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Batteries Half Full? An Analysis of Electric Vehicles and a Proposal for Charging Stations at the University of Virginia

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Batteries half full? An Analysis of Electric Vehicles and a Proposal for Charging Stations at the University of Virginia

by

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Report

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Abstract

Batteries half full? An Analysis of Electric Vehicles and a Proposal for Charging Stations at the University of Virginia

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Electric Vehicles (EVs) have been hailed by some as a revolutionary new technology whose adoption will clean our air, reduce our dependence on foreign oil, and change the way we drive. A key step to achieving this vision is the installation of charging stations, which EVs require if they run out of energy if not plugged in at special charging stations. Most charging will take place at home, but public charging stations are necessary to prevent EV drivers from getting stranded with no energy. Many universities across the country have installed charging stations on their campus, while enthusiastically embracing the above vision.

This report examines the promise of EVs and makes is a proposal for the University of Virginia to also install charging stations. However, it finds that EVs present a much more complicated picture: there are as many downsides as upsides, and the weaknesses in demand call into question the actual need for charging stations. The report finds that a cost-benefit analysis is difficult, if not impossible.

That said, the rest of the report looks at case studies from other universities to determine good practices for installing charging stations. Building from this analysis, the report offers five sample proposals, ranging in involvement from none to "aggressive" are proposed with the conclusion that a moderate amount of involvement is the recommended course. In the end, it seems wiser to err on the side of a sustainable future than to reject EVs before their full potential is known.

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Introduction

The purpose of this report is to outline a proposal for electric vehicle charging stations at the University of Virginia. (UVa.) Electric vehicles (EVs) of all kinds, and principally electric cars, are an emerging and promising new technology. They can promote sustainability in communities that have them, reduce total carbon footprints, and reduce air pollution locally. In sustainability circles all over the country they are being heralded as the future, and a major solution to all sorts of environmental problems. An example of this hyperbolic rhetoric, the president of the University of Maryland, made these remarks when cutting the ribbon on his school's new EV stations:

> "This is the beginning of a new day. To think that some day we will have electrically powered cars contributing to a greener future for the university and the community. This is our obligation to future generations to make this a more sustainable planet."

A similar scene has played out at many other college campuses across the country. At North Carolina State, the director of sustainability said that the charging stations ""NC State is committed to being **a** leader in sustainable energy**,** and that includes providing the infrastructure to support sustainable energy initiatives."[1] In Little Rock, a utility company paired with the University of Arkansas – Little Rock to bring charging stations there[2] and at Western Michigan, a senator showed up to tout the unveiling of 12 new charging stations. These case studies suggest that to some degree a

[1] North Carolina State University
[2]

new day is indeed coming and that UVa should get ready and also install some charging stations for this emerging technology.

But the forecast for EVs is not as bright as a new day. As this report shows, the future is considerably murkier than the list of benefits in the opening paragraph suggests. EVs are constrained most pressingly by the need to frequently recharge their batteries. It is this problem that the report addresses, but it is far from the only one that EVs have. “Range anxiety,” the fear of running out of batteries, is not the only problem facing widespread adoption: EVs are significantly more expensive than conventional cars using internal combustion engines (ICEs). That expense comes from the car’s lithium-based batteries, which ultimately control both the range and the cost of an electric vehicle. But lithium is a scarce commodity, and mining it is an ecologically problematic, to the extent that it calls into question the environmental good of EVs. Additionally, the carbon reduction abilities of EVs are connected to the kind of power generation providing the electricity for their batteries. If that power is from hydroelectricity or wind or solar, then there will be far less CO2 emissions. But in Virginia most power comes from coal , which is as dirty and is arguably dirtier than burning gasoline. Given all of these negatives, are EVs worth it? This report argues yes, ultimately, EVs are better than ICE cars, but that it is a complicated picture. The proposals at the end vary in support for charging stations because of this complication.

The report is divided into 5 chapters. Chapter 1 gives an overview of EVs, and the tricky calculus of their costs and benefits. Chapter 2 investigates the technology involved in EVs, batteries and charging stations and surveys the current field of EVs . By looking at the technology and the cars themselves this chapter tries to determine where EVs are going technologically. The next chapter looks at demand for EVs globally and locally, and attempts to discern rates of adoption. Analogies are made to the adoption of hybrid vehicles, cell phones, and recycling, as proxies for global demand trends. Local demand can be estimated better by examining the demographics of the residents. There follows a discussion of the theory of adoption, with application to Charlottesville specifically.

The second half of the report relates more directly to specific proposals for an electric charging station at UVa. Part III is a catalog of case studies from other universities. Case studies are good way to both benchmark against UVa's peers, and gain ideas for how best to proceed developing charging stations. Finally, Part IV lays out the elements a proposal can draw upon and uses those elements to craft four proposals based on engagement. The proposals vary from "do nothing" to "aggressive" engagement, and explore motivations as much as specific details. That is, the brightness or murkiness of EVs are construed in different ways in each scenario.

Chapter 1: Electric Vehicles

An electric vehicle is any vehicle that uses electricity to power its drive train. They contrast with most cars today, which run on an internal combustion engine (ICE) fueled by gasoline, although several electric cars also have gasoline engines. There are three principle types on the market right now. Hybrid cars, such as the Toyota Prius are technically electric cars, even though their battery is not recharged at an outlet. Plug-in hybrid vehicles, such as the Chevrolet Volt, have a rechargeable battery as well as a gasoline engine. Finally, there are all-electric vehicles, such as the Nissan LEAF, which only run on electricity.

Electric vehicles are not new. The earliest cars ran on massive lead batteries, until eventually internal-combustion engines proved capable of higher speeds and greater range. However, electric vehicles remain in use in some niche places: golf carts are electric, most scooters and Vespas are electric, and many warehouses use electric fork lifts. All of these vehicles are small and cover limited ranges, so the problem of limited battery storage is not so great. They are also in contexts where it's helpful to be electric: imagine a golf course full of fumes, or fumes choking up a warehouse. And much of the value of scooters is that they don't need gas. But for the last 100 years, almost all the vehicles on the road have been propelled by gasoline.

Benefits

EVs have several reported advantages over conventional cars. They are more efficient than conventional cars: EVs have fewer moving parts and they lose less energy to heat and noise. An internal combustion loses about 60-65% of its energy to heat exhaust, while an EV does not.[3] EVs do not use energy when at a rest or coasting. Finally, braking is completely lost energy for an ICE vehicle, but EVs have regenerative braking, which recharges the battery using stopping energy. These differences are highlighted in a comparison of miles per gallon and miles per gallon equivalent. MPG is how far a car gets on a single gallon of gas, and MPG (equivalent) is a rating for how far EVs get on an equivalent amount of energy. The contrasts are large: a good mpg for a small car, like the Chevy Cruze is 30 mpg; the Prius gets 50 mpg; the Nissan LEAF gets 99 mpge[4].

Another advantage is fuel cost. Because electricity is cheaper than gas, in the long run, EV drivers will realize significant fuel cost savings. At the time of writing, gas in Charlottesville cost $3.80 a gallon and a kWh of electricity cost $.11. A Nissan LEAF getting 40 miles per 24kwh charge would have a fuel cost of 3.6 cents/mile., whereas a Toyota Camry getting 40 miles to the gallon would have a cost of 9.6 cents/mile.[5]

There are benefits to the community as well as the consumer. The benefits of electric vehicles are principally environmental: there are no tailpipe emissions from an entirely electric vehicle. This reduces air pollution locally, which is good for the university. Even when the emissions at the power plant are considered, the greater efficiency of electric vehicles still makes them cleaner. Even if all the electricity were generated by coal, the "dirtiest" form of power, an EV would have a carbon footprint

[3] Shah.

[4] US Department of Energy: Alternative and Advanced Fuels

[5] Gas prices from virginiagasprices.com; electricity rates from dominion.com, mileage estimates from fueleconomy.gov

smaller than the size of a conventional vehicle. If solar charging stations are adopted, the carbon footprint could go to zero.

CONCERNS

Alongside these benefits, EVs also have substantial problems that are delaying their widespread adoption. From the consumer perspective, there are a number of drawbacks, including price, range anxiety and limited models. Collectively, these drawbacks reduce demand for EVs and will depress their market share for the near future. There are environmental concerns too. The lithium needed for an EV's battery is mined at heavy environmental cost, and processing it increases the carbon footprint of a car. It is disputed whether, over the life-cycle of the car, any actual carbon savings are made

The biggest problem commercially is cost. Even though there are fuel savings, the upfront cost of an EV is significantly more than conventional vehicles at the moment, mostly because batteries are much more expensive than combustion engines. Even with a $7500 tax credit, a Nissan LEAF starts at $27,700, whereas a comparable Nissan Versa starts at $15,560.[6] Chevy Cruze, another mid-size car, also costs almost $15,000 less than the Volt, even with credits. The fuel savings, described above are not sufficient to offset these differences.

