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ELECTRIC VEHICLE DC FAST CHARGING ON VERMONT HIGHWAY CORRIDORS

Vermont Energy Investment Corporation

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Contents

Overview

This report provides an analysis of the feasibility and costs for expansion of Vermont's DC fast charge (DCFC) electric vehicle supply equipment (EVSE) network along Vermont highways. The DCFC are intended to be a highly visible resource to plug-in electric vehicle (EV) users on Vermont's major routes that are available to residents and visitors.

This analysis includes, but is not limited to the following considerations: potential priority locations needed to close gaps in current DCFC availability; availability of 3-phase power required for DCFC, and costs to provide it; preferred types and cost of DCFC equipment; amenities and site conditions associated with preferred EV charging locations; and funding options and potential business models to support ongoing DCFC operations.

Goals

1. Provide DCFC to enable long distance EV travel in Vermont, with priority to fill gaps in DCFC coverage on interstate and arterial highway corridors to provide charging within 30 miles for 99% of Vermonters.
2. Identify issues and obstacles to providing DCFC.
3. Identify costs and potential funding for installation and operation of DCFC.

Methodology

- Identify desirable characteristics for fast charge sites.
- Identify candidate sites, including private and public. Gauge willingness and enthusiasm level of site owner through outreach.
- Screen sites for feasibility in terms of availability of 3-phase power supply necessary for DCFC, amenities, convenience to highway corridor, and enthusiasm of site owner.
- Analyze feasibility in more detail for selected sites, including cost and permitting.
- Recommend options for equipment and business / financing options.
- Identify issues and obstacles that may need to be resolved for implementation.

Building a Fast Charging Network in Vermont

Introduction to EV Charging

Powered by electric motors and batteries, electric vehicles are available in a variety of models with different ranges and capabilities. To recharge, they need to be plugged into a source of electric power through EVSE, often referred to as "charging equipment". Public charging is especially important for All-Electric Vehicles like the Nissan LEAF or Chevy Bolt, which are powered solely by energy stored in a battery. Plug-in hybrids have batteries paired with gasoline engines to enable longer trips without stopping to charge. There are three levels of charging described in Table 1 below.

Table 1: EV Charging Levels

Level 1 (120 Volts)	Level 1 charging uses the same 120 volt current found in standard household outlets and can be performed using the EVSE that comes with an EV from the automaker. This typically provides about 5 miles of range per hour of charging. Offering level 1 charging can be as simple as installing dedicated 120 volt outlets in a parking area, as VTrans has done at a number of recently constructed park and ride facilities.
Level 2 (240 Volts)	Level 2 charging uses 240 volt power to enable faster regeneration of an EV battery system – usually about 10-20 miles of range per hour of charging depending on the vehicle and EVSE power capability. Providing this type of charging requires installation of a dedicated EVSE charging device and electrical wiring capable of handling higher voltage power.
DC Fast Charging	DCFC provides compatible vehicles (generally all-electric models) with an 80% charge in 20-30 minutes by converting high voltage AC power to DC power outside of the vehicle for storage in EV batteries. This provides 100+ miles of range per hour of charging. Currently most DCFC compatible vehicles can handle up to 50 kW of DCFC power, but higher powered, faster charging DCFC is expected to be widely available in vehicles arriving over the next few years with charging power up to 300 kW or more.

EVs use several different types of plug connectors. Tesla has its own proprietary connector for all three levels of charging. Other manufacturers have standardized on the Society of Automotive Engineers (SAE) "J1772" standard plug connector for level 1 and level 2 charging. For non-Tesla DCFC there are two additional plug types - the CHAdeMO used by Nissan and Mitsubishi and the SAE Combined Charging System (or SAE CCS, sometimes called SAE Combo) used by American and European automakers (Figure 2). We highly recommend any investments in expanding the DCFC network utilize "dual plug" (CHAdeMO and SAE CCS) EVSE which offers both types of non-proprietary plugs. Tesla also offers an adapter to use CHAdeMO DCFC equipment and is rumored to be developing a similar adapter for SAE CCS.

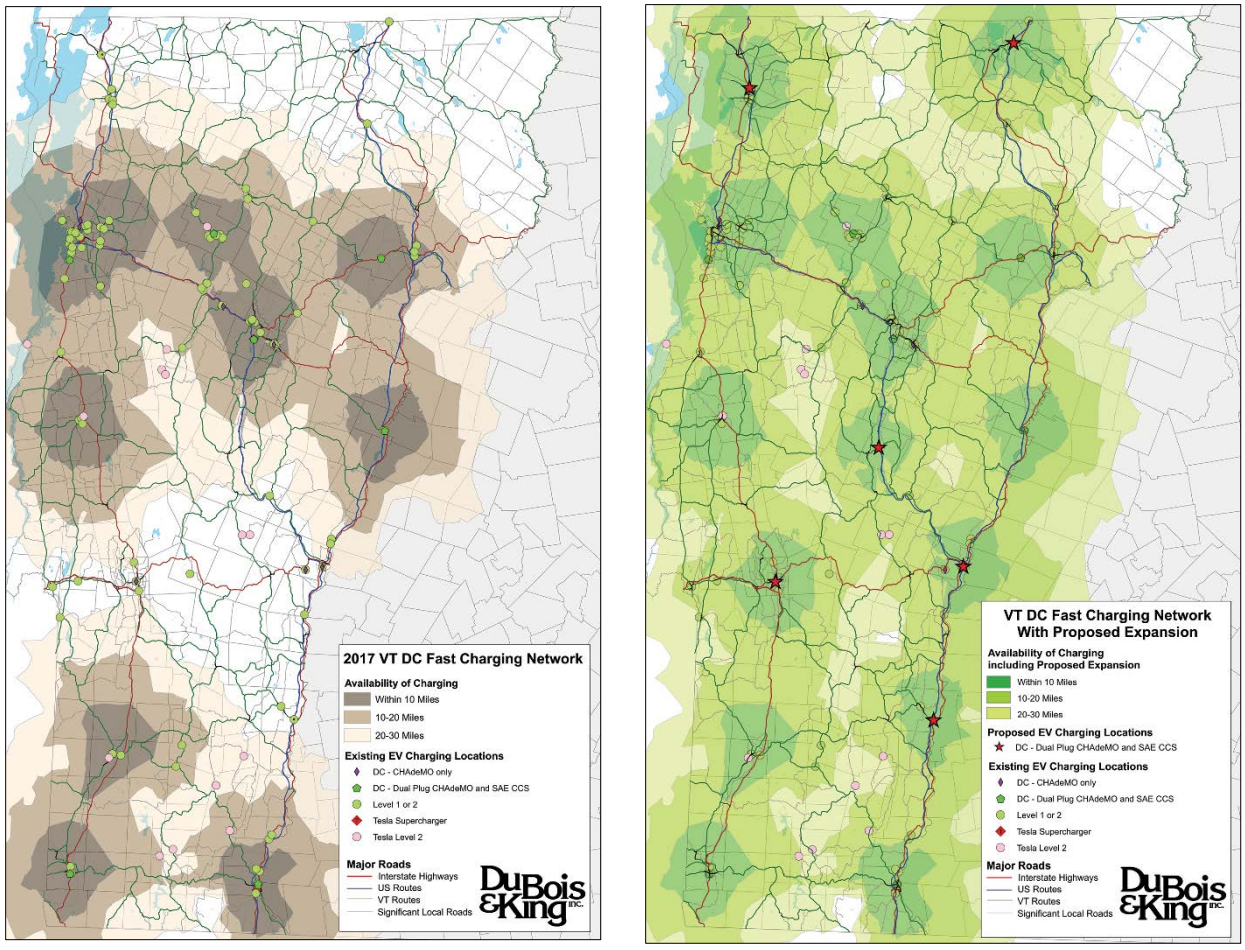
DCFC is ideal for travelers as it enables most vehicles to charge in 20 – 30 min. Widespread availability of DCFC is critical to EV growth as range anxiety has long been cited as one of the more significant barriers to EV ownership. For the purposes of this study, DCFC is the primary type of equipment considered, but we do recommend also including Level 2 charging when feasible as a backup and to provide charging for vehicles which are not equipped with DCFC capability.

Existing DCFC Network and Gaps

There are about 160 public EV charging locations in Vermont, 23 of which are DCFC. Of the DCFC currently in operation, only 11 are dual plug (CHAdeMO and SAE CCS). In order to provide the broadest level of service, new DCFC should be dual plug. Seventy-nine percent of Vermonters are already within 30 miles of a dual plug DCFC; however a number of these chargers are not near Vermont's significant transportation corridors.

