Beyond Charging Stations: Complementing the EV Charging Infrastructure with Dynamic Charging

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***Abstract*—Whether the future of transportation is going to be electric or not is no longer a question. Electric vehicles (EVs) offer several benefits toward global sustainability. However, without a variety of charging infrastructures that cover diverse forthcoming charging needs, the speed of vehicle electrification may be slow and limited. In this research, we present our perspective on the future of charging infrastructure for EVs. We propose that charging stations will still likely meet most personal demands. However, novel charging alternatives, such as wireless dynamic charging roads, will fit into various public and commercial scenarios. Using computer simulation on actual transportation datasets in New York City (USA), we find that numerous EV drivers can benefit from on-the-go charging, thus reducing their commuting time. Our research provides the evidence to encourage researchers, EV manufacturers, urban infrastructure planners, and policymakers to explore future charging infrastructures for EVs.**

***Index Terms*—Sustainable transportation, vehicle electrification, electric vehicles, charging infrastructure.**

I. Introduction

Sustainable transportation has been one of the world's most prominent goals for several years, mainly because transportation contributes a significant portion to the global emissions of air pollutants. For example, the United States Environmental Protection Agency (US EPA) reports that the transportation sector is responsible for over 50% of total nitrogen oxides (NO_x) emissions in the US [7]. In addition, transportation accounts for about 29% of total US greenhouse gas (GHG) emissions, making it the most significant contributor to US GHG emissions [4]. Acknowledging this fact, several governments have expressed a strong commitment to vehicle electrification, i.e., replacing internal combustion engine (ICE) cars with electric vehicles (EVs). For example, the US targets 50% of EV sale share in 2030 [3]. The UK plans to totally ban diesel and gasoline cars by the same time [10].

Thanks to incentives from public officials all over the world, EVs are gaining increasing popularity. In 2021, 6.3 million EVs were sold globally, almost double the total from 2020 [6]. The global market share of EVs in 2021 is about 8.3%, with sales that made up 4.4% of total new car sales in the US, 13.3% in China, and 17% in Europe [5]. Even though the rate of EV adoption is encouraging, those small market shares of EVs compared to ICE cars signify that some challenges remain for EVs to be adopted by the general public. Research by Castrol (a British oil company) on nearly 10,000 participants reveals that the tipping points to mainstream EV adoption are a retail price of $36,000 per unit, a charging time of 31 minutes, and a driving range of 469 km [1]. Currently, on the market in May 2022, the EV model closest to those tipping points is the Tesla Model 3, which is also the best-selling EV model in the US. It has a starting price of $46,990 and 350km of driving range after 31 minutes of fast charging. Industry advances like the Model 3 may lead to believe that we are only a few years behind the tipping points, as progress in battery design and charging technology will continue to come. However, the caveat is the availability of those fast-charging stations.

UBS Group (a multinational investment bank and financial services company based in Switzerland) estimates that an American, on average, lives 4 minutes away from a gas station, but 31 minutes away from a Tesla supercharging station [9]. To match the 4 minutes distance of gas stations, Tesla needs to build 30,160 more supercharging stations. A supercharging station typically costs $250,000, so Tesla needs $7.6 billion, roughly 1.5 times its annual profit from 2021 [8]. A similar situation is also applied to non-Tesla charging stations, e.g., a typical Electrify America fast charging station costs $350,000 to build [2]. Therefore, the solution to future EV charging infrastructure is not simply adding more fast charging stations. It is essential for policymakers, EV manufacturers, and academic researchers to explore other charging alternatives to accelerate vehicle electrification.

In this article, we paint our view about the prospect of charging infrastructure for EVs, as illustrated in Fig. 1. We project that while charging stations will continue to be mainstream, the future of EV charging infrastructure will be much more prosperous with new charging alternatives. Specifically, we discuss dynamic charging, a technology that enables EV batteries to be charged while parking or in motion. We elaborate on how dynamic charging can complement the shortcomings of charging stations and benefit EV drivers in their daily commute. In the literature, several works on the deployment impact of dynamic charging systems have been introduced. For example, in [11], using real world mobility data in the city of Lisbon, Portugal, the authors have found that at least 15% more drivers could switch to EVs if dynamic charging were available, compared to when only stationary charging was ready for use. In [13], a life cycle assessment on the environmental impact of constructing and maintaining dynamic charging roads has been reported. In [12], [14], the impact of dynamic charging on power distribution networks has been examined. Different from those studies, we focus on the vision that the future of EV charging infrastructure will not be about only charging stations or dynamic charging. Instead, charging stations and dynamic charging will co-exist

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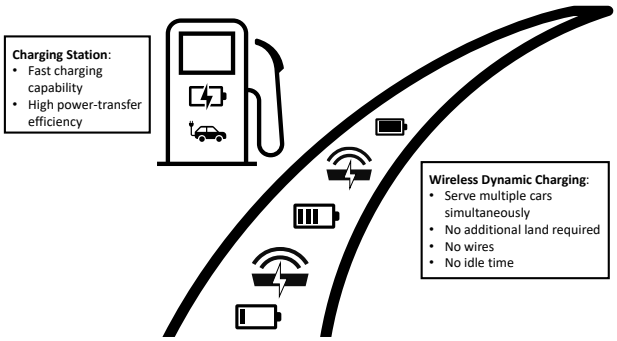

Fig. 1: A sketch of future charging infrastructure.

as complementing solutions to EV charging. In addition, to the best of our knowledge, our work is one of few attempts that investigate the impact of both charging infrastructures on urban mobility, from the EV drivers' perspective. With our findings, we aim to encourage researchers, urban planners, and EV manufacturers to continue exploring and implementing dynamic charging solutions to accelerate EV transformation.

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