Another problem is "range anxiety." Right now, the best batteries in commonly available cars get about 100 miles on a full charge. If a driver runs out of charge, at the moment it is unlikely that there is a charging station nearby for him or her to get recharge

[6] Fill in the numbers

the car. This lack of infrastructure and the fear of being stuck with no charge is another deterrent to many buyers.

Finally, there are no Electric SUVs yet; anyone who wants an SUV must buy one with a conventional engine. In 2010, according to data from the National Auto-Dealership Association (NADA) 46% of all registered cars in the United States were SUVs, and 42% of registered cars in Virginia were.[7] Some electric SUVs are in development, and will be released in a few years but until then, this is a huge segment of the car market that cannot be touched.

There are environmental concerns. Lithium is the critical component of modern batteries and it is difficult to extract and difficult to refine. The largest lithium deposits are in the South American countries of Bolivia and Chile on large, shimmering desert salt flats. Lithium mining ruins these salt flats. Lithium salts are extracted from the earth and allowed to separate in big vats of brine, next to piles of tailings. The process takes a lot of precious desert water that becomes so toxic it must be treated with chlorine to "…water down the potentially carcinogenic lithium and magnesium salts..[8]" But even though the contaminated water does not seem to be leaking into the groundwater, lithium ining uses two thirds of the available water, leaving local villagers with severe shortages.[9] It is a horrifying and unseen consequence of the green revolution EVs are bringing to America.

That said, the claims are not entirely convincing. Almost all mining operations have inevitable ecological consequences and almost all desert communities have water

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[7] NADA
[8] McDougall
[9] Bart

shortage issues. And mining will probably provide some economic opportunity without huge risk – though toxic, lithium mining is less hazardous than many other kinds of mining.[10] Finally, the lithium is going to EVs, which are a good cause. as MacDougall says well, it is easy to argue that "we should accept the destruction of this land as a small price for such good."[11] With arguments like these, it becomes easy to rationalize another third world plight and hard to determine where in the calculus of overall costs and benefits lithium mining should fall.

A much more measurable problem resulting from lithium is the additional manufacturing costs it creates. Lithium takes a lot more energy to refine than the components of an ICE. Therefore, a "life cycle analysis" or a "cradle-to-grave analysis," that looks at the entirety of the car's cumulative carbon footprint, could find that the EV "catches up" with an ICE in the manufacturing stage and winds up with a higher carbon footprint over its life span. This would be another blow to EVs, but the numbers still seem to work in their favor. One study found that while EVs had a manufacturing footprint 2.2 metric tons higher than an ICE vehicle, it wound up generating 5 fewer metric tons over a 150,000 km (93,375 miles) lifetime.[12]

Finally, there are major equity concerns, in that society is investing so much money into a car only the wealthy can afford.. The average pre-registrant of a Nissan LEAF in 2010 had an annual income of $125,000 a year. In 2011, it was found that those who had actually bought the LEAFs they registered for had an income of $140,000. The

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[10] MacDougall
[11] *id*.
[12] Covington.

average buyer of Chevrolet's Volt in 2011 had an income of more than $170,000. By comparison, the average income of a Cadillac purchaser was 130,000; of a Lexus, $141,000; of a Mercedes, 174,000. Unfortunately, these numbers are flawed. *average* annual income is not the best metric for determining the wealth of these vehicle owners. If a wealthy person, making $1 million a year, pre-registered for a LEAF, he or she could offset 13.3 middle class consumers, making only $50,000. An ultra-millionaire, making $10 million could offset 133 people. Without *median* income data it is harder to parse an actual profile of a LEAF buyer. It could be a vehicle exclusively bought by the top 10% of society, or it could be a vehicle many families afford, but that also happens to be a favorite of the wealthy. It is probably some of both.

Either way, taxpayers are subsidizing electric cars by $7,500 a vehicle. Therefore, taxpayers are subsidizing car purchases for the upper class. And billions of dollars of infrastructure are going to enable cars for the rich. At a time of record deficits, service cuts across the board, and massive unemployment, is this really the best use of federal money? The federal government is subsidizing many other things - roads, social security, benefit the wealthy; social security checks also go to the wealthy. Housing breaks are a great example. They are a subsidy to achieve a policy objective – home ownership and they help many people afford homes who otherwise couldn't. But the wealthy still get tax breaks for their houses, and the wealthy are more likely to be buying houses.[13] This might also be an inequity – they might both be inequitable, but in the federal government such things are not unprecedented and not particularly out of the ordinary either.

[13] AOL Autos Staff

Nothing is clear cut in the world of EVs: the above section demonstrated that well. Every major benefit has a downside or a caveat; so too does every concern have an upside or a reason to believe things will improve. For the individual, gas savings are outweighed at the moment by the high cost of EVs, and the drawback to going gas-free is the insecurity of where the next recharging comes from. For the environment, the clean air at the tailpipe is offset by emissions from smokestacks in power plants across the country and from auto-assembly plants, and by the ruined deserts of Bolivia and Chile. And for society, the promise of a society free of car emissions and smog, and no longer dependent on foreign oil, is offset by accepting subsidies for cars and infrastructure being driven and used predominantly by the wealthy. For all of these, there is also the possibility that consumers will ultimately reject EVs, and the whole endeavor will fade out amidst a sea of wasted infrastructure.

Any kind of cost-benefit analysis is almost impossible given as many factors with as many different possible outcomes as are in the EV world. Imagine trying to calculate lives saved due to air pollution reductions against total amount of investment: it would take a reliable adoption forecast, a forecast of where the power is coming from and where the source point emissions are (near major cities or not?); actual health data; and the total investment, from the government, thousands of smaller institutions, and millions of consumers. And that would be just one aspect of many possible positive and negative aspects. In sum, deciding on the future of EVs takes some guesswork, some intuition and probably some faith that it will fulfill its promise or that it will fail in a powerful torrent of taxpayer dollars and wasted effort.

Chapter 2: Technology

This chapter and the next one continue to flesh out the dynamics involved in the future of EVs and their adoption (or nonadoption.) This chapter is about the cars themselves, the technology that goes in them and the state of the current market of cars. Any EV charging proposal must, *de rigeur*, have a good understanding of the chargers and the batteries they are charging.

BATTERIES

Batteries are the most important component of an electric vehicle, and improved batteries are behind their resurgence. The invention of Lithium-Ion batteries has greatly increased storage and has allowed cars with greater range and more power. Earlier EV batteries used nickel-manganese batteries, or lead-acid batteries, which were both heavier and stored less energy. In the 1910s, these limitations led to electric cars being outpaced by internal combustion engine cars, and they have held back electric vehicles since. But lithium-ion batteries have flipped the switch, as it were, and allowed EVs to compete against ICE cars again.

Batter capacity is measured in kilo-Watt hours (kWh.) A kilowatt-hour is a measure of energy, equivalent to using 1000 watts of power for an hour. A microwave on a low setting uses 1000 watts, so using a microwave for an hour would consume one kWh of energy. Alternatively, a 100 watt-bulb lit for ten hours it will use one kilowatt-hour of energy. Pure electric cars currently batteries have a capacity around 24 kWh, while plug-in hybrids have between 5 and 12 kWh of storage. An electric car can go about 3 miles for every kWh it uses. By way of comparison, a gallon of gasoline, the fuel for ICE cars, has the equivalent of 33 kWh of energy. This means that the average ICE car (20 mpg) is going much less far than a EV for the same amount of energy. This is another illustration of the superior efficiency of EVs. More importantly, the amount of storage determines the price of the battery, which itself determines the price of the car. The government bases its tax breaks for EVs on their kWh capacity too, and the quest to make cheaper batteries defines the industry right now.

Batteries are expensive. Their cost is measured in dollars per kilo-watt hour of capacity. In he middle of the 2000s $1,000 was considered a baseline cost of a kWh of capacity, but this has been dropping[14]. Since so much depends on the battery, cost is an important secret for carmakers - the "Fort Knox" of trade secrets. Car companies keep them secret and batteries give different cost quotes depending on how far along they are when built. That is, a built battery will cost less than that battery in the car which costs less than when that battery has to be marketed or have a warranty. When Nissan claimed to have brought their price to $375 per kWh, it caused a stir and then a backlash. Eventually, hybridcars.com figured out that that was either a lie or the price at a very early part of the process[15]. The real price ranged from $750 to $1200. But even at $750 per kWh the cost of the battery would then be $18,000, more than half the total cost of the car, and as much or more as a comparable ICE car. Because of cost issues like this, battery technology is considered the biggest obstacle to widespread adoption of EVs.

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[14] Hybridcars.com
[15] *id*.

“Price parity” is the place where battery technology allows EVs to be equivalent in price to gasoline. Although gas is getting more expensive, it will be improvements in battery technology that achieve “price parity” because they are dropping much faster than gas is rising. But no one really knows what price will achieve price parity, or when technology will achieve it. A 2010 article had estimates from two EV experts – one said that costs would decline between 8% and 10% a year, getting down to $470 per kWh by 2015 and another that “it could down to $350 within three or five years.” A third source was the CEO of Coda Automotive, a small electric car company, notable because he actually sees cost data . His argument was that mass production would drive costs down, that it’s “pushing it in 2010” but that “their 50,000th or 100,000th vehicle will have that pricing.” A more recent source, Lux Research Inc., released a report at the end of March 2012 predicting $397 per kWh by 2020, and that this would not be low enough for price parity. According to Lux, price parity is $150 per kWh, a number they got from the United States Advanced Battery Consortium. Meanwhile, automakers aren’t saying anything. So, in summary, batteries cost anything from $375 to $1200 per kWh in 2010, and will cost $350 to $470 per kWh sometime between 2015 and 2020.