The most significant gaps in the dual-plug DCFC EVSE network are in the areas along I-91 from Springfield to Hartford, I-89 from Hartford to Randolph, and I-91 from Barton to the Canadian border (see Figure 1, left). Other gap areas include I-89 from St. Albans to the Canadian border and US Route 4 through Rutland. This report identifies six sites based on the EVSE site analysis process described below as potential priority locations. If DCFC are installed at these locations, 99% of Vermonters would be within 30 miles of a fast charger (pictured in Figure 1, right).

Figure 1 - Comparison between existing DCFC coverage (left) and coverage with proposed expansion (right).



EV driver feedback to the Drive Electric Vermont program has highlighted the I-89 corridor as a high priority for improved charging, with the Randolph area representing the most frequently cited desired location for

fast charging, with White River Junction and St Albans also commonly identified as areas in need of increased charging by current EV owners. In addition, many drivers are interested in travel to neighboring states and provinces, which suggests ongoing coordination to extend charging networks and EV travel potential beyond Vermont would be beneficial to EV owners and growth of the market.

DCFC Equipment Options

To maximize charging options, each location should (at a minimum) dedicate two parking spaces to dual-plug DCFC. Additionally, it is recommended that a Level 2 charger accompany the DCFC when possible. Users would be unlikely to fully charge their vehicles with Level 2 due to the long waiting times (typically 2 to 4 hours), but they would still benefit by receiving enough charge in a 30 to 45 minute period to get further on their trip if the DCFC is temporarily out of service. Also, some EVs are not equipped with DCFC capability, so equipping charging stations with both Level 2 and DCFC is an industry best practice. If limited space is available at a particular site we recommend DCFC be the priority.

DCFC is the highest powered EV charging currently available in the consumer marketplace. DCFC can provide over 100 miles of range per hour of charging with most vehicles able to receive an 80% charge in 30 minutes or less. The increased charging speed makes this technology ideal for serving longer distance corridor travels or other EV motorists who desire more of a "fueling station" type of experience.

As described above, there are several types of DCFC equipment, primarily distinguished by three unique plug socket designs: CHAdeMO (Nissan and Mitsubishi), SAE CCS (US and European automakers), and Tesla. These plugs are not cross compatible, although Tesla does sell an adapter that will allow Tesla owners to plug into a CHAdeMO unit.

Figure 2 - SAE Combo and CHAdeMO DCFC plug socket designs

Charging power is the second distinguishing trait, with existing DCFC ranging up to 120 kW for Tesla and 25-50 kW for CHAdeMO and SAE CCS charging equipment currently in use in Vermont.

Tesla Superchargers are unique in providing 8-10 charging spaces at each location which ensures near 100% availability in current market conditions, even if a maintenance issue requires one or more of the charging ports to be out of service. This is in contrast to other DCFC installations in Vermont which can only charge one vehicle at a time (although a few offer 240V Level 2 charging as a second option if the DCFC is occupied). Tesla has made a significant investment in building out its Supercharger network for cross-country travel.

The majority of DCFC equipment installed through Green Mountain Power's EVgo program was manufactured by ABB. ChargePoint, Fuji, Sumitomo and Signet units are also in use by Burlington Electric, Stowe Electric and private owners. Additional DCFC manufacturers in widespread use in the US include Efacec, BTC Power, and Blink along with a few other vendors with smaller market share.

Many more EV models with SAE Combo receptacles are anticipated in the next few years, with higher powered vehicle charging capability up to 300 kW or more anticipated by 2019. Nissan's recently re-designed the LEAF for 2018 and continues to use the CHAdeMO plug. While a unified DCFC standard would simplify equipment purchasing it is not likely to occur in the near future. As a result, we recommend the State of

Vermont require future DCFC installations accessing public funding to provide for vehicles equipped with either CHAdeMO or SAE CCS ports.

ABB and ChargePoint DCFC are two well-regarded DCFC equipment vendors making “dual plug” equipment and both are developing new/updated charging options with increased power for the faster charging vehicles expected in the coming years. Both manufacturers intend to offer modular power supply systems where owners can add modules to increase the DCFC output, provided adequate electric service is available to supply the equipment. Figures 3 and 4 below illustrate the design of their higher powered DCFC in the context of multiple port charging stations envisioned in the future.

Figure 3 - ABB High Powered DCFC Equipment Rendering with EVgo Branding

Figure 4 - ChargePoint Express Plus DCFC Equipment with Power Cube Modules

We recommend installations of at least two 150 kW capable chargers at each location under consideration in this study, accompanied by one or two Level 2 chargers as parking allows. This would require 480V three phase service at 600 Amps, plus a 208/240V 80 A service for the standard Level 2 units, which are typically on 40A breakers. While few vehicles would be able to take advantage of the full charging power in the next year, it is highly likely many models that could use this equipment will be available within a planned ten-year equipment life for the proposed installations. By using one of the modular equipment options described

above, the installations could initially offer 50-75kW charging power and then upgrade the DCFC equipment for higher powered operation as vehicles are available that can take advantage of this.

Site Selection

Site Development Costs

Installation costs are impacted by distance to 3-phase power, current price of copper wire, amount of underground conduit needed, site work, etc. Vaults and pad mount transformers may be included in some or all locations, regardless of expansion potential. Cost estimates vary from site to site, but based on information collected from Dubois & King's electrical engineering staff, GMP and Vermont Electric Company representatives, the following are presented as relatively conservative estimated costs:

Table 2: Potential Installation Costs and Fees (excluding DCFC Equipment)

Type of Expense	Cost Range
Application fees	$250-$500
Traffic Control	$0-$1000
Pole and transformers (if pole mounted)	$3,000
Primary power (power to location)	$20/ft.
Vault (required for pad-mounted transformers) and groundwork	$5000-$6000
Secondary power (power to DCFC from pole/transformer)	$35/ft.
Taxes	$2000 or more

Site Criteria

With the primary goal to fill gaps in fast charge coverage on Vermont's major highway corridors (interstates and principal arterials), our team worked with VTrans and other state agencies to develop a checklist of desirable characteristics of EVSE fast charge sites.

- **Convenience to highway corridor and AADT**: Identified locations were in close proximity to interstates and principal arterials to ensure that they would serve the highest number of travelers.
- **Availability of, and proximity to, 3-phase power supply**: Cost effective DCFC installations currently require 3-phase power supply from the local electric utility. To keep installation costs down, sites where 3-phase power is in immediate proximity were prioritized.
- **Enthusiasm of site owner**: Most locations identified would involve a public-private partnership. Site owners were asked to indicate their level of interest in further discussions regarding EVSE on their property. Those properties that were not interested were removed from further consideration.
- **Amenities:** Identified locations include a range of amenities that are important to travelers including availability of rest rooms, extended hours of operation, a safe and well-lit place to wait, access to food and beverages and adequate cellular phone coverage. Pedestrian access, specifically the ability to reach surrounding amenities safely, was also identified as important.
- **Adequate parking**: To avoid non-electric vehicles taking up a charging space, site locations need a minimum of two available parking spaces that could be dedicated to EVSE without overburdening existing parking.
- **Potential for expansion**: The potential for future expansion of DCFC equipment was considered. Ideally, it would be possible to increase the number of DCFC at as many locations as possible to keep pace with increasing demand. However, this was not seen as a critical barrier if expansion was not possible due to site constraints.

Initial site locations identified included areas that were part of Vermont's Village Center/Downtown Designation program. These areas were ultimately not selected due to distance from major travel corridors, which is a priority for improved coverage. This is not to imply that villages and downtowns are not appropriate locations for EVSE. Villages and downtowns are excellent locations for EV charging, particularly Level 2, as they generally offer opportunities for visitors to participate in activities that take longer 30-45 minutes, such as sightseeing, shopping or eating at restaurants.

Site Screening

Based on the gap area indicator map shown in Figure 1 (left), the project team initially identified 33 potential locations for DCFC facilities. Several were immediately removed due to a lack of interest from landowners, and more were eliminated due to distance from highway corridors or from 3-phase power.

