The Electric Vehicle Infrastructure at UMass Amherst: Analysis and Recommendations

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Table of Contents

1. Introduction

Electric vehicles represent a rapidly growing segment of the U.S. transportation system. Nationally, there are an increasing number of electric vehicles on the road, since the Toyota Prius' introduction in 2000. In 2011, 17,731 plug in electric vehicles were on the road in the U.S., while in 2015 there was 113,869 on the road. [1] This rise in electric vehicles (EV) use can be attributed to several factors, including the fact that EVs use less energy than gasoline powered cars and usually cost about a third as much as gasoline powered cars to run.[2] All electric vehicles convert about 59% -62% of electrical energy to power, whereas gasoline vehicles convert only about 17%–21% of the energy stored in gasoline to power at the wheels. Furthermore, EVs have no tailpipe emissions, provide quiet operation, and better acceleration than internal combustion engines. [3]

Reflecting national trends, the use of EVs at the University of Massachusetts Amherst (UMass) is also on the rise. For example, at Robsham, a fast charging station in the visitor's center, the number of sessions increased from approximately 100 in 2016 to 300 in 2017. Since 2013, UMass has instituted several measures to encourage and support the use of EVs on campus. One campus incentive encourages fleet managers to buy only electric vehicles as departments purchasing Non-Alternative Fuel Vehicles will be charged $1,000.[4] Additionally, commuters are offered a 20% discount on their parking permit if they have a zero emitting vehicle.[5] In 2014 UMass Amherst became the first location in Massachusetts to install a public level 3 charging station, which charges a vehicle up to 80% in 30 minutes. Since then, the university has continued to install electric vehicle charging stations across campus to encourage the reduction of vehicle emissions.

However, barriers to EV adoption remain. Much of the general public is hesitant to switch toward electric vehicles due to factors such as range anxiety. One study shows that even though 78% of Americans drive less than 40 miles per day, there remains a nagging fear among potential EV drivers that they could run out of charge before they reach their destination.[2] This fear can be reduced with the introduction of charging stations, like the ones here at UMass Amherst.

This report illustrates a general increase in usage of EV charging stations on campus since the first ones were activated in April of 2014. With an ever increasing number of electric vehicles on the road, it's important that UMass develops strategies that ensure that the campus EV infrastructure is operating soundly, being utilized in the best possible ways, and is designed for the expected growth in EV usage in the coming years. Through examining the current policies in place at UMass, analyzing usage trends at campus charging stations, and investigating case studies at other schools, this report aims to elucidate

[1] http://www.afdc.energy.gov/data/10567

[2] http://www.consumerreports.org/hybrids-evs/electric-cars-101-the-answers-to-all-your-ev-questions/

[3] https://www.fueleconomy.gov/feg/evtech.shtml

[4] https://www.umass.edu/transportation/vehicle-acquisition

[5] https://www.umass.edu/transportation/clean-vehicle-permits

current infrastructure usage patterns and provide general recommendations for strengthening the electric vehicle infrastructure at UMass Amherst.

2. Review of Electric Vehicle Incentives and Regulations

Developing an understanding of the larger regulatory landscape surrounding EVs is critical to shaping the development of EV usage on campus. The following is a selected summary of incentives and regulations related to EVs and electric vehicle supply equipment (EVSE) at the federal, state, and campus levels.

Federal EV Incentives and Regulations

- **Alternative Fuel Infrastructure Tax Credit:** 30% tax credit for residential and business owners installing EVSE, good for both hardware and installation costs, retroactively.
- **Qualified Plug-In Electric Drive Motor Vehicle Tax Credit**: A tax credit is available for the purchase of a new qualified plug-in electric drive motor vehicle.[6]

