U.S. DEPARTMENT OF ENERGY | OFFICE OF ELECTRICITY

Planning Considerations for Electric Vehicles in Vermont

DOE Resources and Technical Assistance options to inform the smart, equitable, and grid-aware planning of Electric Vehicle infrastructure.

CONTENTS

THE FUTURE OF TRANSPORTATION ELECTRIFICATION

Across the country, policymakers, regulators, state and local officials, and industry partners are developing plans, evaluating investments, and making decisions that will impact the future of transportation electrification. The move to electrified transportation introduces many new considerations and is more than a one-for-one switch from petroleum-based fuel to electricity. There are innovative, fast-evolving technologies associated with this transition that necessitate a reevaluation of conventional infrastructure planning processes. Electrification will require not only the deployment of electric vehicle (EV) charging infrastructure, but also electric grid infrastructure that supports charging, and there will be nuanced considerations of both that will be tangled in broader social and policy goals, including equitable access, affordability, and reliability, as well as other factors.

The new Infrastructure Investment and Jobs Act (IIJA), also known as the Bipartisan Infrastructure Law, aims to accelerate the transition to electrified transportation by establishing a nationwide charging network that will ensure a convenient, reliable, affordable, and equitable EV charging experience for all users. The rate of electrification has accelerated to a feverish – or electric – pace. Decision makers will have to become knowledgeable about a growing array of complex, interdependent topics as they support and influence the switch to electricity as a fuel source. There are important lessons that can be shared from early experiences and there are a range of tools that can assist decision makers in their journey. The U.S. Department of Energy's (DOE) Office of Electricity (OE) has compiled this report to illuminate tools available, provide options for assistance, and share knowledge that may be helpful to inform combined infrastructure planning. It is not meant to be a definitive solution, but it can highlight the value of some available tools and offer insights that might be useful. Each decision maker will have to explore further and apply the criteria that are important for them, their state, and their constituents. The information provided below is an attempt to provide state decision makers with high-level early information from DOE analysis tools. It must be emphasized that this report provides preliminary information and is by no means sufficient for decision-making purposes.

Overview of IIJA Provisions

NEVI Goal: 500,000 electric vehicles (EV) chargers in the United States by 2030. Support the Justice40 Initiative, which established a goal that at least 40 percent of the benefits of federal investments in climate and clean energy infrastructure are distributed to disadvantaged communities.

Investments:

- $7.5 billion to build out a national network of EV chargers in the U.S.
  - $5 billion available through the National Electric Vehicle Infrastructure (NEVI) Formula Program
  - $2.5 billion in a Discretionary Grant Program for Charging and Fueling Infrastructure

For over 100 years, the residential and commercial sectors have influenced the design and operation of the electricity system, while the transportation sector has not. Transportation electrification will change this. It requires a reassessment of how the grid is designed and operated to account for this new use and type of customer.

As of 2020, the transportation sector was 90% dependent on petroleum, 5% on biomass, 4% on natural gas, and less than 1% on electricity. Therefore, the electricity and transportation sectors are currently only weakly coupled, with few interdependencies. By comparison, the residential and commercial sectors were both approximately 50% dependent on electricity, strongly coupled with extensive interdependencies.

The use of electricity for transportation is different than that for service to a building though. Vehicles represent a new type of load and integrating electric vehicles onto the grid will be a transformational activity. Strong sector coupling will require a different scale of analysis with emphasis on the big picture and the long term, both because of the extent of the interdependencies and due to the time needed to alter the structures of the electric grid. With this in mind, OE is providing this report to inform and assist stakeholders at the state and local levels to better prepare for EV infrastructure deployments.

ABOUT THIS REPORT

This report introduces some high-level concepts around electricity and charging infrastructure planning and highlights two free, online, self-service analysis tools from DOE that can be accessed to begin analyzing, planning, or mapping potential EV charger deployments within each state: The Electric Vehicle Infrastructure Projection Tool (EVI-Pro) Lite and the Energy Zones Mapping Tool (EZMT). Additionally, the report will introduce a suite of available DOE resources, including other analysis tools and direct technical assistance opportunities.

Perhaps the most immediate opportunity currently in front of stakeholders is the $5 billion available for EV charger deployment through the NEVI program, which requires each state to submit an EV Infrastructure Deployment Plan to the Joint Office of Energy and Transportation. A strong deployment plan will require partnership between state highway entities, energy offices, regulators, local governments, utilities, and others.

OE is interested in ensuring the smoothest possible coordination and integration of new EV charging infrastructure with planned and existing grid infrastructure.

Need Help?

For general questions, additional resources, or to discuss technical assistance needs please reach out to:

Joint Office of Energy and Transportation
https://driveelectric.gov/contact/
833-600-2751

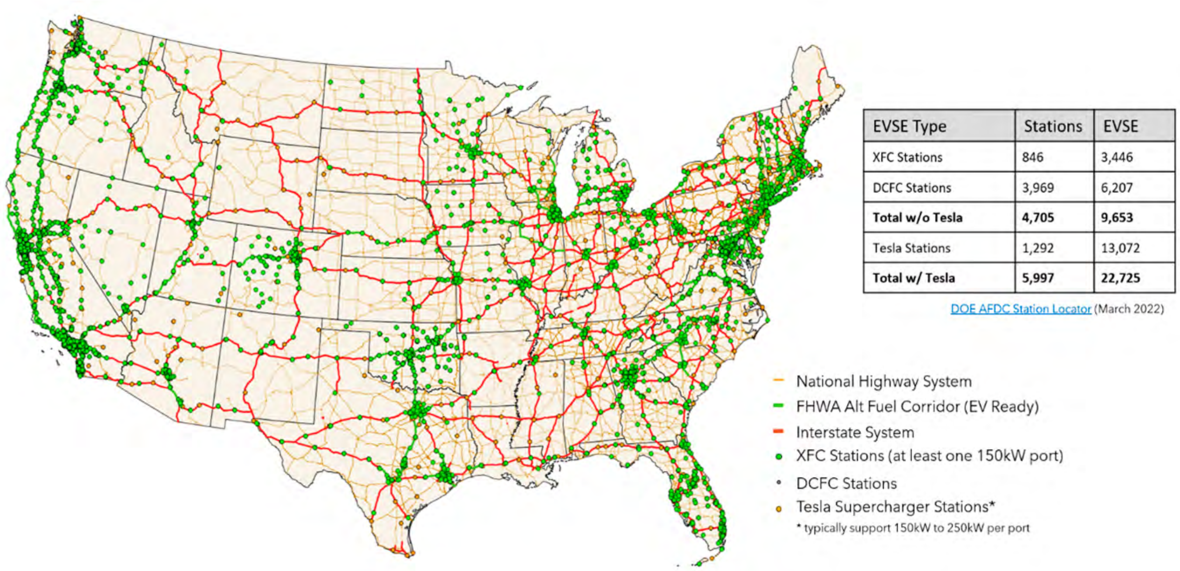
DOE's Office of Electricity
EVGrid@hq.doe.gov

Therefore, the information presented in this report is general in nature. It is intended to be thought provoking and to open new lines of inquiry **but should not be taken as recommendations.** OE is only providing resources and information. Each state's decision makers are in the driver's seat and will dictate the solutions appropriate to meet their state's goals.

If readers disagree with anything in this report or have unanswered questions, they are encouraged to contact OE. The Office of Electricity welcomes outreach and partnership and wants to reiterate that many technical assistance opportunities are available as needed.

ELECTRIC VEHICLE CHARGING

Mobility is key for America's economy. Vehicles transport 18 billion tons of freight annually — about $56 billion worth of goods each day — and move people more than 3 trillion vehicle-miles. The transportation sector accounts for approximately 30% of total U.S. energy needs and, because petroleum currently fuels over 90% of transportation, recently surpassed electricity generation to become the largest source of carbon dioxide emissions in the country. As such, vehicle electrification offers a technology pathway for continuing to move America's people and goods with lower greenhouse gas (GHG) and air pollutant emissions, improved air quality, and reduced reliance on foreign petroleum.



EVSE Type	Stations	EVSE
XFC Stations	846	3,446
DCFC Stations	3,969	6,207
Total w/o Tesla	**4,705**	**9,653**
Tesla Stations	1,292	13,072
Total w/ Tesla	**5,997**	**22,725**

DOE AFDC Station Locator (March 2022)

Locations of DC Fast Charging (DCFC) and Extreme Fast Charging (XFC) chargers in the continental United States

While most EV owners are expected to charge their vehicles primarily at home, public charging infrastructure will provide them with options for charging while on the go, as well as affording critically important charging opportunities for owners who do not have access to residential charging.

In March 2021, more than 40,000 public charging stations offering over 100,000 charging outlets were operating in the United States.