In July of 2017, the project team presented a list of 22 locations (Figure 5) to stakeholders including representatives from VTrans, Buildings and General Services, the Department of Public Service, Agency of Natural Resources and the Agency of Commerce and Community Development. Based on the feedback provided, all locations that were over half a mile from the interstate (with the exception of the Rutland location) were removed from consideration. Likewise, remaining locations that were more than 100 feet from 3-phase power were eliminated. The remaining list of 12 locations was identified for closer consideration relative to site-specific criteria. This included the following:

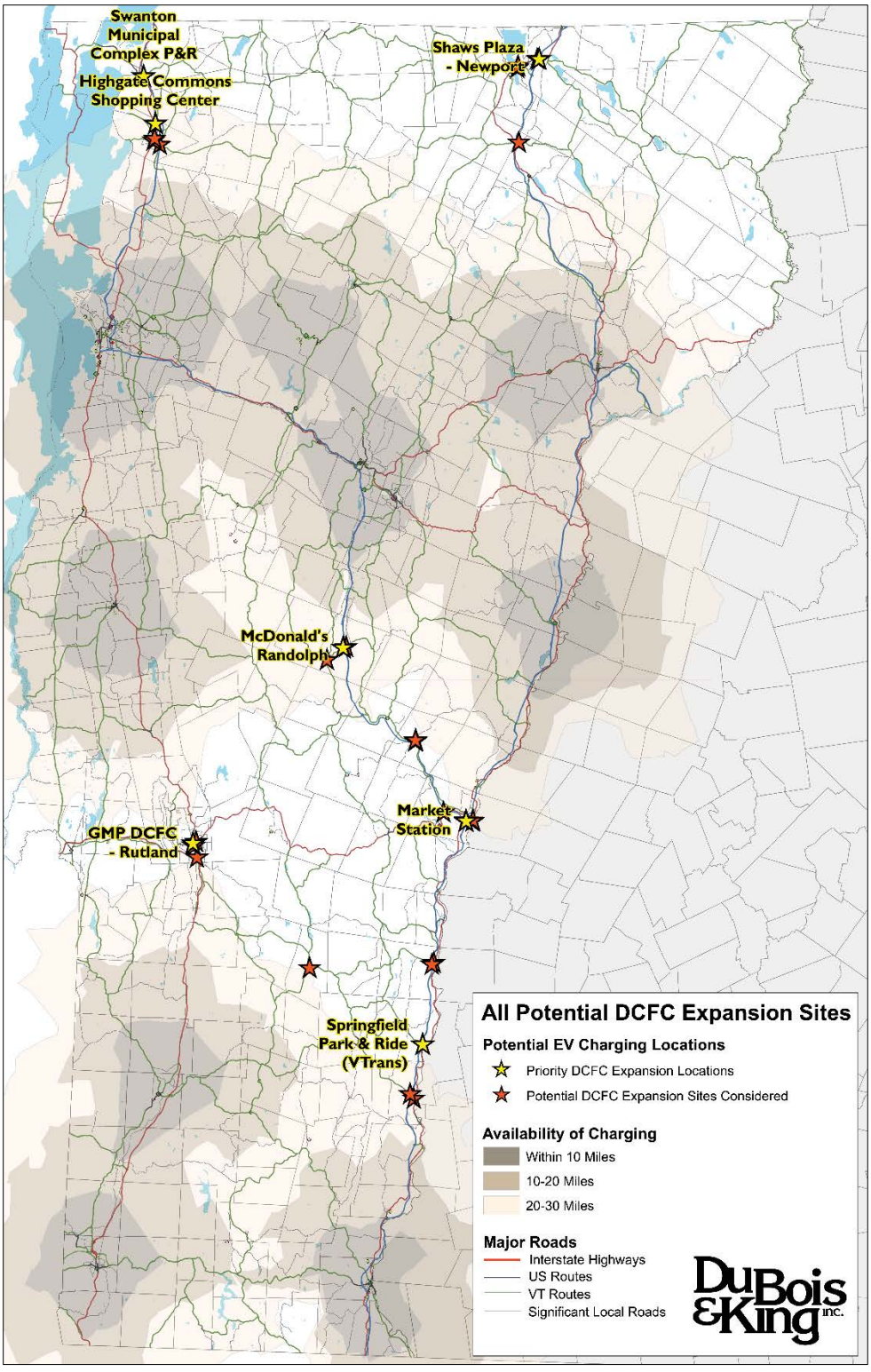
- Highgate Commons Plaza, St. Albans - (Northwest)
- Shaws Plaza, Derby - (Northeast)
- Sandri Sunoco, Orleans - (Northeast)
- Department of Motor Vehicles Parking Lot, Newport - (Northeast)
- McDonalds, Randolph - (Central)
- The Barn (Summit Distributing), Randolph - (Central)
- Sharon Trading Post, Sharon (Central)
- Market Station (Summit Distributing), Hartford (Central)
- Junction Marketplace, Hartford (Central)
- VTrans Park & Ride, Springfield (Southeast)
- Sandri Sunoco, Bellows Falls (Southeast)
- GMP DCFC, Rutland (Southwest)

The screening process removed the Department of Motor Vehicles Parking Lot from consideration due to complications relative to the availability of 3-phase power. In other cases the distance from three phase was greater than other locations nearby (such as The Barn or the Junction Marketplace). Several locations did not offer parking optimal locations for EV charging.

Priority Site Locations

Site analysis and elimination resulted in the selection of six priority sites (with one additional option) for filling gaps in the DCFC network statewide. (Figure 5.) Priority site locations are outlined in this section. More detailed site maps for each priority location are included at the end of this report.

Figure 5 – All Potential DCFC Sites Considered



Northwest: St Albans Highgate Commons Plaza

The Highgate Commons Plaza in St. Albans, VT is in close proximity to exit 20 of I-89 and less than 15 miles from the Canadian border in Highgate. (Figure 6.) This location covers the northwestern gap between Chittenden County and the Canadian border. The Plaza includes a grocery store and several restaurants. Additional restaurants, and two convenience stores (one of which is open 24 hours) are within walking distance.

Figure 6: Highgate Commons Shopping Plaza (Source: Google Maps, 2017)

Infrastructure Costs and Other Considerations – Highgate Commons Plaza, St. Albans	
Estimated Power Infrastructure Costs *(estimate does not include DCFC equipment or contingency allowance)*	$9,000-$20,000
Permitting Considerations	Local permit may be required. This property has an Act 250 permit that may require amendment.
Expansion Potential	The potential for expansion at this location is low. Insufficient property in the proposed site location would make placement of a pad mount transformer challenging.

Northwest: Swanton Municipal Complex Park and Ride

Locations in Swanton were initially ruled out due to differences in operational costs between Swanton Electric and Green Mountain Power (see p.18, Table 4 for more information). However, Swanton presents an opportunity to strengthen coverage to the Canadian border. The Swanton Municipal Park & Ride (Figure 7) already offers Level 2 charging and is located less than one mile from I-89 Exit 78 at the Swanton Municipal Complex. Amenities within walking distance include convenience stores, one of which is 24 hours, a fast food restaurant, a snack bar and a supermarket.

Figure 7: Swanton Municipal Complex Park and ride (Source: Google Maps, 2017)

Infrastructure Costs and Other Considerations – Swanton Municipal Park & Ride	
Estimated Power Infrastructure Costs *(estimate does not include DCFC equipment or contingency allowance)*	$9,000-$14,000
Permitting Considerations	Local permit may be required.
Expansion Potential	The potential for expansion at this location is good. This location has direct access to 3-phase power. If sufficient capacity exists for additional charging units, it may be possible to site a pad-mounted transformer in the median or to reconfigure the parking lot to allow for placement adjacent to EVSE spaces.

Northeast: Derby Shaw's Plaza

The Shaw's Plaza in Derby, VT is immediately adjacent to exit 28 of I-91 and less than 10 miles from the Canadian border in Derby Line. (Figure 8.) This location covers a significant portion of the DCFC gap in the Newport Area. Amenities within walking distance of this site include two convenience stores (one of which is open 24 hours) and several restaurants.

Figure 8: Shaw's Plaza, Derby (Source: Google Maps, 2017)

Infrastructure Costs and Other Considerations – Shaws Plaza, Derby	
Estimated Power Infrastructure Costs *(estimate does not include DCFC equipment or contingency allowance)*	$15,000-$20,000
Permitting Considerations	Local permit may be required. There is an existing Act 250 permit associated with this property that may require an amendment.
Expansion Potential	The potential for expansion at this location is excellent. Within the area identified above, there is an existing 3-phase pad-mounted transformer that can provide power access. It may be possible to provide additional opportunities for EVSE in this location if the infrastructure capacity is sufficient to allow for additional load.

