

Plug-in Vehicles and the Plug - Policy to Address the Chicken or the Egg Problem

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Abstract—People are hesitant to purchase plug-in capable vehicles without the necessary infrastructure to support them. Charging infrastructure is unlikely to be spontaneously installed without a demonstrated need. This “Chicken or the Egg” situation is a major roadblock to the widespread adaptation of efficient plug-in vehicles. This paper presents some of the roadblocks to implementation of charging infrastructure and how they can be addressed by local and state governments, electric utilities, and organizations like the IEEE. Our focus is to address implementing policies for vehicle charging infrastructure at the local municipality level. We present a draft zoning by-law that was proposed in 2008, and discuss the reactions and questions that arose as a result of the proposal. Finally, we discuss the current state of plug-in vehicle infrastructure standards and how it relates to creating local policies to require the infrastructure necessary to speed the adaptation of plug-in vehicles.

1. INTRODUCTION

Plug-in vehicles need infrastructure for reliable recharging. People are hesitant to purchase such vehicles without the necessary infrastructure to support them. Moreover, developers and businesses are unlikely to install charging infrastructure without a demonstrated need. This situation is commonly called a “Chicken or the Egg” dilemma, and it is a major roadblock to the widespread adaptation of efficient plug-in vehicles.

This paper presents some of the roadblocks to implementation of charging infrastructure and how they can be addressed by local and state governments, electric utilities, and organizations like the IEEE. The purpose of this paper is threefold: to highlight the need for plug-in vehicle charging infrastructure, to demonstrate that policy can be used to address this need, and to report on the current challenges and difficulties faced in implementing these policies at the local level.

In the United States, building codes and zoning laws are governed by a combination of federal, state and local governments. Each state may have its own regulations, and municipalities within each state may have varying amounts of control over the aspects that would govern plug-in vehicle charging infrastructure. To make matters even more complex,

the process by which regulations are changed vary from location to location. Electric utilities have their own policies, especially for enabling Vehicle-to-Grid (V2G) power storage and demand response capability.

This complex situation suggests a multi-tiered policy approach, where regulations at each level must be up-to-date to allow such infrastructure, encourage its construction, and require its availability when needed. The breadth of the policy issues is well covered by the Electrification Coalition’s Electrification Roadmap report [1].

We focus on vehicle charging infrastructure policy at the local municipality level. In many places, local municipalities have control over parking requirements, such as how many parking spaces are required for various permitted uses (residential, retail, restaurant, etc.). Therefore, it’s reasonable that municipalities may require a number of charging station spaces within those regulations.

Municipalities have different means to update such codes. Cities may have regulations created by city departments. Towns may have them created by planning boards or town meetings. While these groups may employ knowledgeable professionals to assist them, such boards and town meetings usually consist of volunteer citizens without technical knowledge. These municipalities need easy-to-understand recommendations, standards, and bylaw templates in order to ease the adaptation of such infrastructure policy.

Some of the challenges to address in such local policy include the following: How many charging capable parking spaces will be needed? It will depend on use: short term (e.g., retail), medium term (e.g., offices, commuter), and long term (e.g., residential, hotel). What kind of electrical connections will fulfill current, near-future, and long term needs? How can these be upgraded in a cost-effective manner? Requiring pre-wiring or conduits in new parking could reduce the cost to create additional charging locations in the future. How can the number of required spaces grow? It will depend on the number of such vehicles sold or registered in the area. What standards must be implemented to ensure all vehicles can be charged?

If the major players in plug-in vehicle development can provide concise answers to these questions, or ideally, sample bylaw templates, we can speed the adaptation of charging infrastructure. By addressing this “Chicken or the Egg” problem, we also speed the adaptation of the plug-in vehicles themselves.

2. THE NEED FOR LOCAL POLICY

While the Electrification Roadmap offers detailed suggestions on federal-level policies, there is less detail for local policies. Many of the higher level policies focus on encouraging people to purchase such vehicles. Purchasers of plug-in vehicles will need a place to charge them. Adaptation will likely be slowed by lack of available charging infrastructure. While the majority of people will be able to charge their vehicles overnight while they sleep, the need for a more widespread infrastructure is apparent.

