Vermont Municipal Vulnerability Indicator 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 Indicator tool
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.[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.[1]

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. Over time, the MVI could be used to create a statewide index of climate vulnerability.

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.

---

[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.

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

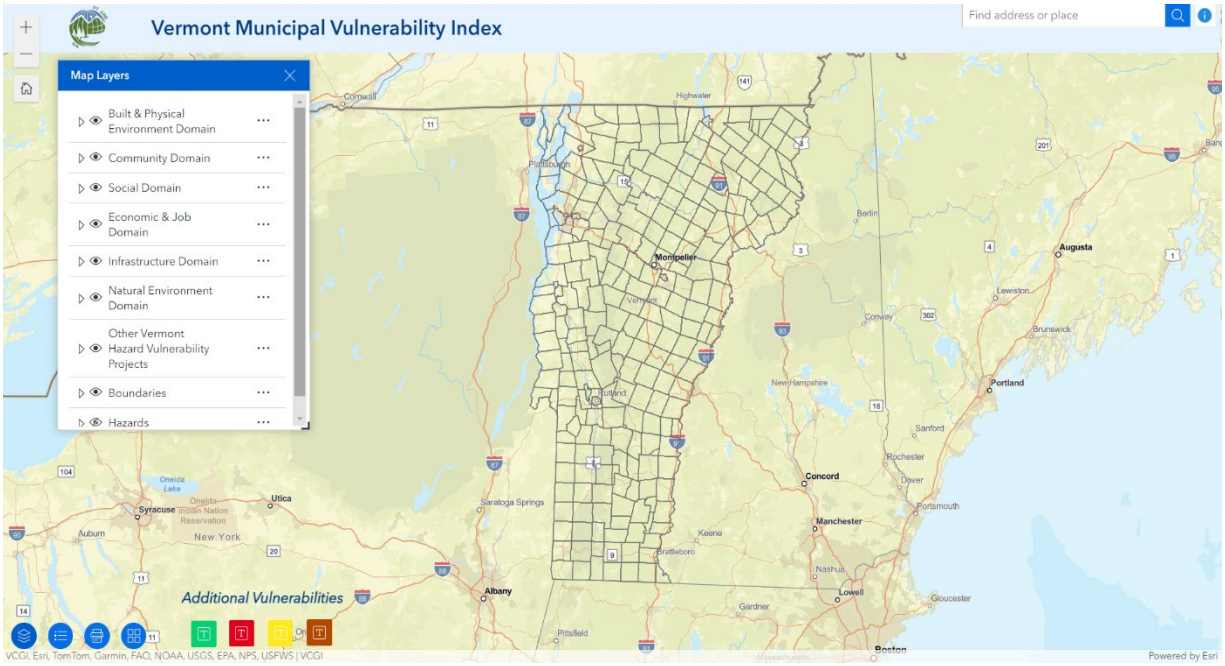
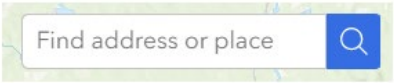
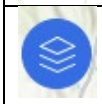
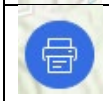


Table 1 below describes what each button on the tool's user interface does.

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.