Central: Randolph McDonalds

The proposed Randolph EVSE site is one of three locations that contribute to improved coverage in Vermont's Upper Valley. (Figure 9.) The McDonalds (open 4:00AM-12:00AM) is located at Exit 4 on I-89 and is immediately adjacent to a 24-hour convenience store.

Figure 9: McDonalds, Randolph (Source: Google Maps, 2017)

Infrastructure Costs and Other Considerations – McDonalds, Randolph	
Estimated Power Infrastructure Costs *(estimate does not include DCFC equipment or contingency allowance)*	$9,000-$14,000
Permitting Considerations	Local permit may be required. There is an existing Act 250 permit associated with this property that may require an amendment.
Expansion Potential	The potential for expansion at this location is low. This site may only allow for the use of two spaces for a single DCFC. Due to limited availability of overflow parking, it is unlikely that this would be a good location for expanded charging options.

Central: White River Junction Station Market

Located off Exit 11 on I-91, the Station Market in White River Junction provides an excellent location for EVSE. (Figure 10.) The Station Market building includes the Greyhound Bus Terminal (open 8:00AM-8:00PM) and the Market, which is open 24 hours. The site is within easy walking distance to several restaurants. Ready access to 3-phase power may make it may possible (if a suitable site location can be identified for a vault and pad mount transformer), to provide additional opportunities for EVSE in this location.

Figure 10: Station Market, White River Junction (Source: Google Maps, 2017)

Infrastructure Costs and Other Considerations – Market Station, White River Junction	
Potential Power Infrastructure Costs *(estimate does not include DCFC equipment or contingency allowance)*	$15,000-$17,000
Permitting Considerations	Local permit may be required.
Expansion Potential	The potential for expansion at this location is good. There is sufficient 3-phase power capacity for additional charging units, provided that there is adequate space to locate a vault and pad-mounted transformer.

Southeast: Springfield Park and Ride

The VTrans I-91 Exit 7 Park and Ride is located at the southern end of the Upper Valley DCFC gap area. (Figure 11.) The facility is a short walk to a 24-hour Truck Stop which provides food and other services for the traveling public.

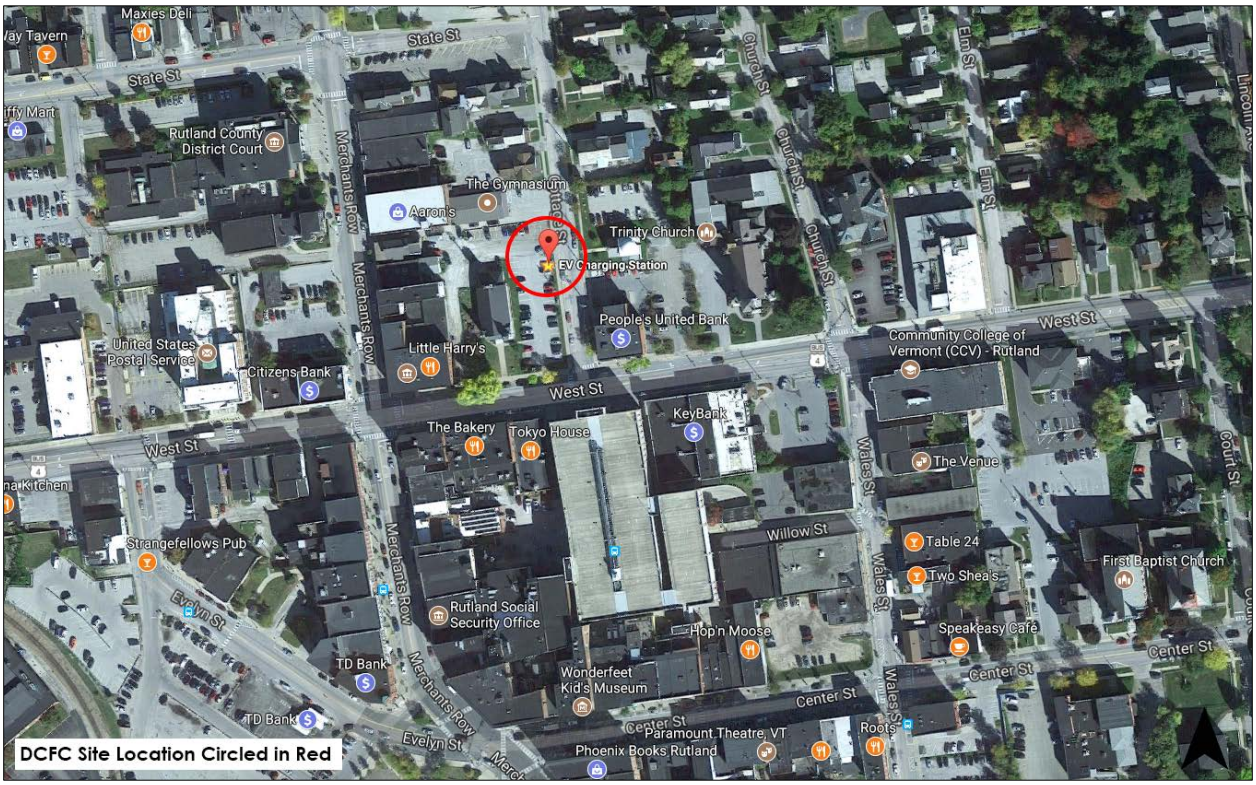
Figure 11: Springfield VTrans Park and Ride

Infrastructure Costs and Other Considerations – Springfield VTrans Park & Ride	
Potential Power Infrastructure Costs *(estimate does not include DCFC equipment or contingency allowance)*	$15,000-$20,000
Permitting Considerations	Local permit may be required.
Expansion Potential	Ample 3-phase capacity may make it possible (if a suitable site location can be identified for a vault and pad-mounted transformer), to provide additional opportunities for EVSE in this location.

Southwest: Rutland Green Mountain Power DCFC Upgrade

Green Mountain Power (GMP) owns a single-plug CHAdeMO-only DCFC in downtown Rutland. (Figure 12.) Based on communications with GMP, it is possible to upgrade the single plug charger to a new dual-plug unit, although costs are not insubstantial. Located in downtown Rutland, this EVSE provides access to multiple amenities including restaurants, cafes and shopping.

Figure 12: Green Mountain Power CHAdeMO DCFC, Rutland (Source: Google Maps)



Infrastructure Costs and Other Considerations – GMP CHAdeMO DCFC, Rutland	
Potential Power Infrastructure Costs *(estimate does not include DCFC equipment or contingency allowance)*	$12,000-$17,000 *This cost estimate represents a reconfiguration of existing infrastructure to a 3-phase 277/480 volt service, which is not currently available.*
Permitting Considerations	None.
Expansion Potential	Access to additional 3-phase capacity may be possible; however, there is insufficient room for a pad mount transformer in this location.

Costs and Funding Options

Equipment Costs

Current pricing for dual-plug 50 kW DCFC equipment is around $35,000 per unit, compared to an expense of about $5,000 per port of Level 2 charging. DCFC manufacturers have not yet started delivering the higher powered (100+ kW) equipment options, although both ABB and ChargePoint expect this to occur by the first quarter of 2018.

Initial conversations with ChargePoint and ABB on pricing for the higher powered options suggests future equipment cost could range from $50,000-$120,000 per DCFC, depending on maximum charging speed and expansion capability. One significant cost driver is the use of new liquid cooled cables which will be necessary as charging power increases.

Since there are very few vehicles capable of handling the 150kW at present, a potential cost reduction measure would be to install two units with 60 kW charging each and bridge the power between the units. This would allow for up to 120 kW charging if only one station is in use at a time. We received an approximate price from ChargePoint for this type of configuration of $100,000 for two DCFC. A significant increase in this cost would allow for adding a "power cube" containing several "power modules" which would increase the power output to 300kW per DCFC at an additional cost of $140,000 (or $240,000 total). This power increase could require a new transformer or other site electric service upgrades if this is added in the future and the initial installation did not include capacity for future power upgrades. The rapid evolution of DCFC equipment suggests further review may be warranted as implementation plans develop.

The equipment cost for Level 2 EVSE recommended to be paired with DCFC can vary depending on the equipment capabilities and vendor. Dual port charging equipment with cellular data networking required in most cases to charge a fee and monitor usage is approximately $10,000.

