Deployment, Managed Charging, and Equity:

How can U.S. distribution utilities support and enable equitable electrification of transportation?

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1. Abstract

This study examines the critically important ways in which electric distribution utilities can support and enable the U.S. transition to full electrification of the transportation sector in an equitable manner. It evaluates the state of the market, reviews characteristics of charging behavior for different use cases and applications, and identifies what roles electric distribution utilities can, and should, play. The study finds that utilities have key roles in two broad respects: deployment and energy management. Without utility involvement in deployment of charging infrastructure, the electrification of transportation likely be inadequate to meet policy targets, and without utility involvement in managing the load, the electrification of transportation will require costly grid upgrades that will undermine the value proposition of electrification. Additionally, a cross-cutting theme applicable to both of these roles has to do with equity – ensuring that all demographics have access to – and can benefit from – transportation electrification.

2. Introduction

It is widely accepted that the burning of fossil fuels and their associated greenhouse gas emissions are rapidly accelerating anthropogenic climate change. Without bold and urgent action to transform and decarbonize the global economy, the impacts of climate change will be catastrophic, so much so that climate change has been described as the existential crisis of our time.

In the United States, the transportation sector is now the leading source of climate change-causing greenhouse gas emissions, having overtaken the electric power sector in 2016 to claim that dubious distinction. (EIA, 2019) To reduce America's carbon emissions – partly to meet its nationally determined contributions under the 2015 Paris Accord, and partly for broader policy reasons – the Biden Administration and many states have established transportation decarbonization goals.

The Biden Administration is also centering the notion of equity throughout its approach to government. (The White House, 2022b) This focus on an equitable transition means that it is insufficient for the U.S. to achieve its transportation decarbonization goals without also ensuring that disadvantaged and underserved communities participate proportionally.

Achieving these two interrelated goals will have enormous implications for the nation's electric grid. Electric vehicles have been described as "the most significant new electric load since the rise of air conditioning" (SEPA, 2019). But EVs are an even more complicated load than fixed, stationary load like air conditioning because EVs are mobile, and drivers often have flexibility as to where – and when – to charge. Though this flexibility poses challenges for grid planning and investments, it also creates opportunities to shift and shape EV load, thereby optimizing the efficiency of the system.

A number of factors will determine the speed and success of this transition. The full scope of the challenge is far too large to adequately explore in a single paper.[1] Instead, this paper will focus

[1] Some of the many related topics outside the scope of this paper include the availability of and access to critical minerals, the development of a robust supply chain, and the new electricity generation and transmission required to power this new EV load. Moreover, this challenge of meeting EV-specific load will be compounded by the concurrent push to electrify the U.S. building sector and decarbonize the entire U.S. economy to achieve economy-wide net-zero by 2050.

on the grid edge where vehicles plug into the grid, and on a critically important participant in the emerging EV ecosystem: the electric distribution utility.

Distribution utilities are responsible for the grid's "front lines," responsible for making sure electricity is instantly available wherever and whenever customers want it.[2] Proper utility planning and programming will be vital to support the transportation electrification ("TE") transition. Conversely, inadequate planning and programming will hinder the transition, delay the decarbonization of the economy, and exacerbate climate change.

The purpose of this paper is to address the question of how the U.S. electric distribution utility can support and enable the equitable electrification of transportation.

3. Methods

This study is a qualitative examination of a broad range of academic literature, filings from docketed proceedings at public utility commissions, whitepapers by non-profit organizations, and coverage by trade media and other sources. The review focuses on three elements of utility involvement in EV charging: charging infrastructure deployment, charging energy management, and equity.

This study first reviews charging basics and consumer behavior to establish a baseline understanding, then reviews the current EV charging market landscape. This involves a review of policy drivers shaping EV adoption, and the related implications for charging infrastructure and

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[2] Unless otherwise specified, this paper uses the term "utility" to mean the electric distribution utility, and not generation and/or transmission utilities.

power needed to support that adoption. It examines the profitability of charging stations, and the electric utility's unique positioning in the market.

The study then describes a number of strategies for supporting charging deployment, energy management, and equity, and cites a diverse sampling of specific utility programs and examples. This study does not endeavor to provide a comprehensive review or quantitative comparison of such utility strategies, policies, and programs, either of which would be a mammoth undertaking far outside of the scope of this study. Rather this study endeavors to paint a broad picture of utility programs and strategies by providing illustrative examples from different utilities serving different types of regions across the country.

Based on these results, the study discusses implications for future utility programs and strategies to support continued equitable deployment of charging stations and management of load, and it concludes with a summary of findings.

4. Results

4.1 Charging Basics

The intent of this section is to paint a broad picture of different types of EV charging needs and behaviors, which is necessary to inform thinking about different types of strategies and programs to support charging.

There are three broad categories of charging. The simplest – "Level 1" – is to plug into a standard 110-120V wall outlet. It generally delivers between 1 kW to 1.5 kW of power. Level 1 charging can typically recharge 40 to 50 miles of range to an EV when parked overnight, and can fully charge an EV in two to three days. Level 2 charging is generally at least five times more powerful than Level 1 charging, depending on the configuration. It requires a 240V AC circuit, similar to that of a large appliance such as an electric dryer or induction cooktop, typically rated for between 30 and 80 amps. This configuration can output power at between 5 and 15 kW.