An important initial step in transportation electrification planning is estimating the amount and types of EV chargers needed in the state. EVI-Pro Lite, a DOE-funded tool, provides high-level estimates based on user-selected inputs that reflect local policy goals and market projections. These estimates can inform new planning processes or complement and enhance existing efforts. Using Vermont data, the figure below shows two examples, a conservative and an aggressive EV growth scenario to demonstrate the tool's capabilities. Detailed information about the tool, including more in-depth analysis for Vermont, can be found within the EVI-Pro Lite section of this report.

EV Charger Types

- **Level 1 Charger:** Standard 120V outlet powering 2-5 miles of range per hour of charging
- **Level 2 Charger:** Specialized equipment at 240V powering up to 25 miles of range per hour of charging.
- **DC Fast Charger (DCFC):** Grid connected equipment at 50kW powering up to 100 miles of range per hour of charging.
- **Extreme Fast Charging (XFC):** Grid connected equipment at 150-400 kW powering 300 miles or more of range per hour of charging

CONSERVATIVE ADOPTION SCENARIO

Your Results

In Vermont, to support 2,729 plug-in electric vehicles you would need:

52 Workplace Level 2 Charging Plugs

39 Public Level 2 Charging Plugs
There are currently 705 plugs with an average of 2.5 plugs per charging station per the Department of Energy's Alternative Fuels Data Center Station Locator.

82 Public DC Fast Charging Plugs
There are currently 88 plugs with an average of 2.4 plugs per charging station per the Department of Energy's Alternative Fuels Data Center Station Locator.

AGGRESSIVE ADOPTION SCENARIO

Your Results

In Vermont, to support 55,189 plug-in electric vehicles you would need:

1,028 Workplace Level 2 Charging Plugs

702 Public Level 2 Charging Plugs
There are currently 705 plugs with an average of 2.5 plugs per charging station per the Department of Energy's Alternative Fuels Data Center Station Locator.

1,316 Public DC Fast Charging Plugs
There are currently 88 plugs with an average of 2.4 plugs per charging station per the Department of Energy's Alternative Fuels Data Center Station Locator.

Sample Results of Chargers Needed to Support Transportation Electrification

ELECTRIC GRID INFRASTRUCTURE

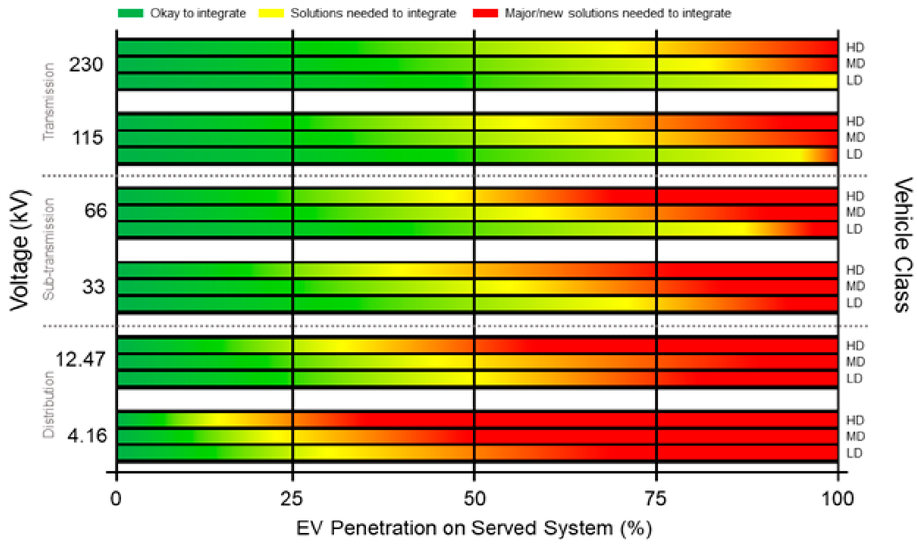
Affordable, reliable power for U.S. customers and businesses requires various generation, transmission, and distribution assets that are seamlessly controlled and coordinated to meet current and future demand. Utilities must forecast and plan for future electricity use, meaning investment decisions will need to be made today in anticipation of tomorrow's demand growth. While connecting EVs to the grid might appear simple on the surface – customers plug in to charge and utilities meet that demand – it is much more complex and involved. Utilities must account for more than just an increased demand on the system. In some instances, EVs will introduce new constraints or require new power system design considerations. Adapting the grid for these changes will require thoughtful consideration and planning as these new technologies are integrated into the nation's legacy grid. Electric grid operations encompass many different time frames, from the near-term out to multi-year infrastructure investments.

Grid capacity is the ability of the power system to provide electricity to a given location. Large-scale electrification of the transportation fleet, especially if medium- and heavy-duty vehicles are included, can significantly increase the amount of load on the power system. This increased load not only needs an appropriate amount of power generated into the system, but also the appropriate infrastructure to deliver that electricity from the source to the vehicle. Customer rooftop solar generation can help meet additional generation needs, but it also introduces additional operational considerations.

Several studies have examined the large-scale capacity issues of wide-spread electrification of transportation. Under prior, less aggressive EV adoption rates, many of these studies concluded that current generation resources could provide the necessary power. While the bulk grid (or transmission-level) will be able to better handle increases in load, transportation electrification can create local (or distribution-level) constraints and impacts requiring the need for proactive planning.

Distribution-level constraints can occur for a variety of reasons, but one is the size of the conductor that determines how much energy can be transmitted. Many distribution systems have been upgraded to use higher voltages; however, there are still feeders and systems that operate at lower voltages. Low voltage systems move lower amounts of electricity and, thus, are more likely to encounter overload and operational issues. This may be more the case in residential neighborhoods that have had negligible changes in electricity demand over the years. Upgrades to grid infrastructure take time, and early planning for necessary upgrades will be important for meeting increased electricity demand for vehicle charging.

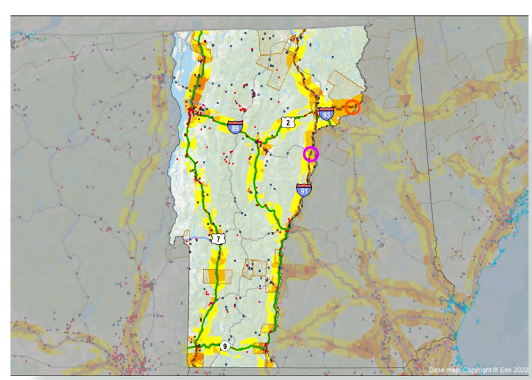
The figure to the right shows the notional impacts of EV penetration for different voltage levels, illustrating the penetration levels of EVs (i.e., number of EVs) on a system that can lead to constraints for a given conductor size (i.e., voltage level). Less electricity is able to flow through lower voltage wires which leads to capacity constraints and reduces the number of EVs that can be connected and charged before grid impacts emerge.



As the image shows, for a 4.6 kV line (distribution level), impacts might start to occur before a penetration level of 25%, whereas a 230 kV line (transmission level) may not see impacts until closer to 75% penetrations.

Utility wires in low-to-middle income areas or federally identified disadvantaged communities (DACs) may not have been upgraded as demand for electricity may have remained flat or declined over time. As such, these areas may have smaller conductor sizes, creating more acute distribution constraints than in other areas. This demonstrates how EV charging infrastructure deployment decisions are intrinsically linked to electricity infrastructure investment decisions, and specifically the broader social equity and accessibility landscape.

Similar planning concepts can be examined with the aid of EZMT, a free tool that allows users to creatively explore abstract planning scenarios. For example, the map below shows transportation corridors in Vermont, along with existing EV charging and electrical grid infrastructure. Overlaid on the map are locations representing disadvantaged communities or tribal areas. The tool can help decision makers to determine the suitability of potential locations for EV charging stations based on both technical and social factors by selecting different map layers. For example, an area that has existing grid infrastructure and is on a transportation corridor that passes through a disadvantaged community may signal a compelling opportunity for a new EV charging site. See the EZMT section of this report for additional information on EZMT, including the sample analysis for Vermont.

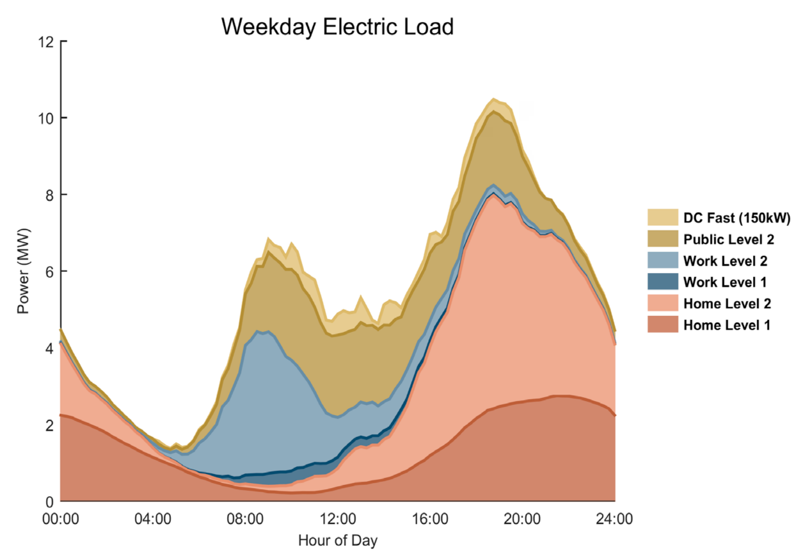


Planning, Forecasting, and Modeling the Impacts on Electricity Load

To serve a growing population of electric vehicles, utilities will have to anticipate the increased demand for electricity and account for the specific characteristics of this new load. As a grid load, EVs are unique in their mobility, in the magnitude of power flow, and in the optimum duration in which to provide it. New opportunities and challenges will occur on multiple timescales, which can be characterized into “planning” (decades to years) and “operational” (years to seconds) time horizons. Utility planning studies help utilities evaluate the overall grid capacity and assess anticipated trends and future scenarios. Planning studies include future loads (such as EVs), but also the increasing energy output from other sources, such as solar or battery storage. Grid planning generally looks ahead a minimum of five years, and out to a many as 40 in some cases.

