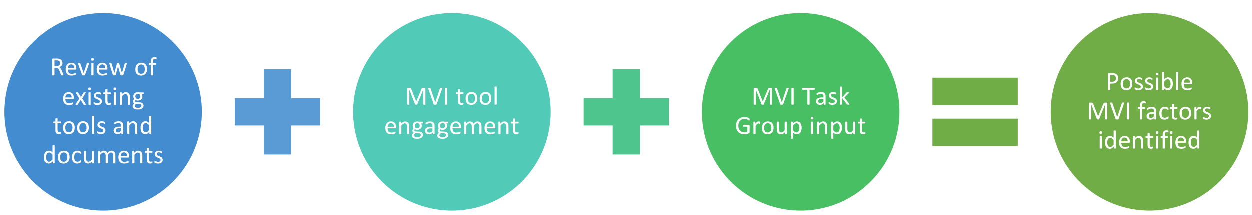

Figure 8. Process of MVI Factor Identification

After identifying a list of over 100 possible factors to consider including in the tool, this list was then narrowed and refined to a list of factors that most greatly influence climate vulnerability or resilience, represented a priority for those engaged during the stakeholder process, or were described in the GWSA legislation. The key considerations used to help refine the list of factors are shown in Figure 9 below.

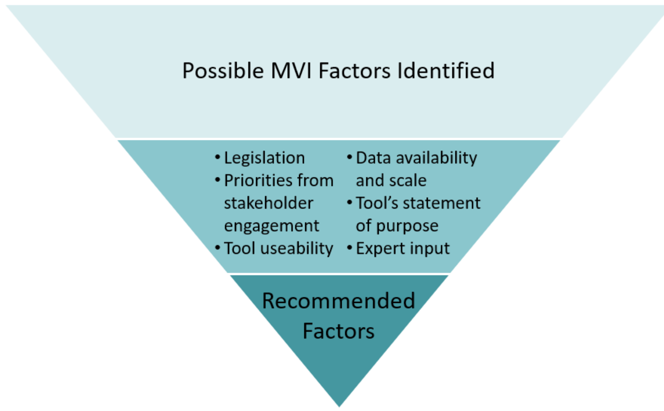

Figure 9. Overview of Factor Selection Process

The final list of factors included in the MVI tool are presented below in Section 3.2, as well as a more detailed description of tools and reports reviewed to support the selection of factors, and a description of how each factor relates to climate vulnerability or resilience. Factor thresholds are included in Table 2 in Section 2.3. The climate hazards were selected to align, as much as possible, with Vermont's State Hazard Mitigation Plan (SHMP). A more thorough description of how hazards were selected is included below in Section 3.1. Additional information about tool development is provided in the Phase 2 Report: MVI Factors and Framework Methods (available here).

3.1 Hazards

The MVI tool includes climate hazards that are likely to expose Vermont. These hazards were selected to align with the hazard impacts included in Vermont's SHMP. The hazard analysis included current and future climate hazards likely to expose the Northeast region of the United States based on regional and federal resources including the U.S. Climate Resilience Toolkit, the National Climate Assessment for the Northeast Region, and the Northeast Regional Climate Center. Though infectious disease outbreak is included in the SHMP, it is not included in the MVI due to a lack of data and because it is difficult to geospatially represent. Earthquakes are also included as a hazard impact in the SHMP but are not included in the MVI due to a lack of sufficiently downscaled geospatial data related to earthquake risk, such assoil and geologic conditions across the state. Additionally, a link between earthquakes and climate change is not yet settled among researchers and scientists. All other hazards included in the SHMP are included in the MVI.

Extreme precipitation is not included in the SHMP; however, it was selected for inclusion in the MVI because it provides an additional understanding of the potential for flooding based on climate change and land use change. Extreme precipitation is expected to increase due to climate change over the coming decades, and understanding this expected change can provide additional context for how flooding could increase.

Climate Change Projections

While most of the climate hazard data displayed in the tool were created using historical data, climate projections were also used where possible. These hazards include extreme precipitation and high and low temperatures, and their projections were created using data from global climate models. Global climate models are very coarse-resolution gridded data sets (meaning that a single grid square may cover hundreds of miles).

The Intergovernmental Panel on Climate Change featured a group of approximately 100 climate models known as the Coupled Model Intercomparison Projects 6 (CMIP6) in their latest assessment report in 2022.[67] To make these models meaningful at a more local scale, scientists use statistical methods and historical data from a certain area to "downscale," or localize, the data. These methods decrease the resolution of a grid square to just under 4 miles, which is much more helpful for viewing changes to regional and state areas like Vermont. Scientists use many different methods to statistically downscale global climate models, but the MVI tool includes downscaled data developed using the LOCA version 2 method (obtained from UC San Diego). This downscaling method is widely used and was one of the methods used by the Fifth National Climate Assessment to downscale CMIP6 climate data.[68]

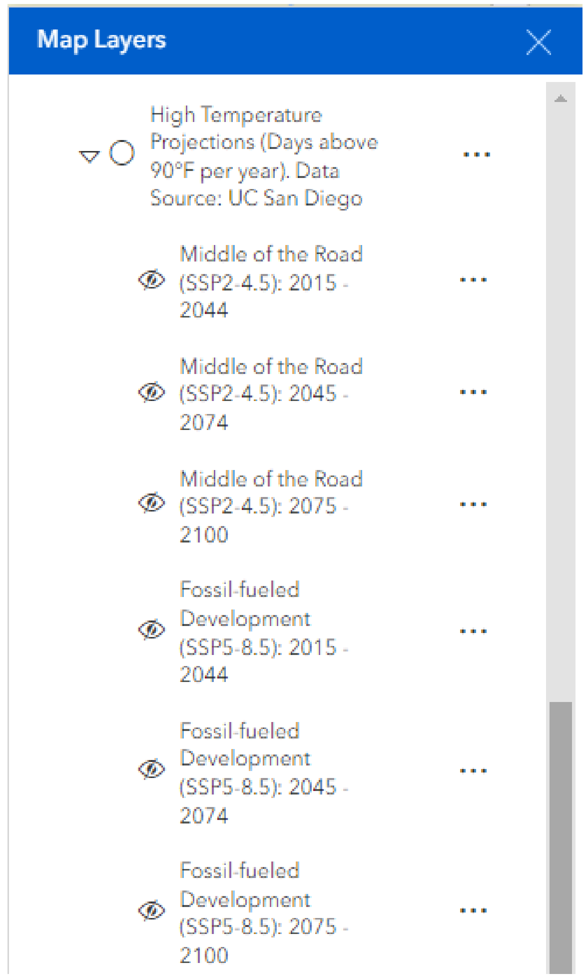

Figure 10. High Temperature Projections Layers

When viewing a hazard layers that includes scenario-based projections, such as high temperatures shown in Figure 10, the user can see two main categories of layers: Middle of the Road (SSP2-4.5) and Fossil-fueled Development (SSP5-8.5). These categories are known as shared socioeconomic pathways (SSPs). SSPs are different pathways, or scenarios, that scientists use to project future climate change outcomes. Each pathway has a different narrative about how global security, demographics, and economics might change over the century.