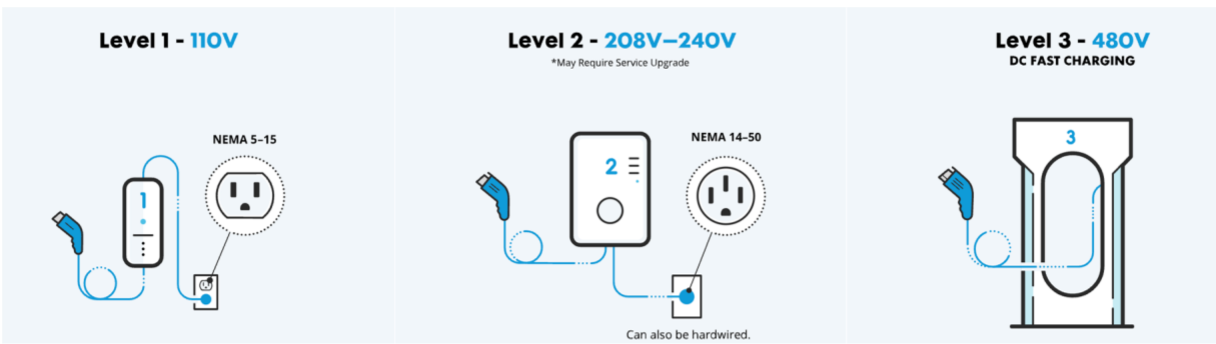

Figure 1: Illustration of Charging Levels
(ConEdison, 2023a)

Finally, Level 3 charging (more commonly referred to as DCFC or Direct Current Fast Charging) delivers between 50 to 350 kWh of direct current. Generally speaking, a higher powered DCFC can fully charge a light duty passenger vehicle in about half an hour, sometimes even less. (Satterfield and Schefter, 2022).

<u>Charging Availability</u>

Just as a driver of a gasoline-powered vehicle needs to fill up its tank with gasoline to drive anywhere, so too does an EV driver need to recharge its battery. Unlike drivers of gasoline vehicles, however, EV drivers cannot yet rely on convenient and ubiquitous charging stations. Ever since Harvey Dauler, an employee of Gulf Oil Company in Pittsburgh, opened what some researchers consider to be the world’s first drive-up “filling station” in 1908, gas stations have proliferated across the country. (Butko, 2022). Today, roughly 145,000 stations across the U.S. offer drivers retail sale of gasoline, the vast majority of which are aptly named convenience stores. (API, 2022). Charging stations do not yet enjoy a similar ubiquitous presence.

Figure 1: Harvey Dauler's Filling Station (Neville Chemical Company, 2016)

A large body of research indicates that one of the main barriers to TE is the lack of availability – both real and perceived – of charging stations. (Krishna, 2021; Wood, 2022). Many potential EV buyers opt against purchasing an EV because of concerns that charging won't be available when and where they need it. This is commonly referred to as "range anxiety." Even though a typical U.S. household's average daily mileage ranges between 30 and 50 miles depending on household size, many prospective EV buyers are concerned about charging availability on longer road trips. (VTO, 2018). Overcoming range anxiety is a critical need to support widespread EV adoption.

Additionally, different customer segments, vehicle classes and use cases have different charging needs. Residents of some multifamily buildings may lack any onsite charging. Local delivery drivers who return to a depot where they can charge overnight have different charging needs than long-haul truckers who must rely solely on en-route charging. For-profit companies considering an EV purchase may have different priorities than a public agency also considering an EV. In short, electric vehicles' charging behaviors and needs are as varied as those who own and operate them.

4.2 The Market Landscape for EV Charging

EV Adoption and Charging Station Deployment

An understanding of the state of the market is essential to evaluate the appropriate role and extent of utility involvement.

By many accounts, EV adoption in the U.S. has reached an inflection point of growth. Much of this growth has been driven by both federal and state policy actions which have proven to be impactful at moving the market forward. Recent federal examples include Biden Administration executive orders to strengthen vehicle emission standards, set a national target for 50% of all light-duty vehicle sales to be zero emission by 2030, and require federal government fleet procurements to be zero emission by 2027 for light-duty vehicles and by 2035 for all vehicles. (The White House, 2022a).

Examples of state policies include California's Advanced Clean Cars II ("ACC II") rule, which establishes ever-increasing ZEV sales targets for light-duty vehicles, reaching 100% by 2035; the Advanced Clean Trucks ("ACT") rule, which sets increasing ZEV sales targets for medium- and heavy-duty vehicles from 2024 to 2035; and – just finalized last month – the Advanced Clean Fleets ("ACF") rule, which establishes increasing milestones for certain fleet operators to fully transition to ZEV vehicles between 2035 and 2042 (depending on the type of fleet), and further mandates an end to sales of combustion engine-powered truck sales by 2036. (Veysey and

McNamara, 2023, CARB, 2021, and CARB, 2023). Together, these two latter rules – ACT and ACF – address both the supply side and demand side of the equation for trucks.

Because Section 177 of the U.S. Clean Air Act allows states to either follow federal emissions standards or adopt California's, California's actions are impactful beyond its borders. To date, six other states have announced plans to adopt ACC II, and nine other states have adopted or are in the process of adopting the ACT rule. (Avery, 2023, and CALSTART, 2023).

As an illustrative example of the power of policy action, RMI estimates that ACC II adoption "translate over time into an increasing proportion of EVs in the vehicle mix," which in turn will lead to states "[reducing] their GHG emissions by an additional 40 percent by 2050, compared to a scenario with no policy in place." (Veysey and McNamara, 2023).