Government tax credits are also based on batteries. The government credit of up to $7,500 is based entirely on the storage capacity of the battery. Any car with at least a 5 kWh battery is eligible for a $2,500 credit. For every kWh over 5, a car is eligible for another $417 credit, to a maximum of $7,500. In effect, the government is subsidizing cost per kWh down to something closer to price parity.

CHARGING STATIONS

Regardless of how cheap, light, capacious, or cleanly mined an EV battery is, at some point it will be depleted, and the driver will have to recharge it. Besides cost, this is the biggest drawback to EVs, and their biggest disadvantage with respect to ICE vehicles, which refuel at gas stations. Whereas the nation has roughly 127,000 gas stations[16], each with 6-10 pumps, but the country only has 3200 public charging stations. It takes 5-10 minutes to pump The entire state of Virginia only has 60[17]. By contrast, the nation has very few charging stations, and recharging an EV takes 20 minutes to 8 hours. EV drivers are anticipated to do most of their charging at night, at home, and then plan their days carefully to avood running out of charge. But it is entirely likely that many drivers will also find themselves needing to recharge when they are out of their homes, and drivers wanting to commute beyond the range of their vehicles will have to. So it is critical that there be charging stations in place and available so that drivers do not get stranded.

This produces the fundamental chicken-and-the-egg problem that this report is attempting to address. Widespread adoption of EVs is limited by the lack of support infrastructure. However, there is no incentive to build support infrastructure if there are no cars on the road. Governments, corporations, universities, and private citizens have been building up the nation's stock of charging stations. The USA is a big nation, though, and it takes far more stations to provide ample coverage than has happened so far. ChargePoint America, a huge initiative supported by the American Reinvestment and Recovery Act, that is, the stimulus, only had the goal of providing a network to 10 cities

[16] US Census

[17] Department of Energy.

in the United States. Charlottesville was not chosen to be a city: Washington D.C. is the closest ChargePoint city to UVa. Even in those ten cities, there is public infrastructure enough in the cities themselves, but it tapers off as drivers get into the suburbs. This would not affect a commuter to the city too seriously, but it is still worth noting how daunting the task is.

At the same time, as the figures below show, consumers have yet to purchase EVs in mass. This means that the charging stations are sitting empty, not charging anything. This situation has provoked criticism and scorn from the right-wing, including George Will and Rush Limbaugh, who point to the government-funded chargers as an example of pure government overreach and waste.[18] No infrastructure without demand, and no demand without infrastructure: this is the chicken-and-egg and UVa must decide where it wants to fit in – whether it wants to make chargers for EVs that might never materialize.

	Voltage	Charging Time	# in Virginia	Approx. Cost
Type 1	120	15 hours	52	--
Type 2	240	4-7 hours	84	$2-3,000
Type 3	480	20 minutes	0	$10-50,000

Table 1: Charging Stations Basics

The actual specifics of charging stations are more straightforward. There are three levels of charging station, based on voltage and rate of charging. Level 1 charging can be done at a standard 120V household outlet, but it takes a very long time – up to 15 hours.

[18] AOL Autos Staff

Level 1 charging is generally only used for Level 2 charging takes a 240V outlet, and can charge a 24 kWh battery in 4-7 hours[19]. Most households with EVs will get a level 2 charging station installed and almost all commercial charging stations are level 2.

Level 3 is the final type. So-called "fast chargers," they use a 480V current and can charge a battery to from empty to 80% full in 20 minutes. 480V is too much for residential use, so they are only at commercial locations. They are also very expensive and only a handful of public charging stations around the country have fast chargers. Current models cost between $30,000 and $50,000, but Nissan is introducing a version that costs under $10,000.[20] If widely spread, the fast charger could become an EV equivalent of the gas station.

But a handful of stations is not enough. Creating a network of charging stations is necessary to fully assuage range anxiety. The EV networks being developed are significantly more sophisticated than gas station infrastructure. Gas stations are on the side of the road of almost every major highway and intersection, You just drive til you find one. But EV charging stations are harder to see, and there are fewer of them; the major charging station networks, Blink, Chargepoint, and SemaCharge, have developed web and smartphone applications that can show charger locations and whether they're in use, and allow drivers to reserve them. Once charging, the network will let drivers know how full their car is, and how much time is needed to fully charge.

CURRENT FIELD

Let us turn now to the commercial EVs currently being sold. Both Chevrolet and Nissan have introduced electric models, and other car companies are following suit. Chevrolet's car is called the Volt, and is a "Plug-In hybrid." It is not completely electric;

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[19] The variance is due principally to what make of car is being charged.
[20] Motavali

if its battery runs out, a gas generator kicks in to generate more electricity. That is, it is always propelled by electricity, but the gas engine is there as a back-up. This is to prevent people from getting stranded if they outdrive the electric range of the car: it is a response to “range anxiety.” However, data from Chevrolet suggest that many Volt drivers rely extensively on their internal-combustion engines. Chevrolet keeps track of Vehicle Miles Driven in all its Volts, putting a counter on their website. As of April 2012, the roughly 15,000 Volt drivers had driven 33 million miles purely off the battery and 55 million total miles[21]. So gas-powered travel accounted for slightly more than 40% of total miles driven. This is important: it suggests that Volt drivers are completely comfortable not charging their car charged to full every time they drive.

By contrast every mile driven on the Nissan LEAF has been electric. Nissan’s all electric model, introduced at the end of 2010, has a bigger battery than the Volt, but no back-up. Although the battery is bigger, the range is unclear. Nissan says 100 miles on its website, but has a range disclaimer qualifying that claim. The EPA lap test that resulted with the number 100 miles was done on a temperate day at an average speed of 20 miles an hour with no dramatic acceleration or stops. However, Nissan acknowledges “a infinite number of range scenarios.” Under less ideal conditions, such as rush hour traffic, or extremely hot days, the battery range will be shorter. Nissan’s worst-case scenario, stop-and-go traffic on a very cold winter day (14 degrees) the LEAF would only go 62 miles. Other estimates differ as well: the Department of Energy gives its range as 73

[21] http://www.chevrolet.com/volt-electric-car/

miles.[22] The staff at Cars.com shared a Nissan LEAF for a month and found the range to be around that.[23]

Regardless of the theoretical range, Nissan test data have found that most drivers only drive 25 miles before plugging their car back in. This is an interesting and unfortunately limited piece of data: it could either suggest short trips and then going back home, or it could be that most LEAF owners have found a charging station away from home and are getting their car recharged while they're at work or shopping. Still, it is worth keeping this figure in mind when assessing the actions of all-electric EV drivers.

Most other carmakers plan to roll out all-electric or plug-in hybrids in the next few years. Their choice of model shows the split direction of EVs. Two noteworthy examples are the Ford Focus Electric, and Toyota's Plug-in Prius. The Ford Focus is all-electric, will have a 23 kWh battery, and is expected to get 76 miles to a charge.[24] Thus, it has very similar specifics to the LEAF. But though it has a similar model, Ford is rolling out the Focus Electric much more slowly than Nissan did. Whereas Nissan has run constant promotions of the LEAF, Ford is having a very small roll out of its first EV, with little to no fanfare. So far it has only been sold to commercial fleets; three markets - New York, New Jersey, and California – will get the Focus Electric in spring of 2012, and another 16 cities will get it in the second half of 2012. Additionally, unlike Nissan and Chevrolet, Ford is building the Focus Electric on the same line as its gas and hybrid Focuses (Foci?) so that they can respond more easily to demand, and not wind up with

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[22] http://www.fueleconomy.gov/feg/evsbs.shtml
[23] http://blogs.cars.com/kickingtires/2011/11/nissan-leaf-range-gets-more-predictable.html
[24] http://www.fueleconomy.gov/feg/evsbs.shtml

either gaps or surpluses in inventory. This is another cautious step, and shows that Ford does not have full confidence in its demand numbers.