The MVI uses the Middle of the Road and Fossil-fueled Development SSPs because they represent pathways where the world follows its current approach to fossil fuel use, with moderate but uneven progress occurring under the Middle of the Road scenario, and an economy focused on fossil fuel and capitalism occurring under the Fossil-fueled scenario. Full summaries of each narrative, copied from Riahi et al., 2017, are included below:

- **SSP2 - Middle of the Road (Medium challenges to mitigation and adaptation):** The world follows a path in which social, economic, and technological trends do not shift markedly from historical patterns. Development and income growth proceeds unevenly, with some countries

[67] https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_SummaryVolume.pdf

[68] https://nca2023.globalchange.gov/

making relatively good progress while others fall short of expectations. Global and national institutions work toward but make slow progress in achieving sustainable development goals. Environmental systems experience degradation, although there are some improvements, and the overall intensity of resource and energy use declines. Global population growth is moderate and levels off in the second half of the century. Income inequality persists or improves only slowly and challenges to reducing vulnerability to societal and environmental changes remain.

- **SSP 5 - Fossil-fueled Development – Taking the Highway (High challenges to mitigation, low challenges to adaptation):** This world places increasing faith in competitive markets, innovation, and participatory societies to produce rapid technological progress and development of human capital as the path to sustainable development. Global markets are increasingly integrated. There are also strong investments in health, education, and institutions to enhance human and social capital. At the same time, the push for economic and social development is coupled with the exploitation of abundant fossil fuel resources and the adoption of resource and energy intensive lifestyles around the world. All these factors lead to rapid growth of the global economy, while global population peaks and declines in the 21st century. Local environmental problems like air pollution are successfully managed. There is faith in the ability to effectively manage social and ecological systems, including by geo-engineering if necessary.

Users can also choose from different time horizons, including 2015–2044, 2045–2074, and 2075–2100.

3.2 Factors of Climate Vulnerability and Resilience

All non-hazard factors in the MVI were selected based on vulnerability and resilience relationships between the selected hazards and the factors. The factors selected were determined to most likely influence climate vulnerability and resilience within Vermont and its communities. These factors were selected based on a review and analysis of Vermont's Vermont Global Warming Solutions Act of 2020 requiring the MVI, Vermont's State Hazard Mitigation Plan, vulnerability assessments within the Northeast and within Vermont including Vermont's Department of Public Health Vulnerability Indicators, Vermont's Environmental Disparity Index, and tools such as the Social Vulnerability Index, the Community Resilience Index (currently under development), BioFinder, and Vermont's Transportation Resilience Planning Tool.

Findings were reviewed from FEMA, EPA, and from assessments and similar tools in California, Massachusetts, New York, and other states in the Northeast to determine the social, community, environmental, physical, and economic vulnerabilities likely to occur in Vermont. The resources used to identify these vulnerabilities include the EPA's Climate Change and Human Health, Who's Most at Risk, EPA's 2021 Social Vulnerability Report, the National Institute of Environmental Health Sciences report on Environmental Health Disparities and Environmental Justice, and the ResilientMass Plan, the Maine Adaptation Toolkit, and Vermont's 2021 Initial Climate Action Plan.

Based on the review and analysis of existing climate vulnerability and resilience tools and reports, the initial factors of vulnerability and resilience and the data available to represent these factors were selected and presented to an advisory group in Vermont and to Vermont community organizations. The initial list of factors was revised and refined based on input from these groups, and a final list of spatial and demographic factors were selected for inclusion in the MVI. All factors included in the final list were determined to be critical to vulnerability or resilience in Vermont to one of the six domains included in the MVI.

The final list of factors included in the MVI tool are listed in Table 4 below, along with the specific data layers of the tool that correspond to each factor. In some instances, multiple data layers within the tool correspond to a specific factor. For example, the "electric utility infrastructure" factor is represented within the tool by multiple data layers (e.g., electric substations, power lines, power plants). Some factors are not represented geospatially within the tool but rather are addressed through a written narrative. These factors have "N/A" listed in the "layer(s)" column of the tool. Table 4 also includes a description of how each factor relates to climate vulnerability or resilience.

Table 4. Factors Included in the MVI and How They Relate to Climate Vulnerability

Factor	Layer(s)	Relation of Factor to Climate Vulnerability/Resilience
Social Domain		
Adult asthma	- Adult asthma	People with asthma and other respiratory illnesses are at an increased risk to climate impacts such as poor indoor and outdoor air quality and a prolonged allergy season. [Source: EPA's Climate Change and Human Health]
Population	- Population	Understanding where there are greater or fewer number of people that may be exposed to a climate hazard event can help planners prepare for events, including ensuring that adequate resources for preparing and recovering from events are available for the community.
Low income	- Low income	Low income individuals are more likely to live in areas with greater air pollution, work in industries with exposure to extreme temperatures, and live in areas with higher rates of land lost to inundation, all of which are exacerbated by climate change. [Source: EPA's 2021 Social Vulnerability Report]
Elderly	- Elderly residents	Older adults may have greater difficulty evacuating in advance of a climate hazard (e.g., severe flooding, wildfire) due to mobility limitations. Older adults are also more vulnerable to high heat effects. [Source: EPA's Climate Change and Human Health]
Children	- Children	Children are dependent on adults for their safety and well-being, which makes them more vulnerable during climate hazard events (e.g., severe flooding, wildfire). [Source: EPA's Climate Change and Human Health]
People with disabilities	- People with disabilities	Emergency warnings and other climate resources may not be designed to be accessible to people with disabilities, and they may have greater difficulty evacuating in advance of a climate hazard event (e.g., severe flooding, wildfire). [Source: EPA's Climate Change and Human Health]
Single parent households	- Single parent households	Single parent households may be more susceptible to experiencing financial strain, particularly if impacted by a climate hazard event.
Linguistic isolation	- Linguistic isolation	Adults who do not speak English well may have trouble accessing or understanding climate resources, including emergency warnings that can be critical during a climate hazard event (e.g., severe flooding, wildfire). [Source: CalEnviroScreen]
Vehicle access	- Vehicle access	Access to a vehicle can be critical to evacuate or access resources before, during, or after a climate hazard event.
Internet access	- Internet access	Access to the internet can be critical to receive information before, during, or after a climate hazard event. Internet disruptions can increase climate vulnerability by preventing people from accessing important information that can help them safely manage a climate hazard event.
Rentership	- Rentership	Renters may be more vulnerable to climate hazard events such as extreme heat or cold that place greater demand on heating and cooling because they have less control over

Factor	Layer(s)	Relation of Factor to Climate Vulnerability/Resilience
		their ability to weatherize their homes. When climate-related disasters occur, "renters may lack the appropriate insurance to cover their losses or have little standing to access federal recovery assistance". In addition, low- and moderate-income "renters may find themselves in buildings that may already be suffering from disinvestment and, therefore, even less likely to withstand extreme weather impacts, such as recurrent flooding, wildfires, or other risks." nationalhousingtrust.org
Race & ethnicity	- Asian/Asian American - Black/African American - Hispanic/Latino - Indigenous Americans/Alaskans - Indigenous Hawaiians/Pacific Islanders - Multiracial Groups - White/European Americans - Additional Racial Groups	Not all race and ethnicities experience the same climate impacts. Climate change disproportionately impacts historically underserved groups such as Black, Indigenous, and people of color due to social, economic, historical, and/or political factors and impacts their capacity to prepare for, cope with, and recover from climate change impacts. [Sources: Fifth National Climate Assessment, EPA's Climate Change and Human Health]
Housing cost burden	- Mortgage households - Rented households	Housing affordability is an important determinant of health and well-being and can put families at an increased risk to climate change impacts because families that spend a significant portion of their income on housing costs have fewer financial resources to prepare for or recover from a climate hazard event. [Source: Fifth National Climate Assessment]
Energy and transportation burden	- Energy and transportation burden	Families that spend a significant portion of their income on energy and transportation costs have fewer financial resources to prepare for or recover from a climate hazard event.
Healthy food access	- Healthy food access	Access to healthy foods is important to be able to sustain a healthy diet. Poor diets can lead to chronic illnesses, and these health impacts can increase climate vulnerability (for example, obese individuals are more susceptible to heat stress). Low-income and minority communities often lack accessible and affordable healthy food options. [Source: CDC Nutrition, CDC NIOSH]
	Community Domain	
Designated areas	- Designated growth center - Downtown district boundaries - Neighborhood development area - New town center boundaries - Village boundaries	Designated areas include areas in Vermont that have a commercial district or have been designated as an important development area. These areas may have a larger impact on the broader community if they are impacted by a climate hazard event (e.g., if businesses flood in a downtown area it could impact people's ability to work, access resources, etc.)

