From Geotargeting to Geoenlightenment: Overlaying Disparate Data to Best Target Program Funds and Manage the Grid

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ABSTRACT

Successful promotion of energy efficiency and renewable energy is fundamentally dependent on and interactive with the geographic nuances of the grid. Current program approaches may not adequately reflect and utilize those nuances, leading to missed opportunities for supporting a reliable total energy system.

VEIC is pioneering use of GIS methodologies and data visualization to geo-target efficiency programs to address electrical load constraints and maximize use of renewable heating fuels. This paper reviews the process of statewide geospatial analysis that provides insights on the thermal and electric delivery systems (the grid and the delivered fuels equivalent) and guides implementation to maximize impacts of program funds.

Using Vermont as a test bed for this research, this analysis includes:

- Anticipated excess load and capacity on the VT electric grid
- Grid data on load, generation, and capacity
- Expected growth for heat pumps and electric vehicles
- Existing biomass heating supply chains

Through this analysis, we demonstrate how GIS methodologies and data visualization can be used to guide strategic electrification and deployment of delivered heating fuels (oil, propane, and biomass). By overlaying existing data and identifying areas with low projected load growth and high solar penetration we identified target locations for strategic electrification. Analysis would be improved with better data on grid capacity and projected electric growth. However, these techniques will allow utilities, grid operators, and delivered fuel providers to develop and deploy a geographically nuanced strategy to best meet heating demand while effectively managing the grid in a more complex and electrified environment.

Introduction

Grid operators have managed—and will continue to manage—the grid proactively, balancing supply, demand, and infrastructure capacity to maintain safe, reliable power at the lowest cost. As the grid rapidly modernizes, these goals remain fundamental and are joined by state, federal and customer-driven desires to reduce environmental impact and accommodate new technologies. Increasingly, these goals are applied to the total energy system, which encompasses all energy needs, including electric power, heating fuels, and transportation. Strategic electrification and distributed generation are key trends transforming the electric grid and providing new challenges to grid operators (Bade 2015). In light of these key trends, system operators, utilities, and organizations administering efficiency programs must undertake a full system analysis to identify best-fit and lowest-cost solutions.

Strategic electrification (SE) occurs as new electric technologies replace traditional fossil fuel technologies, most commonly in the home heating and transportation markets. There are many benefits to strategic electrification. First, modern electric technologies are typically more efficient than their fossil fuel counterparts, particularly in heating and transportation (DOE 2016). Second, as renewable generation becomes a larger part of the generation portfolio, SE will help meet state targets. Third, SE could bolster otherwise stagnant electric load growth. Many utilities are faced with replacing aging infrastructure despite little or no projected load growth. Because infrastructure investment costs are recouped through per-kWh retail rates, SE could alleviate infrastructure-driven rate increases. Strategic electrification can also negatively impact the electrical system. Because local peaks drive the need for transmission and distribution infrastructure, load that increases demand at peak times can increase costs for utilities and, ultimately, ratepayers (Baruah et al. 2014). Devices deployed through strategic electrification can help mitigate peak loads if they are equipped with demand response and load shifting capabilities. Other technologies might equally exacerbate peak demand issues. For example, heat pumps increase cooling peaks when installed in homes otherwise without cooling. The timing of load increases and the load shapes of new electrical devices inform utility planners working to balance supply and demand on existing infrastructure.

Distributed generation (DG) refers to electrical generation located on the distribution system, which serves lower voltage electricity to end use customers. Rooftop solar panels, micro-hydro, small scale wind turbines, and diesel generators are some typical examples of DG. In areas with high peaking load growth approaching the capacity of existing infrastructure, DG can provide local supply and alleviate the need for expansion of the transmission system (DOE 2007). If DG operates during peak times, it can help alleviate the peak loads.[1] On some circuits, particularly those where the load does not align with peak DG operation time, supply can exceed load. Excess generation results in either two-way flow, where electricity is fed back on to the distribution system, or in curtailment, where renewable generation is halted to prevent overloading the grid (Mulkern 2013). The former situation can cause overvoltage and other issues for the grid operators, and the latter reduces sales and cost recovery for the curtailed generation. Increased load from strategic generation can mitigate these issues if demand occurs concurrently with over supply.