Massachusetts EV Incentives and Regulations

- **Zero Emission Vehicle (ZEV) Parking Space Legislation:** Cities can restrict parking spots for ZEV. A person who violates this may receive a $50 penalty and their car may be removed from the space.
- **Public Electric Vehicle Supply Equipment Requirements**: Owners and operators of public EVSE that require payment must provide payment options that allow access by the public. In addition, owners and operators of public EVSE must provide the location, hours of operation, payment, and characteristics of each EVSE for the U.S. Department of Energy's Alternative Fuels Data Center.
- **Plug in Electric Vehicle (PEV) Discounts**- Mass Energy: Mass Energy's Drive Green with Mass Energy program provides discounts on qualified PEVs purchased or leased from participating dealerships.
- **Alternative Fuel Vehicle and Infrastructure Grants**: The Massachusetts Department of Energy Resources' Clean Vehicle Project offers grant funding for public and private fleets to purchase alternative fuel vehicles and infrastructure, as well as idle reduction technology. For information about how to apply for funding, visit the Massachusetts Clean Cities website.
- **Workplace Electric Vehicle Supply Equipment Grants:** The Massachusetts Electric Vehicle Incentive Program (MassEVIP) provides grants for 50% of the cost of Level 1 or Level 2 workplace EVSE, up to $25,000.
- **Plug in Electric Vehicle and Electric Vehicle Supply Equipment Grants:** The Massachusetts Electric Vehicle Incentive Program (MassEVIP) provides grants for the purchase or lease of qualified PEVs, zero emission electric motorcycles (ZEMs), and Level 2 EVSE. Eligible applicants include local governments, public universities, colleges, and state agencies. [7]

[6] http://www.afdc.energy.gov/laws/fed_summary
[7] http://www.afdc.energy.gov/laws/state_summary?state=MA

UMass Amherst EV Incentives and Regulations

- **Rules and Regulations**[8]:
    - Full year UMass parking permit holders may register their electric vehicles at either of the UMass Parking Services offices by presenting their ChargePoint membership card and their full year permit. Registered permit holders ChargePoint accounts will be updated so that these customers will pay a fee of $0.10 per KWh at the charging stations.
    - Registered permit holders may use any of the chargers located on campus for the $0.10 per KWh except those chargers located at the Robsham Visitors Center and at the Campus Center Parking Garage.
    - All those that use the EV chargers located at the Robsham Visitor's Center and the Campus Center Parking Garage will pay the current parking rate per hour. Current rate per hour at the Robsham is $1.50 and at the CC Parking Garage is $1.75 per hour.
    - Those that charge their vehicles at the Robsham Visitor's Center will be charged $1.50 per hour as long as the charging hose is attached through ChargePoint. There is no need to pay at the pay station for time as well.
    - Those that charge at the CC Parking Garage will pay for their time when exiting the garage.
    - Registered users are required to move their vehicles within 30 minutes of when the vehicle is fully charged. These users are required to return their vehicles to their designated/permitted lot.
    - Registered users of the EV stations on the UMass Amherst campus are subject to all UMass parking regulations.
- N**issan Leaf**: Discounts to faculty, staff, and students who purchase a Nissan EV through Balise Nissan in West Springfield. The dealership offers Leafs, to faculty and students sat the price they are available to the auto manufacturer's employees. It is called VPP pricing, and the code is needed to receive special pricing. It is a set price and you must finance through Nissan. In 2016, 16 vehicles have used VPP pricing in the fiscal year and 3 in 2017.[9]

3. Charging Stations at UMass Amherst

Since the first UMass Amherst EV charging station went operational in April 2014, campus charging infrastructure has been rapidly expanding to the point where there are now 10 stations throughout campus. **Table 1** below provides details about each of the 10 charging stations at UMass Amherst, including their location, type of charging station and date they were activated for customer use.