Factor	Layer(s)	Relation of Factor to Climate Vulnerability/Resilience
Historic districts	- State register of historic districts	Historic resources are important to consider as they cannot be replaced once they are damaged or lost.
Municipal financial capacity	- Municipal financial capacity	Municipal financial capacity plays a significant role in the ability of a municipality to prepare for, respond to, or recover from a climate hazard event. Municipalities with less financial capacity may face greater challenges when recovering from climate hazard events such as such as repairing damaged public infrastructure.
Municipal staff capacity	- Municipal staff capacity	Municipal staff capacity plays a significant role in the ability of a municipality to prepare for, respond to, or recover from a climate hazard event. For example, municipalities with limited staff capacity may not have the ability to adequately prepare for a climate hazard event through drafting and adoption of Local Emergency Management Plans or Local Hazard Mitigation Plans, decreasing their overall capacity to implementation adaptation actions.
Adaptation and mitigation actions	- ERAF rate	Participating in the National Flood Insurance Program, adopting road and bridge standards, and adopting plans such as a local hazard mitigation plan or a local emergency management plan are important adaptation and mitigation actions that can help make a community more resilient and manage their vulnerability to climate hazard events such as flooding by ensuring measures are in place to help mitigate flooding and recover after experiencing flood damage.
Town plans and land use regulations	- Plan + regulation status	Adopting local land use regulations and town plans are important measures that communities can take to increase their resilience and decrease their climate vulnerability. These regulations and plans can help to reduce urban sprawl, preserve natural areas, promote use of green infrastructure, encourage energy-efficient development, and more.
Public and civic organizations	N/A	Many past disasters and research studies have found that the presence of public and civic organizations increases social cohesion and community capacity which reduces vulnerabilities from climate change. Public and civic organizations provide community members with ways to get to know one another, increase opportunities to get involved in climate mitigation and adaptation, and can serve an important role in hazard preparedness, response, and recovery. [Sources: Social cohesion, Wildfire preparedness, community cohesion and social–ecological systems, Building community resilience, Climate Preparedness Planning]
Cultural resources	N/A	The vulnerability of cultural and tribal resources is important to consider as many of these critical assets cannot be replaced once they are damaged or lost. Working with community and technical experts to identify these resources and map their locations will help municipalities reduce risks to resources that contribute meaning and a sense of history and place to the people of Vermont. [Sources: Safeguarding cultural property, Cultural heritage resources in climate action, Climate adaptation and resilience]

Factor	Layer(s)	Relation of Factor to Climate Vulnerability/Resilience
		Economic and Job Domain
Outdoor workers	- Outdoor worker	Outdoor workers are particularly vulnerable to the effects of extreme temperature and poor air quality due to the amount of time they spend outdoors. [Source: EPA's Climate Change and Human Health]
Tourism	- Tourism	The Vermont tourism industry may be significantly impacted by climate change due to changing snowfall patterns, increased wildfire risk, flooding impacts, and other climate hazards. Impacts to tourism can have broader economic impacts for the state such as loss of jobs and tourism revenue.
Natural resource industries	N/A	Vermont's economy and employment includes several industries that rely on the health of the environment and natural resources, including timber, maple syrup, skiing, and outdoor recreation. These industries are important to Vermont's economy and culture and climate change poses a risk to all four them due to increased risks from flooding, heat, drought, wildfire, invasive species and pests, and habitat and species shifts.
Small businesses	N/A	The damage and disruption caused by climate change can affect multinational corporations, large companies, and small businesses. However, small businesses tend to be more vulnerable than larger companies and corporations with less access to capital to prepare for or recover from climate change impacts. Small businesses report lacking the time, the financial resources, and the expertise to reduce their risks from climate change or to rebuild after a disaster. [Sources: Small Business Climate Action: Barriers & Bridges, Climate Change Preparedness and the Small Business Sector]
		Built and Physical Environment Domain
Critical assets	- Critical assets	Critical assets are those that may have an outsized impact on the community if they are impacted from, or not accessible during or shortly after, a climate hazard event. For example, if a school is flooded and cannot be reopened for weeks, it has a compounding effect on the community because children cannot attend school, parents may be unable to work due to childcare, etc.
Emergency services	- Emergency services	The ability for emergency services to access an impacted area is critical during a climate hazard event.
Residential dwellings	- Residential dwellings	Knowing the location of residential dwellings can provide an understanding of how different climate hazard events may impact different parts of a community. For example, knowing that a large number of residential dwellings are located within a floodplain can help planners prioritize flood mitigation measures.
Mobile homes	- Mobile homes	The vulnerability of housing to climate change can vary greatly based on housing materials, construction methods, and maintenance. Mobile homes and homes that are not tied to their foundations are often more at risk of damage or loss. Residents and occupants

Factor	Layer(s)	Relation of Factor to Climate Vulnerability/Resilience
		without the resources to maintain and upgrade their dwelling units to reduce risks from climate change are also more at risk of damage or loss. [Source: HUD PD&R]
Other site types	- Other site types	Knowing the location of sites such as commercial buildings or farms can provide an understanding of how different climate hazard events may impact these different site types. For example, knowing that a large number of commercial buildings are located within a floodplain can help planners prioritize flood mitigation measures.
Housing age	- Housing built 1939 and earlier - Housing built between 1940 and 1959 - Housing built between 1960 and 1979 - Housing built between 1980 and 1999 - Housing built 2000 and after	The vulnerability to climate change can vary greatly based on housing materials, construction methods, and maintenance. Older homes are often more at risk of damage or loss. Residents and occupants without the resources to maintain and upgrade their dwelling units to reduce risks from climate change are also more at risk of damage or loss. [Source: HUD PD&R]
Wildfire mitigation	N/A	While large-scale wildfires are not a risk for Vermont, the risk of wildfire has increased in the Northeast due to droughts, higher heat, and changes in timing and amount of precipitation. Wildland fire mitigation actions such as obtaining open burning permits, forest restoration and management actions at the landscape scale, vegetation management, and home hardening at the building scale, and the development of plans such as Community Wildfire Protection Plans can reduce wildfire risk to Vermont's communities even as climate change increases the risks. [Sources: Why Should My Community Plan for a Wildfire?, Firewise Resources for Residents]
Wells at risk of drying up	N/A	Communities that rely on wells for water supply are more at risk from drying up from even localized and seasonal droughts. Communities and households that rely on well water often lack redundant sources of water, leaving them much more vulnerable to overdraft, subsidence, and decreased water quality, as well as water scarcity issues. With 60 percent of Vermont residents receiving their water from groundwater supplies, climate change influences on drought and wells could have a widespread impact across the state. [Source: Vermont Climate Assessment]
Heating and cooling centers	N/A	The presence of accessible and well-advertised heating and cooling centers in a community reduces life safety and health risks from extreme heat and extreme cold. It is important to consider location, accessibility, familiarity, and hours of operation when determining the value of heating and cooling centers to a community. Locating them in areas that are familiar to the community, having longer hours of operation, and including other benefits such as internet connections, games, clean water, and other necessities will increase their