Geographic targeting is an energy efficiency program technique used by Consolidated Edison, Efficiency Vermont, and many other utilities to avoid expensive transmission line upgrades (Neme and Grevatt 2015) Forward capacity markets also use geographic zones to target demand response as needed based on local constraints (Neme and Cowart 2014). However, it does not appear that any programs explicitly target strategic electrification as an answer to increasing distributed generation or decreasing electric load.

In this paper, we assert that by utilizing GIS analytical approaches, energy efficiency programs can geographically target their efforts to maximize positive impacts associated with SE and DG. Energy use is inherently local and geographic. For example, while the electric grid spans multi-state regions, utility grid operators and planners must ensure that there is adequate supply, demand, and infrastructure at each circuit, feeder, and substation. Grid operators and efficiency program administrators can deploy grid balancing solutions, such as energy efficiency, demand response, active grid management, distributed generation, and strategic electrification. However, they must understand the geographic nuances of the total energy system to most

[1] Depending on the fuel, DG may or may not provide peak load support. When DG is fueled by intermittent renewable resources, timing cannot be controlled.

effectively deploy these solutions. Nuances include all factors that change over a discrete geographic scale, including load growth and decline, peak times, renewable energy resources, grid infrastructure, and the spread of new technologies by word-of-mouth through neighborhoods. Despite the need for localized solutions, state total energy planning documents encourage and rely upon DG and SE as part of a system-wide approach to meet renewable energy targets and balance supply, demand, and infrastructure capacity. This paper presents an approach to developing a geographically nuanced perspective for deploying strategic electrification, DG, and targeted alternatives.

Approach

This approach uses GIS mapping and a supplemental non-geographic analysis to identify areas that would benefit from strategic electrification and distributed generation, and those that would be better served by alternatives. GIS mapping is a well-established technique that enables the analyst to explore geographic elements of data sources by adding layers of data to a base map.

This analysis specifically examines space heating strategies in Vermont, in light of ambitious state targets for electrification and modern wood heating. However, this approach could apply more broadly to any rapidly electrifying end use with viable alternatives.

In Vermont, local planning authorities, the state legislature, and many other stakeholders are grappling with best practices for siting solar and other distributed generation. Regional planning commissions have created maps identifying ideal locations for solar and other distributed generation given prime solar requirements, town land use priorities and access to three phase power lines. These maps reflect the complexities of community priorities, however, even they do not include the systems level analysis relating to load balancing and system constraints (Northwest Regional Planning Commission 2015).

Our approach supplements existing analyses by layering electrical infrastructure, existing constraints and opportunities, projected change in load and supply, and infrastructure supporting or limiting alternative technologies to identify areas appropriate for specific strategies.

First, the authors selected a region to investigate. For this study, we selected the state of Vermont given that VEIC implements the statewide energy efficiency program in this territory. This analysis could easily be conducted, however, at smaller scales (for example, utility territory) and at larger scales (for example, regional). Once a region was selected, the authors identified data that would inform the analysis. Generally, the following data would best inform the analysis:

- **Grid capacity.** The first layer categorizes each circuit's capacity to accept additional demand or distributed generation at its critical time. For circuits without distributed generation, this could be as simple as the maximum daily load compared to the transformer's top nameplate rating or as advanced as AMI data. A circuit with DG would need peak and minimum demand net of DG. If the minimum demand is approaching zero and DG is going to exceed load on the line, heat pumps, electric vehicles and other strategic electrification might be appropriate depending on the time of the peak and the load shape of the device.
- **Projected load changes.** As or more important than current loads are the changes in load projected over time. Many utilities have extensive projection mechanisms for anticipating load growth, and those projections should be used where available. Additionally, this

layer should identify areas targeted for accelerated commercial or industrial development, areas experiencing reduced load due to natural disasters or changes in a customer base, or other customized values. This layer is particularly important, given that locations with high DG and projected decreases in load may be targets for SE deployment and locations with constrained grid infrastructure and projected increases in load may be targets for non-electric fuel-switching alternatives such as biomass heat.