The electric grid is designed to have enough electricity to meet peak demand at any time, even if the peak demand occurs for only a few minutes a few times a year. This means that, during off-peak hours, there will be available capacity. If EV charging can be shifted to times and locations where capacity is available, it will minimize the amount of new electricity infrastructure that is needed, increase the utilization of assets that are already part of the system, and potentially result in lower electricity rates for all customers. Examining load trends can help predict how the demand for electricity will change to ensure sufficient supply at the right time and in the right place, and to determine approaches that might help mitigate the need for electricity infrastructure investments to meet the increasing demand.

EVI-Pro Lite shows how demand (i.e., load) will change with increasing numbers of electric vehicles, and the results can provide valuable insight when examining the potential grid impacts for select cities and urban areas. The graph below shows the load profiles generated from EVI-Pro Lite for the Burlington metro area, applying user-selected inputs and an aggressive EV adoption scenario. The next section of this report will further expand on EVI-Pro Lite and provide examples of how EVs can affect grid conditions in Vermont.



Load Forecasts for Burlington under an Aggressive Adoption Scenario

Utility planning studies will often examine infrastructure upgrades and significant capital projects to help determine what solution may be best or how quickly it needs to be deployed. Capital intensive infrastructure upgrades often require lengthy approval processes, from environmental impact reviews to rate adjustments that finance the upgrade. Therefore, utilities are exploring other “non-wires” solutions like demand response or time-of-use rates to influence customer behavior and help defer costly infrastructure upgrades. Simulation and modeling, helpful for both long- and short-time horizons, can aid decision makers in considering thousands of variables and dozens of alternatives for future scenarios. The same is true in operational environments where the implications of decisions must be evaluated across seasons with a diversity of both good and bad weather events. An array of DOE-funded tools, some of which are highlighted in the Resources section of this report, can assist simulation, modeling, forecasting, and planning efforts.

Importance of Distribution Planning

Historically, utility distribution system planning, and transmission system planning are separate from each other. Complementary, or integrated, planning processes may be worth pursuing due to the magnitude of change, the potential accelerated pace of EV adoptions, and the higher degree of uncertainty in what the future may look like.

Specific distribution-level planning processes can help accommodate a more rapid pace of change and higher levels of uncertainty as well as account for the elevated importance of distribution control technologies to ensure grid stability.

Some states have opened utility distribution planning processes, where the utility publicly shares distribution system plans for stakeholder input. OE’s Modern Distribution Grid Project provides resources to assist in the development and evaluation of distribution grid modernization, including advanced distribution planning, operations, and market concepts. Another resource is Lawrence Berkley National Laboratory’s trainings on integrated distribution system planning that provide frameworks for developing distribution planning rules, understanding the technologies involved, and identifying the role of the distribution system going forward.

VERMONT SPECIFIC SAMPLE ANALYSIS

This section presents example results from two DOE-funded applications using Vermont-specific data to furnish a glimpse into the type of analysis the tools provide and the value they offer in evaluating and assessing options related to the deployment of EV charging infrastructure. While the analysis is specific to Vermont, the results are preliminary and by no means sufficient for decision-making purposes.

EVI-PRO LITE SAMPLE ANALYSIS

The EVI-Pro Lite tool projects the number of charging stations needed to meet projected demand, as well as how electricity load (demand) profiles change as a result of increased vehicle charging. EVI-Pro Lite leverages analysis of and experience from studies of charging infrastructure requirements at the national level, including behaviors built off evaluations of millions of miles of real-world daily driving schedules and habits. EVI-Pro Lite can be a valuable resource for state agencies, utilities, and transportation planners determining infrastructure needs to support vehicle adoption projections and state goals, and assessing the impact on electrical load. Users can easily select inputs for several variables, allowing for scenario analysis of different vehicle projections and the load impacts of assorted simplified charging strategies.

Two elements of the EVI-Pro Lite tool are high-level estimates of the charging needs (count) and load profile impacts (power consumed). Results are based on user input for the number of additional EVs projected or expected within the system, as well as other user-selected variables (see the following screenshot for selection options). The high-level estimates can then be used for more detailed analysis, including examining where to site specific chargers and how aggressively infrastructure upgrades or control actions need to be deployed.

The following sample analyses demonstrate the results the tool generates and the value it can provide. The samples use a conservative and an aggressive adoption scenario to show how results will differ and how the tool can be used to assess various potential future states. The sample analyses are notional examples of what the tool can produce. To obtain results that reflect Vermont's goals, policy, and considerations, it will be necessary to perform the analysis by inputting values that reflect those goals.

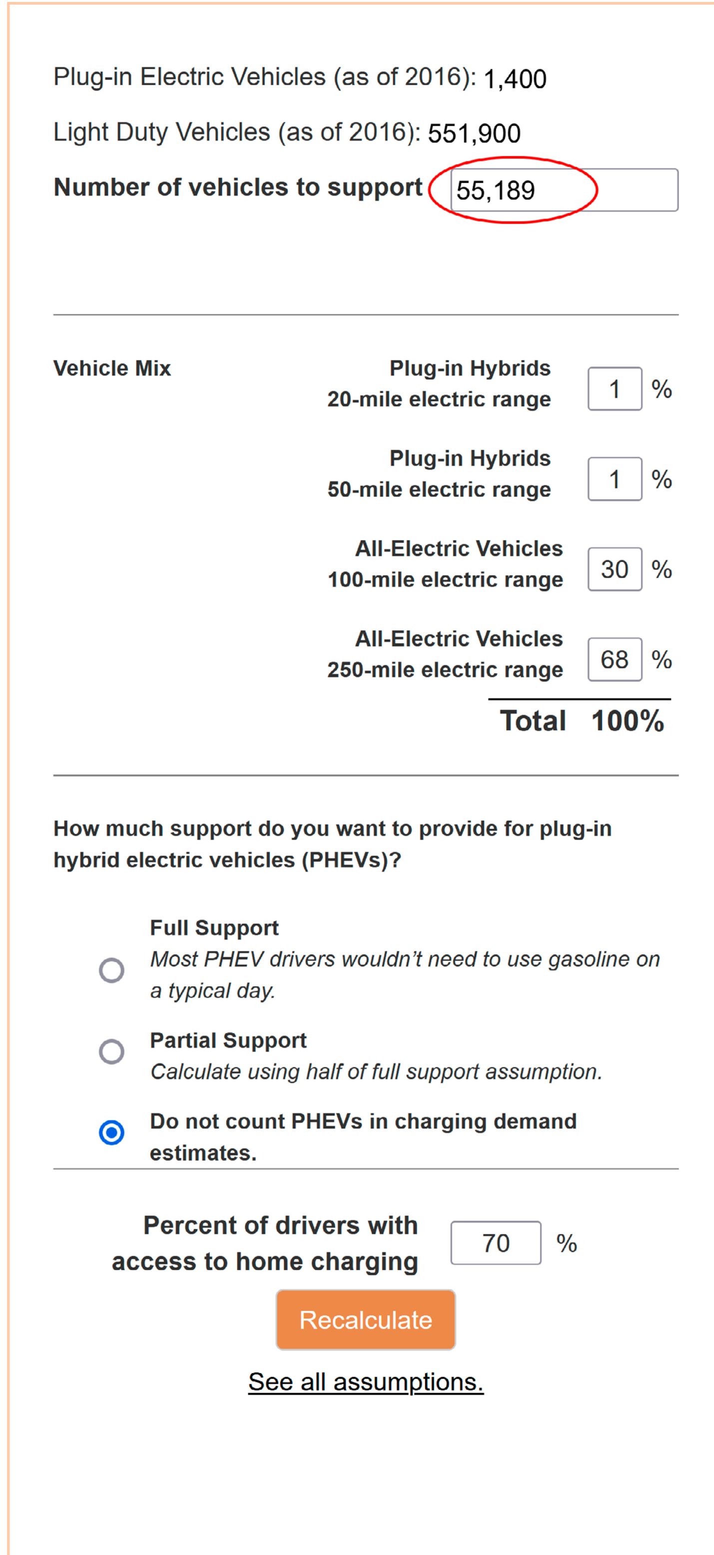
EVI-Pro Lite Vehicle Estimates

EVI-Pro Lite uses 2016 and 2018 vehicle data from both publicly available and contracted sources. However, alternative methods to estimate the vehicle population are possible. If the state highway or transportation department has more recent numbers, those numbers can be used. The U.S. Department of Transportation Bureau of Transportation Statistics offers several statistical data sets that could also be used to select the population of EVs used for these studies.