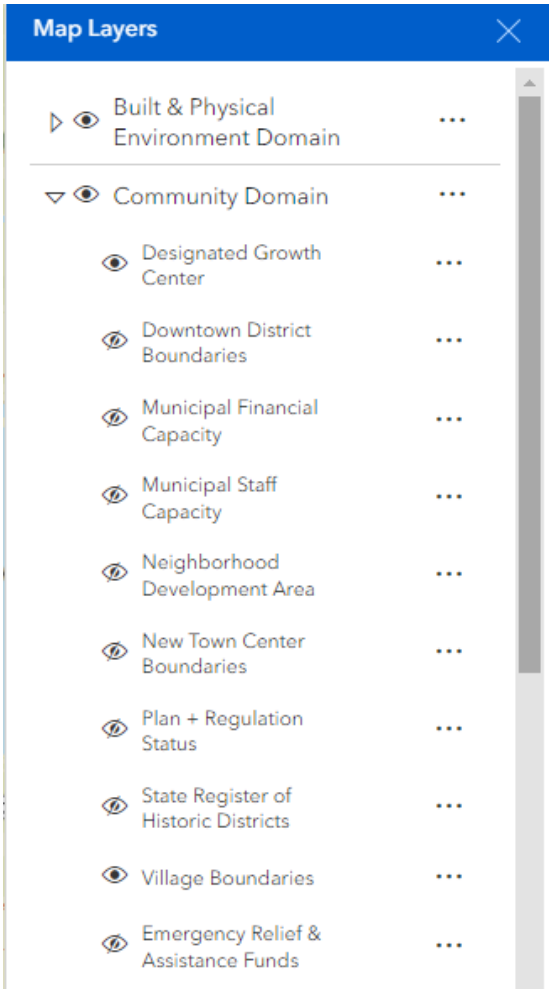


Figure 2: Map Layers Showing the Community Domain and Related Factors

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

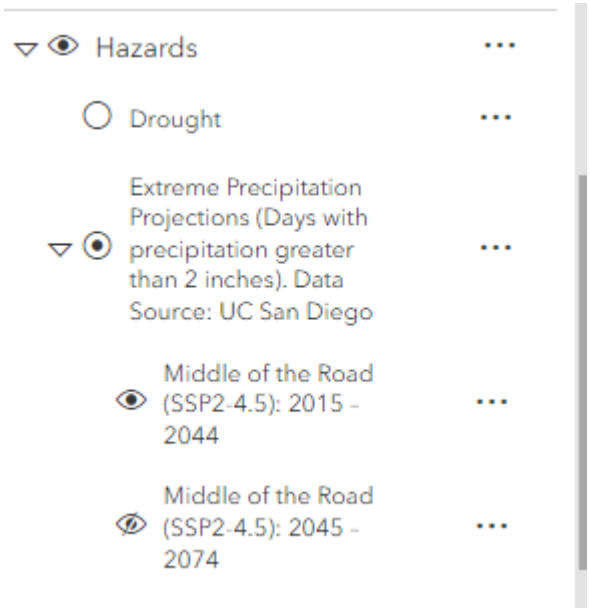


Figure 3: Hazard Layers

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.

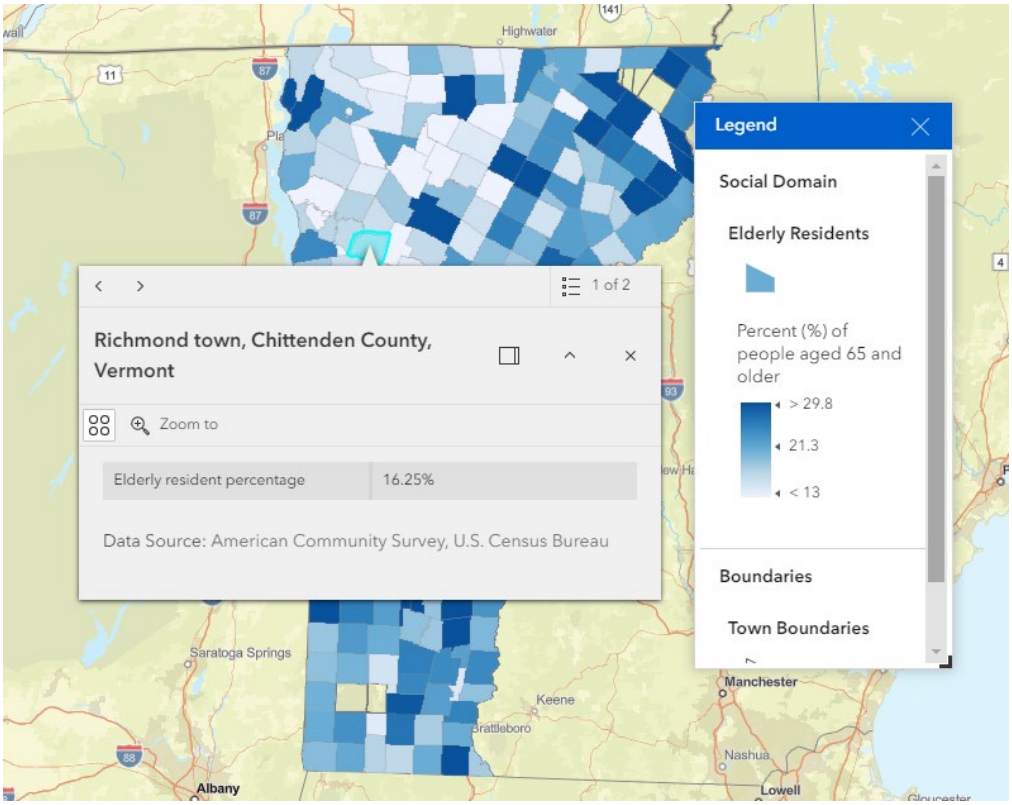


Figure 5. Example Popup Display

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.