Taking the above into consideration, the total cost for two dual-plug DCFC and a dual port Level 2 EVSE is currently estimated at $110,000 per location for the bridged configuration of two 60 kW DCFC. Including higher powered DCFC capability through add-on modules would currently total a cost of about $250,000 per location.

Table 3: Total Estimated Costs of Installation, Equipment and Engineering

	Low	High
Six Priority Sites Installation (includes 15% contingency)	$86,000	$124,000
Equipment	$660,000	$660,000
Design/Management/Permitting (15%)	$112,000	$118,000
Total	**$858,000**	**$902,000**

The Priority Site Locations section (starting on p.9) estimates installation costs for each priority location ranging from $9,000 to $20,000. It is recommended an additional 15% be allocated to account for engineering and permitting work as well as other costs that may occur during installation. Totaling the installation cost estimates for six of the priority locations (not including Swanton) the total installation costs would be between $86,000 and $124,000. Charging equipment for six locations based on the initial cost estimate of $110,000 for two 60kW DCFC and a dual port Level 2 would require an additional $660,000. Engineering, site design, management and permitting would be an additional 15% putting the total capital cost for all six priority locations in the range of $858,000 - $902,000 (Table 3).

Operating Costs

Operating costs will depend primarily on the amount of use of a station and applicable electric tariffs. Maintenance, network access fees, customer support and other ancillary activities will also require operational funding.

Table 4 reflects current electric supply costs for new DCFC installations in three Vermont electric utility territories - Green Mountain Power, Vermont Electric Coop, and Swanton Municipal Electric Department. GMP customers have a "Rate 6 tariff" which is not subject to peak kW demand charges as long as metered usage is under 7,600 kWh cumulative and 200 kW peak in a month. VEC has a similar general service rate for non-residential customers with peak demand lower than 500 kW per month and usage less than 15,000 kWh per month. Swanton has a somewhat different approach and requires any customer requiring 3-phase power to be on their industrial rate, which includes a peak kW demand charge of $14.54/kW from the first kWh sold along with the usual volumetric kWh costs.

Electric rates fluctuate by utility and from year to year, but are much more stable than gasoline prices. As mentioned above, the GMP Rate 6 and VEC general service tariffs do not have peak kW demand charges as long as usage is below set thresholds. These demand charges can add significant additional cost to DCFC activity (approximately $550/month at a likely GMP rate for a 50 kW charger). Many DCFC installations in Vermont are separately metered to avoid demand charge expenses for as long as possible. Other utilities and public utility commissions around the country are grappling with the need to recover electric infrastructure costs associated with peak usage while also supporting DCFC growth that is not overburdened by costs. As a result, there are a number of different approaches to phasing in demand charges under consideration in other states as DCFC activity increases and it is possible Vermont utilities and regulators will find ways to contain these costs for the nascent DCFC market in Vermont beyond what is already in place.

Table 4: Electric Utility Rates and Estimated 2018 Energy Costs for DC Fast Charging

Utility Tariff	Monthly Customer Charge	Peak $ / kW	$ / kWh	Est kW	Est kWh	Est Sessions	Monthly Total	12 Month Total
GMP Rate 6 (< 7,600 kWh)	$18.58	$ -	$0.14	150	5,040	168	$734.42	$8,812.99
VEC General Commercial (< 15,000 kWh)	$18.26	$ -	$0.16	150	5,040	168	$816.60	$9,799.15
Swanton Industrial Rate	$29.48	$14.54	$0.08	150	5,040	168	2,607.98	$31,295.82

Actual usage of DCFC installed along corridors will depend on availability of EVs with DCFC capability, local traffic volumes, proximity to other EV charging infrastructure, amenities and other factors. Based on current 2017 usage for similar public DCFC facilities in Vermont, we estimated 2018 kWh usage of 5,040 kWh and a peak 150 kW demand reflecting a likely "worst case" for peak costs for near term installations. Table 4 calculates the energy related operating costs for this usage for the three Vermont electric utilities mentioned above. The annual cost would be around $9,000-$10,000 for GMP and VEC locations, but Swanton would be over $31,000 due to the addition of demand charges. The obvious operating cost reduction measure would be to avoid utility territories with significant demand charges, but it should be noted that discussions with representatives of Vermont's municipally owned electricity providers have suggested a willingness to adapt current rates to accommodate DCFC.

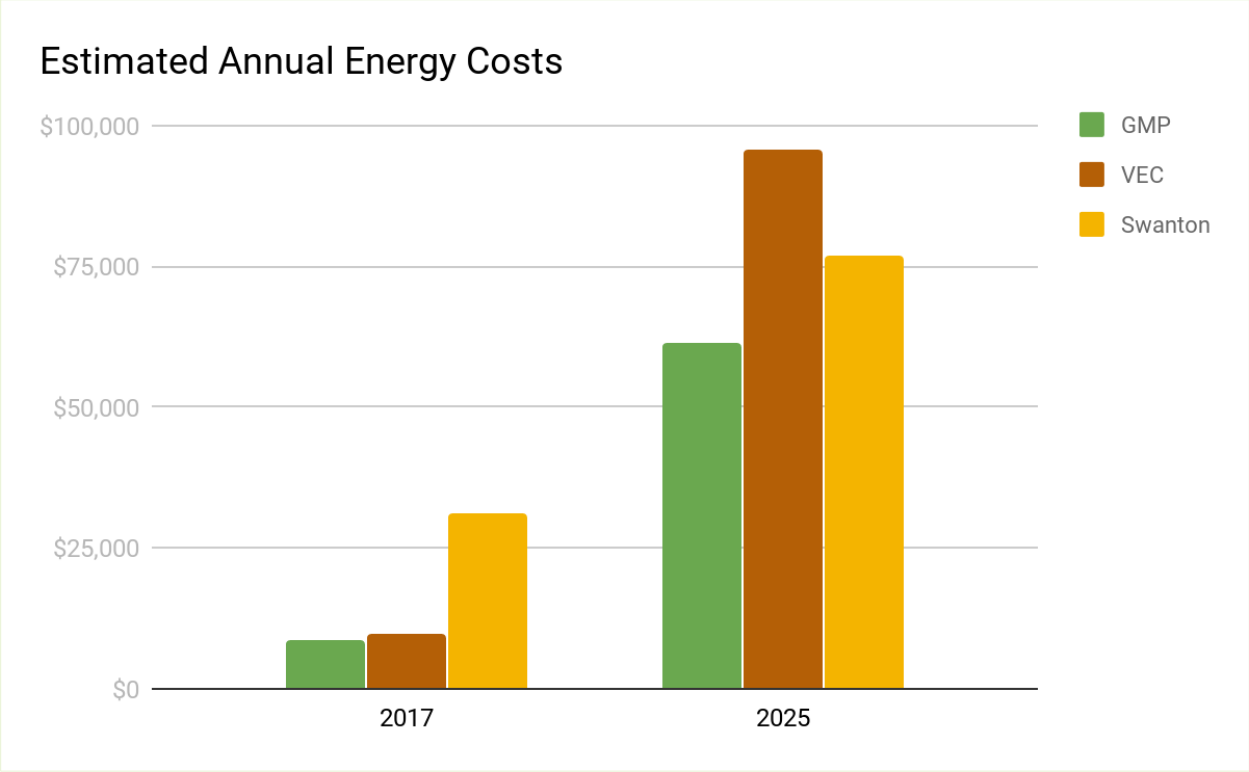
Added costs for networking and maintenance could result in $2,000 - $5,000 or more in annual operating costs beyond the energy costs estimated above. These costs could be offset through charging fees to users of about $5/session.

Vermont EV ownership has grown at a rate of 40% the past several years. Assuming the same rate of growth on charging energy use over the next 7 years we would expect to see an increase to 53,000 kWh for a DCFC location by 2025, although this could be diminished if charging station availability and wait times do not meet customer expectations in the future. Table 5 below includes operating cost calculations for energy use at this level based on current electric tariffs and the chart in Figure 13 provides a quick comparison of energy costs across utilities and electric usage levels estimated for 2018 and 2025. The 2025 electric rates are fixed as a simplifying assumption, but we would expect to see moderate increases in these which would roughly track with economy-wide inflation over the same interval.