- **Projected generation changes.** Generation is important on a geographic and temporal scale—the type of DG is important because it reveals the time of day during which supply will be entering the grid, and when it may not be available to meet increased load. Data projecting new DG, storage, or changes in generation operation should all be included in this layer.
- **Infrastructure for non-electric alternatives**. When examining strategic electrification for a given end use—it is important to understand the constraints and opportunities of non-electric alternative technologies.

The analysis should also consider non-spatial characteristics of the technologies and how they influence placement of each kind of technology. For example, large homes with many heating zones could require multiple heat pumps, which may not be cost-effective (Efficiency Vermont 2016).

Vermont Residential Heating Analysis

While the above data are ideal for the GIS layers in this analysis, not all of the above data were available for Vermont. The analysis we conducted specifically for Vermont is described below. Our analysis evaluated space heating strategies in Vermont, in light of ambitious state targets for electrification and modern wood heating (Vermont DPS 2016), and used the following layers:

- **Grid capacity:** Grid capacity data for Vermont were unavailable to the author at the time this paper was written. The solar map from Green Mountain Power, which compares installed DG capacity to transformer nameplate capacity, was used as a proxy. Data were unavailable for non-GMP territories (GMP 2016).
- **Projected load changes:** Load projections were not available for this analysis. Population projections serve as a proxy for projected load growth (Jones and Schwarz 2013).
- **Projected generation changes.** No projected change was available for this study[2].
- **Infrastructure for non-electric alternatives.** This paper examines strategic electrification of residential home heating and complementary alternatives. Natural gas and modern wood heating fuel delivery are included in this analysis.
    - **Natural gas infrastructure.** Whether or not natural gas infrastructure contributes to meeting state total energy targets, existing natural gas infrastructure is a long term investment currently providing cost effective heating fuels to customers in Vermont. Heat pumps and modern wood heating will struggle to compete with natural gas at its current price. Existing natural

[2] In Vermont, as the DG siting process becomes more refined, as towns begin planning for DG, and as ideal DG sites are identified, utilities will be better equipped to anticipate increased generation on the grid. When available on a state-wide scale, the maps from the regional planning committee siting process will best inform this analysis.

gas distribution infrastructure is included to outline areas in which neither heat pumps nor modern wood heating are likely to compete well as natural gas heating alternatives (Vermont Gas 2016).

- **Modern wood heating delivery systems.** Cost effective heating provided by delivered fuels like heating oil and bulk delivered wood pellets depends on cost effective delivery and an adequate delivery infrastructure. Most pellet mills in the northeast cannot cost effectively bulk deliver pellets more than 150 miles, given that they primarily ship by truck (Sherman 2016). This study conducted a drive time analysis from local pellet mills and determined that any location in the state is within 150 miles of a pellet mill. Pellet delivery limitations were thus omitted from this analysis, but should be included for larger states with limited access to these mills.

Results

The analysis identified areas where strategic electrification could be of the greatest benefit—those areas without natural gas infrastructure that are experiencing high DG compared to transformer nameplate capacity and that are projected to see population decline (and thus decreasing load).

Figure 1 depicts circuit ability to accept new distributed generation based on transformer nameplate capacity in Green Mountain Power service areas (2016).