The Prius plug-in is more like with the Volt, but even more gasoline dependent. Its battery is only 4.4 kWh, and it can only go 11 miles on a charge[25]. Toyota makes no pretense that this can be a pure electric vehicle: on its FAQ sheet, for the question "Can I drive without gasoline in the tank?" Toyota responds, "You should never drive the Plug-in without gasoline in the tank. While you may drive on electricity alone, the vehicle requires gasoline to operate properly." Toyota's goal is not to create an electric car that competes with the LEAF or even with the Volt, but, a car writer explains,

> "In general, Toyota's position is that hybrid and plug-in hybrid vehicles with smaller and less costly battery packs – rather than pure electric cars with larger and very expensive packs – provide the most value and versatility for consumers overall."[26]

What the plug-in Prius accomplishes is not so much a new model of vehicle, as it is a newer, even more efficient regular hybrid. The Prius Plug-In is very efficient, having a MPGe of almost 77.[27] But test data show, from Toyota's demonstration projects, show that only about 12% of the miles driven on the Prius plug-in are in EV mode.[28] As the chart below shows, this achieves only minor gas reductions as compared to a regular Prius. It is still lower than any other car on the list besides the LEAF, but again, the LEAF is revolutionary and the Prius plug-in is not. But Toyota, unlike Nissan, is the

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[25] Hall.
[26] http://www.hyNbridcars.com/vehicle/toyota-prius-plug.html
[27] Hal.
[28] Toyota.com

world's second largest carmaker and the Prius is the far and away the best-selling hybrid of all time. Their gradual approach suggests that the all-electric vehicle has not arrived yet.

Car	Gas used/25 miles
Silverado	1.92
Cruze	.96
Prius	.5
Prius plug-in	.29
LEAF	0

Table 2: Gas used to travel 25 miles by vehicle[29]

The current car market and the models of the near future suggest that the vision of the electric car at the beginning of this chapter is a mirage. With the exception of the LEAF no mainstream[30] automaker seems to have fully endorsed the view of an electric car as a truly no tailpipe-emission vehicle.

Moreover, these vehicles are still an insignificant part of the overall car market. For every Volt sold last year, Chevrolet sold nearly 30 Cruzes, its compact car model.[31] Ford sold 175,000 Focuses in 2011, and was selling 22,000 a month in 2012. Even if Ford reaches its modest goal of 5,000 Focus Electrics, that will represent less than 2% of Focuses sold. Finally, Nissan sold *80 times* as many Altimas as it did LEAFs in March 2012. Overall, in the car market, EVs accounted for roughly 2,600 of 763,000 total sales. And the car market is only half the market; car makers sold another 640,000 light trucks

29 Information from Fueleconomy.gov
30 Tesla Motors sells only electric cars, but they are very expensive and have sold less than 2,000 units.
31 Schoenberger

and SUVs, vehicles that can’t be electrified yet. So when will the revolution come? At what point, from the consumer perspective, will the balances tip, and to what extent? When will the “new day” actually begin? Chapter 3 examines this.

Chapter 3: The Future?

Just as there is no agreement on what the cost of batteries will be in years, neither is there any consensus on EV market penetration over the future. At the global level, demand for EVs is supposed to increase once drivers become more accustomed to them, and batteries become better and cheaper. Optimistic estimates for market share by 2020 range between 5% and 15%. But these numbers take into account the Chinese and European markets; American markets will probably have fewer sales.

This question is a problem of "theory of adoption," or "diffusion of innovation" – how quickly does new technology get adopted. This report examines that from two different lenses: global demand and local demand. This report analyzes global demand at the technological level, and analogizing to other technologies, based on levels on innovation. That is, EVs are like hybrid cars but slightly more innovative, and like cell phones but less innovative. Those two technologies had vastly different adoption rates, and, unfortunately, only limited conclusions can be drawn from those comparisons. The examination of local demand focuses more on demographic trends. Using the analyses of Everett Rogers and census and other data on Charlottesville, the report establishes that there is a sufficient pool of buyers in the UVa community to generate at least some EV car sales, and with that, some demand for stations. Even if definite answers are still elusive at the global level, it is enough for the report to go forward to show that Charlottesville will have some local demand for EVs.

GLOBAL DEMAND

A way to forecast EV sales is to analogize to hybrid vehicle sales in the United States. The first hybrid cars, the Toyota Prius and the Honda Insight, were introduced in the late 90's to very low sales. In the first two years, less than ten thousand hybrids were sold. But as time went on, sales increased and more models were introduced. By 2008, led by the Prius, hybrid sales had increased 35 fold, to almost 350,000 and in March 2012, Prius was the 6th best-selling car in America and the third best selling car, behind only the Camry and the Nissan Altima. If EVs follow a similar track, the shaky sales now could be quite robust by the late 2010s, especially if battery prices keep dropping, as they are expected to.

However, the situation is not that encouraging. 350,000 cars, the peak in 2008, still only represented 2% of auto sales. (After 2008, hybrid sales declined, but so did sales of all cars. Even in the most hybrid-friendly city in America, San Francisco, hybrid car sales represented only 8.5% of all car sales in 2010, 11 years after the first hybrids hit the market.[32] So even in the most favorable market, hybrids barely reached half of the high estimates for EV penetration.

But hybrids are not necessarily the best foil for electric cars. Hybrid vehicles are an alternative to conventional regular vehicles, true, but they still use fossil fuels and they do not require a whole new infrastructure to work successfully. Nor do they require owners to start planning their drives around whatever constellation of charging networks might exist. Therefore, hybrids never had the entry-barriers that EVs have, and can't

[32] This figure actually includes hybrids and EVs, but hybrids make up most of that.

really be comparable. The entry-barriers almost certainly mean that EVs will gain market share more slowly. However, EVs are different enough that the changes may make them attractive enough that people switch at a faster rate. This seems unlikely, but either way, EVs and hybrids do not work as analogues.

There is another problem: because EVs and hybrids are both alternatives to conventional cars, they are rivals to each other. The kind of person buying an EV probably had a hybrid before that. Alternatively, potential EV buyers may get a hybrid instead. Indeed, a passionate, but non-industry, defense of EVs on the pop-culture blog BoingBoing concluded with the very pro-EV author saying her next vehicle would almost certainly be a used Prius. Indeed, this is already a trend: an industry spokesman on LEAF buyers said as much in 2011: ““Early LEAF buyers are typically people who are environmentally conscious and often already drive hybrid vehicles.” It may be that plug-in hybrids, like the new Prius, absorb the hybrid market, but it is entirely possible that the hybrid and EV markets will completely overlap, and EVs will end up as half or less than the 2% share hybrids have right now.

A contrasting analogy to hybrid cars might be cell phones. In 1983, Nokia introduced the Mobira Senator. It weighed 22 pounds, had a battery life of five minutes and needed ten hours to recharge. Today, cell phones are ubiquitous. Kas Kalba, who runs his own marketing firm, and has spent 20 years doing market research notes that, “With about 3.5 billion users worldwide, cell-phones have out-diffused virtually every previous technology, including bicycles, radios, television sets, wallets, and wristwatches, and have done so in 25 years." This is staggering: all of those items seem to have instant appeal.

Cell phone diffusion has been driven principally by three factors: price, technology, and price structure. The difference between an iPhone and a Mobira Senator and an iPhone is one of the marvels of 20th century technology. Moreover its successor , the Mobira Cityman, cost $6,635, whereas the iPhone, one of the most expensive modern phones costs at most $399. In India, there are $25 phones. Clearly the dramatic improvement of cell phones

But another key factor, identified by Kalsa, is the price structure of cell phones. The dominant model of cell phone pricing through its first two decades was a contract with monthly charges. Kalba calls this "postpaid pricing" and it is still dominant in the United States. "Prepaid pricing" by contrast, is a model where the customer buys a number of minutes beforehand, and does not need to sign a contract. Cricket wireless does this in the United States, but it has become much more popular in developing markets than it has here. This structure has allowed nomadic Algerian herders in the Sahara desert to own cell phones, and more generally has had the effect that cell phone penetration is now higher in developing countries like Chile (81%) to have a higher cell phone penetration rate than the United States (77%.)

Finally, it is worth noting that cell phones achieved this massive growth despite the existence of an existing, cheaper, technology – the landline phone. Cellphones have outcompeted landlines to the point that in the United States, in 2010, almost 30% of households no longer had landlines.[33] In a majority of developed countries, cell phone subscriptions outnumber landlines through the entire population. Belgium, for instance, has almost 100 cell phone subscriptions per 100 people, but only 60 landlines per 100 people.[34] In part this is because there has been no improvement on landlines in the past thirty years, whereas, as we have seen, cell phones went from the Mobira Senator to the iPhone in that time. Likewise, electric vehicles have a similar capacity to improve relative to ICE cars.

Reviewing the rise of cellphones, what parallels are there to electric vehicles? First, EVs have the some potential to make the rapid technological leaps that cellphones have, but not the as much potential. As we have seen, the technological progress in electric vehicles will come principally from improved batteries. But, as we have also seen, while the forecast for those batteries is blurry, it is unlikely that batteries will be able to reduce in size at the same scale - from 800 grams (the Mobira Cityphone) to 140 grams (the iPhone 4S) in twenty years. Relative to existing technology, ICE cars, EVs are not making any other gains: the LEAF has a push button start, Bluetooth, a trip computer, on-board navigation and many other technical features[35], but so does the Nissan Altima, a comparable ICE. Finally, any pricing scheme could affect ICEs just as much as EVs[36]. Overall, there is simply not enough innovation in EVs to create the same mechanic as the one that propelled cellphone diffusion.

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[33] Toor

[34] Kalba, 27.