[8] https://www.umass.edu/transportation/sites/default/files/FleetServicesWebsitePDF.pdf
[9] https://www.umass.edu/newsoffice/article/new-charging-stations-expected-boost

Table 1 Current EV Charging Station at UMass Amherst

Station Name	Type	Cost to Charge	Activation Date	Location	Photo
Visitor Center Lot 21	Level 2, 2 ports	$1.50/hour	6/18/14	300 Mass Ave, behind Robshaw Visitors Center off Mass Ave/Swift Way	
Visitor Center Lot 22	Level 2, 2 ports	$1.50/hour	6/18/14	300 Mass Ave, behind Robshaw Visitors Center off Mass Ave/Swift Way	
Visitor Center Lot 23	Level 2, 2 ports	$1.50/hour	1/13/16	300 Mass Ave, behind Robshaw Visitors Center under canopy	
Visitor Center Lot 24	Level 2, 2 ports	$1.50/hour	1/13/16	300 Mass Ave, behind Robshaw Visitors Center under canopy	
Robsham	DCFC, 2 ports	$5.00/hour	1/26/16	300 Mass Ave, behind Robshaw Visitor Center, under the solar canopy	
Slowbody	Level 2, 2 ports	$1.50/hour	12/13/16	101 University Drive	
DC Level 3	DCFC, 1 port	$5.00/hour	1/23/15	Holdsworth Way, inside Transportation Services yard	

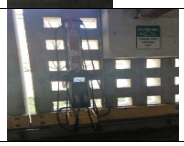
Station Name	Type	Cost to Charge	Activation Date	Location	Photo
Lot 41	DCFC, 2 ports	$1.50/hour	12/04/15	Holdsworth Way and Commonwealth Ave. Physical Plant Parking Lot East Side on wall	
PKGAR	Level 2, 2 ports	Free parking included in parking fee	4/14/14	Campus Center Way, 4th level, to the right of exit booth	
CCGAR	Level 2, 2 ports	Free parking included in parking fee	4/14/14	Campus Center Way, 4th level, to the right of exit booth	

Table 2 below provides details on the types and selected specifications of EV charging stations available within the U.S. EV charging market.

Table 2 EV charging station types and selected specifications

Charging Level	Description	Amps	Power (Kw)	Range per hour of Charging (miles) *Range reflects 20-30 min of charge time	Approximate Charging time (empty battery)	Cost of Station	Average Cost of Installation
Level 1	Slow Charging	Up to 16A	1	5-8	8-15 hours	$400-800	$0-3,000
Level 2	Medium Charging	Up to 80A	3-20, typically 6	10-24	3-8 hours	$800-3,000	$3,000
Level 3 AKA DC Fast Charging	Fast Charging	100-200A	50	40-80	20 min to 1 hour	$10,000-$40,00	$21,000

UMass Amherst charging stations are located at strategic points throughout the campus, as shown in **Figure 1** below.