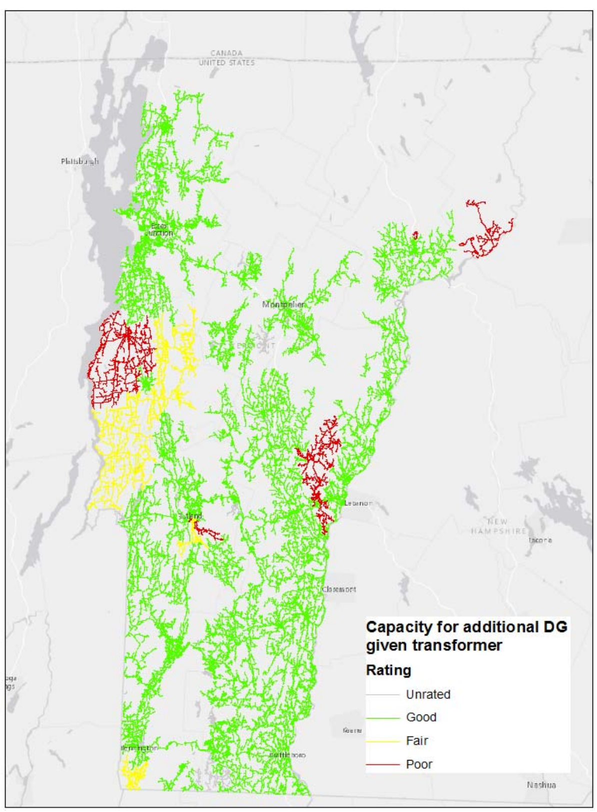


Figure 1. GMP Distribution Circuit Rating for New DG Interconnections. Source: GMP 2016

Figure 2 depicts projected town population change between 2010 and 2030 (Jones and Schwarz 2013).

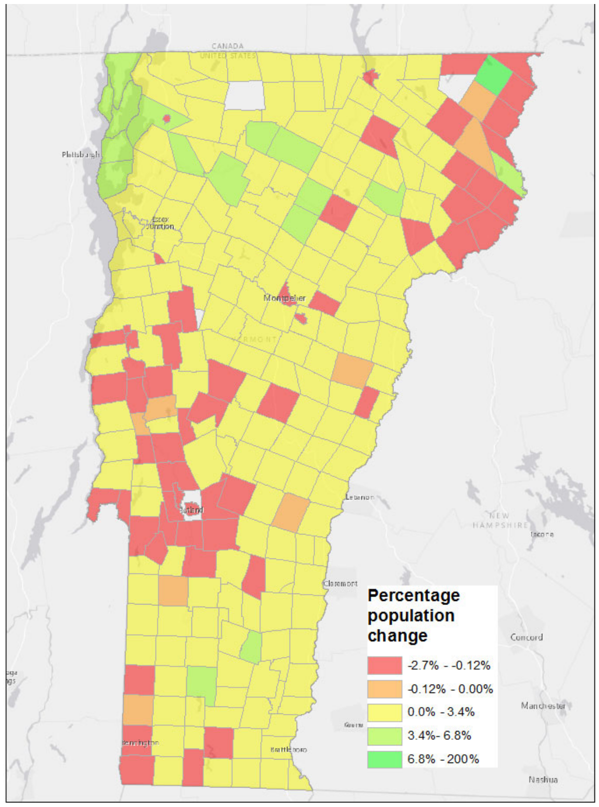


Figure 2. Projected population change by town, 2010-2030. *Source*: Jones and Schwarz 2013.

Figure 3 presents the results of the wood fuel delivery analysis and determines that no Vermont location is more than 150 miles from a pellet mill, and access to bulk delivered wood pellets is not a constraint for wood heating applications in Vermont. As a result, these data were omitted from subsequent analysis. Conducting this brief analysis will be important for other states evaluating geographically nuanced support of modern wood heating.