[35] Nissanusa.com

[36] As Kalba notes, cars are already an example of “prepaid pricing.” Further, in the great depression, more families kept their car than their phone, even though the phone was cheaper. Telephone lines had a monthly service charge: the “postpaid vs prepaid” dynamic arguably caused this. (Kalba 85-86)

The real innovation of EVs, and what they are getting credit for, is not being superior to ICEs as vehicles, but because they are greener than ICEs. In a word, they are a greener, but, at the moment, less effective product. This suggests that the best analogy for EVs may be to recycling in the 90's. At the beginning of the 90s, recycling technologies still could not compete on cost or quality with new goods. But increasing technology has made recycling ever more cost effective, and constant government campaigns, at all levels – municipal, state, and federal, have raised awareness of recycling over and over and over again. This is the exact change that EVs are about to undergo: massive government support and improving technology are the only things analysts can reliably forecast. But if this is the case, the results are mixed: a 2007 *Economist* article reported that while paper recycling had increased greatly in the US from 1990 to 2006, glass recycling had actually declined, from 11 percent to 10 percent.

LOCAL DEMAND

If we cannot intuit the global trajectory of EVs, perhaps we can determine its fate in Charlottesville. Local demand will be influenced far more by the demographics of the people living there than by the overarching fate of the technology. This section will briefly go over some theories of early adoption and then apply them to the Charlottesville area to determine whether there will be sufficient local demand in Charlottesville to justify EV charging stations.

As we have seen, the earliest adopters of EVs were wealthy. The first pre-registers for the LEAFs were wealthy 45 year-old homeowners who had previously owned a Prius. The adopters of the Volt through October 2011 had incomes above

$175,000 and were trading in Priuses and German sports vehicles for their cars.

"Diffusion of Innovation" is the rate at which a new technology spreads through the community. As an academic subject, it has been dominated entirely by Everett Rogers. Rogers himself based his research on a study of farmers adoption rates of products like new fertilizers, antibiotics and contours.[37] Both those authors and Rogers identified four types of buyers: early adopters, the early and late majority, and laggards. He presents these types in a normal distribution with fewer early adopters and laggards at the tails, and two majorities in the center. But Rogers splits early adopters into two categories: early adopters and 'innovators.' Innovators are the earliest 2.5%, for whom "venturesomeness is almost an obsession." They are people willing to try new things for the sake of new things. Academia is imitated in sales: a spokesman for GM said of the earliest Volt Buyers that, "It's more of a lifestyle of taking risks and trying to be first that got them into that upper echelon in the first place."[38] But there are prerequisites.

> Control of substantial financial resources is helpful to absorb the possible loss from an unprofitable innovation. The ability to understand and apply complex technical knowledge is also needed. The innovator must be able to cope with a high degree of uncertainty about an innovation at the time of adoption.

All of these meet the description of LEAF and Volt buyers at the beginning of their run.

[37] Beal and Bohlen, 2
[38] AOL Autos Staff.

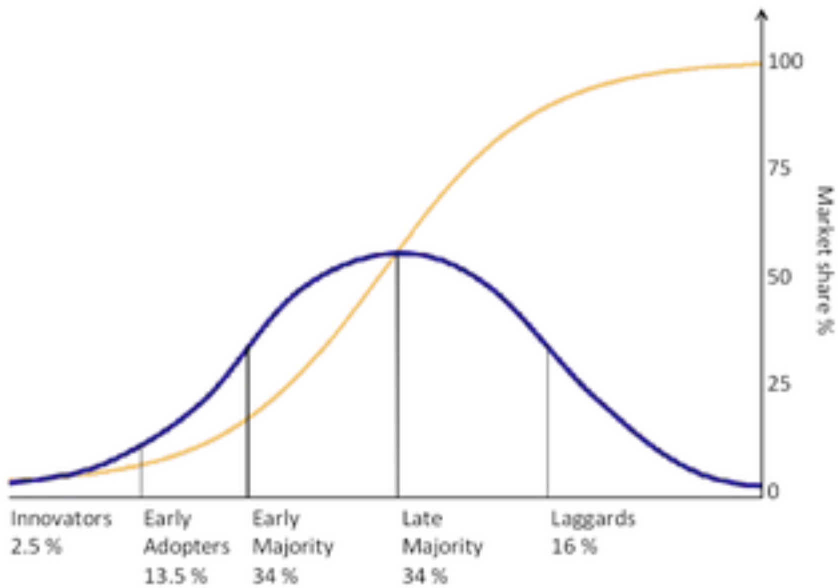

Chart 1: Roger's Normal Curve of adoption

But the innovators are just the vanguard of the early adopters. The next 13.5% of the adoption curve have a different profile than the innovators. According to Rogers, and his predecessors, they are much more integrated with their community, they are more practical and want some feedback before jumping into things, and they are often younger and more highly educated.[39][40] Wealth will still be a critical issue, but this research suggests that there will be a second wave of adopters that are in less rarefied financial circumstances than the first few.

In either scenario, Charlottesville should have some buyers for EVs. If the initial profile remains the same, the UVa community has some wealthy members. In 2010, the student paper, *The Cavalier Daily*, unwisely printed the name and salary of every staff or faculty member who makes more than $50,000. Culling through this data, there are approximately 1,000 UVa employees with a salary more than $100,000, including most

[39] Rogers, 3.
[40] Beal and Bohlen, 2

full professors (average salary $141,600) and associate professors (average salary $90,500.) This provides a pool of reasonably wealthy buyers coming into Grounds every day. If the demographics relax a little bit, and lower income buyers into the market for EVs, Charlottesville remains well-educated[41] and liberal, groups that favor early adoption and sustainability movements, respectively.

The demographic that will not have EVs, I feel, is students. Even though they are young and tech savvy, most students cannot afford an EV. Even if they could, an EV is not a good vehicle for a student. EVs are fine for going in and around the city, but there are not enough charging stations for it to be a road trip vehicle, and it probably could not get you home and back on the weekends.

A final criterion, just for EV adoption, is proximity to UVa. The earliest LEAF buyers reported driving less than 50 miles a day and current users drive around 25 miles before recharging. It seems unlikely that even if a new demographic of buyer emerges, that they would be willing to drive significantly farther. Charlottesville is more spread out than the metropolitan areas where charging stations and EVs are being promoted most heavily, e.g. Washington, New York, or San Francisco, but as the following map shows, a majority of the population still lives within 5 miles of UVa. 12.5 miles is more significant, because 12.5 miles is the halfway point on a 25 mile drive between charges. So if the driver commuted to UVa, but could not yet charge there, if they lived within this circle they could still commute home within their 25 mile threshold. EPA's number for full range of the LEAF, 73 miles, is sufficient to get to UVa from anywhere in Albemarle County to UVa and back.

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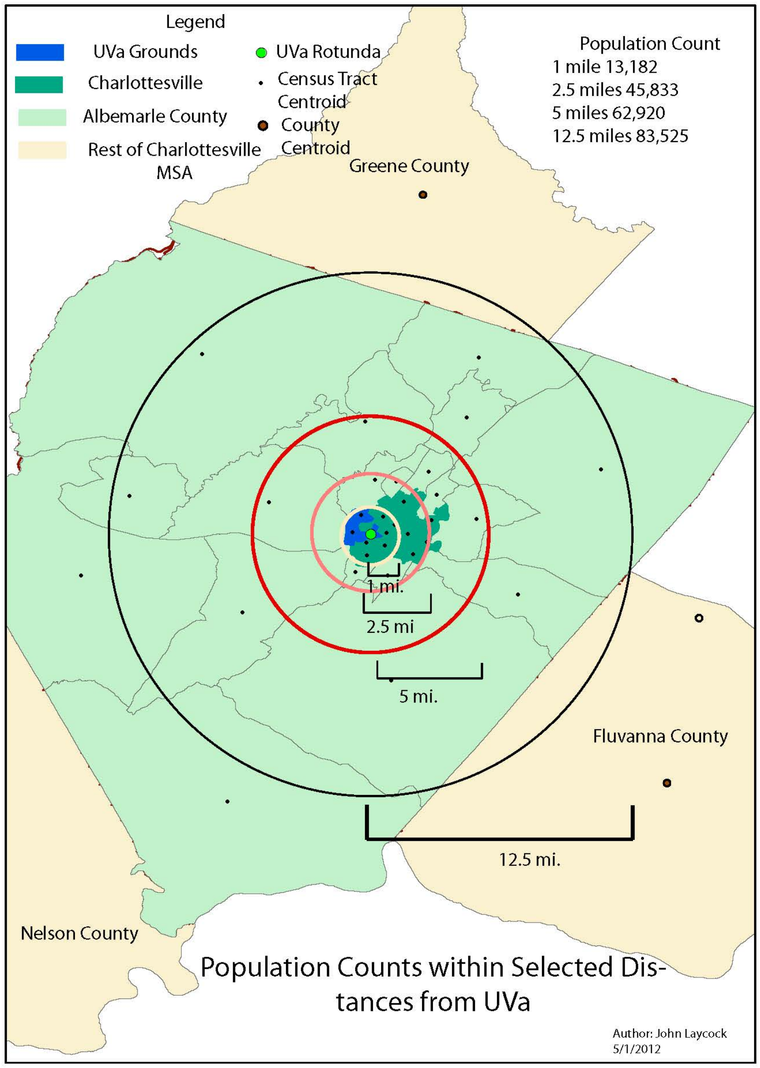
[41] 46.7% of residents over 25 hold a bachelor's degree; a number that does not include college students and recen graduates.