Sample Analysis: Charging Need Estimates

The “Charging Need” tab for EVI-Pro Lite provides a very high-level estimate of the number of different charging stations a state or urban area will need to support an expected population of electric vehicles. EVI-Pro Lite provides estimates for an entire state or urban area based only on the light-duty vehicle population. Medium-duty and heavy-duty vehicle impacts could potentially be estimated by using a more aggressive adoption estimate, but more detailed analysis is recommended to determine the number of charging stations needed for those vehicle types.

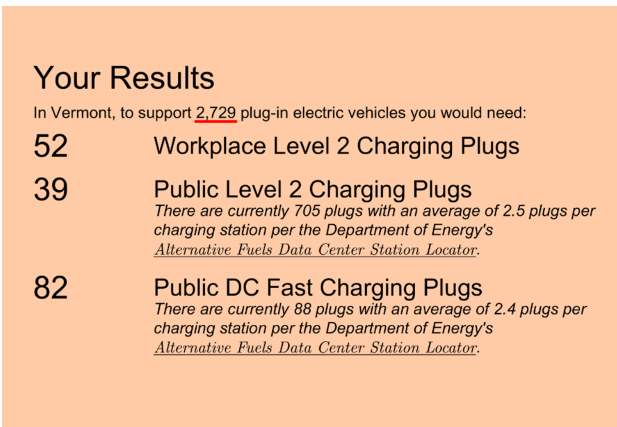
The sample analysis results assume a focus on DC fast charging stations serving primarily battery electric vehicles (BEVs) that may be using the stations in transportation corridors. This sample analysis is based on the user inputs (i.e., assumptions) detailed in the screenshot to the right, specifying a population composed of 1% 20-mile plug-in hybrid electric vehicles (PHEVs), 1% 50-mile PHEVs, 30% 100-mile BEVs, and 68% 250-mile BEVs. Furthermore, PHEVs were not selected to be included in the estimates for charger needs, and the home charging access input was set to 70%, reflecting an assumption that 30% of charging customers will represent pass-through traffic and drivers in multi-residence buildings (e.g., apartments). For the aggressive and conservative scenarios, the only input change was the number of vehicles (circled in red).



Charging Need Results

Two sample “Charging Need” estimates were obtained for the state of Vermont. The conservative scenario estimate uses a 10% annual EV growth rate each year from 2016 to 2023. This results in an increase in the number of electric vehicles on the road to 2,729 in 2023 (a simple exponential increase that neglects any COVID-19 impacts in 2020-2022.) The aggressive scenario estimate considers that 10% of the **entire** 2016 light-duty vehicle population will be electrified, or 55,189 vehicles. The red underline highlights the vehicle count used in each scenario.

CONSERVATIVE SCENARIO



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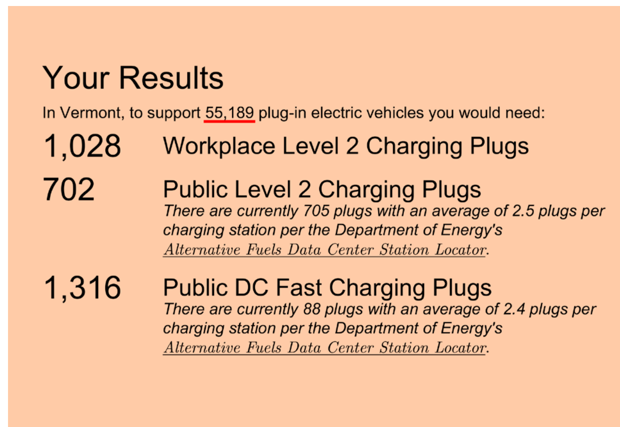
AGGRESSIVE SCENARIO



Your Results

In Vermont, to support 55,189 plug-in electric vehicles you would need:

1,028 Workplace Level 2 Charging Plugs

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1,316 Public DC Fast Charging Plugs
There are currently 88 plugs with an average of 2.4 plugs per charging station per the Department of Energy's Alternative Fuels Data Center Station Locator.

For the conservative scenario, EVI-Pro Lite projects needing 82 Public DC Fast Charging Plugs, with Vermont already having 88 plugs deployed. The geographic locations of these chargers likely factor more strongly into whether more are needed or not. Even though Vermont already has 88 plugs deployed, they may not be collocated where EV adoption or charging need is the greatest.

For the aggressive scenario, EVI-Pro Lite estimates a significantly larger number of Public DC Fast Charging Plugs, as shown above. It is worth noting again that the aggressive scenario is based off the number of vehicles in Vermont, but a high estimate may also account for transient traffic (traveling through the state, but not actually a Vermont vehicle). This aspect will be especially important for electrifying critical transportation corridors.

Sample Analysis: Load Profile Impacts

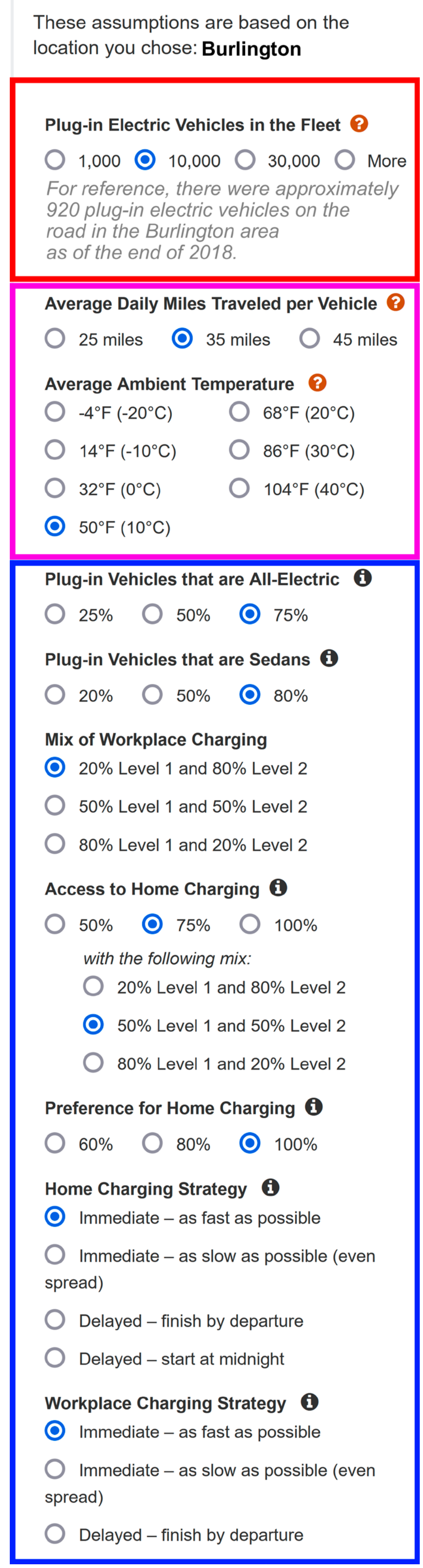
The "Load Profile" tab of EVI-Pro Lite provides an aggregate charge curve for the projected number of EVs at a specific urban area. This helps estimate a population's power requirements for use in infrastructure planning and power system operational strategies.

The sample Load Profile estimates used vehicle numbers from the aggressive scenario (assuming that 10% of the **entire** current light-duty vehicle fleet in that area would be electrified). The assumptions used as an example for the Burlington urban area are shown to the right. A fleet size input of 10,000 vehicles was used (EVI-Pro Lite uses for 920 EVs from a 2018 data set as the basis of the load profile analysis).

The colored boxes represent different areas of input for the load profile results. The red box is user-entered vehicle population data. The magenta box represents average driving distance and average ambient temperature – data that is auto-populated by EVI-Pro Lite but can be adjusted to explore other scenarios or to reflect more recent data. Finally, the blue box represents the various EV population and charge assumptions, with this case assuming most of the 10,000 vehicles are all-electric and prefer to charge immediately at home (for the 75% that have access to home charging).