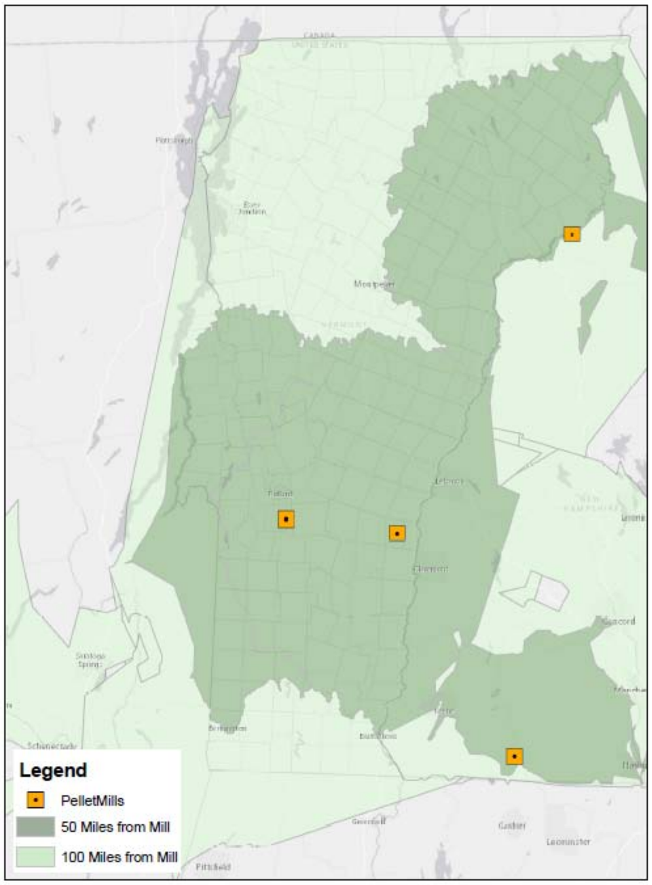
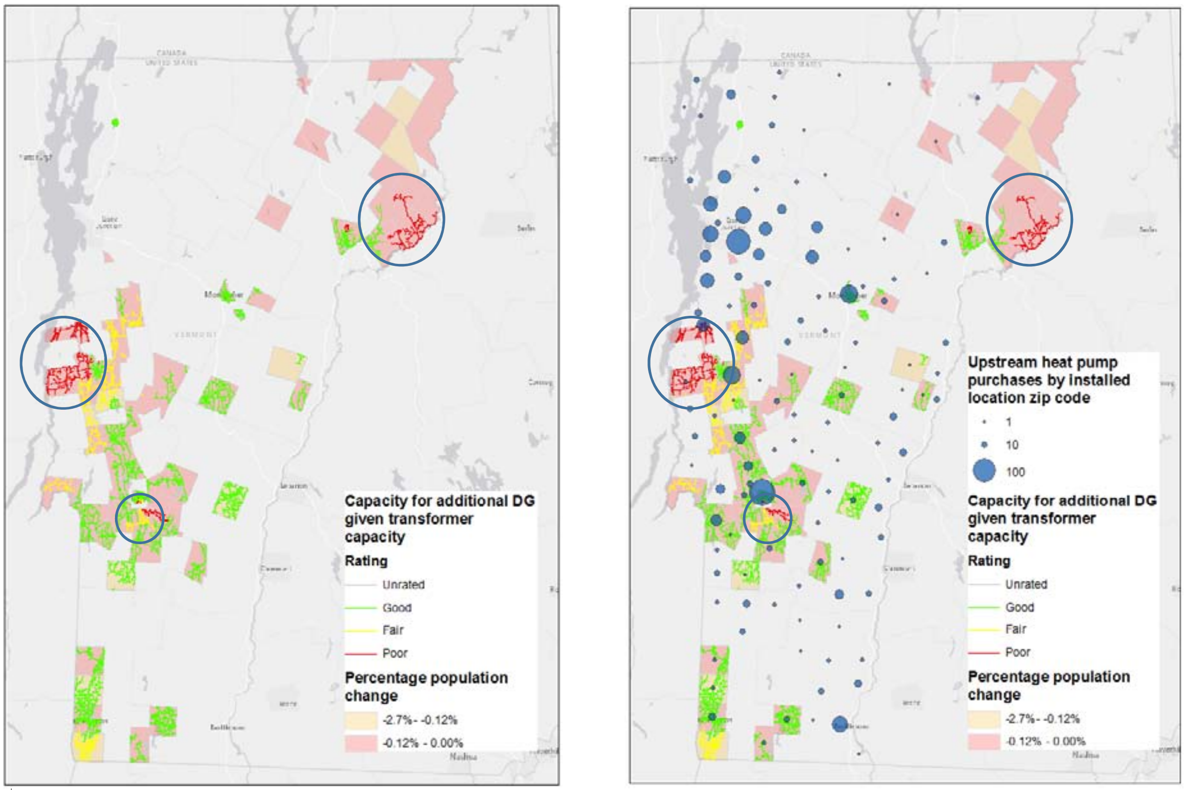


Figure 3. Service Area Analysis determining areas in Vermont within 50 and 100 miles of existing or planned wood pellet mills.