Factor	Layer(s)	Relation of Factor to Climate Vulnerability/Resilience
		value and use. [Sources: The Role of Cooling Centers in Protecting Vulnerable Individuals from Extreme Heat, Five Ways To Increase Use Of Cooling Centers]
Housing materials, construction methods, and maintenance	N/A	How vulnerable housing, schools, or other buildings are to climate change can vary greatly based on housing materials, construction methods, and maintenance. Older homes, modular homes and buildings, homes and buildings with below ground living or usable spaces, and homes and buildings that are not tied to their foundations are often more at risk of damage or loss. Residents and occupants without the resources to maintain and upgrade their dwelling units to reduce risks from climate change are also more at risk of damage or loss. [Sources: The Role of Housing in Climate Change Mitigation and Adaptation Opportunities To Reduce Climate Risks Through Land Use Regulations Resiliency at Work, Durability and Climate Change—Implications for Service Life Prediction and the Maintainability of Buildings]
Infrastructure Domain		
Toxic or hazardous sites	- Toxic or hazardous sites	Chemicals from toxic or hazardous sites can be transported by air or water and negatively impact the environment and people. Climate hazards such as flooding can increase the transport of these chemicals. [Source: CalEnviroScreen]
Airports	- Airports	Airports can be vital during climate hazard events because they could be the only way to efficiently bring in relief supplies and personnel to help a community recover from an event. Ensuring that airports are protected from climate hazard events can be a critical to protecting human life and safety.
Roads, bridges, culverts	- Roads - Bridges - Culverts	Preventing damage and destruction to roads, bridges, and culverts can be vital to ensuring that emergency services can accessed, and that impact to daily life is minimized. Understanding vulnerabilities to roads, bridges, and culverts in a proactive manner can help to avoid or mitigate future impacts. [Source: VT TRPT]
Public transit routes	- Public transit routes	For those without access to a vehicle, public transit may be the only way to evacuate or access resources before, during, or after a climate hazard event.
Drinking water infrastructure	- Drinking water infrastructure	Maintaining a safe and reliable source of drinking water is critical. Drinking water infrastructure that is vulnerable to impacts from climate hazard events can pose a serious risk to human life.
Wastewater infrastructure	- Wastewater infrastructure	Wastewater infrastructure is a critical asset that, when impacted, can cause significant human health impacts.
Electric utility infrastructure	- Electric substations - Power Lines (Green Mountain Power Lines) - Powerlines (VEC "spans" data) - Power Lines (WEC Utility Lines)	Access to reliable electricity can be critical as it may be needed to heat or cool a dwelling unit, as well as to receive updates related to climate hazard events (before, during, and after). Ensuring that this infrastructure has limited chance of failure, including from climate hazard events such as flooding or high wind, is critical to ensuring a community does not have increased climate vulnerability.

Factor	Layer(s)	Relation of Factor to Climate Vulnerability/Resilience
	- Power plants and neighboring communities - Power plant retirements	
Impervious surfaces	- Impervious surfaces (Vermont Open Geodata Portal)	Impervious surfaces are unable to absorb precipitation, leading to increased runoff which can contribute to flooding in a community. Additionally, impervious surfaces contribute to urban heat island effects.
	Natural Environment Domain	
Conserved and protected lands	- Conserved and protected lands	Conserved and protected lands can mitigate climate hazard events such as flooding.
Tree Cover	- Municipal tree inventory	Tree canopy can help to reduce urban heat island effect. Understanding the location and health of trees in a community can help community members better care for and manage their trees and forests. [Source: VT Municipal Tree Inventory]
River and stream protection	- River and stream protection	River and stream protection easements can help reduce impacts from flooding.
Priority Environmental Areas and Biodiversity	- Geological diversity blocks - Landscape scale - Location of community & species scale priorities - Biodiversity	Maintaining important ecosystems, natural communities, habitats, and species is important to maintaining biodiversity and overall ecosystem health and can provide mitigation benefits such as alleviating flooding. [Source: BioFinder]
Air quality	N/A	Extreme heat, wildfires, and flooding can all contribute to degraded indoor and outdoor air quality. Extreme heat increases ground level ozone, wildfires increase particulate matter, and flooding can increase algae and mold. Degraded air quality has health and safety impacts on residents and workers with greater risks for those over 65, under 5, people with pre-existing health conditions, and people with prior or ongoing exposure to other pollutants. [Source: Vermont Department of Health, Climate and Health Air Quality Page]

3.3 Flagging

While all factors included in the MVI are determined to be critical to climate vulnerability and resilience in Vermont, not all factors in the geospatial tool are flagged. Factors that are flagged are identified accordingly in Table 2 in Section 2.3. Flagged factors are those factors that are not represented geospatially in the tool and contribute to climate vulnerability or resilience. Additionally, race/ethnicity factors are flagged because they have been found to be more vulnerable to climate change. Not all races and ethnicities experience the same climate impacts. Populations that are vulnerable due to social, economic, historical, and/or political factors are also more vulnerable to climate change because they have a lower capacity to prepare for, cope with, and recover from climate change impacts. Therefore, only racial/ethnic populations that have been found to be more vulnerable to climate change are flagged. For example:

- ELDERLY is a flagged factor because being over 65 makes a person more vulnerable to most climate impacts. Data are summarized at the county subdivision (town) level and presented as the percent of the county subdivision adults aged 65 or older. These data are not represented geospatially in the sense that it is not possible to identify specific locations within a county subdivision where each elderly resident lives, but rather a percentage of elderly residents who live within a specific county subdivision.
- BLACK/AFRICAN AMERICAN is a flagged factor because, due to social, economic, historical, and/or political factors, Black residents are also more vulnerable to climate change due to the fact that they have historically had a lower capacity to prepare for, cope with, and recover from climate change impacts.
- AIRPORTS is not a flagged factor because the data for the specific locations of each airport are available and depicted on the map layers within the MVI.

The thresholds for flagging were determined based on the type of data associated with each factor. Whenever appropriate, the flagging threshold for the factor is based on the average of the state data (either above or below this average, whichever indicates greater vulnerability). When this threshold is not appropriate (e.g., ERAF rate), a threshold specific to that factor was defined (see Table 2).

4. Data Limitations and Considerations

Two types of data limitations present considerations when using and interpreting the data in the MVI: 1) details of the underlying data and/or characteristics of the tool serving as the data source (e.g., data limitations, likelihood, metadata behind the data, projections) and 2) limitations of the data as applied to Vermont in the MVI. Each of these limitations is addressed below.

4.1 Limitations Associated with Source Data

The limitations associated with the data used in the MVI can be further explored by accessing the sources of the underlying data and reading more about the information provided by those who developed and manage those data sources. The underlying data sources are specified in the MVI and this user guide, with links to each data source provided in Table 2 (factors of climate vulnerability) and Table 3 (hazard layer data). For example, to learn more about the U.S. Census American Community (ACS) Survey data that are used for many of the climate vulnerability factors, users can click on the link provided in Table 2, American Community Survey (U.S. Census Bureau, 2020). Upon arriving at the ACS site, users can access an array of information on the left-hand side of the screen about how the data are developed (e.g., Research and Methodology) and considerations for data use (e.g., Guidance for Data Users). In some instances, additional information about the data or information being generated by the tool is not as clearly labeled as the ACS and requires the user to explore the tool or data webpage. For example, if interested in better understanding the data developed by BioFinder, users can find additional detail about the tool and its mapped information by clicking on the "Click Here for More Help" link on the tool's main webpage.