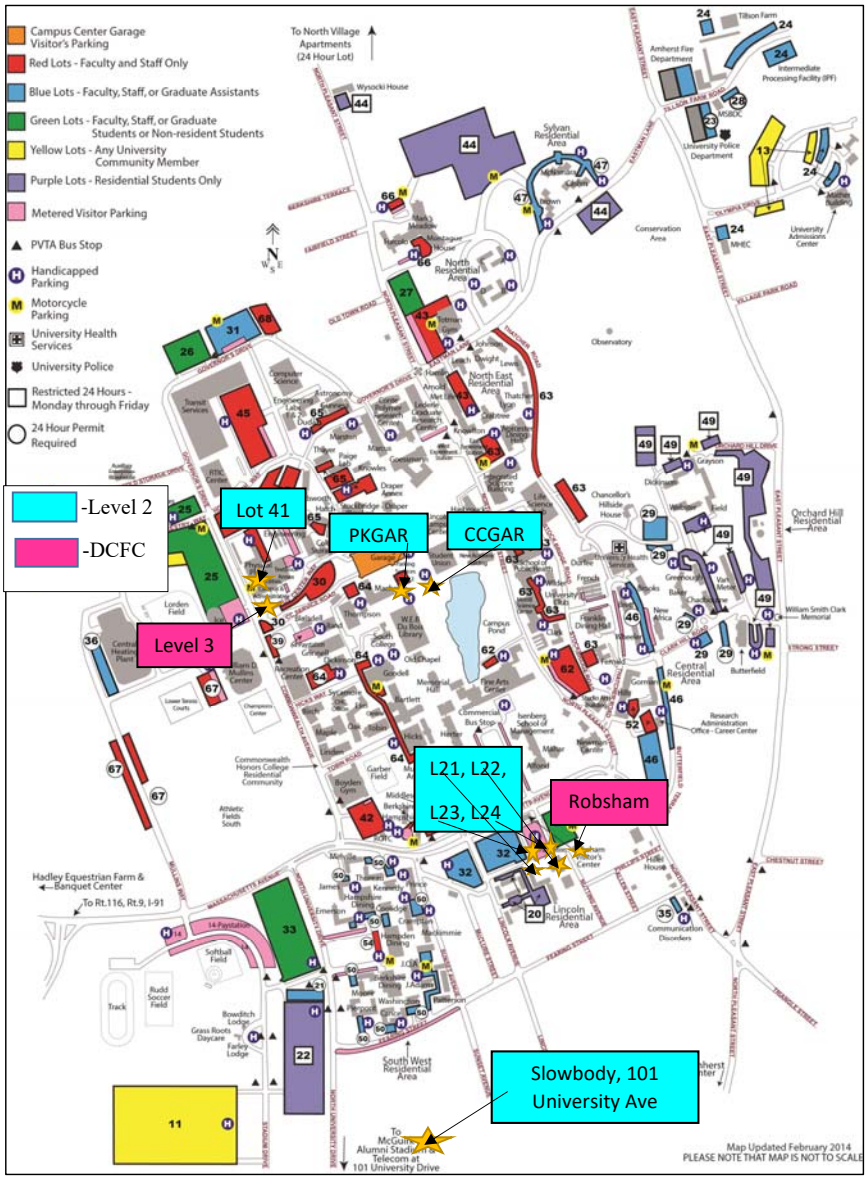


Figure 1 Map showing EV charging station on UMass Amherst campus

4. Analyses of EV Charging Data

Charging stations at UMass Amherst are provided and managed via the ChargePoint charging network and online platform. ChargePoint provides UMass the ability to manage EV charging for students, employees, and visitors – and provides functionality such as web access, mobile apps, mapping capabilities, and analytic tools that help improve EV charging experiences. Findings in this section were derived from the ChargePoint database. These findings may help to UMass decision-makers to better understand how EV users utilize the campus charging infrastructure and inform future infrastructure decisions accordingly.

UMass EV drivers come from throughout the northeastern U.S. and predominantly Massachusetts, as shown in **Table 3** below. These points are based off a zip code each user provided to ChargePoint as their address. If you follow the link pasted in the footnote, there is map with a list of the cities the drivers are supposedly driving to UMass from. Colors on the map designate a specific state.[10]

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Table 3 UMass EV driver location

State	Number of Unique Drivers from State
Massachusetts	175
Connecticut	12
New York	10
Vermont	6
New Jersey	4
New Hampshire	2
California	2
Rhode Island	2
Maine	1
Washington, DC	1
Missouri	1
Mont-Saint-Hilaire, Canada	1
Michigan	1

Figure 2 below compares the number of sessions two months after the activation date of a station to the number of sessions accumulated in the first two months of 2017. Note that Slowbody has overlapping data post activation and in 2017, as it was just activated on 12/31/16. The general trend has shown that electric vehicle charging has increased on campus. With the exception of the of station DC Level 3 and Slowbody, there has been an increased number of sessions at all stations this year than there was in their first two months of activation. This could be attributed to the fact that Slowbody is off campus and DC Level 3 is somewhat secluded in its location near Holdsworth. The sharp increase in sessions at

[10] https://www.google.com/maps/d/u/1/edit?authuser=1&mid=1cv7pQOv0vkZ6Go6T9vFB6RKB3ZI&ll=43.1419575393018%2C-80.78911826875003&z=6

Robsham in 2017 could suggest the need for more DCFC stations as more cars are able to connect to these fast charging stations.