Figure 4a overlays the data in Figures 1 and 2 and removes towns projecting population growth and the circuits within them. This identifies towns and circuits that may experience load decline due to population decline. Figure 4b overlays heat pump purchasing data by zip code, depicting existing trends in heating electrification.



Figures 4*a and 4*b. GMP distribution circuit rating for new DG interconnections in towns with projected population decline, and heat pump sales data. Source: GMP 2016, Jones and Schwarz 2013, Efficiency Vermont 2016.

Strategic electrification in the circled areas, and in other areas projecting population decline, could relieve constraints on the grid. Heating electrification has not grown rapidly in the affected areas. By targeting these areas with strategic electrification through their efficiency programs, utilities and other program administrators can provide benefits not only to end customers but also to the grid. If data were available for circuits experiencing or forecasting local peak constraints, a similar map could be made in areas with projected population growth. This map would identify areas that could best benefit from demand response and non-electric heat, such as pellet-fueled modern wood heating. Taken together with an analysis of wood fuel delivery infrastructure, these analyses would highlight complementary opportunities for each technology.

Non-spatial Considerations

Spatial analysis provides a powerful tool for optimizing strategic electrification and alternative renewable technologies, however, spatial analysis is not effective on its own. To determine which heating option is best for which homes and businesses, the analysis must include review of non-spatial factors, such as those discussed below.

- **Heat pumps:** Heat pumps require little to no frequent maintenance and are best suited to small homes and businesses with open floor plans. Cooling and heating needs shape heat pump demand on the grid, but adequate studies on heat pump loadshapes in Vermont have not been completed (Efficiency Vermont 2016).

- **Pellet boilers:** Pellet boilers provide heat and hot water and are best suited to replace existing hydronic, hydro-air or forced hot air central heating systems currently fueled by fossil fuels. Pellet boilers must be installed in buildings with enough space for pellet storage to support sufficient supply. Pellet boiler also require some maintenance for removing ash, though this task is typically clean and simple (Ecoheat Solutions 2016).

Other Applications

This approach using GIS analysis to geo-target energy efficiency activities can be applied to other end uses, such as transportation. Figure 5 displays plug-in electric vehicle (EV) registrations by town in Vermont, projected population change, and existing grid capacity for distributed generation. Unmanaged EV charging can add to existing peak loads, but EVs have significant potential to support the grid through demand side management programs and new technologies. Time of use rates encouraging charging in off-peak periods and smart charging systems that modulate charging demand to reduce peaks are already in use to shift charging activity to periods when grid capacity is available. EV batteries can also serve as energy storage resources with potential to buffer energy from DG and provide back to the grid or behind-the-meter systems.

In our analysis, areas approaching DG constraints do not currently overlap with areas seeing growth in the adoption of EVs. This could present opportunities to support EVs in these areas as they provide flexible loads and energy storage which could be used to address DG grid constraints.