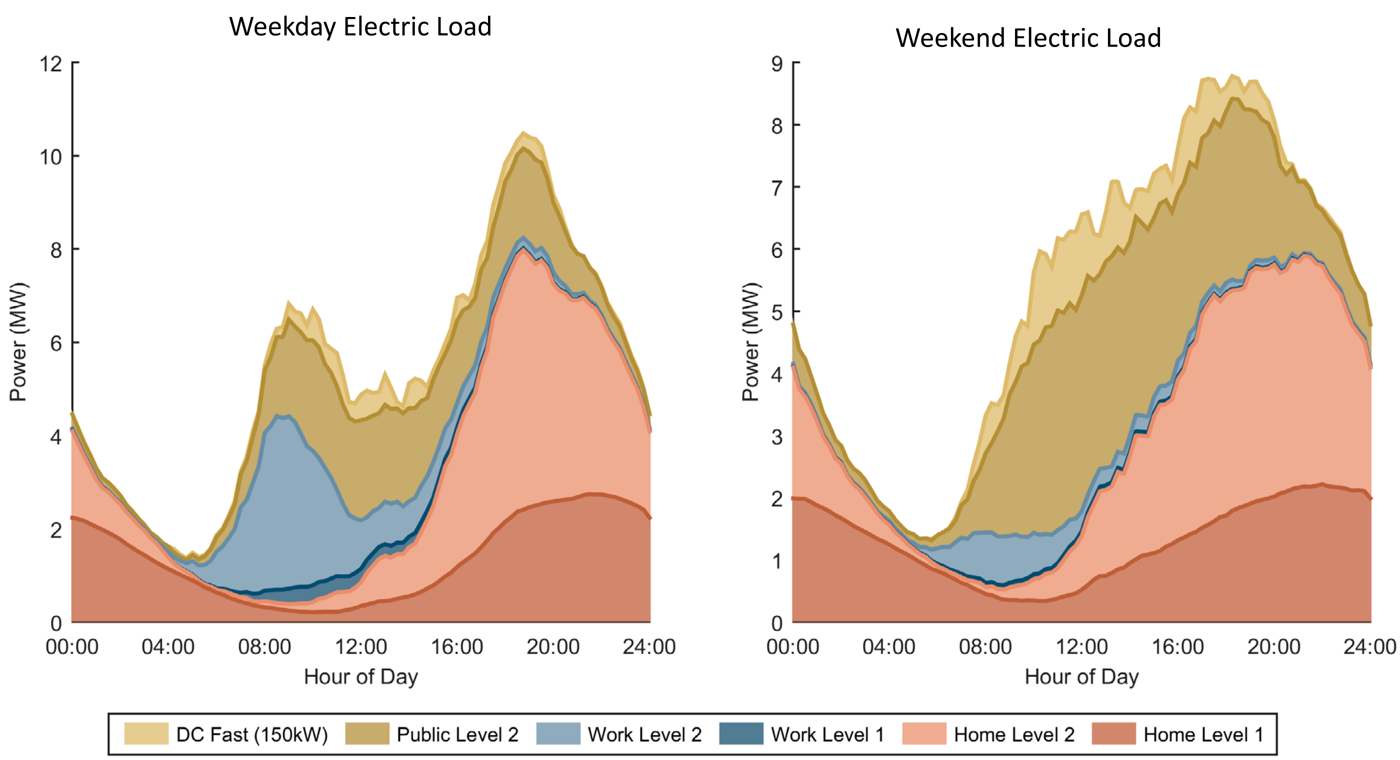
It is useful to note the curves produced represent a typical commuter population, with many preferring to charge at slower Level 2 rates at home or work than at a DC fast charging station. Changes to the inputs regarding consumer habits, the availability of home or work charging, as well as how transient/pass-through traffic charges, however, can create a curve that skews toward a preference for DC fast charging. Detailed analysis is recommended to determine the impacts of medium- and heavy-duty vehicle charging, as well to determine any locational effects of the charging (e.g., home chargers vs. enroute chargers along a transportation corridor).

Screenshot of Load Profile Variable



Load Profile - Base Scenario Curves

EVI-Pro Lite produces a Base Scenario load profile for both weekday and weekend behavior, using the assumptions shown in the Load Profile Variable screenshot (or adjusted by the user). The figure below shows typical weekday and weekend load profiles for the charging of EVs on the system. The population of electric vehicles selected, as well as the charging characteristics selected, will influence the shape of these curves and how much power the 10% light-duty vehicle fleet may require in peak scenarios. The load profile created is substantially different than the load profile for the existing EV fleet in the Burlington urban area. Detailed analysis with the local electric utility will be needed to fully examine the impact and to determine any equipment upgrades and operational changes needed.



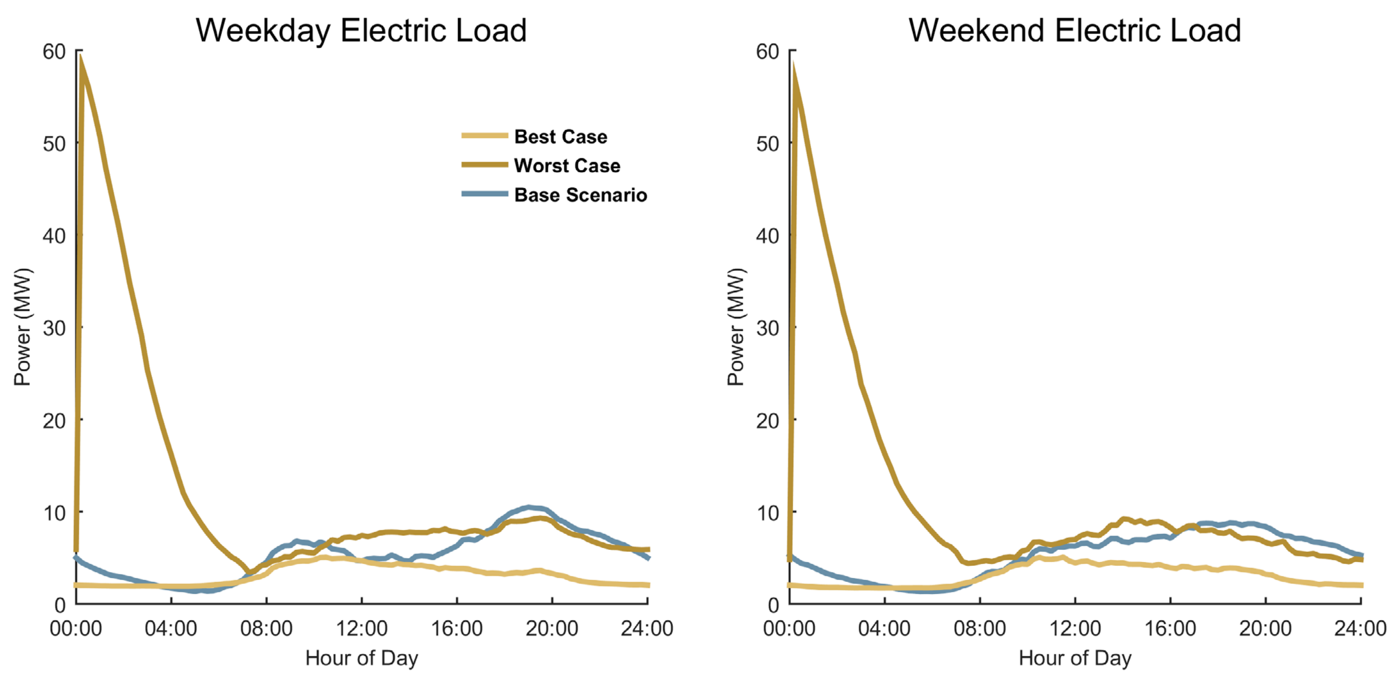
Load Profile for Aggressive EV adoption scenario of Burlington urban area

For the assumptions selected in the Load Profile Variable screenshot, most of the charging is still Home Level 2, begun as soon as the EV arrives home. The significant evening peaks in the graph above could overload existing infrastructure, requiring either capital upgrades or smart charging scenarios. Exploring other charging scenario settings in the Load Profile Variable screenshot can lend some insight into how to manage this charging peak.

Load Profile - Best, Worst, And Baseline Scenario

The Baseline Scenario shown in the figure above assumes vehicles have a staggered arrival time, but all start charging immediately (i.e., most charging is at an evening peak). However, EVI-Pro Lite allows two other scenarios to be quickly examined – a Worst Case and a Best Case. While some charging and environmental parameters change with these scenarios, the main difference is how charging occurs. In the Worst Case scenario, all EVs wait to charge until midnight but all start simultaneously. For the Best Case scenario, the EVs charge any time they're plugged in, but at a rate to fill the battery by the intended departure time (i.e., a longer, slower charge rate).

The figure below shows the difference in these scenarios, with both the Weekday and Weekend "Worst Case" having a peak at midnight that is almost 5-times the evening peak of the baseline scenario. This indicates the significant load change a simple time-of-use or scheduled charging scenario may impose on the system, requiring infrastructure upgrades or other mechanisms to be explored by planners.