Single-family homeowners will most easily be able to install charging locations for their vehicles. Those living in multiple dwelling units, such as apartment and condominium complexes will need to rely on infrastructure in place if they want to be able to use these vehicles. Since there is no current infrastructure, apartment and condominium dwellers will be unlikely to adopt plug-in vehicles. According to the Electrification Roadmap, only 49% of housing units in the northeast have a garage or carport. If plug-in vehicle adoption is to be increased to the entire population, policies must ensure that newly constructed apartments, condominiums, and other housing units install some plug-in vehicle charging infrastructure.

Infrastructure in commercial, retail, and industrial parking would also be needed. While some of the currently planned plug-in capable vehicles will have hybrid modes with the ability to extend their range with traditional fuels, other planned vehicles will be electric only. For potential owners of electric-only vehicles to overcome “range anxiety,” they must have access to a reasonable number of charging locations. Some people may have long commutes, making it necessary or beneficial to charge their vehicle while they work. A smaller number of people will need to plug their vehicles in while making shorter stops for shopping or other needs.

These three uses can be divided into categories: long term parking for overnight charging, medium term parking for commuters, and short term parking for retail or restaurant use. The longer term parking will have the most charging infrastructure demand, while the short term parking will likely have the lowest demand. A policy that addresses plug-in vehicle charging infrastructure must take such varying uses and demands into account.

3. 2008 ZONING PROPOSAL

In 2008, we proposed a Zoning Bylaw that would require charging infrastructure for parking in new construction in the Town of Natick, Massachusetts. The concept of the proposal was to start the discussion amongst the members of town boards, committees, and interested residents, rather than to pass a requirement immediately.

Natick is a suburb of Boston, located approximately 15 miles to the west of the city (Fig. 1). It has a land area of approximately 16.1 square miles, and a population of around 32,000. The town itself is conveniently located with easy access to the Massachusetts Turnpike, the major East/West highway in the state that provides access to Boston. Also the commuter rail service to Boston has two stops in Natick. The town has a large retail complex and many businesses which attract many visitors. These visitors may benefit from having charging stations available.

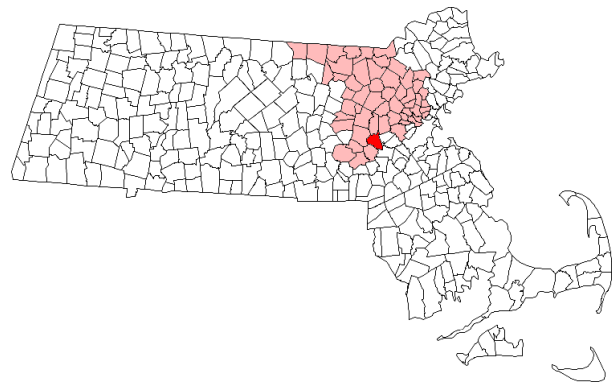


Fig. 1. Natick (darkest), located within Middlesex County, Massachusetts. Image source Wikimedia Commons (J. Petrossek)

Because of the location and demographics of the town, Natick is an ideal candidate to speed the adoption of plug-in vehicles through local policy initiatives. This section details efforts to introduce the idea of requiring charging infrastructure to the town. The Town’s legislative branch consists of a 180 member Town Meeting. An elected Planning Board and an appointed Finance Committee make recommendations to Town Meeting on articles that come up for consideration.

Section 3-A contains the descriptive text of the article, Section 3-B contains the text of the proposed Zoning Bylaw, and Section 3-C contains some frequent questions and answers provided at some of the meetings. Section 3-D discusses the general reactions from the community. The proposal text is provided as it was written in 2008 in order to put the resulting reactions and questions in context. The text was provided to the Planning Board, Finance Committee, and appeared in the recommendations to Town Meeting [2].

A. Text of Zoning Proposal

Proposal to Amend Zoning By-laws for Electric Charging Infrastructure

We are proposing to amend the Zoning By-laws to include a section requiring infrastructure to charge plug-in vehicles. These vehicles can consist of Electric Vehicles (EV), Plug-in Hybrid Electric Vehicles (PHEV), Plug-in Fuel Cell vehicles, and other vehicles capable of receiving and storing energy from the electric power grid. Its also possible that these vehicles will be able to use this stored energy to supply power back to the electrical grid, a technology called Vehicle-to-Grid (V2G) during times of peak load on the electrical system.