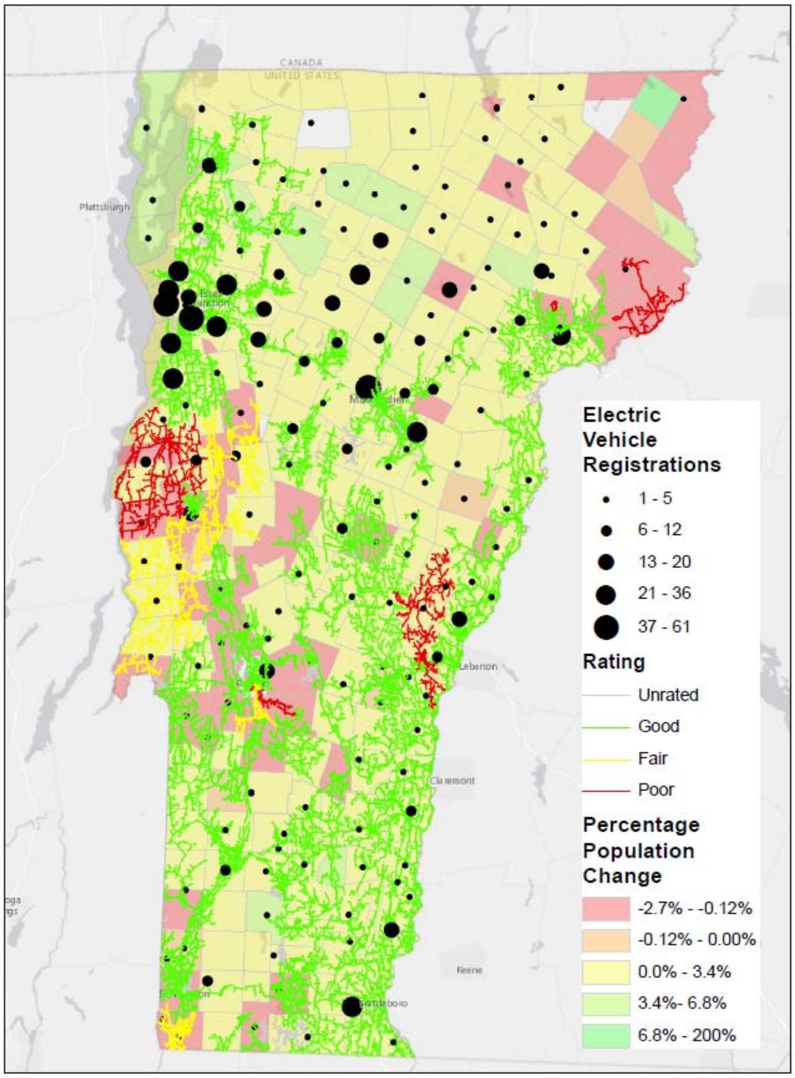


Figure 5. Electric vehicle registration by town overlayed on projected population change and circuit interconnection rating. *Source*: GMP 2016, Jones and Schwarz 2013, VT DMV 2016.

Conclusions

The approach explored here confirms there can be benefit in viewing multiple attributes of an energy system together spatially. Each layer presented alone illustrates a specific relationship between the total energy system and its user. When these layers are reviewed together, they allow users to hone in on areas of constraint or opportunity not visible when looking at one layer alone. Geographic analysis will allow states and utilities to develop and meet total energy goals in a way that supports the grid and optimally utilized alternatives, which vary by end use but can include things like modern wood heating, thermal storage, and alternative forms of transportation. When combined with forecasted data, this approach enables grid actors to identify opportunities today and anticipate future needs and opportunities.

While effective on its own, this process will benefit from improved data and refined methodologies. Additional data with increased locational and temporal specificity will improve understanding of the grid and help identify which solutions are best suited to which locations. Future analyses will leverage growing data opportunities and expand to different markets and end uses. By incorporating all existing relevant data, further analysis could show:

- More complete analysis of thermal end uses to identify ideal fuel switching programs for heat pumps and modern wood heating;
- Evaluation of different generation, storage, and load technologies and their relation to existing peak loads, by mapping time differentiated existing and forecasted load and distributed generation;
- Technology installation trends on circuits of interest to utilities and program administrators;
- The ability of specific technologies to address local peak load, as determined by technology load shapes.
- Targeted opportunities for low income programs, such as weatherization, and other demographically driven programs, in areas that face similar constraints (no natural gas, existing generation opportunities);
- Grid-driven locational analysis for new commercial or industrial facilities, generation, or transmission expansion; and
- Optimal siting of electrical vehicle charging infrastructure given transportation information, points of interest and existing grid support.

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