Because of these and other policy and regulatory actions, EV adoption is projected to increase dramatically across the United States. Automobile and truck manufacturers have announced billions of dollars in investments spanning the full breadth of the supply chain, and dozens of new electric vehicle models over the coming years. This coming tsunami of new EVs will require an electric grid capable of supplying that power, and charging stations to deliver it. Projections for the number of charging ports needed by 2030 vary greatly. Estimates range from 12.9 million at the low end to 29.2 million at the high end. (Satterfield and Schefter, 2022; and Kampshoff, et al., 2022).

Charging Profitability

Different utility strategies and programs for deployment of charging infrastructure may involve investment on both sides of the customer meter. This study reviews many of these approaches below and explores different case studies. First, though, to better understand the value of and need for different types of deployment incentives, this study first reviews the business case for investing in deploying, owning, and operating EV charging stations. The business case depends on several factors, including whether the chargers are intended to be publicly accessible or for private use. The public vs. private nature of the deployment also has implications for regulatory treatment of the utility's role.

Public charging: The business model to own and operate publicly accessible chargers has been challenging at best. The reason for this is that the charging provider is responsible for a large set of fixed costs that include the purchase, installation, and operations and maintenance of the chargers, and the real estate carrying costs, before the provider even sells its first kWh of electricity to a driver. Once the charger starts dispensing those kWh, the charging provider must purchase the electricity at retail prices from the local utility. To be profitable, the charging provider needs to add a surcharge to the electricity the charger dispenses. That surcharge needs to provide sufficient margin to cover all the provider's fixed and variable costs and provide a market ROI on top.

In these early years of the TE transition, when the national EV adoption rate is still in single digits, utilization of public chargers is often low and insufficient to warrant private investment. It is telling that the two largest operators of public charging – Electrify America and EVgo – first entered the market and began investing private capital in charging because they were obligated to by court ordered settlements. (State of California, 2012; U.S. EPA, 2023)

Private charging: the investment case for a private charging is different and often much more favorable than for public charging. When a charger is privately owned and operated, the expense of the charger itself is often considered as part of a broader equation that also factors in the vehicle (or vehicles) purchase costs, repairs and maintenance, and the fuel (or electricity) itself. When viewed in this light, the expense of the charger can often be more than offset by the fueling and maintenance savings over the life of the vehicles.

4.3 The Utility's Unique Position

The electric utility is a central player in the story of TE, and it plays not one but several different roles in it. Two contributing factors to the centrality of its role are that it enjoys both monopoly status and generally high levels of customer trust.

In the U.S., almost 3,000 electric distribution utilities deliver power to customers. These utilities differ in their business models. (EIA, 2019). Large investor-owned, for-profit utilities deliver power to a majority of customer accounts in the U.S. The remaining one-third of customers are relatively evenly split in receiving power from either publicly owned utilities or member-owned cooperatives. The governance and level of regulatory oversight differ among these three business models, but they share an important characteristic: they are the sole entity authorized to deliver electric service to that customer. Unlike cellular service, in which a customer can select from multiple providers such as Verizon, T-Mobile, or AT&T, for example, a customer lacks the ability to choose its electric distribution utility. In many states, the electricity markets allow for retail choice of electricity suppliers, but even in these states, the electric grid infrastructure that delivers that power is owned, operated, and maintained by a monopoly utility.

Electric utilities are viewed as trusted resources by a large majority of their customers. There are exceptions to this, most notably Pacific Gas and Electric ("PG&E") in California whose reputation has suffered significantly due to bankruptcies, forestry mismanagement and tragic deadly wildfires. For many customers, however, the electric utility has been the same familiar name they and their families have known for decades, even generations. In addition to this deep brand recognition it enjoys, the electric utility sector as a whole tends to invest substantial resources in customer engagement and outreach, and perhaps as a result enjoys high levels of customer loyalty. (BusinessWire, 2021).

These two characteristics of the U.S. electric distribution utility – its monopoly for operating the distribution grid within its service territory, and its brand loyalty and trust – make it in some respects uniquely positioned when it comes to TE. In its capacity as the distribution grid operator, the utility has an inherent responsibility to manage the electricity on the grid, and to ensure its reliability. This paper will address ways in which the utility can and should manage the electricity in a subsequent section. But first, this paper will address another key way in which the utility can assist and support the TE transition: deployment strategies and programs to support EV adoption.

Electric utilities already have existing relationships with most every electricity-using account in the country – residential, commercial, industrial, institutional, and more. These relationships inherently involve the delivery of electricity through infrastructure which the utility owns and maintains – often onto the customer’s property – up to the customer’s meter. The provision and deployment of EV charging infrastructure in some respects can be viewed as a natural extension of the electric distribution utility’s role.

4.4 Deployment

EV Purchase Incentives

Direct purchase incentives for vehicles have generally been the purview of the federal and state governments, whereas utilities by comparison have mostly focused on programs and strategies associated with charging and infrastructure. Two general exceptions to this, however, are instructive.

One EV purchase incentive some utilities offer is an EV registration rebate, typically of nominal value. The purpose is not to incentivize adoption by offering a large enough incentive to significantly affect the purchase price. Rather, the purpose is to provide utility visibility and awareness of where EVs are on its system.