Baseline-, Worst- case, and Best-case load profiles for Aggressive EV adoption for Burlington urban area

ENERGY ZONES MAPPING TOOL (EZMT) SAMPLE ANALYSIS

The EZMT is a free, public web-based mapping tool. It includes a large database of mapping layers, such as energy resources and infrastructure, and a modeling capability that is designed to screen and identify areas meeting user-selected criteria. The variety of resource maps and data allows users to prioritize specific considerations, such as equity, proximity to electricity infrastructure, local air quality pollutants, or corridor designations.

Over 360 mapping layers are hosted in the EZMT to help inform siting of energy projects or charging station locations. These include electricity infrastructure, EV charging stations and transportation corridors, and other layers for a variety of equity metrics. Maps can be displayed at any scale and features on the map can be queried to provide additional information.

In addition to its mapping display, the EZMT has a modeling capability that screens for user specified siting criteria allowing users to run pre configured example models, refine settings to fit their needs, or design new models using over 95 criteria. The models generate a "heat map" overlay that highlights locations meeting specified criteria, and that users can study further to identify, assess, and evaluate potential infrastructure project sites.

Analysis Results

There are many dimensions to be considered when planning for EV charging stations. Determining locations for charging stations is not necessarily straightforward, and decision makers will have to answer difficult questions as they consider and balance sometimes conflicting priorities. The EZMT allows users to establish criteria and priorities based on state or community goals and needs. The following examples provide sample outputs to illustrate the type of analysis and results the tool offers. These are not meant to address all the difficult questions nor suggest that these are the right priorities or answers. Instead, they illustrate how the EZMT's data visualization tools can help inform planning and investment efforts, and help users investigate how different factors affect EV charging siting.

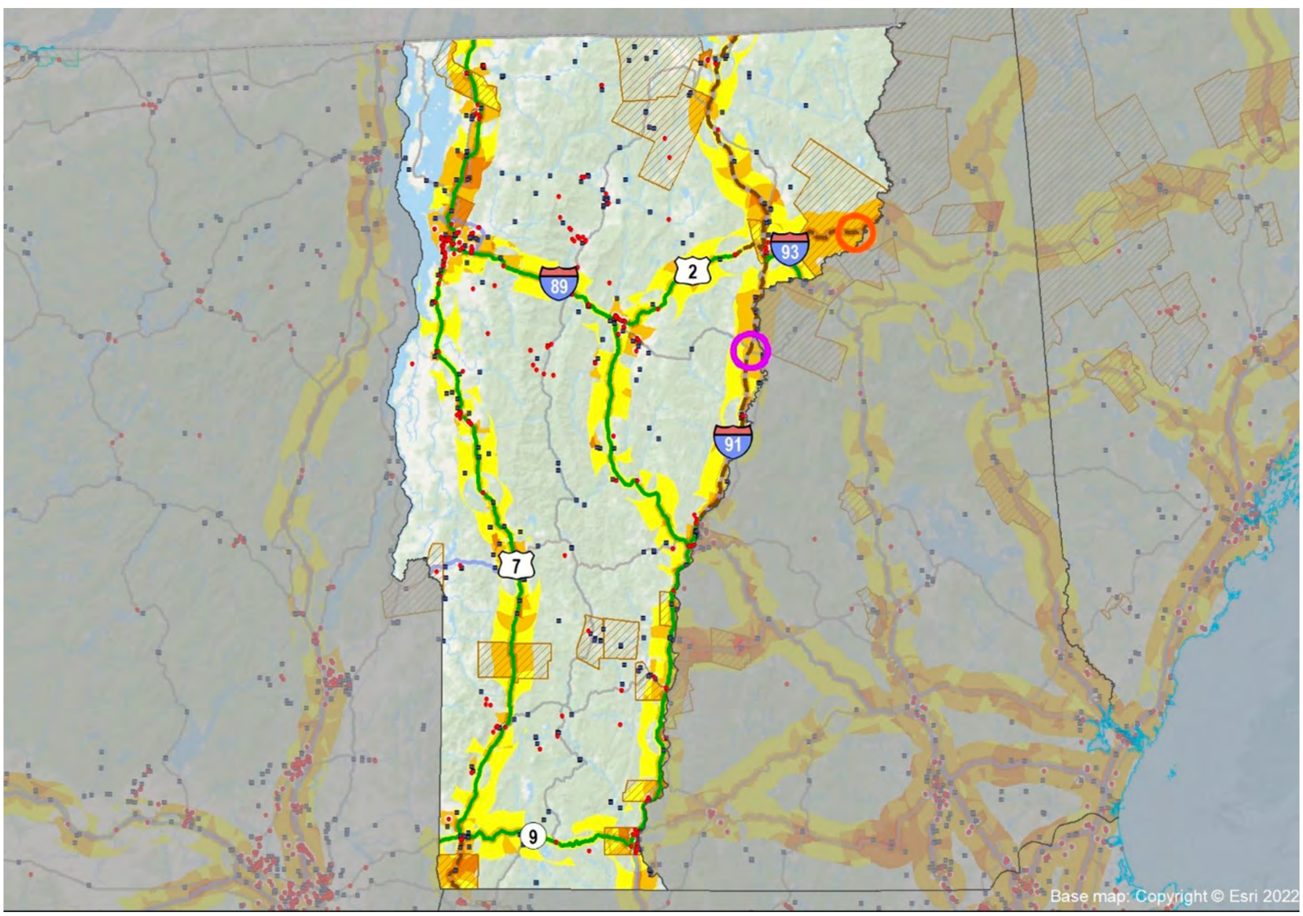
The examples presented focus on different scenarios for transportation electrification planning. Each example provides a state map along with two detailed maps illustrating locations that might be considered for EV charging stations. Brief descriptions provide a synopsis of the characteristics of the locations available in the EZMT that could help inform planning decisions. However, the specific planning objective and other factors beyond the scope of the planning tool would also have to be considered to fully assess the sites.

Sample of EZMT Mapping Layers

- FHWA-designated EV Corridors
- Existing EV Charging Station Locations
- Transmission Substations
- Tribal Lands
- Population Density
- Disadvantaged Communities (DACs)
- Household Transportation Energy Burden
- Transit Desert Index
- HUD Opportunity Zones

Example 1: Corridor Charging Scenario

Areas with the following criteria: near the FHWA-designated corridors, near transmission-level substations, distant from existing charging locations, within a DAC or tribal area, and with high population density. A second model not shown on the map was used to help locate areas along the corridors that might be more challenging for siting EV chargers. Challenges include a lack of infrastructure and lacking the added funding opportunities of being within a DAC or tribal area. The highlighted results could help narrow down areas that might present better opportunities for funding, as well as focus follow-on/detailed discussions with stakeholders. For example, a nearby transmission substation would prompt discussions with the local utility to determine what is feasible or if other factors should be considered. It is important to note, though, that a designated challenge area does not necessarily mean that it is a poor fit for an EV charging station. There may be other factors, such as economic development, that decision makers prioritize.



- **Location of Challenge and Opportunity Maps**
  - Challenge
  - Opportunity
- **Electric Vehicle Charging Stations**
- **Electrical Substation**
- **Designated Alternative Fuels Corridor**
  - EV Corridor Ready
  - EV Corridor Pending
- **Tribal Land**
- **DOE/DOT Interim Guidance DAC**
- **EZMT Model Results**
  Suitability
  - 41-50
  - 51-60
  - 61-70
  - 71-80
  - 81-90
  - 91-100

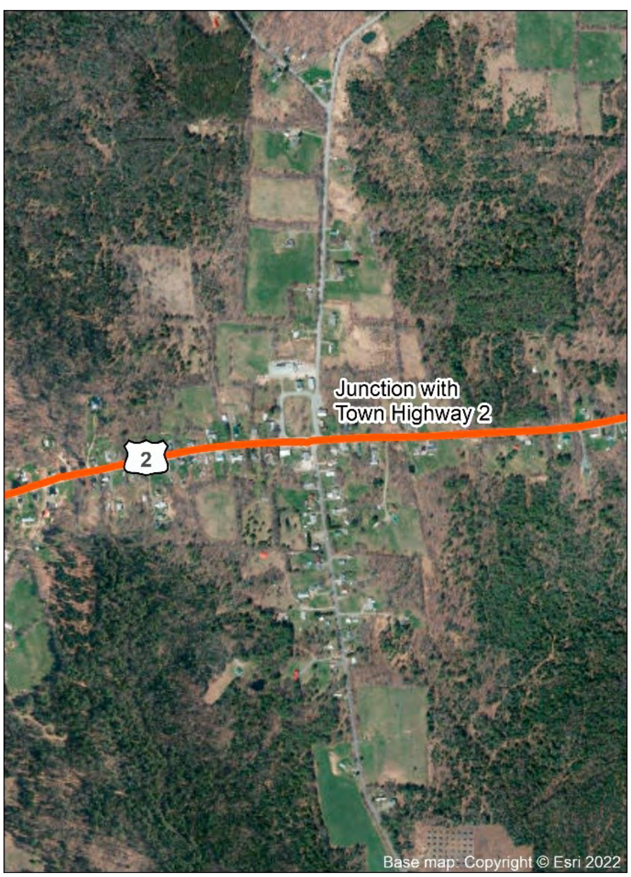
Possible Opportunity Area

One opportunity area, which may be favorable for siting a charging station, is I-91 Exit 17 in Orange County. Wells River, with a 2020 population of 379, is 1.4 miles away.