4.2 Limitations of Data as Applied to Vermont

The MVI used ACS 5-year 2020 estimates for many factors included in the tool, including for the majority of the factors in the Social Domain. It is important to note that ACS data are estimates and users should be careful about drawing conclusions about small differences in ACS metrics between municipalities. As the documentation from the U.S. Census Bureau explains:

> "ACS estimates have a degree of uncertainty associated with them, called sampling error, because they are based on a sample. In general, the larger the sample, the smaller the level of sampling error. Rural communities tend to have smaller samples than large cities, so the "margin of error"—a measure of the precision of an estimate at a given level of confidence—likely will be larger for rural areas. The U.S. Census Bureau provides margins of error at the 90 percent level of confidence for each published ACS estimate." [69]

To increase the statistical reliability of the MVI data for less populated areas, the project team used 5-year ACS estimates rather than 1-year estimates.

For further information about data limitations specific to each data source, please refer to the documentation provided on each data source's webpage at https://www.census.gov/programs-surveys/acs.

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[69] U.S. Census Bureau, 2020. Understanding and Using American Community Survey Data: What All Data Users Need to Know. Accessible at: www.census.gov/programs-surveys/acs/guidance/handbooks /general.html.

5. Contact Information

For questions or additional information on the MVI or its use, please email the ANR Climate Action Office at ANR.CAO@vermont.gov.

Appendix B: Factors for MVI Inclusion

Layer	Metric	Climate Vulnerability Threshold If Factor Flagged (if applicable)	Data Source	Relation of Factor to Climate Vulnerability/Resilience
Social Domain				
Adult Asthma	Percent (%) of adults with asthma	Above state average (10.92%)	Vermont Behavioral Risk Factor Surveillance System	People with asthma and other respiratory illnesses are at an increased risk to climate impacts such as poor indoor and outdoor air quality, and a prolonged allergy season. [Source: EPA's Climate Change and Human Health]
Population	Population size (number of people)	Above state average (2,448 people)	American Community Survey (U.S. Census Bureau, 2020)	Understanding where there are greater or fewer number of people that may be exposed to a climate hazard event can help planners prepare for events, including ensuring that adequate resources for preparing and recovering from events are available for the community.
Low Income	Percent (%) of households with an annual household income less than 2x the federal poverty rate	Above state average (22.99%)	American Community Survey (U.S. Census Bureau, 2020)	Low income individuals are more likely to live in areas with greater air pollution, work in industries with exposure to extreme temperatures, and live in areas with higher rates of land lost to inundation, all of which are exacerbated by climate change. [Source: EPA's 2021 Social Vulnerability Report]
Elderly residents	Percent (%) of people aged 65 and older	Above state average (21.34%)	American Community Survey (U.S. Census Bureau, 2020)	Older adults may have greater difficulty evacuating in advance of a climate hazard (e.g., severe flooding, wildfire) due to mobility limitations. Older adults are also more vulnerable to high heat effects. [Source: EPA's Climate Change and Human Health]
Children	Percent (%) of people aged 5 and younger	Above state average (4.59%)	American Community Survey (U.S. Census Bureau, 2020)	Children are dependent on adults for their safety and well-being, which makes them more vulnerable during climate hazard events (e.g., severe flooding, wildfire). [Source: EPA's Climate Change and Human Health]

Layer	Metric	Climate Vulnerability Threshold If Factor Flagged (if applicable)	Data Source	Relation of Factor to Climate Vulnerability/Resilience
People with Disabilities	Percent (%) of population with a disability	Above state average (14.40%)	American Community Survey (U.S. Census Bureau, 2020)	Emergency warnings and other climate resources may not be designed to be accessible to people with disabilities, and they may have greater difficulty evacuating in advance of a climate hazard event (e.g., severe flooding, wildfire). [Source: EPA's Climate Change and Human Health]
Single Parent Households	Percent (%) of households that are single parent households	Above state average (11.58%)	American Community Survey (U.S. Census Bureau, 2020)	Single parent households may be more susceptible to experiencing financial strain, particularly if impacted by a climate hazard event.
Linguistic Isolation	Percent (%) of households with limited English-speaking proficiency	Above state average (0.33%)	American Community Survey (U.S. Census Bureau, 2020)	Adults who do not speak English well may have trouble accessing or understanding climate resources, including emergency warnings that can be critical during a climate hazard event (e.g., severe flooding, wildfire). [Source: CalEnviroScreen]
Vehicle Access	Percent (%) of households without access to a vehicle	Above state average (4.06%)	American Community Survey (U.S. Census Bureau, 2020)	Access to a vehicle can be critical to evacuate or access resources before, during, or after a climate hazard event.
Internet Access	Percent (%) of households with no internet	Above state average (12.36%)	American Community Survey (U.S. Census Bureau, 2020)	Access to the internet can be critical to receive information before, during, or after a climate hazard event. Internet disruptions can increase climate vulnerability by preventing people from accessing important information that can help them safely manage a climate hazard event.
Rentership	Percent (%) of housing units that are renter-occupied	Above state average (14.19%)	American Community Survey (U.S. Census Bureau, 2020)	Renters may be more vulnerable to climate hazard events such as extreme heat or flooding because they may not be able to implement preparedness measures. Additionally, many renters may not have the financial resources to prepare for or recover from a climate hazard event.
Asian	Percent (%) of population that is Asian alone	NA	American Community Survey (U.S. Census Bureau, 2020)	Not all race and ethnicities experience the same climate impacts. Populations that are vulnerable due to social, economic, historical, and/or political factors are also more vulnerable to climate change due to the fact that they have a lower capacity to prepare for, cope with, and recover from
Black or African Americans	Percent (%) of population that is Black or African American alone	Above state average (0.60%)	American Community Survey (U.S. Census Bureau, 2020)	

Layer	Metric	Climate Vulnerability Threshold If Factor Flagged (if applicable)	Data Source	Relation of Factor to Climate Vulnerability/Resilience
Hispanic or Latino	Percent (%) of population that is Hispanic or Latino	Above state average (1.83%)	American Community Survey (U.S. Census Bureau, 2020)	climate change impacts. [Source: EPA's Climate Change and Human Health]
American Indian and Alaska Native	Percent (%) of population that is American Indian or Alaska Native alone	Above state average (0.4%)	American Community Survey (U.S. Census Bureau, 2020)	
Native Hawaiian and Other Pacific Islander	Percent (%) of population that is Native Hawaiian or Other Pacific Islander alone	Above state average (0.04%)	American Community Survey (U.S. Census Bureau, 2020)	
Two or More Races	Percent (%) of population that is two or more races	Above state average (2.49%)	American Community Survey (U.S. Census Bureau, 2020)	
White, Not Hispanic or Latino	Percent (%) of population that is White alone	NA	American Community Survey (U.S. Census Bureau, 2020)	
Some Other Race	Percent (%) of population that is some other race alone	Above state average (0.3%)	American Community Survey (U.S. Census Bureau, 2020)	
Housing cost burden	Owner-occupied housing units - Percent (%) of owner-occupied housing units where mortgage is 50% or more of household income Renter-occupied housing units - Percent (%) of renter-occupied housing units where rent is 50% or more of household income	Above state average - Owner occupied (13.3%) - Renter (16.25%)	American Community Survey (U.S. Census Bureau, 2020)	Housing affordability is an important determinant of health and well-being and can put families at an increased climate vulnerability because families that spend a significant portion of their income on housing costs have fewer financial resources to prepare for or recover from a climate hazard event. [Source: CalEnviroScreen]