These types of EV registration rebates are generally in the $25 to $100 range. In one such example, the Pennsylvania Public Utility Commission approved a $70,000 budget for the Pittsburgh-area Duquesne Light Company to offer a $60 registration incentive. The Commission shared the utility's perspective that the registration incentive "will permit the Company to enter the EV into the electrical model and evaluate the impacts on the system, which will assist in grid planning." (PA PUC, 2018). Over roughly four years, this incentive has enabled the utility to identify more than 20% of EV drivers in its territory. (SAE International, 2022).

Another less common utility EV incentive is one that is indeed intended to be substantial enough to incentivize adoption by substantively reducing the purchase price. Not many utilities have obtained regulatory approval for such programs, and most of those that do have narrowed eligibility to support more equitable adoption. PG&E, one of the nation's largest utilities, has offered an EV purchase rebate for many years, but evolved it over time. From 2017 through 2020, PG&E's rebate was $800 regardless of whether the EV was new or used, and regardless of applicant income or demographics. PG&E discontinued that program and launched a modified rebate in February 2023. The current version of the rebate applies only to used EVs. It provides either a standard rebate of $1,000 or a higher rebate of $4,000 for applicants with lower household income. Notably, neither PG&E's original EV rebate nor current EV rebate are funded by ratepayer dollars, but by proceeds from selling credits under California's Low Carbon Fuel Standard. (PG&E, 2020 and 2023).

<u>Charger Rebates and Grants</u>

Although the federal government and many states also offer direct charger incentives for chargers, the bulk of utility deployment incentives have focused on this element of the EV ecosystem. Indeed, in the decade since mass-market EVs first because commercially available in the U.S., electric utilities invested over $3 billion in charging infrastructure and other EV-related programs – more than state and local governments combined. (Lepre, 2022).

Utility-provided charger rebates and grants can serve multiple purposes. The most obvious one is to increase customer EV adoption by making chargers more affordable. That's far from the only purpose behind such incentives, however. One purpose is to enable utility awareness and visibility of EV deployment in the utility's service territory – similar to the EV registration incentives mentioned above. Another purpose that utility rebates can serve is to incentivize customers towards certain types of chargers, such as software-enabled chargers that can facilitate load management, and chargers that support certain communication protocols to facilitate utility communication. This study addresses these two considerations below in the Managed Charging section.

Oregon's Portland General Electric ("PGE") is just one example of the numerous utility rebate programs. PGE offers rebates of $500 per port for standard residential chargers, $1,000 per port for income-qualified residential chargers, $1,000 per port for non-residential chargers, and $2,300 per port for chargers at multifamily properties. (2023)

<u>Make-ready</u>

Another common approach to supporting charger deployment is by focusing on the supporting infrastructure leading up to the charger, but excluding the charger itself. The term for this infrastructure is "make-ready." Often the term refers only to the infrastructure on the customer's side of the meter (often referred to as "behind the meter") but in some cases it refers to the infrastructure on the utility's side of the meter (in front of the meter). For purposes of this study, the stand-alone term "make-ready" will refer only to customer-side (or behind-the-

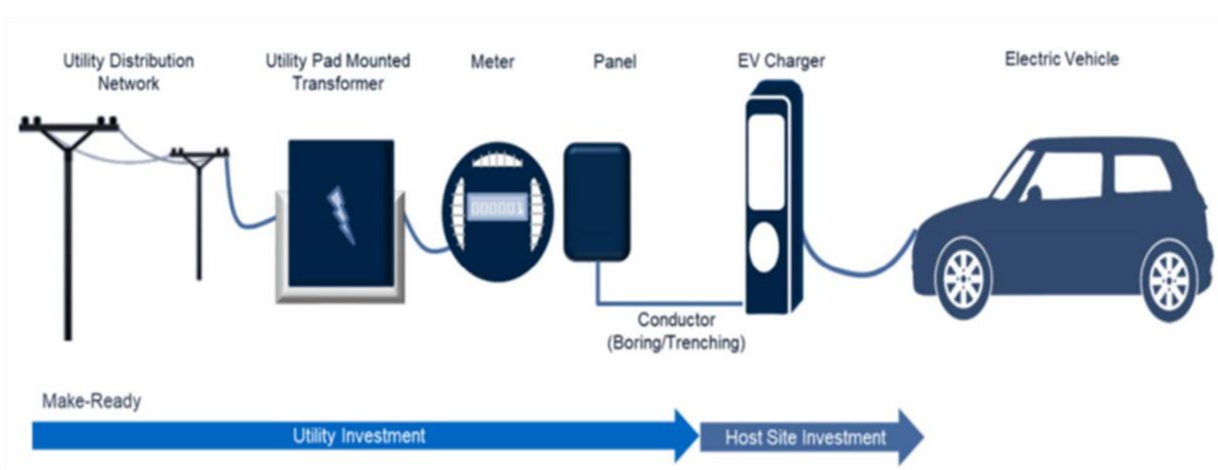

Figure 2: Diagram of Make-Ready Investment
(Allen et al., 2017)

meter) infrastructure. This paper will refer to infrastructure on the utility's side of the meter as "utility-side make-ready."

Make-ready expenses are not insignificant and can often be more costly than the chargers themselves. A typical residential Level 2 charger is priced in the $300 to $600 range; a commercial-grade Level 2 charger is in the $2,000 to $5,000 range, and a DCFC can range anywhere from $20,000 to $150,000 or more, depending on the power level and configuration.[3] With make-ready and installation costs often ranging from three to five times the cost of the charger itself, any one of these cost centers can serve as barriers to deployment, and thus to EV adoption. (Nelder and Rogers, 2019).