Reasons it may make a favorable location include:

- it is along an EV corridor designated in Round 1 that does not yet meet the requirements for signage to be added,
- nearby amenities include a gas station and convenience store,
- for northbound traffic, there are no public DCFC stations along the corridor until its end 85 miles away at the Canadian border, and the nearest Level 2 station is a 2 port ChargePoint Network station at 10 Thaddeus Ln, Saint Johnsbury, 20 miles away, and
- for southbound traffic, the nearest public DCFC station is a 1-port DCFC eVgo Network station at 586 Lower Pln, Bradford, 13.7 miles away.

  (Google Maps link, Street View link)



Possible Challenge Area

This selected challenge area at the US-2 junction with Town Highway 2/S Lunenburg Rd in Essex County seems to present more challenges for siting a charging station. Lancaster, with a 2020 population of 2,125, is 5.6 miles away.

It is along an EV corridor designated in Round 5 that does not yet meet the requirements for signage to be added, and in an DOE/DOT Interim Guidance disadvantaged community.

Westbound the nearest DCFC station is a 1-port eVgo Network station at 421 Route 2 E, Danville, 31 miles away. Eastbound there are no non-Tesla DCFC stations within 100 miles, and the nearest public Level 2 station is a 1-port non-networked station at 265 Main St, Gorham, NH, 30.8 miles away.

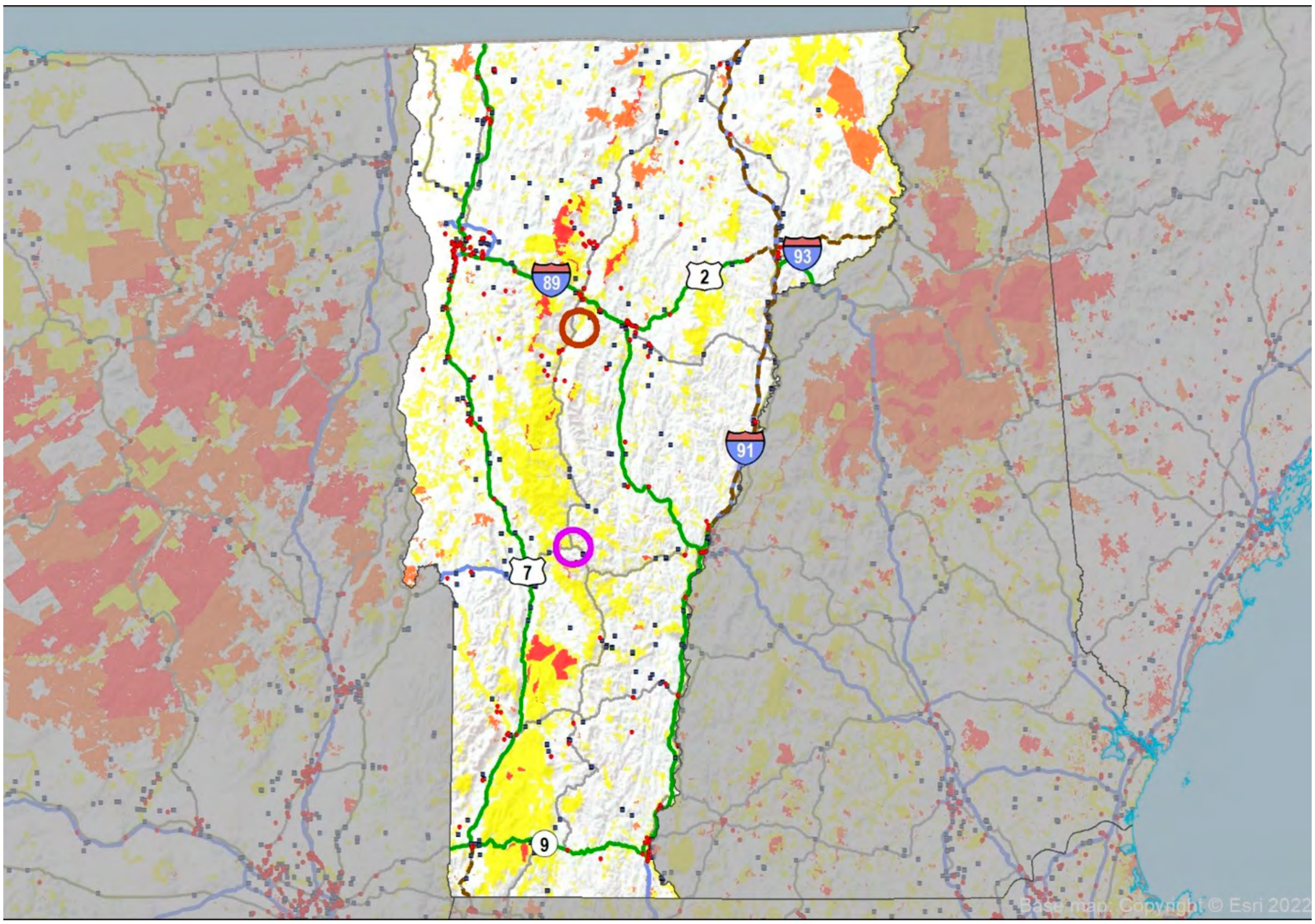
Reasons this location may be more challenging include:

- this exit has no amenities, and
- the nearest transmission-level substation is 6.1 miles away.
- it is not within an DOE/DOT Interim Guidance disadvantaged community or on tribal land.

  (Google Maps link, Street View link)

Example 2: Environmentally Protected or Sensitive Areas Scenario

Environmentally protected areas and locations with sensitive resources may introduce additional complexities for siting EV charging stations. They also may be of special interest for charging privately owned EVs at popular destinations, or for electrifying shuttle busses or other service vehicles. This map shows protected areas, symbolized by their level of protection, along with the Round 1-5 FHWA-designated EV corridors.



- **Location of Example Maps**
  - Map A
  - Map B
- **Electric Vehicle Charging Stations**
- **Electrical Substation**
- **Designated Alternative Fuels Corridor**
  - EV Corridor Ready
  - EV Corridor Pending
- **Protected Areas**
  - Area with Some Protection
  - Area with Moderate Protection
  - Highly Protected Area

Possible Opportunity Area

This location is the US-4 junction with VT-100 in Rutland County. It is adjacent to Gifford Woods State Park, and at a junction of the Scenic Route 100 and Crossroad of Vermont Scenic Byways.

Reasons it may make a favorable location include:

- it could support visitors with EVs stopping at the state park and driving the scenic byways,
- nearby amenities include two hotels and several stores,
- while there are four Tesla charging stations within 7 miles,
- the nearest public non-Tesla DCFC station is a 1 port eVgo Network station at 117 West St, Rutland, 11.3 miles west, and
- the nearest public non-Tesla Level 2 station is a 2-port ChargePoint Network station at 228 E Mountain Rd, Killington, 4.1 miles south.

  (Google Maps link, Street View link.)

Possible Challenge Area

This is location is along the Mad River Byway at the VT-100 junction with Fletcher Road in Washington County. It is in Moretown, with a 2020 population of 1,753.

Reasons it may make a favorable location include:

- it could support visitors with EVs driving the scenic byway,
- nearby amenities include a gas station and convenience store,
- the nearest DCFC station southbound is a 1-port ChargePoint Nework station at 59 Mad River Green, Waitsfield, 6.4 miles away, and
- northbound there are no DCFC stations along the byway, and the nearest Level 2 station is a 2-port ChargePoint Network station at 961 US-2, Middlesex, 7.1 miles away.

  (Google Maps link, Street View link.)

Additional information on how to get started using EZMT can be found in the Appendix of this document.

ADDITIONAL DOE RESOURCES

Readers are encouraged to explore the robust list of resources the Joint Office has provided on its webpage, or within the NEVI guidance document. The additional DOE-funded resources are highlighted below and are available to assist EV planning needs. These tools require a mix of expertise from "self-service" to "expert-assisted" that may require national lab support. Contact details for each tool are provided should questions arise, and readers should feel free to reach out to the Joint Office or the Office of Electricity (contact info provided on page 2) with any questions or technical assistance requests.

An EV Future: Navigating the Transition, *October 2021, A Voices of Experience Initiative.* The report compiles the ideas, advice, and approaches from various stakeholder perspectives about the transition to EVs. The topics vary widely from residential charging to long-haul transportation, from public transit to infrastructure deployment, from regulatory policy to new market entrants. It also includes a broader, more informal collection of experiences and observations from a variety of perspectives. The effort explored successful approaches, as well as not-so-successful ones, to uncover unanticipated challenges or barriers. Download the report here.