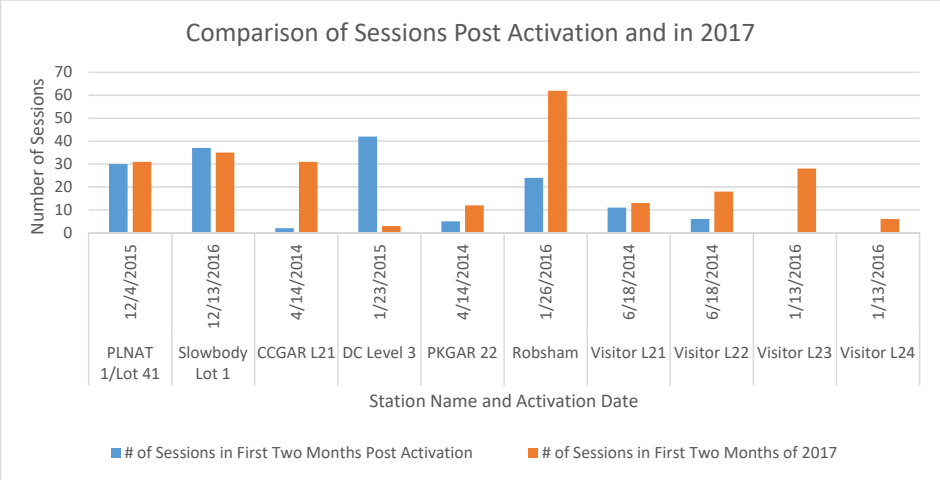

Figure 2 Number of charging sessions in two-month period at each station post-activation and in 2017

Figure 3 below shows the trends in the number of charging sessions at each UMass station from April 2014 until March 2017. Each of the 10 station is coded by a different color. The date that a session occurred is on the x-axis in month/year format. The sessions at stations start at different dates corresponding to when each station was activated for use by ChargePoint. There could have been at most 10 sessions prior to activation of the station, but they were not recorded by ChargePoint. On the y-axis is the number of sessions accumulated at each individual station. The number of sessions starts at 0 for each station and then increases as more sessions are amassed.

Generally, this chart shows a rise in usage of the charging stations since 2014. According to the data, DC Level 3 has not had any sessions since around June 2016. This is peculiar as the other fast charging station has shown a rapid increase in the number of sessions since its activation date. This difference in DC Level 3 could possibly be due to a broken port or the fact that it is secluded and hard to find. Lot 21 and 22 follow almost the same trend as they were both activated during the same period and are located right next to each other in the visitor lot. However, Lot 23 and 24, also located beside each other, are following different trends. Well Lot 24, red line, started to level off in November 2016, Lot 23 has continued to increase. Perhaps, it is due to more people using the Robsham fast charging station, also located in the same vicinity as Lot 23 and 24.