In July of 2020, New York's Public Service Commission launched one of the largest make-ready incentive programs in the country. Funded entirely by New York's six investor-owned utilities (and financed by their ratepayers), the five-year, $701 million program budget was projected to fund the infrastructure for more than 50,000 Level 2 ports and more than 1,500 public DCFC ports. Incentive levels varied, from 50% of the infrastructure cost for privately accessible chargers, to 90% for publicly accessible chargers, and a full 100% if the charger is publicly accessible and also located in or near a disadvantaged community. (NYDPS, 2023).

[3] Recent economy-wide inflationary increases, combined with global supply chain constraints that were exacerbated by the Covid-19 pandemic, have contributed to significant price uncertainty for EV charging infrastructure.

Portland General Electric, in addition to the charger rebates described above, has begun offering make-ready rebates for replacing and upgrading a residential customer panel. This rebate covers up to $1,000, or up to $5,000 for an income-qualifying applicant. (PGE, 2023.)

Utility ownership and operation

Another key deployment incentive is for the utility to own and operate the charger itself. This approach can support deployment by addressing two customer challenges. Cost may be the most obvious one, but the other has to do with know-how – understanding how to right-size a charger installation to meet the need, and navigating the planning, design, permitting, and installation. Unless a utility customer already has experience with EV charging, their lack of understanding and their limited bandwidth to manage the installation process might be even more of a barrier than cost.

Maryland's BGE and Washington's Puget Sound Energy are two examples of utilities that received regulatory approval to offer incentives for both customer-owned and utility-owned chargers in multifamily buildings such as apartments and condominiums. Both found much greater customer demand for the utility-owned option. (K. Groncki, personal communication, May 3, 2023; and D. Kievit, personal communication, April 28, 2023).

Charging as a Service

Charging as a Service, or CaaS, is another way to help reduce barriers to deployment. Instead of needing to pay a large upfront cost for the purchase and installation of a charger, CaaS allows a customer to bundle those capital costs with continuing expenses such as repairs, maintenance, and charging network fees, and spread out the combined expenses over a fixed term, such as three or five years. This enables a customer to operationalize those expenses into a fixed, recurring, and predictable monthly operating expense.

Minnesota's Xcel Energy is one utility that has received regulatory approval for residential CaaS Programs, one of which is utility-owned and the other customer-owned. Xcel bundles them as two variations of "Easy electric vehicle charging at home," with the pitch to customers that "With EV Accelerate At Home, you can save on charging with a Level 2 charger, and we'll do all the work to set you up." (Xcel, 2023) Both options offer monthly CaaS payments, the main difference being that the utility-owned plan requires no up-front payment, whereas the customer-owned plan requires an upfront payment and a three-year term before the customer takes ownership.

Utility-side infrastructure upgrades

Utility-side infrastructure upgrades can be even more costly than customer-side make-ready. Typically, it is the financial responsibility of the customer whose electricity needs require the utility-side upgrade. Some utilities are taking innovative approaches to help defray this cost. One such approach uses the established cost allocation practice of contribution in aid of construction, or CIAC for short. This approach projects the amount of additional revenues attributable to the increased kilowatt hours of electricity sold associated with the infrastructure upgrades. Those revenues are then used to offset the infrastructure upgrade costs incurred by the utility.

While CIAC is a relatively standard utility practice, some utilities find that it is not always suitable for EV charging projects. Florida has a standard five-year timeframe to calculate CIAC revenues and apply it to the utility's costs. Tampa Electric Company (2020) received regulatory approval to extend this five-year period to ten years. Tampa Electric's argument was that revenues for newly installed fast charging stations are "likely very low when the charger is first installed, partly as it takes considerable time to make its market presence known to attract customers, but also partly because there are not many EVs on the road to take advantage of fast chargers."

The State of California has taken an even stronger approach when it comes to utility-side infrastructure upgrades. In 2020 the General Assembly passed Assembly Bill 841 which states the California Public Utilities Commission "should not relegate charging electric vehicles to a lower status than any other use of electricity for which the [utility] provides distribution infrastructure," and requires the Commission to consider utility-side "infrastructure and associated design, engineering, and construction work as a core utility business, treated the same as other distribution infrastructure authorized on an ongoing basis." (California State Assembly, 2020).

4.5 Managed Charging

Most every utility in the country is responsible for ensuring the reliability, safety, and affordability of the power on the grid. As such, the utility is a critical player to not just support the deployment of chargers through strategies such as those described above, but to ensure the grid can then supply the power the chargers require, when they need it, in a cost-effective, safe, and reliable manner, all without compromising the delivery of electrons to the many other end users also requiring power from the grid.

Managed charging refers to shifting and shaping load to optimize load and reduce costs. It is a broad umbrella that includes many different types of strategies, and further variations on those strategies.

The two graphics below illustrate the concept of managed charging by presenting two different charging scenarios for a typical large building such as a condominium or apartment building. The X axis represents 24 hours in a day between midnight to midnight, and the Y axis represents electric load. The gray load curves represent the building's overall load without EV charging – a base load, the HVAC and lighting load, and the residential load. The HVAC, lighting, and overall residential loads ramp up in the afternoon as residents get home from work and school. In both scenarios, the EV drivers come home after work and plug in their vehicles to charge, and the vehicles are fully charged by 7 or 8 a.m. the next morning when it's time to leave.