Map 1: Population Counts

This map shows the population of Charlottesville and Albemarle County within a certain radius of UVa. Population was calculated by taking the centroid of each census tract; if the centroid fell within the ring, that census tract's population was counted.

Chapter 4: Case Studies

Regardless of whether EVs will be more like cell phones or hybrid cars, or whether demographics the minimum threshold of demand is probably high enough to justify at least some electric charging stations. In 2007, UVa had roughly 16,000 parking spaces with an elasticity of 1,000 spaces. So at least 15,000 cars were parking on campus on a regular basis. If 1% of those cars were electric plug-ins, there would be a user supply of 150 cars to take advantage of any charging stations. Even one tenth of one percent – 15 cars – would be enough to occupy three to five charging stations every day. Is that worth it? It is a calculation three other ACC schools, and other schools across the country, have said yes to.

The US Department of Energy has a map of all public charging stations in the country, which I used to determine campuses that had charging stations. Some results are surprising. The University of Arkansas at Little Rock (UALR) has an electric charging station on its campus, but Harvard does not. Three schools in the ACC have them – Georgia Tech, NC State, and Maryland. Additionally, Duke and Clemson have Volt cars incorporated in their WeCar fleets. All of these schools have different levels of engagement and different approaches and sources of funding.

Basically, there have been three approaches. Some schools, like NC State and UALR have installed stations using grant money. Others, like Duke, are elevating the presence of EVs without specifically installing their own stations. And schools like Georgetown and Maryland are aggressively promoting EVs with innovative campaigns.

GRANTS

NC State has 3 three stations at the time of writing, and will have 8 by the end of May 2012. Its first three were established with public grants, and were free. Grant money came from both Raleigh Energy, themselves working with a DoE grant, and the North Carolina Department of Transportation. Because the grants have been to promote and study EV usage, the charging stations have been free so far. UALR got its free charging station from the private sector, negotiating with Entergy, a Southeastern energy giant, to get a grant for the station. Entergy has also partnered with LSU and other college campuses in the Southeast using money from its Environmental Initiatives Fund.

But Western Michigan has succeeded with grant money most successfully. Using money from the ChargePoint America program, they have brought the total number of EV charging stations on their campus to 25, one of the highest in the country. To go with those stations, the school has "a fleet,"[42] otherwise unspecified, of green vehicles that can use the chargers if they're not used by university faculty and staff. Finally, the university has solar arrays and a windmill to power the charging station. In the introduction of this report, it was mentioned that a senator appeared at the unveiling of these charging stations and that was a point of skepticism. But faced with such an excellent set of things,

Unfortunately, the details of the fleet, the windmill, and the charging station grants are not available

[42] Roland

FLEETS

Duke and Clemson are also beneficiaries of working with the private sector. Duke and Clemson both have WeCar fleets, a car sharing system run by Enterprise Rent-A-Car. Duke has had once since September of 2011[43], and Clemson since March of 2012[44]. WeCar is almost exactly like ZipCar, which UVa has. Members sign up online, and any member can reserve any car in the fleet, and rent it for $7.50 to $8.50 an hour. Such systems have the principal benefit that they reduce the total number of vehicles driven: students or faculty who live close may no longer feel the need to bring a car to school if they have guaranteed access to a car in a fleet share. With respect to electric vehicles, fleet shares are even more effective: they give the vehicle high visibility – there will be a car on campus at a charging station most of the time and will be driving around campus at least some of the time. And even if a student never thinks about WeCar again, the burst of publicity at the beginning was hard to ignore. Next, because the car is shared, a wide spectrum of the population can be exposed to the Volt. Finally, Clemson intends to let the general public use the charging station at no cost when the Volt isn't there. This, says a Clemson administrator, will, "Use of the charging station will help officials decide when new stations will be needed."[45] So, without doing anything, without even owning the charging station (WeCar owns it) Clemson and Duke are promoting EVs in the present and laying the future for them.

[43] Enterprise Holdings
[44] Clemson University Newsroom
[45] ibid.

OTHER APPROACHES

The University of Maryland has taken a much more aggressive approach, simply buying and installing five charging stations. The charging stations are free for the time being, and are in public lots so members of the College Park community can use them as well. Members of the university community who drive an electric vehicle get a 50% discount on the cost of parking, as well as free electricity for the time being. It's unclear exactly what Maryland's results have been, but hopefully the strong

Also notable in the DC region, is Georgetown's "Electric Vehicle Research Initiative." In June 2011, Georgetown University installed 2 type-2 charging stations in one of its garages. At the same time Georgetown partnered with Toyota for a demonstration program to show the benefits of electric vehicles. Toyota gave Georgetown two plug-in Priuses to lend out to faculty and staff. That is, staff and faculty apply to be in a lottery to drive the cars for two months at a time. This program is a little more involved than the WeCars at Duke and Clemson, but it would seem to have the same effect in raising the visibility of EVs in and around campus. That being said, as we have seen, Toyota plug-in Priuses are not revolutionary in the same way that the Nissan LEAF is.

Finally, it's worth pointing out Tom Wolf, of Huntington, West Virginia, who has installed charging stations at his McDonald's restaurants.[46] Without grants, or private partnerships, or sustainability plans, he has more stations in his fast food restaurant in rural Appalachia than the entire Ivy League combined.

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[46] Haggerty

UVA?

Before crafting specific plans, can UVa emulate any of these cases? Maybe. While there is a lot of grant money floating around, there is nothing obviously available for UVa. The two main grant distributors to colleges thus far have been Chargepoint America, and various energy companies. Chargepoint America is confined to major cities, and no Charlottesville zipcode is eligible for one. Meanwhile, Dominion Power, which supplies Charlottesville with electricity, has yet to give electric charging stations to any universities. Dominion has installed charging stations for rest areas in the state of Virginia, and in that press release said that, "The Virginia Department of Transportation will continue to work with Dominion to identify other facilities for electric vehicle charging station installations.. However, this program was part of the "Renew Virginia Initiative" promoted by then governor Tim Kaine at the end of the 2000s. In 2010, Kaine was defeated by the Republican Bob McDonnell, who seems to have discontinued the program. Dominion also announced a partnership with Ford to "prepare Virginia for electric vehicles." But, similar to "Renew Virginia Initiative" that partnership, which was announced in 2010, has not produced any results. Overall, they seem like an unlikely source of funding.

The other approach is for UVa to acquire an electric fleet vehicle. UVa does have a car sharing fleet, run by ZipCar, which is quite successful. The Zipcar fleet is already full of very fuel efficient cars, including three hybrids, and an EV seems like a logical next step. Actually, this may happen without the University doing anything. In April 2012, Honda and Zipcar announced a partnership that will bring Honda Fit EVs and

Accord Plug-In EVs to Zipcar's fleet. The press release does not have specifics about locations, but Honda expects to deliver the cars in early 2013. UVa's fleet already has six cars, so they might not be receiving one. If they did, though, it should be regarded more as an excellent place to start then a destination. Duke and Clemson have EVs, but aside from Clemson's data collection, neither of those schools is doing more to bring electrification to the cars on their campus.

Finally, what all of the case studies demonstrate is the incredible interest and money surrounding EVs. Even if, as Chapter 1 suggests, the environmental impacts of EVs are being overstated, their future is murky, and demand might be limited, electric vehicles are having their moment. From grants to electric fleet cars to vehicle demonstrations, the opportunities for bring EV charging stations onto grounds are numerous, and that itself is a good reason to pursue them.

Chapter 5: Proposal Mechanics

Having reviewed the state of the electric car industry, its future, and what other universities are doing, the final part of this report lays out potential scenarios for UVa's implementation of charging stations. First, it is important to consider UVa's other plans for sustainability to see how they interact with any EV proposals. That is, to what extent will installing charging stations and getting EVs on campus advance the overall sustainability goals. Next, I will lay out the elements involved in the proposals. One element, of course, is the number of charging stations, but it is also worth considering such things as their location, their pricing, and incentive structures like reduced parking fees. Then, drawing upon these elements, the report will propose several scenarios based on the level of engagement UVa wishes to achieve.

OTHER PLANS

There are three plans that importantly intersect with a proposal for charging stations. At the highest level, UVa's Sustainability Assessment guides all initiatives, but it is very general;. But under it, UVa has a Carbon Footprint Reduction Plan, which seeks and outlines strategies to reduce carbon dioxide emissions to 2000 levels by 2025. The Traffic Demand Management Plan is a key part of the strategy to promote sustainability. That plan focuses on reducing the total number of car trips to Grounds[47] and is therefore almost in conflict with promoting members of the community to drive in EVs. Finally, the university does not have a parking plan, as such, but their parking strategies emerge as a significant obstacle to implementation of charging stations.