Layer	Metric	Climate Vulnerability Threshold If Factor Flagged (if applicable)	Data Source	Relation of Factor to Climate Vulnerability/Resilience
Energy and transportation burden	Average percent (%) of median household income spent on energy and transportation costs	Above state average (10.58)	Efficiency Vermont (Energy Burden by Town)	Families that spend a significant portion of their income on energy and transportation costs have fewer financial resources to prepare for or recover from a climate hazard event.
Access to healthy foods	At least 500 people or 33% of the population live farther than 1 mile (urban areas) or 10 miles (rural areas) from the nearest supermarket - Yes - No	NA	USDA Food Access Research Atlas	Access to healthy foods is important to be able to sustain a healthy diet. Poor diets can lead to chronic illnesses, and these health impacts can increase climate vulnerability (for example, obese individuals are more susceptible to heat stress). Low-income and minority communities often lack accessible and affordable healthy food options. [Source: CDC Nutrition, CDC NIOSH]
Community Domain				
Designated Growth Center	NA	NA	Vermont Planning Atlas	Designated areas include areas in Vermont that have a commercial district or have been designated as an important development area. These areas may have a larger impact on the broader community if they are impacted by a climate hazard event (e.g., if businesses flood in a downtown area it could impact people's ability to work, access resources, etc.)
Downtown District Boundaries	NA	NA	Vermont Planning Atlas	
Village Boundaries	NA	NA	Vermont Planning Atlas	
Neighborhood Development Area	NA	NA	Vermont Planning Atlas	
New Town Center Boundaries	NA	NA	Vermont Planning Atlas	
Municipal Financial Capacity	- Equalized municipal grand list value ($)	Below state average ($4,254,119)	State of Vermont Equalized Grand List	Municipal financial capacity plays a significant role in the ability of a municipality to prepare for, respond to, or recover from a climate hazard event. Municipalities with less financial capacity are at greater risk to increased impacts from climate hazard events.
Municipal Staff Capacity	Number of paid staff - 1 - 2 - 3 - 4 or more	If town does not have at least one paid manager or administrator	VT League of Cities and Towns	Municipal staff capacity plays a significant role in the ability of a municipality to prepare for, respond to, or recover from a climate hazard event. For example, municipalities with limited staff capacity may not have the ability to adequately prepare for a climate hazard event.

Layer	Metric	Climate Vulnerability Threshold If Factor Flagged (if applicable)	Data Source	Relation of Factor to Climate Vulnerability/Resilience
State Register of Historic Districts	- State registered historic districts	NA	VT Agency of Commerce and Community Development (ACCD)	Historic resources are important to consider as they cannot be replaced once they are damaged or lost.
Plan and Regulation Status	- Unconfirmed planning process and local land use regulation - Unconfirmed planning process and no local land use regulation - Confirmed planning process and local land use regulation - Confirmed planning process and no local land use regulation	If municipality has unconfirmed planning process and/or no local land use regulation *[Rationale: not having either a planning process or local land use regulations indicates higher vulnerability, and less than 50% of all VT municipalities do not have at least one of these.]*	Vermont Planning Atlas	Adopting plans such as a local hazard mitigation plan, local emergency management plan, or local land use regulations are important adaptation and mitigation actions that can help a community manage their vulnerability to climate hazard events.
Emergency Relief and Assistance Funds	Emergency Relief and Assistance Fund (ERAF) rates - 17.5% (Five or more mitigation actions adopted) - 12.5% (Four mitigation actions adopted) - 7.5% (Less than 4 mitigation actions adopted)	ERAF rate = 7.5% [Rationale: ERAF rates greater than 7.5% indicate that the community has adopted at least four mitigation measures]	State of Vermont Agency of Natural Resources	

Layer	Metric	Climate Vulnerability Threshold If Factor Flagged (if applicable)	Data Source	Relation of Factor to Climate Vulnerability/Resilience
Public and civic organizations	NA	NA	NA	Many past disasters and research studies have found that the presence of public and civic organizations increases social cohesion and community capacity which reduces vulnerabilities from climate change. Public and civic organizations provide community members with ways to get to know one another, increase opportunities to get involved in climate mitigation and adaptation, and can serve an important role in hazard preparedness, response, and recovery. [Sources: Social cohesion, Wildfire preparedness, community cohesion and social–ecological systems, Building community resilience, Climate Preparedness Planning]
Cultural resources	NA	NA	NA	The vulnerability of cultural and tribal resources is important to consider as many of these critical assets cannot be replaced once they are damaged or lost. Working with community and technical experts to identify these resources and map their locations will help municipalities reduce risks to resources that contribute meaning and a sense of history and place to the people of Vermont. [Sources: Safeguarding cultural property, Cultural heritage resources in climate action, Climate adaptation and resilience]
Economic and Job Domain				
Outdoor Worker	Percent (%) employed civilian population aged 16 years and older in farming, fishing and forestry occupations and construction, extraction, and maintenance occupations	Above state average (13.21%)	U.S. Census Bureau Decennial Census (PCT086)	Outdoor workers are particularly vulnerable to the effects of extreme temperature and poor air quality due to the amount of time they spend outdoors. [Source: EPA's Climate Change and Human Health]

Layer	Metric	Climate Vulnerability Threshold If Factor Flagged (if applicable)	Data Source	Relation of Factor to Climate Vulnerability/Resilience
Tourism	Percent (%) employed civilian population aged 16 years and older in tourism industry (transportation, tourism, and lodging attendants)	Above state average (0.13%)	U.S. Census Bureau Decennial Census (PCT086)	The Vermont tourism industry may be significantly impacted by climate change due to changing snowfall patterns, increased wildfire risk, flooding impacts, and other climate hazards. Impacts to tourism can have broader economic impacts for the state such as loss of jobs and tourism revenue.
Natural resource industries	NA	NA	NA	Vermont's economy and employment includes several industries that rely on the health of the environment and natural resources, including timber, maple syrup, skiing, and outdoor recreation. These industries are important to Vermont's economy and culture and climate change poses a risk to all four them due to increased risks from flooding, heat, drought, wildfire, invasive species and pests, and habitat and species shifts.
Small businesses	NA	NA	NA	The damage and disruption caused by climate change can affect multinational corporations, large companies, and small businesses. However, small businesses tend to be more vulnerable than larger companies and corporations with less access to capital to prepare for or recover from climate change impacts. Small businesses report lacking the time, the financial resources, and the expertise to reduce their risks from climate change or to rebuild after a disaster. [Sources: Small Business Climate Action: Barriers & Bridges, Climate Change Preparedness and the Small Business Sector]
Built and Physical Environment Domain				

Layer	Metric	Climate Vulnerability Threshold If Factor Flagged (if applicable)	Data Source	Relation of Factor to Climate Vulnerability/Resilience
Critical Assets	- School K/12 - Library - Health Clinic - Town Garage - Wastewater Treatment Plant - Communication Tower - Substation - Town Office - Utility - Nursing Home / Long Term Care - Hydroelectric Facility - City/Town Hall - Public Water Supply Well	NA	Vermont Open Geodata Portal E911 Data (Libraries, Schools, other buildings and houses)	Critical assets are those that may have an outsized impact on the community if they are impacted from, or not accessible during or shortly after, a climate hazard event. For example, if a school is flooded and cannot be reopened for weeks, it has a compounding effect on the community because children cannot attend school, parents may be unable to work due to childcare, etc.
Emergency Services	- Fire station - Law enforcement - Hospital / medical center - Ambulance service	NA	Vermont Open Geodata Portal E911 Data	The ability for emergency services to access an impacted area is critical during a climate hazard event.
Mobile homes	Mobile homes	NA	Vermont Open Geodata Portal E911 Data	Knowing the location of residential dwellings can provide an understanding of how different climate hazard events may impact different parts of a community. For example, knowing that a large number of residential dwellings are located within a floodplain can help planners prioritize flood mitigation measures.
Other Site Types	- Accessory Building - Commercial - Commercial Farm - Other Commercial - Accessory Barn - - Other	NA	Vermont Open Geodata Portal E911 Data	How vulnerable housing is to climate change can vary greatly based on housing materials, construction methods, and maintenance. Mobile homes and homes that are not tied to their foundations are often more at risk of damage or loss. Residents and occupants without the resources to maintain and upgrade their dwelling units to reduce risks from climate change are also more at risk of damage or loss. [Source: HUD PD&R]