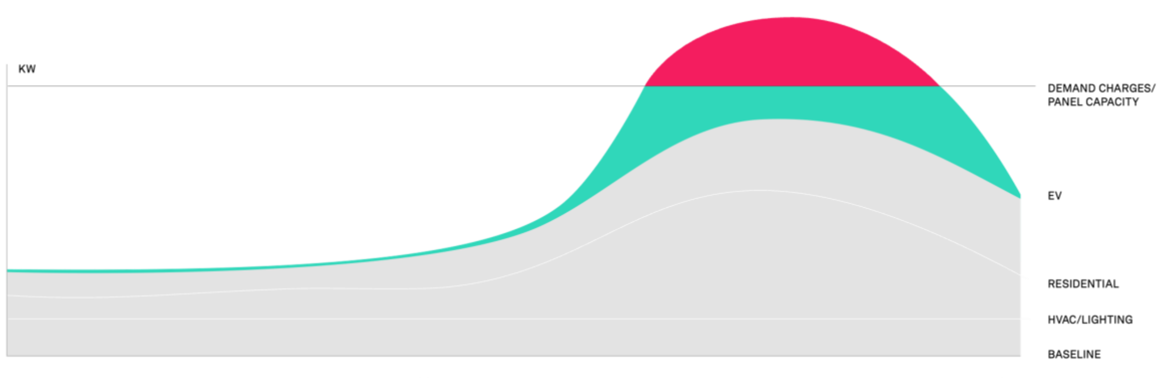

Figure 3: Unmanaged Charging Scenario

(SWTCH Energy, 2023)

In the unmanaged charging scenario, the EVs start charging as soon as they are plugged in. This adds additional load to the evening peak. With the addition of this EV charging load, the overall building load exceeds its panel capacity and/or perhaps incurs demand charges.

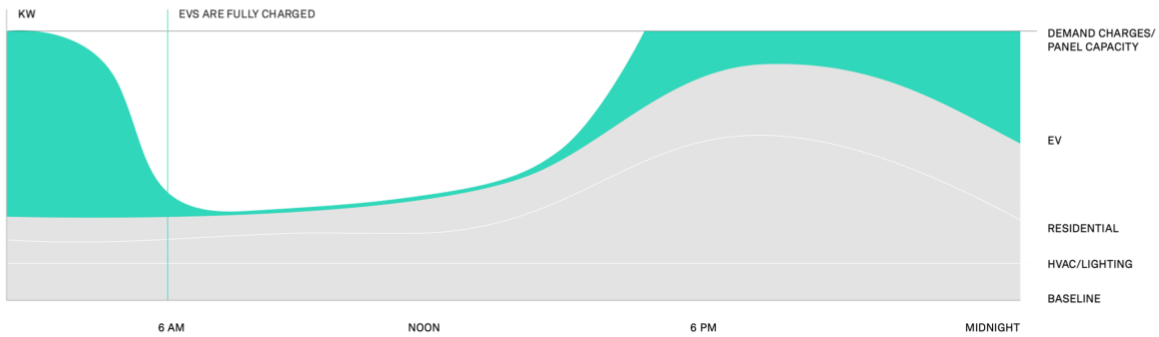

Figure 4: Managed Charging Scenario

(SWTCH Energy, 2023)

In the managed charging scenario, the charging is shifted so that the bulk of the charging occurs after midnight when building load is low, the panel has ample capacity, and electricity is often cheaper.

A large amount of research shows that the coming EV load, if unmanaged, will require billions of dollars in grid upgrades, from the generation capacity to provide the power, to the transmission lines to bring that power to load centers, to the distribution system at the grid edge. As one illustrative example, the Indiana Utility Regulatory Commission (2020, pg. 56) found, "Scenarios with high adoption and charging of EVs result in large peaks that require substantial new generation capacity and higher system costs," but with a caveat that its study "did not look at rate design...[which] is especially important for the timing of EV charging and the associated impact on utility infrastructure."

The ability to manage when and where EVs charge can make the EVs themselves a grid asset. Shifting charging to times and locations when and where the distribution grid can handle more load is a way to optimize electricity on the grid. Every ratepayer's electric bill includes some costs associated with maintenance of the grid itself. These costs are relatively fixed, regardless of how much or little electricity the ratepayer uses. With managed charging, utilities gain the ability to spread out their often-substantial fixed system costs across a greater volume of kilowatt hours sold. This in turn creates the potential to apply downward pressure to rates to benefit all ratepayers.

This theoretical benefit of managed EV charging is borne out by data. Synapse Energy Economics has analyzed a decade of utility EV charging programs in California, the state with both the highest number of registered EVs and the largest amount of utility investments in EV charging-related programs. Synapse's research found that even after accounting for all of the direct and indirect expenses associated with utility EV charging programs, "EV drivers in PG&E's, SCE's, and SDG&E's service territories have contributed approximately $1.7 billion more in revenues than associated costs, driving rates down for all customers." (Fitch, Frost, and Whited, 2022) This research points to the tremendous economic value of managed EV charging programs at scale.

Utilities have several different tools in their regulatory toolboxes to manage charging. These range from the relatively ordinary, like rate design, to more sophisticated strategies that use software, often integrate multiple resources, and may involve multiple participating parties.

Rate design

The most basic managed charging strategy is through rate design. The intent of rate design as it pertains to EV charging is to incentivize, via price signals, a driver to charge at a particular time of day. This type of rate in which the price for electricity varies depending upon the time of day is known, appropriately enough, as a time varying rate ("TVR") or a time of use ("TOU") rate.