The purpose of the proposed Zoning By-law is to require either pre-wiring electrical wires or installation of conduits to run future electrical wiring to serve a certain percentage of new construction parking spaces.

There are several reasons why this proposed By-law change would be good for Natick. Rising gasoline prices are causing more and more people to think about alternatively powered vehicles. While most hybrid vehicles on the road now do not have the capability to connect to the power grid, vehicles planned for the near future will use electrical power to store energy and achieve greater efficiency. General Motors plans the Chevy Volt for 2011, and Toyota plans a version of the Prius that will plug in by 2010. These vehicles will drive for up to 40 miles using only electricity, a range that meets most Americans daily driving needs, and then automatically switch to a traditional hybrid mode with an engine. Other vehicles, such as the Tesla Roadster use only a battery to travel up to 200 miles on a single charge.

The problem is that people will need a place to plug these in and charge them. If there is no infrastructure in place, then adaptation is likely to be slow. These cars are being designed so that for the most part they will be charged overnight at peoples homes while they sleep, and they will not need to worry about how long the vehicle has to charge. Those living in single-family homes will have the most leeway to have infrastructure to charge their vehicles installed.

Those living in multi-dwelling units will need to rely on infrastructure in place if they want to be able to use these vehicles. Additionally, there are reasons why people might need or want to connect their vehicle to power during the day, for instance while shopping or working. Some people may have long commutes, making it beneficial to charge their vehicle while they work. A smaller percentage may have electric-only vehicles and need access to charging infrastructure at other locations in order to make their vehicle use feasible. Vehicle-to-grid technology may also make it possible for a car owner to buy cheap power at night, and then sell back some power

during peak time at a higher rate. This has the benefit of load balancing the electrical grid capacity, therefore reducing the need for power companies to rely on peak power plants.

Since there are not many of these vehicles on the road today, and there isn't readily available charging infrastructure, this proposed Zoning By-law only requires the electrical infrastructure to be installed when new parking is constructed. This essentially means installing or burying wires or conduits in parking garages or lots. When plug-in vehicles become more popular, this electrical infrastructure will be in place and charging stations can be easily installed using this existing infrastructure. Having the infrastructure in place will encourage property owners to put it to good use and complete the capability to charge these vehicles when the time is right.

This proposed Zoning By-law is consistent with the Natick 360 plan:

Goal: Encourage Natick's transition to an environmentally sustainable community. Natick 360 Strategic Plan [3] 2008-2012, page 15:

- "Promote and develop environmentally sustainable zoning and building codes."
- "Promote energy conservation, waste reduction and minimal environmental impact within Town government and among residents and businesses."

Additionally, the proposed Zoning By-law has the following advantages:

- Promotes the use of primarily domestically generated electric power over the use of foreign fossil fuels."
- It is reasonable. It does not overreach by trying to require something that does not yet exist. The additional cost required to install the required infrastructure is small, and could save money when it is later used.
- Promotes Natick as being environmentally friendly and a leader in environmental initiatives.
- By enacting this By-law, other towns may follow and enact similar regulations.
- By enacting this By-law, car manufacturers will get the message that people are interested in alternatives to gasoline powered vehicles.

B. Draft Zoning-Bylaw Article

Proposed Draft Town-Meeting Warrant to amend the Zoning By-Laws.

Amend Zoning By-laws Off-Street Parking Electric Charging Infrastructure

To see if the town will vote to amend the Zoning By-laws

section V-D to include regulations for charging of vehicles that can obtain power from the electric grid.

Amend the Zoning By-laws Section V-D (“Roman numeral five, subsection capital D”) by adding the following subsection:

20. Electric Vehicle Charging Infrastructure

- a) Purpose and Intent - It is the intent of this section to provide for reasonable facilities and infrastructure to connect vehicles to electric power for the purpose of charging or storing energy used in propelling the vehicle. This includes but is not limited to Electric Vehicles (EV), Plug-in Hybrid-Electric Vehicles (PHEV), and Plug-in Fuel Cell Vehicles. The infrastructure is intended to support Vehicle-to-Grid (V2G) technology for potentially supplying power back to the electric grid. Communication infrastructure is also intended to provide metering, control, or billing of electric power usage. The required minimum infrastructure is intended to ensure that the capability to add electric connection to parking spaces can be done in the future with minimal additional cost and reconstruction.
- b) Required Infrastructure Coverage - The percentage of parking (target percentage) required by this section depends on the number of Plug-in capable vehicles sold or registered in Massachusetts in the previous year. The Community Development office will publish the target percentage based on this number sold or registered plus 10
The required infrastructure coverage is based on the target percentage and the estimated usage of the parking in the following categories (See Table I).
- c) Minimum Infrastructure - The minimum infrastructure to be built to each parking space required by this section consists of:
- Electrical Cabling or Conduits - Either electric cabling, or the conduits to run future electric cabling capable of providing dual voltage (both 110-120v and 220-240v) with at least 80 amperes.
 - Communications/Network Connection Either communications/network cable or the conduits to run future cabling. Such cabling shall consist of either Category 5e or Category 6 network cable, or other cable capable of enabling computer network communications. The cabling or conduits must be configured to prevent interference from electrical cabling.
- d) Infrastructure Connection - The electrical infrastructure required by this section shall lead to a location or multiple locations suitable for connection to electrical power of capacity in aggregate of the combined minimum electrical capacity of each parking space.
- e) Off-Street Parking and Loading Plan Requirement - If

an Off-Street parking and Loading Plan is required, the plan shall also show the locations of the infrastructure required by this section and designate which parking spaces are served by the infrastructure. This information may be presented on a separate page.

- f) Exceptions - Exceptions to this section may be made by the Board of Appeals under conditions specified in Administration & Policy Exceptions.

C. *Supporting FAQ Supplied*

Q: When are electrically charged vehicles expected?

A: Several large companies have announced electric or plug-in hybrid vehicles for 2010-2011. These include General Motors, Ford, Volkswagen, Toyota, and Nissan.

Q: Will the electrical power grid be able to handle charging all new vehicles.

A: Yes. Most vehicles will be charged overnight during off-peak and low demand time. Smart Grid and Vehicle-to-Grid technologies will enable electric utilities to balance loads and for vehicles to actually push power back to the grid in high demand periods.

Q: Does this just shift emissions to the power plants and the cost from gas to electricity?

A: No. Power plants benefit from a large economy-of-scale efficiency that will significantly reduce overall energy need, reduce overall emissions and pollution output, and provide transportation energy at lower prices. Electric power may also be purchased from other more environmentally friendly sources such as wind.

Q: Why the option for either cables or conduits?

A: This would provide the most flexibility for those implementing the requirements. Conduits would allow future needs to be more easily met at reduced cost.

Q: How was the required power calculated?

A: It is expected that most vehicles will be capable initially of charging from standard electrical connections. However, future vehicles may require larger power connections to charge within a reasonable amount of time. It appears that the current Tesla Roadster home charging station requires 220v 70A.

Open Questions:

Q: Are the specifics reasonable? What are reasonable power requirements? Should there be some communication requirement? What should we call the “Target Percentage”? Is the

TABLE I
REQUIRED CHARGING INFRASTRUCTURE BASED ON PARKING USE.

Term	Length	Parking Examples	Minimum (based on 20% target)	Percent of target percentage
Short Term	Less than 6 hours	Retail, restaurant	2%	10%
Medium Term	6 hours to 10 hours	Employee, commuter	10%	50%
Long Term	Over 10 Hours	Residential, Hotels	20%	100%

concept of “Percent of Target Percentage” clear?

Q: There is a need to define short term, medium term, long term parking uses? Does it overly complicate the concept? Should it be more or less explicit?

Q: Would this apply to single family construction?

Q: What other changes are needed?

D. Reactions to Zoning Proposal

The proposal was first presented to the Natick Planning Board, where the reaction was mostly positive. Members of the board were eager to discuss the proposal and had many questions on how it could proceed. Only a small minority felt that vehicle charging infrastructure should be the domain of private individuals or companies.

Most of the questions focused on lack of clearly defined and established standards for charging infrastructure. At the time, plug-in vehicles were still a few years away, and the standards for plug shapes and electrical connections had not been fully developed. Questions such as “what will be the shape of the plugs”, “will they use a physical connection or inductive charging device”, or “what electrical requirements would be needed” could not be answered. Even where some of the standards did exist, there was no guarantee that actual production vehicles would use them.