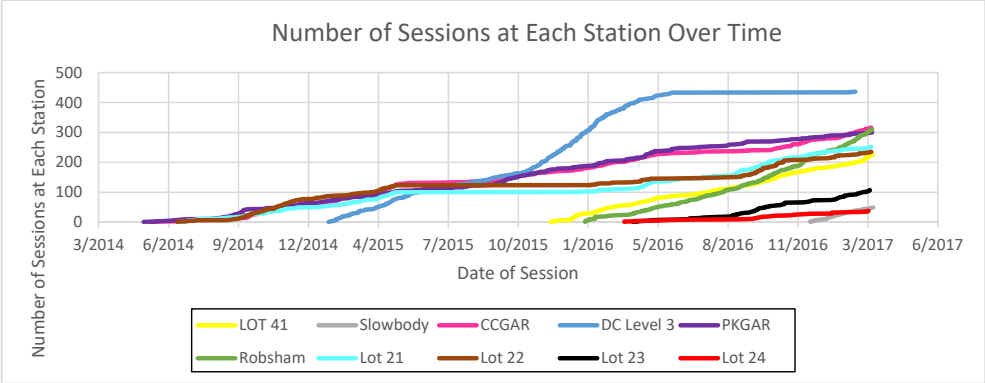

Figure 3 Number of charging sessions at each charging station over time

Figure 4 below illustrates the number of unique drivers using UMass charging stations and the distance it takes them to arrive at UMass. Each distance, in miles, represents a different city a customer is driving from. There have been 21 unique drivers from Amherst, MA, 2 miles from campus, whereas there has been only one driver from a town in New Jersey, 206 miles from campus. There were 6 drivers coming from distances above 250 miles that were omitted from the data to better view the other drivers. Also, 2 of the vehicles coming from Amherst are probably fleet vehicles because of their 01003 zip code. Please note that unique drivers are based on the zip code of users ChargePoint allowed us access to. This zip code is either from a user's credit card information or the address they used when registering a Chargpoint account. Therefore, there is a possibility that drivers are coming from a place other than the zip code assigned to them on ChargePoint.

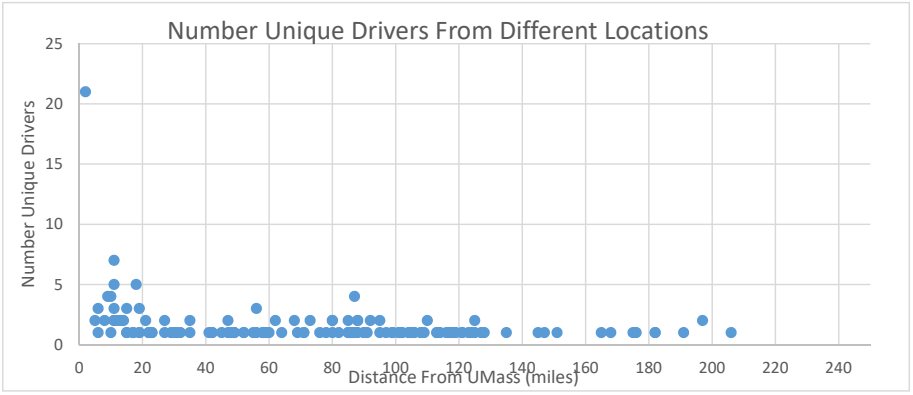

Figure 4 Number of unique drivers from different distances utilizing UMass charging stations

Table 4 below shows the average lost productivity at each station since its first charging session up until March 2017. The lost productivity was calculated by subtracting the charging time of a session from the total duration. Charging time is equivalent to the amount of time a vehicle spent receiving a charge from the station. Whereas total duration is how long the vehicle was plugged into a station, but wasn't necessarily receiving a charge. This is due to a vehicle being completely charged already or user error in not knowing how to appropriately plug in their vehicle to the station.

Robsham, a fast charging station, has the lowest lost productivity of 11 minutes. This could be due to people waiting to unplug their vehicle from Robsham because it can take as little as 20 minutes to completely charge a vehicle from this method of fast charging. On the other hand, Slowbody has an average lost productivity of 8 hours, which is far above the averages of the other stations. This is possibly because it is off campus, so users are likely to leave their car plugged in, while they go onto campus and then return many hours later to unplug their car. Additionally, it is a level 2 charging station so it takes more time to fully charge a vehicle. It might also be heavily utilized by fleet vehicles that don't need to be retrieved from the charging stations for immediate use. The total average lost productivity for all the stations is 1:30:13. For future research, it would be helpful to compare this to another college lost productivity at their charging stations.

Table 3 Lost productivity at UMass charging stations

Station Name	Average Lost Productivity (hh:mm:ss)	Type of Charging Station
Robsham	0:11:53	DCFC
Lot 24	0:16:14	Level 2
Lot 22	0:21:15	Level 2
Lot 41	0:31:24	Level 2
Lot 21	0:33:58	Level 2
Lot 23	0:53:52	Level 2
PKGAR	0:55:31	Level 2
DC Level 3	0:57:58	DCFC
CCGAR	1:59:11	Level 2
Slowbody	8:20:58	Level 2

5. Advice and Lessons Learned from EV Professionals and Other Universities

With the goal of identifying best practices regarding campus-based EV systems, the author researched EV case studies and conducted several interviews with EV professionals. Given what we know from the previous sections on UMass Amherst's charging stations the following provides a valuable comparison to other college campus' electric vehicle systems of charging.