Every utility in the country sets rates for its electricity usage, and TVRs are fairly standard. Not every utility has an EV-focused TVR, however, instead relying on a “whole house” TOU rate that measures EV charging load combined with other household or building load.

Some utilities are offering “super” off-peak charging rates to generously incentivize drivers to charge overnight. Some examples include Minnesota’s Xcel Energy (2.8¢ per kWh), New York City’s ConEdison (1.8¢ per kWh), and Arizona’s Tucson Electric Power (1.46¢ per kWh). (2023)

Software-based smart charging

If one views static rates as an important first step to manage charging, then software-enabled charging represents the next stage in managed charging. Software can amplify the benefits of rate design more dynamically in real time, according to parameters or preferences entered by the charging station operator or EV driver. The value of software increases with the number of vehicles charging. As an example, a fleet manager can establish prioritizations for different vehicles and enter the “charge by” times when the vehicles will need to be fully charged. The software can then dynamically share the power among multiple chargers and vehicles to assure that a facility’s overall electric load stays within capacity, while also taking advantage of lower overnight rates.

Software can also integrate other distributed energy resources (DERs). Integrating DERs such as solar panels or batteries into a charging installation can allow the chargers to draw power from solar panels or batteries, further optimizing energy consumption and avoidance of peak electricity charges. (Fachrizal, et al., 2020; Engelhardt, et al., 2022; Kouka, 2020)

Demand Response

Demand response expands dynamic smart charging to the macro level to manage charging on the grid and help avoid outages, congestion, and other grid challenges. An example could be on a hot July afternoon when every household has its air conditioner on full blast. A utility may offer residential customers a bill credit if they set their thermostats a few degrees higher than normal, or may pay a large industrial customer to curtail their energy consumption for an hour.

Massachusetts' EverSource offers a residential EV charging demand response program in which a customer receives $50 for enrolling and an additional $20 for each demand response session the customer participates in. Virginia's Dominion Energy offers a similar but less generous residential EV charging demand response program: $40 annually for each year a customer participates. (EverSource, 2023; Dominion Energy, 2023). Despite the win-win potential of EV charging demand response programs to offer value both to customers and to the grid, participation rates are mediocre at best. One study found customer participation to often be below 10 percent of utility's targeted enrollment. (Parrish et al., 2019). This implicates a need for evaluation and refinement of customer participation incentives.

<u>Bidirectional charging</u>

Bidirectional charging could be considered as another variation on managed charging. As the name implies, it involves the EV battery discharging energy back to the grid (known as vehicle-to-grid, or V2G for short) or to the building (vehicle-to-building, or V2B). The most widely publicized application of V2B is the Ford F-150 Lightning all-electric pickup. If plugged into the home charger when grid power goes down, the charger will automatically draw power from the F-150's battery to power the house's panel.

These different variations of V2X all reflect the electric vehicle's inherent quality as, in essence, a large mobile energy storage battery. By charging when electricity is inexpensive and grid demand is low, such as overnight, and reversing flow when electricity demand is high, an EV owner can monetize the electricity the EV stores while also providing grid benefits. The purpose of the grid benefit may vary; it could be for resilience during grid outages such as with the F-150, or it could be to serve as a distributed energy resource and help balance peak demand on the grid.

Theoretically, when one considers the aggregate amount of mobile battery capacity in EVs on the road – Canary Media (2021) estimates 1.3 terawatt hours of new capacity per year by 2035 – bidirectional charging offers tremendous potential to the grid. In practice, however, its economic viability depends in part on its use case. The most common use case being explored today is that of the electric school bus. Its unique dispatch cycle makes it perhaps uniquely well-suited to bidirectional charging, because it runs a fixed route in the morning and a fixed route in the afternoon, but otherwise remains stationary during the middle of the day and overnight.

Nevada's NV Energy, Colorado's LaPlata Electric Association, and Indiana's Duke Energy are just three examples of more than a dozen utilities across the country with electric school bus bidirectional charging pilots. (Hutchinson and Kresge, 2022)

<u>Third party services</u>

Utilities can also enable new companies to participate in and add value to the EV charging ecosystem. The EV charging industry – and cleantech more broadly – is fertile ground for new startups. These companies often start with an idea to fill a need by offering a new product or delivering a service in a more cost-effective way. Three such examples are AutoGrid, WeaveGrid, and EnergyHub (2023). All three are third party service providers that serve as a single point of integration among multiple charging network companies. In this way, they enable a utility to implement a demand response event at chargers operated by multiple charging networks, all by using the third-party service provider as a single point of contact and implementation.

The key to enabling this participation by third-party service providers is interoperability.

<u>Interoperability</u>

Interoperability is a broad concept that refers to the integration of different types of elements within the EV charging ecosystem. Open communication protocols and standards are the key to enable interoperability. A communication protocol is like a common language – it enables the receiver to understand the information being communicated by the sender. Different protocols govern different elements of the communication:

- Open Charge Point Protocol (OCPP) is for the physical charger-to-software network; OCPP allows a charger built by one manufacturer to be operated by different charging network providers.
- Open Charge Point Interface (OCPI) is for network-to-network communication. Similar to cellphone roaming, OCPI allows a driver who has a charging account with one network provider to charge at a charger operated by a different network provider, because the two networks coordinate on the back end.
- Open Automated Demand Response (OpenADR) is for utility-to-network communication; as the name implies, it enables a utility to implement a demand response event with multiple network operators.