Table 5: Electric Utility Rates and Estimated 2025 Energy Costs for DC Fast Charging

Utility Tariff	Monthly Customer Charge	Peak $ / kW	$ / kWh	Est kW	Est kWh	Est Sessions	Monthly Total	12 Month Total
GMP Rate 6 (>7600 kWh)	$93.20	$13.11	$0.09	150	53,128	1,771	$5,124.62	$61,495.39
VEC General Commercial (>15,000 kWh)	$30.44	$20.88	$0.09	150	53,128	1,771	$7,979.06	$95,748.74
Swanton Industrial Rate	$29.48	$14.54	$0.08	150	53,128	1,771	$6,400.72	$76,808.61

Figure 13: Estimated Energy Costs by Utility and Year of Operation



Business Models, Partnerships and Funding

While nearly all large scale deployments of EVSE in the US have involved grants or other incentives, there is growing interest in the role of the private sector and public-private partnerships in supporting the deployment of EV charging equipment. As of late 2017 there are few, if any, locations in the state which would have enough usage to fully recover both capital installation costs and long term operating costs for a private business. Much of the charging infrastructure installed to-date has been supported by automakers (primarily Tesla and Nissan), in many cases in partnership with electric utilities. Private businesses have made very limited investments in DCFC at a few locations.

The higher costs for DCFC installations and greater uncertainty of usage and consumer willingness to pay are expected to continue limiting private investments in DCFC infrastructure, making the role of the government more important in developing a basic infrastructure network to prime the market and support greater private investment in the future as equipment costs are expected to come down and EV adoption grows. The text below presents an initial review of potential Vermont funding sources and partners that could contribute to growth of DCFC in the state.

Volkswagen Diesel Settlement

The VW settlement includes two potential sources of funding for DCFC. The "Appendix C" settlement dollars which VW is controlling through their Electrify America (EA) subsidiary has approximately $2 billion to invest nationwide. EA is working with Burlington Electric Department to potentially install a number of DCFC in downtown Burlington. There is also potential for future corridor charging investments in Vermont of the sort described in this study, but it is likely several years away as EA is focusing most of their early investments in major metropolitan areas.

The "Appendix D" funds will flow through the Vermont Agency of Natural Resources as the state's designated beneficiary of $18.7 million in funds to be spent on eligible diesel emissions mitigation activities, which may include replacing older heavy-duty diesel vehicles with lower emission diesel technology or electric heavy-duty or transit vehicles. Up to 15% of these funds, or about $2.8 million, can be spent on light duty EV charging, including DCFC. These funds are expected to be available for project funding in early to mid-2018, following the state's development of a beneficiary mitigation plan.

Under the settlement terms the Trust can cover up to 100% of the cost for public charging on government property, or up to 80% of the cost for public charging installations on private property.

These state controlled funds are likely the most straightforward option for funding implementation of study recommendations. Finding ways to leverage these dollars will support the greatest potential of these one-time dollars.

Electric Utilities

Many electric utilities in Vermont have already invested in and supported DCFC installations and most are very interested in supporting the transition to EVs and making sure charging is available at reasonable cost. At this time most of the utilities have reported they are not considering additional investments in charging infrastructure as they await greater usage of their existing EVSE installations.

A number of utilities in other states have developed programs to invest utility ratepayer funds in EVSE development through direct utility ownership or "Make Ready" programs which cover the majority of installation costs and in some cases provide grants to private owners to purchase and install their own EVSE.

These programs are usually proposed by the utility and vetted by regulators and stakeholders (e.g. Public Utility Commissions) prior to implementation.

Vermont electric utilities are subject to "Tier 3" energy transformation requirements of the state renewable energy standard which requires them to offset a growing amount of their customers' fossil fuel use. EVs are one of the measures approved for meeting these requirements. Most utilities have focused more attention on incentives for new electric vehicles for transportation fossil fuel reductions, but it is possible some may consider DCFC investments to contribute toward their tier 3 obligations, especially for charging stations that have significant usage that could generate more tier 3 fuel reduction credits.

Vermont utilities currently have varying fee schedules for DCFC as shown in Table 6 below. The estimated fee is based on a 30 minute session consuming 30 kWh and the associated dollar per gallon of gasoline equivalent assumes an average EV efficiency of 3.5 miles/kWh and 25 mile per gallon gasoline vehicle. In some cases owners of current EVs with smaller batteries see gasoline equivalent rates over $4/gallon. While it could be beneficial to EV owners to lower these fees (particularly the EVgo rates), electric utilities are likely covering only a fraction of the overall capital and operating costs with current revenues.

Table 6 - DCFC Fees for Current Electric Utility Owned Locations

Utility	Fee Structure	Estimated Fee	$ / Gallon Gasoline Equivalent
GMP EVgo	$4.95 session + $0.20 /min[1]	$ 10.95	$ 2.61
Burlington Electric Dept	$0.17 / kWh	$ 5.10	$ 1.21
Stowe Electric Dept	$1.93 session + $0.48/hr	$ 2.17	$ 0.52

Regardless of direct investment by utilities, they can also support DCFC through favorable tariff structures that limit the cost of DCFC demand charges. This is particularly helpful while usage remains relatively low. As an example, the current equivalent cost for DCFC energy compared to a 25 mile per gallon gasoline vehicle (the Vermont average efficiency) is like $12/gallon gasoline at GMP's non-demand charge rate, while Swanton is similar to a $44/gallon gasoline with their demand charge rate factored in, albeit at a higher peak kW rate than we would likely see in the next 1-2 years due to a lack of EV models with capability of charging at power levels over 80 kW.

The State of Vermont

The State of Vermont has a number of potential resources to support DCFC installations in addition to the VW settlement funds mentioned above.

While it is critical not to dis-incentivize EV adoption, Colorado and Washington have both established somewhat higher registration fees for EVs to offset reduced gas tax revenues, with a portion of the fee going toward EV charging infrastructure development. Washington State has established an Electric Vehicle Infrastructure Pilot Program (EVIPP)[2] to leverage these funds through a publically available grant application

[1] EVgo also offers high-use EV drivers a $19.95/month subscription plan which eliminates the $4.95/session fee.
[2] WSDOT EVIPP program details available at: https://www.wsdot.wa.gov/Funding/Partners/EVIB.htm

process. Alternatively, Vermont could consider exempting electricity used to charge an EV from the Energy Efficiency Charge and instead assess a per kWh Transportation System Benefits Charge (TSBC).

The state can also put federal transportation funds and state general funds toward EV charging, although the many demands on these sources could present complications on their use.

Potential future legal settlements may also present opportunities similar to VW. While these are not a source the state can presently rely on, having an EV charging infrastructure plan in place to take full advantage of future windfalls may be beneficial.

The State Infrastructure Bank does offer low interest loans for publically available DCFC, but the lack of a clear business model to repay a loan has limited the application of this funding source for EV charging to-date.

Automakers

Nissan helped to fund DCFC equipment purchases for several early installations in Vermont. Tesla continues to support their Supercharger installations in the state. VW is considering a DCFC investment in Burlington through their Electrify America subsidiary and could consider additional locations in the future. It is possible Nissan and/or other automakers would also be willing to contribute to future DCFC development. Although Vermont's relatively small market for new vehicle sales could present challenges with the approach, Vermont could be positioned as a demonstration state for EV deployment in rural communities, as Vermont EV use per capita is higher than any other state in the northeast.

Some automakers have partnerships with EV charging networks to provide free or reduced cost charging, such as the "No Charge to Charge" program Nissan offers with free EVgo charging for the first 2 years of EV ownership. This program has been offered in several US markets, but unfortunately Vermont has not been included. These types of agreements may be very helpful in developing viable business models for DCFC development.

Vermont's ongoing participation in the multistate Zero Emission Vehicle (ZEV) action plan could present opportunities to engage with automakers on these partnerships and other potential charging infrastructure investments in the state.

Charging Vendors and Networks

DCFC equipment vendors and their associated network operations will be key in recovering fees from users. These operations can offer convenient payment solutions and round-the-clock customer support in case users experience any issues. We recommend any future network ownership or partnerships include options for both US and Canadian citizens to ensure the charging is available to the broadest possible audience.

In some cases the charging networks and/or equipment vendors offer optional extended warranty and service programs that deal with any maintenance or support issues for an additional fee. These programs include assurances of quick response times based on an extensive nationwide network of electrical contractors. These programs may greatly simplify DCFC ownership options for owners by shifting service responsibilities from maintenance staff to vendors.

Some of these networks may be willing to invest in charging equipment, but initial feedback suggests they would be most interested in very high throughput locations in populated metro areas which would not include the types of sites identified in this study.