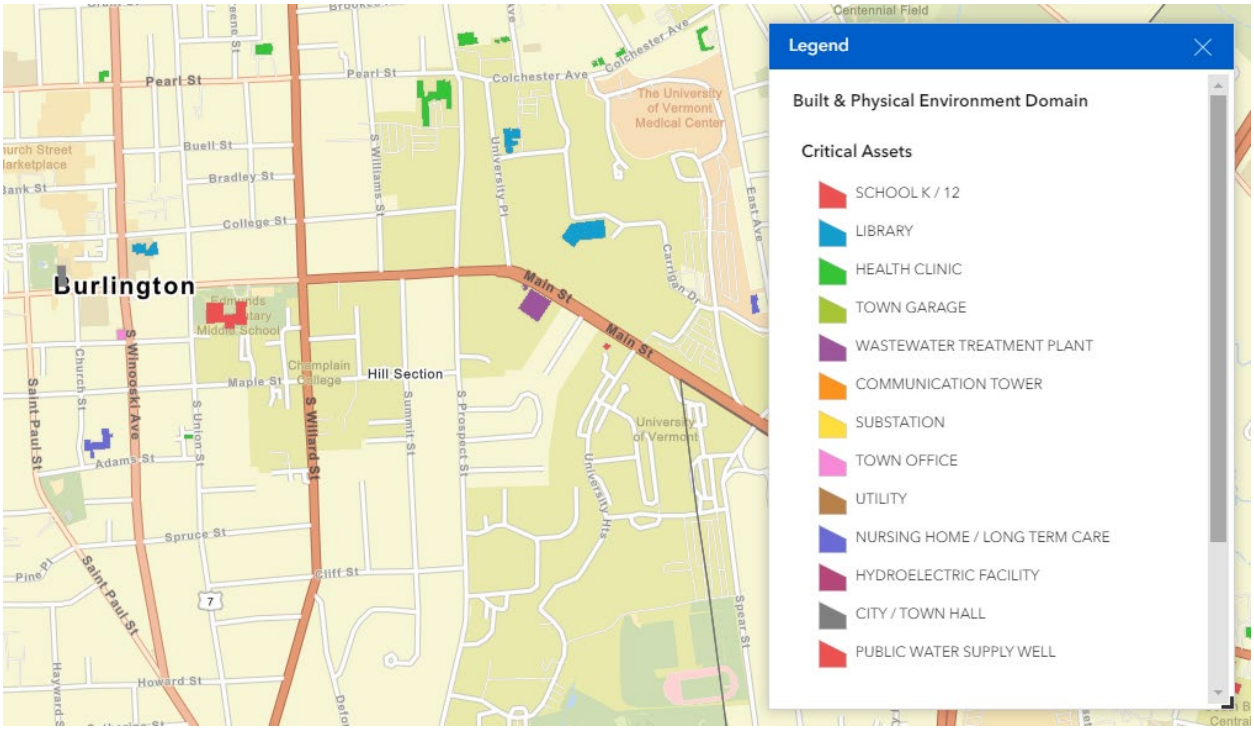


Figure 6: Example Legend Information Symbology

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.[5]

- **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

[5] 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.[6]

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.[7]
    - **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.[8]
    - **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).[9]
- **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

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

[7] 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

[8] 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 .

[9] 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.[10]

- **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.[11]

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.[12]
- **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.[13]
- **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.[14]
- **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

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

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

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

[13] Vermont Climate Assessment

[14] 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.[15]

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.[16]

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.

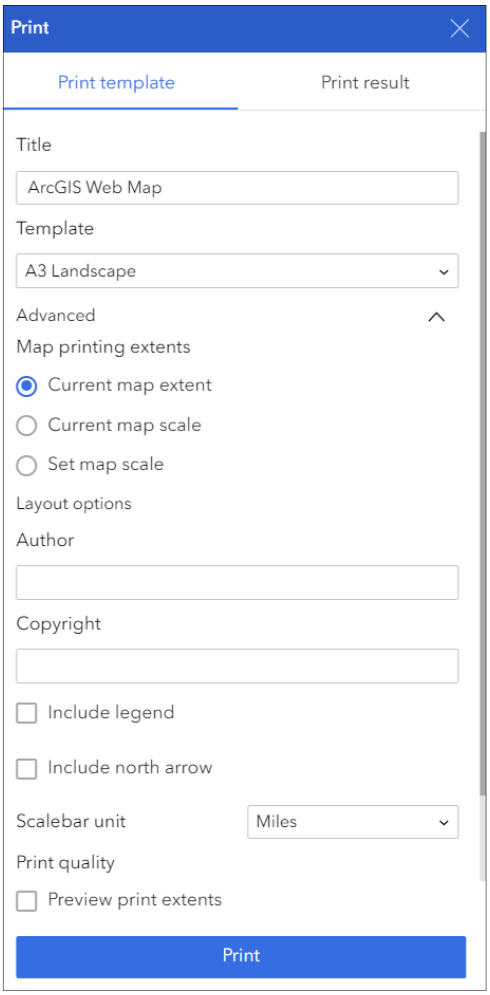


Figure 7: Print Options by Selecting Print Button

[15] 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

[16] 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 Indicator tool (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.