Layer	Metric	Climate Vulnerability Threshold If Factor Flagged (if applicable)	Data Source	Relation of Factor to Climate Vulnerability/Resilience
Residential Dwellings	- Single family - Multi family - Camp - Condominium - Other residential - Seasonal home	NA	Vermont Open Geodata Portal E911 Data (Libraries, Schools, other buildings and houses)	Knowing the location of sites such as commercial buildings or farms can provide an understanding of how different climate hazard events may impact these different site types. For example, knowing that a large number of commercial buildings are located within a floodplain can help planners prioritize flood mitigation measures.
Housing age	Percent (%) of houses built: - 1939 and earlier - 1940 to 1959 - 1960 to 1979 - 1980 to 1999 - 2000 and later	Above state average for houses built before 2000 (83.95%)	American Community Survey (U.S. Census Bureau, 2020)	How vulnerable housing is to climate change can vary greatly based on housing materials, construction methods, and maintenance. Older homes are often more at risk of damage or loss. Residents and occupants without the resources to maintain and upgrade their dwelling units to reduce risks from climate change are also more at risk of damage or loss. [Source: HUD PD&R]
Wildfire mitigation	NA	NA	NA	While large scale wildfires are not a risk for Vermont, the risk of wildfire has increased in the Northeast due to droughts, higher heat, and changes in timing and amount of precipitation. Wildland fire mitigation actions such as obtaining open burning permits, forest restoration and management actions at the landscape scale, vegetation management, and home hardening at the building scale, and the development of plans such as Community Wildfire Protection Plans can reduce wildfire risk to Vermont's communities even as climate change increases the risks. [Sources: Why Should My Community Plan for a Wildfire?, Firewise Resources for Residents]

Layer	Metric	Climate Vulnerability Threshold If Factor Flagged (if applicable)	Data Source	Relation of Factor to Climate Vulnerability/Resilience
Wells at risk of drying up	NA	NA	NA	Communities that rely on wells for water supply are more at risk from drying up from even localized and seasonal droughts. Communities and households that rely on well water often lack redundant sources of water, leaving them much more vulnerable to overdraft, subsidence, and decreased water quality, as well as water scarcity issues. With 60 percent of Vermont residents receiving their water from groundwater supplies, climate change influences on drought and wells could have a widespread impact across the state. [Source: Vermont Climate Assessment]
Heating and cooling centers	NA	NA	NA	The presence of accessible and well-advertised heating and cooling centers in a community reduces life safety and health risks from extreme heat and extreme cold. It is important to consider location, accessibility, familiarity, and hours of operation when determining the value of heating and cooling centers to a community. Locating them in areas that are familiar to the community, having longer hours of operation, and including other benefits such as internet connections, games, clean water, and other necessities will increase their value and use. [Sources: The Role of Cooling Centers in Protecting Vulnerable Individuals from Extreme Heat, Five Ways To Increase Use Of Cooling Centers]

Layer	Metric	Climate Vulnerability Threshold If Factor Flagged (if applicable)	Data Source	Relation of Factor to Climate Vulnerability/Resilience
Housing materials, construction methods, and maintenance	NA	NA	NA	How vulnerable housing, schools, or other buildings are to climate change can vary greatly based on housing materials, construction methods, and maintenance. Older homes, modular homes and buildings, homes and buildings with below ground living or usable spaces, and homes and buildings that are not tied to their foundations are often more at risk of damage or loss. Residents and occupants without the resources to maintain and upgrade their dwelling units to reduce risks from climate change are also more at risk of damage or loss. [Sources: The Role of Housing in Climate Change Mitigation and Adaptation Opportunities To Reduce Climate Risks Through Land Use Regulations Resiliency at Work, Durability and Climate Change—Implications for Service Life Prediction and the Maintainability of Buildings]
Infrastructure Domain				
Toxic and Hazardous Sites	Hazardous sites	NA	Vermont Agency of Natural Resources	Chemicals from toxic or hazardous sites can be transported by air or water and negatively impact the environment and people. Climate hazards such as flooding can increase the transport of these chemicals. [Source: CalEnviroScreen]
Roads, bridges, and culverts	- Roads - Bridges - Culverts	NA	VT TRPT	Preventing damage and destruction to roads, bridges, and culverts can be vital to ensuring that emergency services can accessed, and that impact to daily life is minimized. Understanding vulnerabilities to roads, bridges, and culverts in a proactive manner can help to avoid or mitigate against future impacts. [Source: VT TRPT]
Airports	Airports	NA	Vermont Open Geodata Portal	Airports can be vital during disaster events because they could be the only way to efficiently bring in relief supplies and personnel to help a community recover from an event. Ensuring that airports are protected from climate hazard events can be a critical to protecting human life and safety.

Layer	Metric	Climate Vulnerability Threshold If Factor Flagged (if applicable)	Data Source	Relation of Factor to Climate Vulnerability/Resilience
Drinking water infrastructure	Drinking water infrastructure - Existing - Abandoned - Potential - Proposed	NA	Vermont Open Geodata Portal	Maintaining a safe and reliable source of drinking water is critical. Drinking water infrastructure that is vulnerable to impacts from climate hazard events can pose a serious risk to human life.
Electric Substations	Electric utility substations	NA	Vermont Open Geodata Portal	Access to reliable electricity can be critical as it may be needed to heat or cool a dwelling unit, as well as to receive updates related to climate hazard events (before, during, and after). Ensuring that this infrastructure has limited chance of failure, including from climate hazard events such as flooding or high wind, is critical to ensuring a community does not have increased climate vulnerability.
Power Lines (Green Mountain Power)	Green Mountain Power lines - Underground structure data - Pole data - Line data	NA	Vermont Open Geodata Portal	
Power Lines (VEC "spans" data	VEC power lines	NA	VEC "spans" data	
Power Lines (WEC Utility Lines)	WEC utility lines	NA	Vermont Open Geodata Portal	
Power Plants and Neighboring Communities	- Operating - Retired or plan to retire	NA	Power Plants and Neighboring Communities Mapping Tool	
Impervious Surfaces	Impervious surfaces	NA	Vermont Open Geodata Portal	
Public Transit Routes	Public transit routes	NA	Vermont Open Geodata Portal	For those without access to a vehicle, public transit may be the only way to evacuate or access resources before, during, or after a climate hazard event.
Wastewater Infrastructure	Wastewater treatment facilities	NA	Vermont Open Geodata Portal	Wastewater infrastructure is a critical asset that, when impacted, can cause significant human health impacts.
		Natural Environment Domain		
Biodiversity		NA	Vermont Open Geodata Portal	Maintaining important ecosystems, natural communities, habitats, and species is important to maintaining biodiversity and overall ecosystem health and can provide
Conserved and protected lands	Protected lands	NA	Vermont Open Geodata Portal	