Using Mapping Tools to Prioritize Electric Vehicle Charger Benefits to Underserved Communities, June 2022. The report describes the important role mapping tools play in incorporating equity goals in the planning, implementation, and evaluation of investments in electric vehicle (EV) chargers. Building upon the Justice40 Initiative, the report provides examples of how to apply mapping tools to identify priority locations for installing EV chargers with the best potential to benefit energy and environmental justice (EEJ) underserved communities. Four approaches are described: corridor charging, community charging, fleet electrification, and diversity in STEM and workforce development. The report also explores various methodologies for calculating low public-EV charger density. Download the report here.

Oak Ridge National Laboratory

REVISE: a nationwide modeling tool to help infrastructure planners decide where and when to locate electric vehicle charging stations along interstate highways. The goal is to encourage the adoption of EVs for cross-country travel. The free open-source software, called REVISE-II, takes into account EV growth forecasts, charging technology capabilities, intercity travel trends and driver demographics to help planners fill infrastructure gaps for charging facilities. By inputting various assumptions, planners can generate scenarios for future charging infrastructure requirements to encourage acceptance of EVs and accommodate growth as more EVs are adopted. **To learn more, visit: https://www.ornl.gov/news/electric-vehicles-charged-planning Media contact: Stephanie G Seay, seaysg@ornl.gov, 865-576-9894**

Pacific Northwest National Laboratory

GridLAB-D: Enables modeling from the substation all the way down to an individual device within a home. Researchers and utilities have used this detailed modeling capability to examine and evaluate distribution automation technologies, demand response markets, feeder reconfiguration strategies, and both the feeder-level and localized impacts of technologies like Distributed Energy Resources (rooftop solar and local energy storage), energy efficient appliance deployment, and electric vehicle adoption. These analyses have included everything from evaluating feeder electrical characteristics (feeder power or individual location voltages) to impacts to customer billing, across both short term (seconds) and long term (annual to multi-year) time horizons. GridLAB-D™ is considered an expert-level self-service tool or expert-assisted tool as part of analysis approach via technical assistance opportunities.
To learn more and to get started, visit https://www.gridlabd.org.
For questions or support, please email the GridLAB-D™ team: gridlabd@pnnl.gov

Idaho National Laboratory

Caldera: Caldera is an EV charging infrastructure simulation platform designed to inform the complex, future-looking decision making that is required today to enable the electrified transportation of tomorrow. By representing EV Charging with individual vehicle and infrastructure agents and high-fidelity charging profiles, it is possible to forecast potential electrical loads with great precision based on transportation and proposed infrastructure inputs. The suite of tools includes *Caldera Charge* for EV charging load forecasting, *Caldera Operate* for mitigating EV charging load with battery storage, and *Caldera Plan* for resource constrained, incremental infrastructure deployment. *Caldera is currently a research tool that which requires a license and some introduction from our researchers.* **For more information visit: https://cet.inl.gov/caldera/SitePages/Caldera.aspx or contact Timothy D. Pennington at Timothy.Pennington@inl.gov**

National Renewable Energy Laboratory

In addition to EVI-Pro Lite, the free online tool, NREL has a suite of expert-assisted EV Grid Integration software: the EVI-X Modeling Suite of Electric Vehicle Charging Infrastructure Analysis Tools. NREL's modeling suite informs the development of large-scale EV charging infrastructure deployments from the regional, state, and national levels to site and facility operations. In addition to identifying the number and type of chargers needed to meet a given demand, the tools enable researchers to pinpoint efficient charging station locations and find ways to mitigate the impact of charging loads on the electric grid by tapping into renewable energy and employing smart-charge technologies. Specialized modules that may be of interest include: EVI-EnSite to optimize site location; EVI-Fast (Financial Analysis Scenario), which estimates break-even prices to charge EVs based on input parameters such as installation costs, operation maintenance, utilization, grid-infrastructure upgrades; EVI-RoadTrip, which analyzes charging infrastructure for long-distance travel; and EVI-Equity, which analyzes the accessibility of charging infrastructure from environmental-justice perspective. **To learn more about other tools in the EVI series, visit https://www.nrel.gov/transportation/evi-x.html**

Argonne National Laboratory

JOBS: Argonne's **JOBS** models evaluate how installing infrastructure for existing and emerging fuels (e.g., EV charging stations, natural gas, and hydrogen) affects jobs, earnings, ripple-effect spending, and gross economic output in an economy. Expenditures for fueling infrastructure are translated into dollar flows among industries, with impacts analyzed according to location and deployment level. JOBS tools enable scenarios at national, regional, and state scales. Within the spreadsheet tools, users define scenarios to estimate economic impacts for individual states, regions, or the United States as a whole. The tools contain default input values, but users can override default data with their own data for more project-specific results. Each tool contains user instructions. **Register to download JOBS models https://www.anl.gov/es/jobs-models**

Sandia National Laboratories

DEFCAM (Distributed Energy Feeder Capacity Analysis & Mapping): Conducts EV hosting capacity analysis on distribution feeders and exports GIS files for the mapping of results. This tool may be used by utilities to evaluate the impact of different sized EV loads at various locations and adoption rates. For example, distributed vs. concentrated charging impacts of level 2 chargers at 50% electric customer EV adoption. The results can help identify when and where distribution level voltage and equipment capacity issues arise as EV adoption increases. DEFCAM is currently an "expert-assisted" tool intended to become "self-service" as development progresses. **For assistance or more information, contact Thad Haines, 505-280-0950, jthaine@sandia.gov**

EZMT APPENDIX

Registering and Using the Energy Zones Mapping Tool

The Energy Zones Mapping Tool is available at http://ezmt.anl.gov. While the tool is free, users can create an account to save map settings, analysis results, and other work between sessions. Several helpful resources are available both on the home page and within the EZMT, including a series of short videos explaining the elements of the interface. Brief videos about Adding Map Layers, Using the Map Tools, and Running a Model are available from the EZMT YouTube Channel.

GETTING STARTED WITH EZMT

Registering for an account

- Click the Register link at the top right of the home page
- Complete and submit the form
- An email will be sent to confirm the registered email address via a confirmation link.
- After email confirmation, allow up to one business day for account activation
- Once activated, return to the home page to launch the tool and login
- Contact ezmt@anl.gov with any problems or questions

Viewing Map Content

- Click the Library tool at the top left,
- Click the first action icon next to any desired layer to add it to the map
- The map will display with the resources for each designated layer

Running a Model

- Click the Analyze icon at the top left,
- Click the "Run this model" icon next to the model of interest.

EZMT includes several example models designed for EV charging station analysis. These can be run as-is or modified to fit specific priorities or interests. Alternatively, clicking the "Create New Model" button in the Analyze dialog allows users to design their own model using any of the over 90 model input layers in the system.

MAPPING SYMBOLOGY AND DATA SOURCES

Layer	Symbology	Data Source	Details
Location of Challenge and Opportunity Maps	Challenge Opportunity	Argonne National Laboratory	Locations selected for the example maps
Electric Vehicle Charging Stations		Alternative Fuels Data Center	Public non-Tesla Level 2 or DCFC charging station
Electrical Substation		Homeland Infrastructure Foundation-Level Data	Electric power substations primarily associated with electric power transmission
Designated Alternative Fuels Corridor	EV Corridor Ready EV Corridor Pending	U.S. Department of Transportation, Federal Highway Administration	EV alternative fuel corridors designated by the U.S. Department of Transportation (DOT), Federal Highway Administration as of 4/22/2021. It includes rounds 1–5 for electric vehicle corridor designations.
Tribal Land		Homeland Infrastructure Foundation-Level Data	Locations of federally recognized tribal entities. Tribal areas are included as disadvantaged communities in NEVI Formula Program Guidance.
DOE/DOT Interim Guidance DAC		U.S. Department of Energy and U.S. Department of Transportation	DOE/DOT interim guidance disadvantaged communities under the NEVI Formula Program Guidance
EZMT Model Results	Suitability 41-50 71-80 51-60 81-90 61-70 91-100	Energy Zones Mapping Tool	Example EZMT model results used by the authors to help identify "opportunity" locations for the example maps.
Ozone Concentration National Percentile	60% - 65% 81% - 85% 66% - 70% 86% - 90% 71% - 75% 91% -95% 76% - 80% 96% - 100%	U.S. Environmental Protection Agency EJSCREEN	National percentile of summer seasonal average of daily maximum 8-hour ozone concentrations.
PM2.5 Concentration National Percentile	60% - 65% 81% - 85% 66% - 70% 86% - 90% 71% - 75% 91% -95% 76% - 80% 96% - 100%	U.S. Environmental Protection Agency EJSCREEN	National annual average percentile of airborne fine (2.5 micrometer) particulate matter (PM2.5).
Locations of Example Maps	Map A Map B	Argonne National Laboratory	Locations selected for the example maps
Protected Areas	Area with Some Protection Area with Moderate Protection Highly Protected Area	Energy Zones Mapping Tool	EZMT composite protected areas modeling layer based on multiple sources