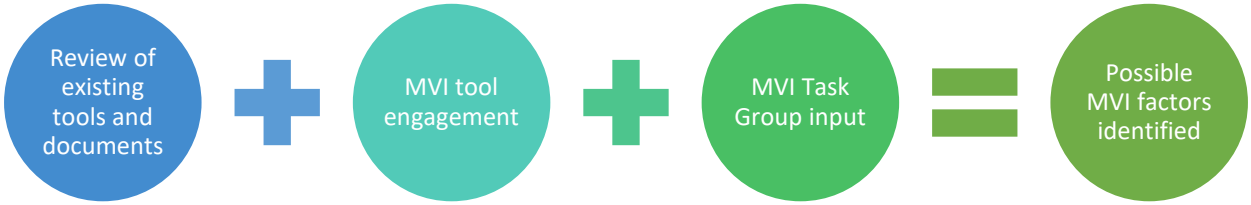


Figure 8. Process of MVI Factor Identification

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.

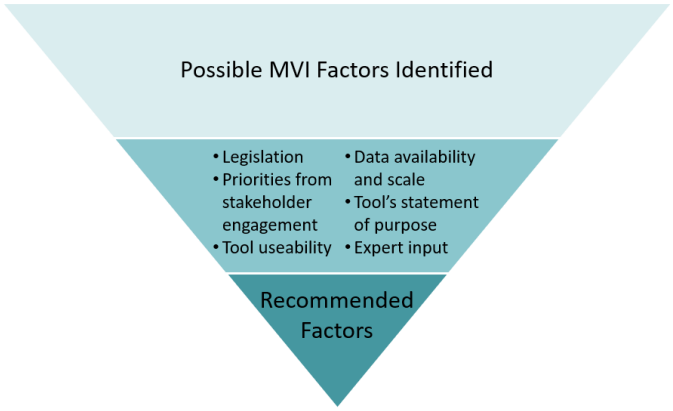


Figure 9. Overview of Factor Selection Process

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.[17] 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.[18]

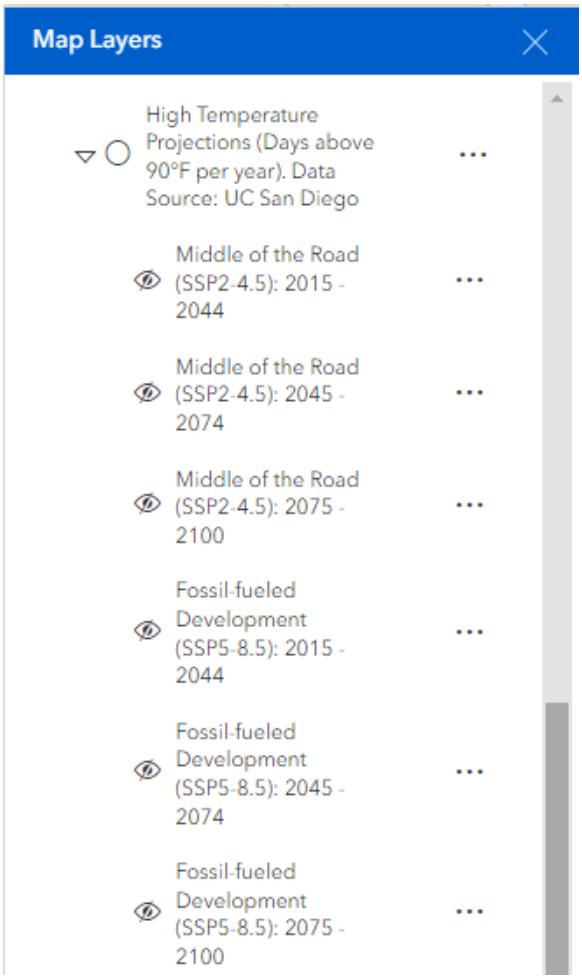


Figure 10. High Temperature Projections Layers

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

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

[18] 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." [19]

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.

[19] 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 Indicator Tool Beta Testing Questionnaire

Thank you for your willingness to participate in this Municipal Vulnerability Indicator tool (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.