Another important question was who would pay? Although the zoning proposal did not specify, it was envisioned that charging stations would have some kind of metering device to allow the vehicle owner to pay for use of electricity. However, once again without clearly defined standards, the question of who pays for the electricity and how it would be accomplished could not be fully answered.

The will is there to implement a policy, but the technical details of what standards to require were not yet ready. It was decided to request that the article be referred to the Planning Board for further study and a possible future return.

The article was also presented to the Finance Committee and included in their recommendation book, and finally to Town Meeting as a whole. Since referral was requested, there was no further debate on the article.

4. STATUS AS OF 2010

In November 2009, the Electrification Coalition released its report “Electrification Roadmap”[1]. This report helped answer many of the outstanding questions in one concise document. However, the report’s policy recommendations don’t provide much help at the local policy level, suggesting that building codes could be modified without specifying what requirements would meet the needs of future plug-in vehicle owners.

The issue of a standard plug seems to have been addressed. In 2010, the Society of Automotive Engineers (SAE) approved a standard SAE J1772-2009 [4]. This standard defines both the electrical requirements and plug shapes for two levels of vehicle charging. Level 1: 120 V AC, 1 phase, up to 16 A; and Level 2 240 V AC, 1 phase, up to 80 A. Level 1 charging will use standard household electrical outlets and plugs, while Level 2 charging will use a new standard connector. More importantly, the major vehicle manufacturers have agreed to this standard and will begin to produce vehicles this year that charge with the standard connectors. Providers of charging station equipment are also beginning to deploy such equipment to meet the needs of these vehicles.

A. Natick Revisited

In July 2010, we met again with the Natick Planning board, now armed with the above updated information. We distributed copies of the Electrification Roadmap ahead of time and were prepared to go through some of the highlights important to a local town. The board showed enthusiasm, as it had in the past, for moving forward with the idea of creating plug-in vehicle charging infrastructure requirements. While some of the issues from 2008 have been addressed, there still remain too many unknowns.

Some of the questions, concerns and comments were:

- How are the current standards and current equipment adaptable to changing technology? We don’t want to require something that will be obsolete in a few years.
- What is the right balance of public charging versus home charging? If most people will charge at home overnight, how many will need to plug in at work or while shopping?
- What is the scope of our power as a local municipality to require vehicle charging infrastructure? Building codes at the state level govern most single-family construction,

zoning bylaws can govern multi-family and commercial properties.

- How many vehicle charging spaces should be required? How would the number of spaces be calculated? How would the required number change over time?
- Would the spaces be reserved for plug-in vehicles only? How would that be enforced? Where would they be located?
- Would this policy cover town-owned parking lots? What about metered street parking? Can they be put or combined with parking meters?
- Are there any other municipalities that have such requirements? We are not opposed to leading the way.
- Is there anything we could model this on?
- What is established? Level 2: 220V AC 30A? If we go with that how do we know it will be enough in the future?
- What unforeseen complications could arise?

Even with the mostly positive reaction, there is some hesitation:

- Why not rely on the entrepreneur? If there is demand, then someone will come along and do it.
- Why should the town take the risk?
- We should be careful about placing unreasonable requirements on property owners and developers.
- Electricity still has to be generated; is there really a benefit?

In general, even with the enthusiastic and positive response, the ability to make policy at the local level is hampered by the lack of concise documentation and information as to the specifics of what the actual requirements should be.

5. CONCLUSION

Adoption of plug-in vehicles will require the necessary vehicle charging infrastructure support. To move beyond the early

adopters, policy will have to ensure that such an infrastructure exists.

At the local level, there is a demonstrated desire to create such a policy, but the technical details of the actual requirements are either not standardized, not clear, or not accessible to non-technical policy makers.

Organizations like the IEEE and SAE, vehicle manufacturers, electric utility companies, researchers, and other stakeholders in the future of plug-in vehicles need to be able to provide concise requirements that will meet current and future vehicle charging infrastructure needs. Ideally, sample bylaws could be produced and distributed so that local municipalities will have something to base their policies. To help speed the the adaptation of the plug-in vehicles, we must first address the “Chicken or the Egg” problem of where to charge them – a good public policy could be the answer.

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