Private Businesses

As discussed in this report, private business partners will likely be critical partners in expanding the availability of DCFC across the state as host locations. Our discussion with potential host sites over the course

of this study has suggested many are very willing to provide space on their property, but few expressed interest in providing financial support to install or operate the units.

A possible exception to this is private fueling station owners who may view EV charging services in a similar light to gasoline sales. DCFC could bring customers to their stores where they could purchase beverages, food and other profitable goods. However, operators we have talked with to-date have been more cautious in their approach to EV charging, with only minor investments in Level 2 charging as of late 2017. Until electric vehicles make up a more significant percentage of vehicles statewide, we anticipate it will be several years before private businesses feel it is worth the risk to pursue DCFC installations on their own. To close gaps in the DCFC network in the near term, the State of Vermont will need to lead the way.

Conclusion and Next Steps

Major increases in electric vehicle adoption will be necessary to meet Vermont's long term climate and energy goals. Many observers have long cited the "chicken and egg" dilemma between EV adoption and charging infrastructure development. Concerns over low use of expensive charging infrastructure investments are well-founded, but can be addressed by balancing investments between activities designed to encourage the EV market (e.g. EV incentives and marketing) with charging infrastructure to ensure the State has a balanced approach to pursuit of EV goals.

While many EV owners will be able to meet the majority of their charging needs at home, an expansion of DCFC across the state will reduce one of the most commonly cited barriers to EV ownership and also support Vermont's vital tourist industry in meeting needs of long distance travelers.

This study estimates a total capital cost of about $875,000 to complete building out a basic network of six additional DCFC along key travel corridors to provide DCFC within 30 miles of 99% of Vermonters. The significant capital and operating expenses of DCFC combined with relatively low use mean there are few options for developing profitable business models to support their installation at the present time.

Several different partnership and funding opportunities are described in this report. It is highly likely the state will need to provide significant financial support and leadership on several fronts to grow DCFC availability, potentially leveraging VW settlement funds controlled by the state, and accessing other sources.

Due to the rapidly evolving market and state procurement requirements for open bidding opportunities, we recommend the state consider issuing a Request for Information (RFI) as a next step in this process. The State of Maine went through a similar effort in 2016 as they developed a plan for a Quebec-Maine EV charging corridor[3]. This RFI would allow potential partners an open opportunity to offer suggestions on the various means of funding and operating a robust network of DCFC in Vermont and provide a solid foundation for a future RFP soliciting proposals for implementation support and/or partnership arrangements.

The State may also want to work with utility regulators to convene electric utilities and other EV stakeholders in a discussion on the appropriate role for utility investments in EV charging, including the role of rate-paying customers in supporting these investments and appropriate tariffs for power supplied to EV charging equipment. Similar proceedings in other states (e.g. California) have resulted in major expansions of utility investments in EV charging infrastructure.

Completing the DCFC network recommended in this study would be an important step in supporting EV owners and reducing barriers to future adoption in the state. Additional investments beyond those identified in this study will likely be needed as the market continues to develop, such as additional charging ports at busy locations or continued filling in of gaps in the network. Greater opportunities for private investment may be possible in the future, but for now the State of Vermont will continue to serve a critical role in advancing the EV market in Vermont and beyond.

[3] Details on the Maine RFI and responses are available at http://maine.gov/energy/news-events.html

Attachments

- All Potential Sites Map
- Existing DCFC Coverage Map
- Proposed New DCFC Coverage Map
- Site Maps
    - St. Albans
    - Swanton
    - Derby
    - Randolph
    - White River
    - Springfield

Swanton Municipal Complex P&R

Highgate Commons Shopping Center

Shaws Plaza - Newport

McDonald's Randolph

Market Station

GMP DCFC - Rutland

Springfield Park & Ride (VTrans)

All Potential DCFC Expansion Sites

Potential EV Charging Locations

- Priority DCFC Expansion Locations
- Potential DCFC Expansion Sites Considered

Availability of Charging

- Within 10 Miles
- 10-20 Miles
- 20-30 Miles

Major Roads

- Interstate Highways
- US Routes
- VT Routes
- Significant Local Roads

DuBois & King inc.

2017 VT DC Fast Charging Network

Availability of Charging

- Within 10 Miles
- 10-20 Miles
- 20-30 Miles

Existing EV Charging Locations

- DC - CHAdeMO only
- DC - Dual Plug CHAdeMO and SAE CCS
- Level 1 or 2
- Tesla Supercharger
- Tesla Level 2

Major Roads

- Interstate Highways
- US Routes
- VT Routes
- Significant Local Roads

DuBois & King inc.

VT DC Fast Charging Network With Proposed Expansion

Availability of Charging including Proposed Expansion

- Within 10 Miles
- 10-20 Miles
- 20-30 Miles

Proposed EV Charging Locations

- DC - Dual Plug CHAdeMO and SAE CCS

Existing EV Charging Locations

- DC - CHAdeMO only
- DC - Dual Plug CHAdeMO and SAE CCS
- Level 1 or 2
- Tesla Supercharger
- Tesla Level 2

Major Roads

- Interstate Highways
- US Routes
- VT Routes
- Significant Local Roads

DuBois & King inc.

Legend

- Storm line
- Storm line (old Sanitary line)
- Tunnel (storm)
- Combined sewer
- Sanitary line
- Swale
- Footing drain
- Under drain
- Roof drain
- Infiltration pipe
- French drain
- Trench drain
- Emergency spillway
- Stream
- Overland flow
- GMP Power Pole Data
- 3 Phase Power
- GMP Power Distribution
- PARCELS St. Albans Town 2008
- Potential Site Location

160 80 0 160 Feet

VTrans DCFC Coverage Expansion Project

Potential Location:

Highgate Commons Shopping Center
St. Albans Town, VT

DuBois & King inc.

VTrans DCFC Coverage Expansion Project

Potential Location:
Swanton Municipal Park & Ride
Swanton, VT

Potential Site Location

Legend

- Swanton Power Pole Locations
- PARCELS Swanton 2009

Stormwater_Infrastructure

Type

- Storm line
- Storm line (old Sanitary line)
- Tunnel (storm)
- Combined sewer
- Sanitary line
- Swale
- Footing drain
- Under drain
- Roof drain
- Infiltration pipe
- French drain
- Trench drain
- Emergency spillway
- Stream
- Overland flow

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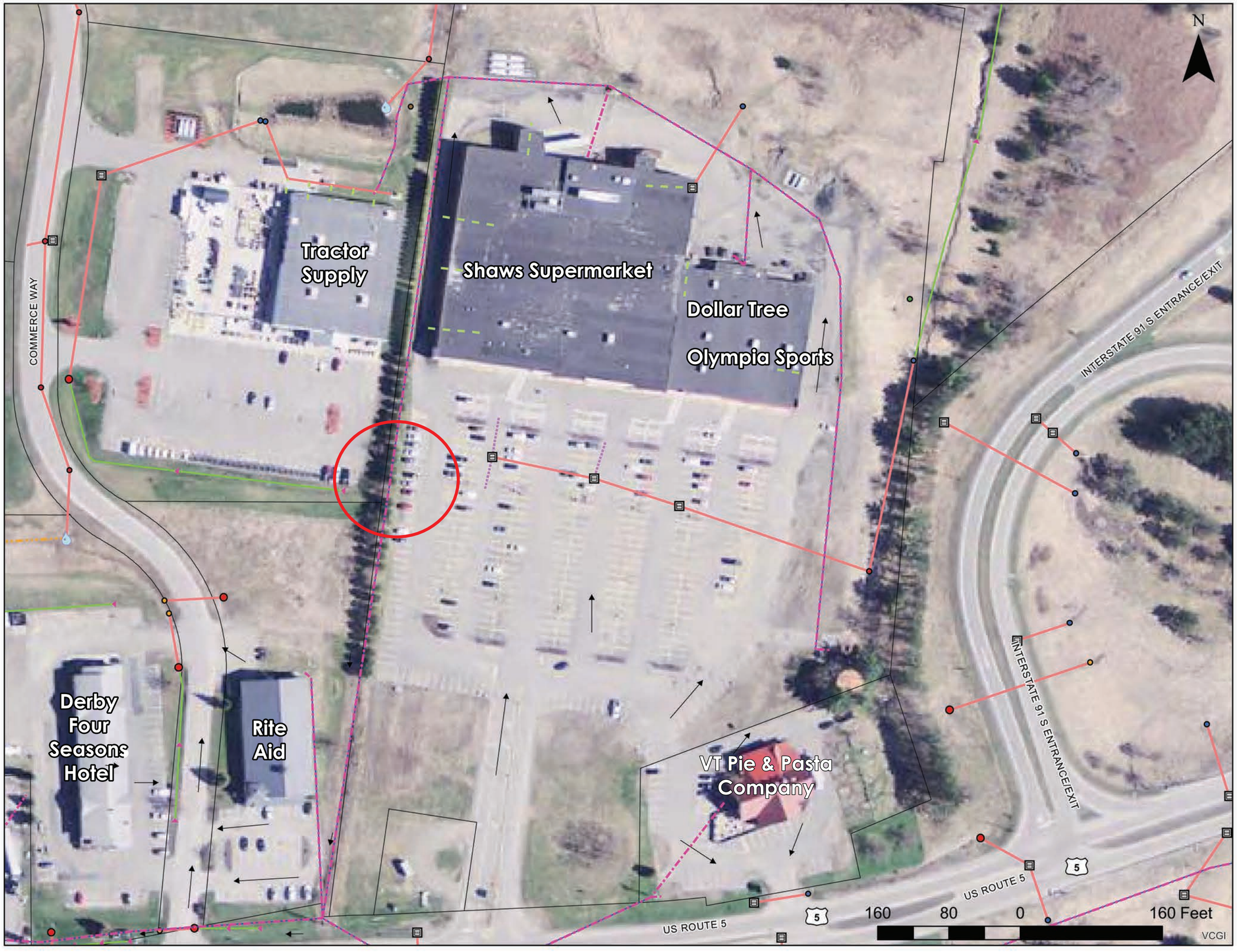
VTrans DCFC Coverage Expansion Project