UMass Lowell Case Study

- 50% of its student population commutes to campus and 90% of its staff drives to work

- Smart Dual Level 2 chargers are located in three of its large parking facilities and an additional dual Level 2 is in a neighboring public parking lot.
- Students who register a PEV are allowed access to any garage (usually, they are assigned a lot); there is otherwise no written policy.
- Students pay for access to the Level 2 charging stations; and the public lot charges a flat rate of $1.00 per hour with a maximum stay of two hours
- Monthly usage currently amounts to one hundred and twenty hours of charging
- Cost them approximately $3,000 to install each station and the hardware cost was $7,000 per station
- If they build, they add conduit and create room in their electrical panel. They also try to avoid trenching.
- They say it is critical to reach out to existing companies providing charging to learn the amount of commitment involved when providing charging.
- Ruairi O'Mahony, Office of Sustainability at UMass Lowell, says UMass Lowell averages about 200 hours of charging a month. Most heavily utilized locations are in staff lots only, the locations where students primarily park are not that well used.

Stephen B. Russell, MA Clean Cities Program Director

- Believes beneficial to install fast charging stations because more cars are going to be coming out with long driving range that are adaptable to DC outlets. I.E. Chevy Volt with 200-mile range.
- Informed that there is EV legislation in MA, which has two years to be passed, that says there has to be one standard method of paying for all charging stations.

Eric Friedman, Director of Leading by Example

- MA was chosen by Volkswagen, along with 8 other states, because of commitment to zero emission electric vehicles.
- MA dedicated to 300,000 electric vehicles by 2025, so need infrastructure to support them.
- VW wants to quickly install stations in places that are ready with fast chargers.
    - UMass was picked as one site that can have stations installed quickly.
- VW will pay for entire project, but using their own vendor.
- VW looking to install charging stations (Eric thinks 2) at UMass in the lot where there are solar canopies. Possibly will install more in other places.
    - Eric mentioned UMass already has a lot of stations, so probably not looking to add a lot more of them, unless we show need.
- If renovating parking lots, should potentially put in EV wires, because that is the most expensive part, if installing a charging station in the future

5. Recommendations

This section seeks to compile and synthesize lessons learned to create a set of recommendations for the improvement of charging stations on campus – and help inform plans for future EV infrastructure build-out. If implemented, these recommendations could lead to greater awareness of EV charging stations at UMass and broader adoption of EV usage on campus. This section also provides possible topics and

questions for future research in the areas of EV policy, economics, and technology of charging stations on campus.

Location/Visibility

- Increased signage around campus to inform users where charging stations are located. The signs now can only be seen when you get to the charging stations. Users connected with ChargePoint are given a general location of where the charging stations are, but even with this information I struggled with finding the stations around campus. With better signs more people might also feel inclined to purchase an electric vehicle if they were aware of the charging station services on campus. This is especially important because most of people's fears associated with electric vehicles are due to range anxiety.
- Make it apparent to staff and students that Nissan Leafs can be offered at a discounted price to them.
    - Expand discount to other Nissan dealerships near UMass
- Add symbol for charging stations on campus map, so users are more aware of where to find charging stations.

Infrastructure and Technology

- If there are problems with people moving their cars after completing their charge there is a company in Enfield, CT that has technology that allows someone to move the charging stations to a new spot. Therefore, if User 1 has completely charged their car, but can't get back to move it, User 2 can just move that charging station to a new spot so they can charge their car.
    - Contact: Daniel J. Shanahan, Control Module Industries, 860-745-2433 (work), 860-253-4244 (work), 860-916-7162 (cell), dshanahan@cabaire.com
- If we place more charging stations around campus, I believe installing DCFC stations would be most beneficial. More cars are being made that are compatible with these stations and based on Robsham's trajectory and the amount of sessions accumulated on DC Level 3, both fast charging stations shown in Figure 2, these stations are attracting the most users. However, in places where users are more likely to be parking for an extended duration, i.e. Slowbody, level 1 would appear to be the most cost efficient option.