Layer	Metric	Climate Vulnerability Threshold If Factor Flagged (if applicable)	Data Source	Relation of Factor to Climate Vulnerability/Resilience
Geological Diversity		NA	Vermont Agency of Natural Resources	mitigation benefits such as alleviating flooding. [Source: BioFinder]
Landscape Scale	- Interior Forest Blocks - Connectivity Blocks - Surface Water and Riparian - HP Riparian Wildlife Connectivity - HP Physical Landscape Diversity - HP Physical Landscape Blocks	NA	BioFinder (Vermont Agency of Natural Resources)	
Location of Community and Species Scale Priorities	- Natural Communities - Aquatic Habitats - Wetlands - Vernal Pools - Terrestrial Wildlife Crossings - Riparian Wildlife Crossings - Species	NA	BioFinder (Vermont Agency of Natural Resources)	
Municipal Tree Inventory	- Good condition - Fair condition - Poor condition - Dead - Vacant - Unknown	NA	VT Agency of Natural Resources	Tree canopy can help to reduce urban heat island effect. Understanding the location and health of trees in a community can help community members better care for and manage their trees and forests. [Source: VT Municipal Tree Inventory]

Layer	Metric	Climate Vulnerability Threshold If Factor Flagged (if applicable)	Data Source	Relation of Factor to Climate Vulnerability/Resilience
Air quality	NA	NA	NA	Extreme heat, wildfires, and flooding can all contribute to degraded indoor and outdoor air quality. Extreme heat increases ground level ozone, wildfires increase particulate matter, and flooding can increase algae and mold. Degraded air quality has health and safety impacts on residents and workers with greater risks for those over 65, under 5, people with pre-existing health conditions, and people with prior or ongoing exposure to other pollutants. [Source: Vermont Department of Health, Climate and Health Air Quality Page]

Appendix C: Tool Beta Testing Questionnaire

Municipal Vulnerability Index Beta Testing Questionnaire

Thank you for your willingness to participate in this Municipal Vulnerability Index (MVI) beta testing exercise and questionnaire! The objective of this questionnaire is to gather feedback on the draft MVI regarding its general usability, functionality, performance, content clarity and ease of use as well as general feedback on the tool. Your feedback will be used to identify and address any key user issues prior to finalizing the tool and making it available to users.

To test the functionality of the draft MVI and gather user feedback, you will be asked to walk through the draft MVI tool using two scenarios outlined below and then provide overarching feedback about the tool and your experience using it. We encourage you to explore the tool and its features outside of the specific scenarios prior to completing the tool feedback section of the questionnaire.

The draft MVI can be accessed here: [tool link].

An explanation of key tool functions and buttons can be found in the user guide excerpt attached to the questionnaire email.

Beta Test Scenarios

Please use the MVI to complete the tasks under each scenario.

Scenario 1: You are developing a Local Hazard Mitigation Plan and are responsible for writing up a section on specific hazards of concern to your community. More specifically, you are interested in understanding whether there are wildfire risks in your area. Using the MVI, try to understand:

1. Which areas of Vermont are exposed to wildfire risk?
   a. Which communities/areas of the state face the highest wildfire risk?
2. Of the communities exposed to wildfire risks: select a community and identify whether any of the following are within that wildfire risk area
   a. Built or physical environment critical assets
   b. Critical infrastructure
   c. Conserved and protected Lands

Scenario 2: You are trying to understand if certain hazards disproportionately impact certain members of your community and their jobs. For a community of interest to you, please:

1. Choose 3-4 hazards of interest
2. For each hazard (one by one), select:
   a. At least 3 types of demographic information under the “Social” domain to see what populations might be most impacted by the selected hazard.
   b. Select each type of employment under the “Economic and Job” domain to see if any jobs might be heavily impacted by the selected hazard.

Tool Feedback

This section asks for your feedback on the MVI based on your experience completing the scenarios above as well as any other exploration of the tool that you may have conducted outside of those scenarios.

General Usability and User Experience

1. Did you find the layout and design of the MVI visually appealing?
    - Yes
    - No/It could be improved
        - Please describe how the MVI could be more visually appealing.

2. Did you encounter any difficulty finding the information or options you needed when using the MVI?
    - No
    - Yes
        - If yes, please describe the difficulties you encountered.

Feature functionality

3. Did you find the following MVI features helpful and easy to use? Please select a response for each feature listed:

    a. Map legend
    - Yes
    - No/It could be improved
        - How could this feature be improved to better meet your needs?

    b. Map layer buttons
    - Yes
    - No/It could be improved
        - How could this feature be improved to better meet your needs?

    c. Written narrative buttons
    - Yes
    - No/It could be improved
        - How could this feature be improved to better meet your needs?

    d. Printing
    - Yes
    - No/It could be improved
        - How could this feature be improved to better meet your needs?

    e. Data export
    - Yes
    - No/It could be improved
        - How could this feature be improved to better meet your needs?

Performance

4. Did you experience any errors, delays, or crashes while using the MVI?
    - No
    - Yes
        - Please describe the error or issue that you encountered.

- What were you doing (or attempting to do) when the error occurred?

Tool Content Clarity

5. Was the MVI interface and its content easy to understand and follow?
    - Yes
    - No/It could be improved
        - Please describe any particular aspects of the content that were unclear.
6. Did the MVI's content align with your expectations for the tool?
    - Yes
    - No/It could be improved
        - In what way(s) did the MVI not align with your expectations for the tool?
        - Please describe how the MVI can be improved to better align with your expectations for the tool.
7. What suggestions do you have for improving the clarity and effectiveness of the MVI? [open ended]

Overarching Feedback

8. Will you use the MVI once it is released?
    - Yes
    - No
    - Unsure

    Please elaborate on your response.
9. Are there any other suggestions you have for improving the MVI to provide a better overall experience that you have not yet shared? If so, please elaborate. [open ended]

Closing

Thank you for taking the time to review and provide feedback on the draft MVI. We appreciate your participation. Your input will be valuable in helping refine and finalize the tool.

Appendix D: Instructions for Updating the MVI

Instructions to Refresh the Flagging Layer used in the MVI

1. Execute the supporting scripts to regenerate Geopackage files (built_phys_vuln.gpkg, com_vuln.gpkg, econ_job_vuln.gpkg and soc_vuln.gpkg).
2. Unzip the MVI_Flagging_Geoprocessing.zip file (provided separately).
3. Open ArcGIS Pro and open the MVI.aprx file found in the unzipped directory from #2.
4. Move the Geopackage files created from #1 from this list into the same directory and add the specified layers to the map.
    - built_phys_vuln.gpkg
        - housing_age
    - com_vuln.gpkg
        - eraf_rate
        - financial_capacity
        - staff_capacity
    - econ_job_vuln.gpkg
        - outdoor_worker
        - tourism
    - soc_vuln.gpkg
        - adult_asthma
        - census_data
        - energy_burden
    - Unzip boundary.zip file provided to the same directory and add the FS_VCGI_OPENDATA_Boundary_BNDHASH_poly_towns_SP_v1 shape file to the map.
5. Open the toolbox(MVI.atbx) for the project in edit mode.
6. Validate and run the model – this should take less than 5 minutes to complete.
7. Republish the newly generated flagging layer (named Flagging_Layer) from #5 up to https://anrmaps.vermont.gov/arcgis/rest/services/map_services/MAP_ANR_MVIHAZARDS_WM_NOCACHE/MapServer/87.

Additional Notes

- The flagging layer text can become truncated when moved around in different formats. To address this issue, ERG provided the text in a layer package to VT ADS and that didn't truncate the text.
- The planning & regulation layer is brought on automatically with the project file provided via service. If the URL ever changes for it, it will break this process and need to repointed to the new URL- https://anrmaps.vermont.gov/arcgis/rest/services/map_services/MAP_ACCD_DHCD_WM_NOCACHE/MapServer/5.