Potential Location:
Shaw's Plaza
Derby, VT



Potential Site Location

Legend

- 3 Phase Power
- VEC Distribution Lines
- PARCELS Derby 2014

Stormwater_Infrastructure

Type

- Storm line
- Storm line (old Sanitary line)
- Tunnel (storm)
- Combined sewer
- Sanitary line
- Swale
- Footing drain
- Under drain
- Roof drain
- Infiltration pipe
- French drain
- Trench drain
- Emergency spillway
- Stream
- Overland flow

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VTrans DCFC Coverage Expansion Project

Potential Location:
McDonalds/Summit

McDonalds

The Barn

VT ROUTE 66

66

N

75 37.5 0 75 Feet

Potential Site Location

Note discrepancy in 3 Phase line Data Location

Legend

- Manually Acquired Power Pole Locations
- 3 Phase Power
- GMP Distribution Lines
- PARCELS Randolph 2010

Stormwater_Infrastructure

Type

- Storm line
- Storm line (old Sanitary line)
- Tunnel (storm)
- Combined sewer
- Sanitary line
- Swale
- Footing drain
- Under drain
- Roof drain
- Infiltration pipe
- French drain
- Trench drain
- Emergency spillway
- Stream
- Overland flow

DuBois & King inc.

VTrans DCFC Coverage Expansion Project

Potential Location:
Station Market
White River Junction, VT

N MAIN ST
N MAIN ST
BEECH ST
5
5
Station Market
Greyhound Bus Station
N HARTLAND RD
N HARTLAND RD
SYKES MOUNTAIN AVE
BESWICK DR
McDonalds
Crossroads Cafe
N
90 45 0 90 Feet

Potential Site Location

Legend

- GMP Power Pole Data
- 3 Phase Power
- GMP Distribution Lines
- PARCELS Hartford 2013

Stormwater_Infrastructure

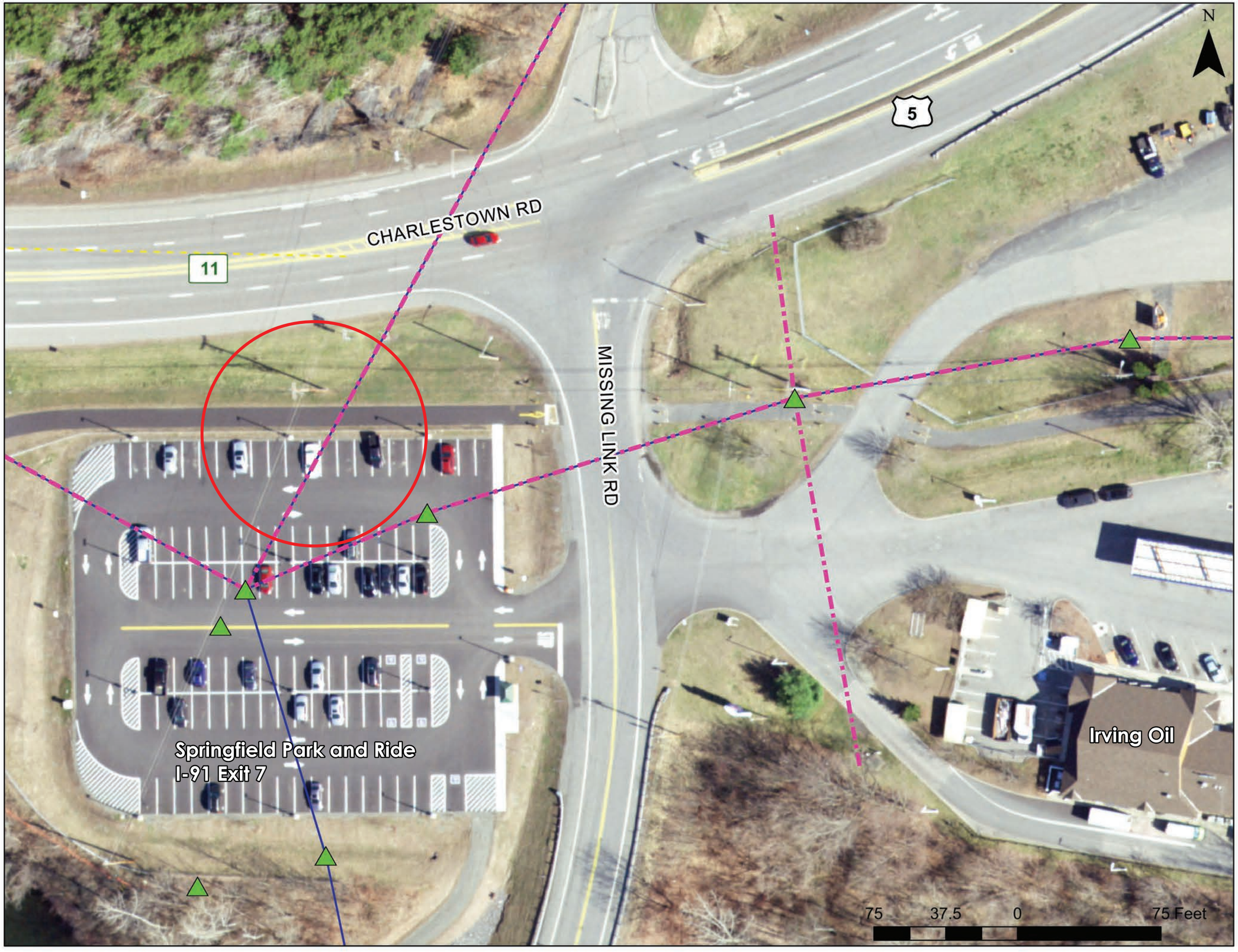
Type

- Storm line
- Storm line (old Sanitary line)
- Tunnel (storm)
- Combined sewer
- Sanitary line
- Swale
- Footing drain
- Under drain
- Roof drain
- Infiltration pipe
- French drain
- Trench drain
- Emergency spillway
- Stream
- Overland flow

DuBois & King inc.

VTrans DCFC Coverage Expansion Project

Potential Location:
I-91 Exit 7 Park and Ride
Springfield, VT



Potential Site Location

Note discrepancy in 3 Phase line data and pole location

Legend

- GMP Power Pole Data
- 3 Phase Power
- GMP Distribution Lines

Stormwater_Infrastructure

Type

- Storm line
- Storm line (old Sanitary line)
- Tunnel (storm)
- Combined sewer
- Sanitary line
- Swale
- Footing drain
- Under drain
- Roof drain
- Infiltration pipe
- French drain
- Trench drain
- Emergency spillway
- Stream
- Overland flow

DuBois & King inc.