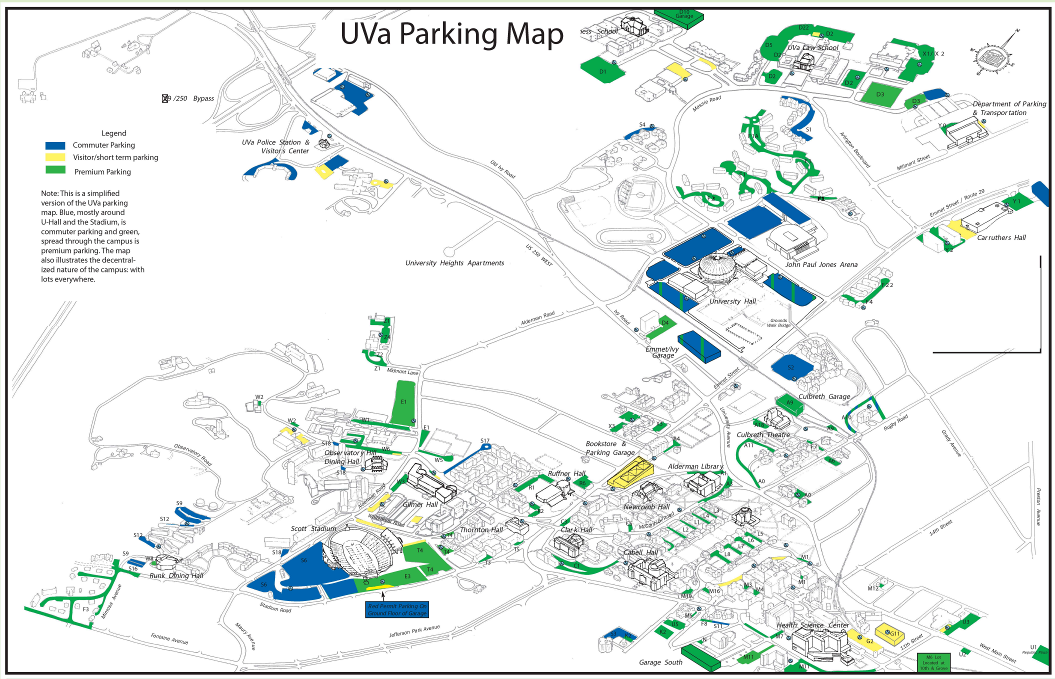
The Carbon Footprint Reduction Plan documents UVa's carbon footprint and charts UVa's three major strategies for reducing it. The plan divides emissions into three categories, or scopes: emissions from on-site electricity generation; emissions from purchased electricity; and emissions from cars and trucks driving to and from the university. This last category includes deliveries and the buses, but it is mostly commuting vehicles. Here is where EVs could play a role. Unfortunately, UVa gets most of it's on-site and purchased electricity from coal, so EVs are not as carbon efficient as they would be in other parts of the nation. However, as the chart in Appendix A shows, EVs are still more efficient than all but the most efficient hybrids. Notably, they emit a

[47] The Campus of UVa is referred to as 'Grounds.'

third as much carbon as a large pick-up truck, and half as much as a compact vehicle. A strategy proposed in the plan to switch from coal to more renewable energy would make this gap even wider. So widespread adoption would help UVa achieve its emission reductions from commuters. The plan includes such strategies, suggesting UVa transition its fleet to more carbon efficient vehicles, including EVs. Additionally, it suggests discounts for commuters driving zero emission vehicles.

However, the chief mechanism UVa has for reducing transportation-related carbon emissions is Transportation Demand Management (TDM.) TDM, as laid out in the TDM plan is "the art of influencing travel behavior for the purpose of reducing demand for single occupant vehicle (SOV) use. The TDM plan includes strategies to promote walking, biking, and car-pooling. The incentives to promote car-pooling, such as reduced parking costs, and dedicated or premium parking spaces could also be used for EVs. The plan's goal was to reduce Single Occupancy Vehicle commutes to 50 to 55% of all commutes, down from 62% in 2007. As a tool for reducing carbon footprint, this is significantly more effective than EVs – every SOV commute prevented reduces the footprint 100%, and not just by a third. Still, if 55% of the UVa community is commuting alone in a car, significant carbon gains would be made if some of those cars were electric.

UVa does not have a parking plan, as such, but the details of its parking permitting are worth consideration. UVa does not have enough spaces next to most of its buildings for everyone to park. That is, the law school parking lot, for instance, does not have nearly enough parking spaces for every faculty member, faculty assistant, secretary, and student to have their own parking space, even with their vigorous TDM plan. Instead, the university has two large garages and big surface lots at the center of campus, with shuttle buses running from them to the buildings.



Map 2: UVa Parking Map.

This map is based on the UVa parking map. It shows commuter parking in blue, and premium parking in green. Note how diffused the premium parking is as compared to the centralized commuter parking. Sources: UVa Parking Map.

That system has led to two levels of parking: reserved and commuter. Reserved parking passes are more expensive but allow access to the close-in lots, while commuter passes only give access to the center lots. The premium parking passes cost $600 a year, almost $400 dollars more than most commuter passes, but nevertheless “these types of permit are in high demand, their availability is limited. Some permit types may require you to sign onto a waiting list until more permits become available," says the university website. That there are so many people willing to pay $400 a year to park closer that there has to be a list is not terribly surprising - people like parking next to their buildings. And unlike carpooling or riding a bike to work, there is no premium of environmental satisfaction for driving alone to work and then parking far away. Nor is the math wrong: surprising calculus – if taking the bus to and from the commuter lots takes even 15 minutes a day more than parking next to your building, and a worker works 300 days a year, then a commuter permit that saves $400 also costs 75 hours.

Such a parking arrangement has several implications poses for EV stations. First, the two large commuter lots make it easy to give access to everyone on campus. If UVa installs banks of charging stations there, anyone from any part of campus can park use them and still easily get to their office or dorm. There are 37 reserved lots across Grounds and not every one of them can have a charging station, not at first. Even the most aggressive strategy here only suggests 12-15 stations, and Western Michigan, the most electrified campus in the country, only has 20. Therefore it is impossible to give access at charging stations in reserved lots to everyone on campus. Which means, that for someone, charging an EV will mean a demotion to the commuter lot. If $400 is not a sufficient incentive to park in the commuter lot, can there be any material incentive to give someone to drive an EV to work but park it there. Also, early adoption is a means of prestige: who wants to buy a $35-40,000 vehicle and then park it several miles from his or her peers and coworkers? And then ride a bus?

Finally, the pent-up demand for parking permits in the individual lots makes it difficult to phase in EV stations at the premium lots. Basically, it would be politically impossible to put in charging stations without demonstrated demand. To demonstrate demand someone in the building, let's say Steve, would need an EV; everyone would know who that person was; and the charging station would be seen as a several thousand dollar subsidy to Steve. And everyone would be angry: at Steve and at UVa. The great president of the University of California at Berkeley, Steve Kerr, said that a university has three purposes "To provide sex for the students, sports for the alumni, and parking for the faculty.[48]" An ancillary purpose, to promote sustainability, cannot take precedence over those three.

A final point: ICE cars do not just emit carbon dioxide. They also emit other pollutants, such as smog-forming nitrogen oxides. EVs do not emit any of these locally. Charlottesville has good air quality, but it is in a sensitive zone near Shenandoah national park. So even though the city is not in any danger of being a non-attainment zone, maintaining clean air is important. It is true that these benefits are negated at the smokestacks where the electricity propelling the cars is generated, but those areas have bad air anyway.

CHARGING STATIONS:

The centerpiece of a charging station plan is, of course, the charging stations. Benchmarking from other schools which have anywhere between 1 (UALR) and 20 (Western Michigan.) Each charging station can charge two cars at once, so that represents

[48] Clark Kerr

a charging capacity of 2-40 cars. Fortunately charging stations can be phased in easily, so it is not necessary to commit to a large number all at once.

Regarding charging type, it is easy to see that Type II is standard. These are the standard commercial charging stations across the country and are sufficient for charging EVs used on a daily commute. As batteries improve, Type II stations will charge a car to full in only 3 hours, so even faculty or staff coming in for half a day could charge to full. Still, an interesting idea is to install a fast-charging type III station that can charge a car to full in 20 minutes. No other school has one, but it makes recharging a car on par with getting gas in terms of convenience, and might be another tipping point for drivers who don't have one.

Charging station location is another issue, and depends on how many charging stations UVa plans to install. If only one, clearly it should go in Emmet/Ivy Garage, the most centralized parking garage on campus. But UVa is a spread-out campus, with three precincts: allocating stations across those precincts is another component, especially given the numerous different parking lots. Additionally, the UVa precincts are based solely on geography, not on groupings of specific buildings – i.e. the West precinct does not contain only science or only dorms. Nevertheless, it is possible to discern some useful patterns. Here are some basic suggestions:

1) The lots around undergraduate student housing are being triaged.
2) Existing Zipcar sites would be a good place to put charging stations, especially since ZipCar is moving to EVs as well.

3) The Darden school garage should be able to accommodate both the business school and the law school
4) Although McCormick garage is right now, visitor and parking only, it is roughly in the center of the Central Precinct, and EV stations there would serve the whole precinct fairly well

INCENTIVES:

Another element is the extent to which UVa wants to incentivize EVs. Maryland, for instance, has heavy incentives for Electric Vehicles right now: their charging stations are free, and EV drivers get half off parking. But other schools don't subsidize EV usage at all, besides having stations. UVa's Traffic Demand Management plan provides for incentives to alternative transportation, that is, biking, walking, or carpooling to Grounds. However, TDM is not the same thing as Electric Vehicles. One of the goals of these programs is to reduce air pollution and the university's carbon footprint, like EVs would, but the principle goal is to take cars off the road and off the parking lots, reducing traffic and congestion, which driving an EV will not do. Nevertheless, EVs do have some benefits that may be worth subsidizing through either reduced parking costs or free electricity.

Placement is another form of incentive that does not require money. Whereas the location maps mentioned above contemplate where on campus to put EVs, this incentive is about where in the individual parking lots to put the charging stations. Putting the stations at the spaces closest to the buildings, that would be a powerful incentive to drive an EV every day. On the other hand, if premium parking spaces sat empty every day because no one was driving an EV, there would probably be many angry faculty members.

A final idea, suggested by the high demand for close-in parking spaces, is to bump EV drivers to the top of the waiting list when considering who gets close-in permits. Alternatively, EV drivers could get "super-permits" allowing them to park in a wider range of lots than a normal reserved permits. This strategy would probably enrage ICE drivers who suddenly lost a place, though, and should only be done under the most aggressive of plans.

VISIBILITY:

Visibility is the final way element of a strategy to promote EVs. As discussed above, the more visible a new technology is, the faster it will be adopted. So visibility is an easy way to promote EVs without doing any work. The most prominent example from the case studies are the share fleet vehicles at Duke and Clemson, and the circulating Priuses at Georgetown. By getting members of the university community behind the wheel is by far the most direct way to raise awareness of EVs. But it is not the only way. The schools that received grants all had press releases for their charging stations: it was on the front page of UALR's website; the presidents of Maryland and NC State cut ribbons at a ceremony for those schools' stations; and a US Senator, Debbie Stabenow, made an appearance at the unveiling of Western Michigan's charging stations. The charging stations themselves raise visibility, though again, empty parking spaces can engender resentment.

Two other ideas for visibility: UVa has an annual sustainability day, where students and faculty demonstrate various sustainability initiatives they have undertaken that year. It would not be at all difficult to incorporate EVs into this day. Another idea is to incorporate EVs in prominent places at UVa. That is, put EVs in places that have a lot of public exposure. For instance, charging stations deftly placed at the stadium would be visible to all 60,000 fans at UVa's home football games. Alternatively, important people could drive them. Following the prestige aspect of the theory of adoption, UVa could work with fraternities to have them drive EVs. Then the "cool kids" would have them, and others might follow suit. If the president bought an EV, the not only would the public face of UVa be showcasing an electric car everywhere she went, students would see it parked in at Carr's Hill every night.

COST

It is difficult to calculate the actual cost of these proposals. Most of the schools with charging stations received them for free from grant money and schools that didn't, like Maryland nevertheless did not disclose the cost of their charging stations. Moreover, commercial vendors of charging stations do not list prices on their websites. Therefore, like so much else in EV-world, it is hard to pin down an exact number, though *I am fairly certain* the cost is around $2,500[49] In any event, that is the figure I have used in the proposals. One plan includes a fast charger, for which I am using Nissan's figure of $10,000.

[49] Garlington

Figures for subsidies are easier to calculate. The cost of subsidizing parking is whatever fraction of $600 and the daily cost of charging an EV, assuming the owner is charfing from zero to full is 1 to 2 dollars a day, or 350 to 700 dollars a year.

Proposals:

The following proposals have 5 levels of commitment: Do Nothing, Minimal, Moderate, Moderate/Aggressive, and Aggressive. Each proposal has a basic statement of justification and then suggestions in the three categories established above: number and placement of stations; level of incentivization; and suggested visibility projects. The proposals are simplified to the point that each level of proposal has an equivalent level of content. That is, the minimal proposal has suggestions for minimal visibility projects only. This is for the purpose of illustration only. In reality, a proposal would be more nuanced and have varied levels of involvement across the three areas. For instance, visibility strategies are generally cheaper than buying more stations or subsidizing to a greater extent. So if UVa decided to install only two charging stations, as per the minimal plan, it could still have a slightly more involved visibility project, like demonstrating EVs at sustainability day. Moreover, the specific number of charging stations could be viewed as phased development, starting with 'Minimal' and adding stations until 'Aggressive' was achieved.

Maps accompany the proposals. They indicate where suggested charging stations should go and summarize the suggested incentive schemes and visibility projects.

DO NOTHING.

This is a legitimate conclusion from the research in this report. Electric Vehicles have many question marks – about whether they're commercially viable, or if they actually have substantial environmental gains, and it is risky to invest in them. And especially if UVa is getting an EV for its Zipcar fleet in 2013, resources can be diverted to other sustainability initiatives. This is a very cautious approach, but it is legitimate in its own way.

Map 3: A Minimal Plan

MINIMAL:

A minimal approach recognizes that there is a chicken-and-egg problem regarding EVs. Without any charging stations, no one will drive EVs, but without any EVs, there is no demand for the charging stations. To break this cycle, at least one charging station is necessary. The cost benefit-analysis is perhaps clearest at this level – just one charging station makes EVs a viable choice for almost anyone in the UVa community. And a minimal approach is very easy to scale up; once there is more demand, it will be easy to add more charging stations. Demand can be organic, developing slowly without any real assistance from the university – charging stations will not be subsidized, forcing users to ration their energy drawing.

Map 4: A Moderate Plan

MODERATE:

A moderate approach concludes that there is a critical mass that must be met to achieve wider adoption of EV technology and that it is worth investing significant university resources to try to achieve this mass. UVa would install between five and ten stations around campus so that every precinct would have several. EV drivers would have reduced, but not free parking, and still pay for electricity. There would be visibility projects only to the extent that they were convenient.

Map 5: A Moderate to Aggressive plan

MODERATE/AGGRESSIVE:

Unsurprisingly, the Moderate/Aggressive proposal is somewhere between the Moderate plans and the Aggressive plan. There would be enough stations to fully cover all the precincts, and parking and charging would be subsidized substantially, but not completely.

Map 6: An Aggressive plan

AGGRESSIVE:

An aggressive approach is one that recognizes EVs as certain to be widely adopted and that this adoption is vital to the interests of the university. The number of charging stations need not be significantly higher than 5-10, but every precinct would be covered and EV drivers would be significantly subsidized. There would be major visibility projects - the football stadium will have charging stations, so that all the alumni can see them, and the president will drive a new Nissan LEAF to all her official functions. An aggressive approach probably carries as much political risk, as financial risk, though. If UVa throws a lot of weight behind EVs, and they never materialize, the empty charging stations will be a serious liability.

Conclusion

This report has started with the premise that an EV revolution is coming which will change the way we drive, and the way we fuel our cars in overwhelmingly positive ways. Then it proceeded to show the ambiguities, trade-offs, and downsides of EVs – the mixed environmental results, the social justice questions, and the drags on consumer adoption. Then it showed the technology and the state of the field, which raised another set of answerless questions about price parity, range anxiety, and the chicken and the egg. The survey of the field showed that the EV revolution is full of compromises, like the Prius plug-in, that make it seem more like gradual improvement. But even this gradual improvement is hampered by a lack of demand, and more questions – if, when, and to what extent will EVs penetrate the market. Indeed, at no point during this entire analysis did we find any conclusive answers or any unequivocal sign that the promised future will come true.

But after that dark place of equivocation, the report changed focus from the cars being charged to the chargers themselves and the universities, governments, and utilities that are putting them up across the country. These are all entities that have looked at the situation and seen not ambiguities but progress and the legitimate hope of a sustainable future. Drawing on those case studies, we established the elements of a charging plan – all the components that must be kept in mind to make sure a successful plan is implemented. Even assuming EVs are a good thing, it is difficult to balance the logistics around them.

The reported ended with a series of proposals, ranging from no involvement to an investment of almost $100,000. Of course, the latter strains credulity; it could at best be seen as the result of a lengthy phase-in of charging stations measured with an equal increase in the number of EVs on campus. On the other hand, it would be just as unwise to do nothing. EVs are not perfect, and they may never penetrate the car market fully enough to effect large-scale changes in the nation's fuel dependencies. But at the same time, each EV has an individual benefit to local air quality and to local gasoline consumption. The cost-benefit analyses, are, again, impenetrable, but the cost to implement even a modest plan is not particularly large. And even if the vision is improbable, it is not impossible, and is worth funding.

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