- ISO 15118 governs vehicle-to-charger communication. It is a broad standard that covers several elements of the EV ecosystem including bidirectional charging and "plug and charge" – a simplified approach to charging in which the driver simply plugs in the charger, and the vehicle automatically communicates with the charger and the network to authenticate, authorize, and commence the charging session.

Many utilities include various interoperability requirements in their incentive programs. It is so foundational to ensuring a seamless and innovative EV charging ecosystem that the national association for state public utility commissioners and a national research organization focused on the electric grid both published reports on the topic. (Villarreal, 2022; EPRI, 2019)

4.6 Equity

Over the past decade, as the EV and EV charging market landscape has taken shape, so too has its contours. This maturation of the landscape enables utilities, regulators, and other stakeholders to better understand these nuances of the market, and of the utility programs intended to shape it. If one considers incentives such as charger rebates or time varying rates as "what" a utility does, then thematic considerations, such as those around equity can be considered as the "how."

A focus on equity has been integral to transportation electrification policy from its early days. Indeed, of the more than $3 billion utilities invested over the first decade of the industry, almost one quarter of that budget was earmarked specifically to expand access in underserved communities. (Lepre, 2022) These programs have covered a range of incentives and strategies, from charging station deployment incentives to education and outreach to support for different modes of transportation such as transit and rideshare.

Examples of utility strategies and programs that prioritize equity are numerous. The evolution of PG&E's EV purchase rebate described earlier is one such example of how, with the benefit of time and experience, regulators and other stakeholders were able to evaluate the first iteration of a program and subsequently refine it to focus more on underserved groups of customers. As originally designed, with a flat rate $800 rebate for all customers without regard to income, PG&E's "rebates were concentrated to a large number of high-income individuals who could afford to purchase a [plug-in electric vehicle] without an incentive." Following subsequent evaluation and guidance from the California Air Resources Board (CARB), PG&E restructured the rebate so that "lower income applicants were eligible for an increased rebate amount." (Brown et al., 2021)

Colorado regulators took a similar approach with another one of the few utility-provided EV rebate programs in the country. The Commission there only approved Xcel Energy's EV rebate proposal after Xcel modified it to set eligibility limits both on the vehicle price and on the applicant's household income, specifically to address concerns around equity. (McAdams, 2022)

It may seem inherently evident, but a major reason for this focus on equity is because electric transportation offers well-documented economic and health benefits. In terms of economic benefits, EVs are far cheaper to own and operate than comparable gasoline-powered vehicles; an EV owner will generally pay less than half on fueling costs and on maintenance and repair costs over the life of a vehicle. When it comes to health benefits, EVs have zero tailpipe emissions and no pollution. Air pollution – unlike greenhouse gas emissions – is localized, and its impacts are felt locally. These twin benefits mean those who drive or ride in electric vehicles benefit from lower transportation energy burdens compared to those who don't, and both they and the communities where they operate enjoy better air quality and corresponding respiratory health outcomes. (Vega-Perkins, et al., 2023; Orvis, 2022; Garcia, et al., 2023) Disparities in EV adoption, therefore, have implications for economic and health disparities as well. This is why equity matters for transportation electrification.

The U.S. policy emphasis on equity has become even more pronounced since the inauguration of the Biden Administration in January 2021. The Administration's Justice40 Initiative requires that 40 percent of the benefits of certain programs must accrue "to disadvantaged communities that are marginalized, underserved, and overburdened by pollution." (The White House, 2022b) The Administration is applying Justice40 to the two major EV infrastructure-related programs funded by the Bipartisan Infrastructure law – the $5 billion National EV Infrastructure ("NEVI") Formula Program and the Charging and Fueling Infrastructure ("CFI") Discretionary Grant Program.

Although Justice40 applies to certain federal programs and not to utility programs, the Administration's emphasis has helped to normalize and center equity in the broader policy conversation around electric transportation. High-ranking Biden Administration officials such as Transportation Secretary Pete Buttigieg, Energy Secretary Jennifer Granholm, and the Executive Director of the newly created Joint Office of Energy and Transportation, Gabe Klein, have all spoken at recent utility regulatory and EV-focused conferences about the importance of equity.

Utility ownership and operation of charging stations – as opposed to private, third-party ownership and operation – has proven to be especially valuable to support equitable charging access for certain use cases. Multifamily buildings such as apartments and condominiums have historically been a particularly complex and challenging segment in which to deploy chargers, due to the complexities and need for multiple layers of approval by condominium association boards, property management companies, and other factors. Apartment buildings add yet another layer of complexity because renters are disinclined to invest in an infrastructure upgrade when they don't own their apartments, and landlords are often disinclined to invest to benefit a renter who may not renew their lease. Utility ownership is a way to circumvent many of these challenges in this particularly hard-to-serve customer segment. BGE and Puget Sound Energy's experiences described earlier are indicative: despite the availability of financial incentives for third-party ownership, customers expressed much more interest in the utility-owned offering.

Prioritizing equity also requires understanding that not everyone owns their own car. Many low-income households have no vehicles and instead rely upon public transportation, rideshare, and/or micro-mobility as their modes of transportation. In recognition of this, BGE partnered with the rideshare company Lyft to support electrification of Lyft vehicles throughout Baltimore, a city with many low-income neighborhoods. Maryland's Public Service Commission authorized BGE to offer Lyft and other operators of fleet vehicles a 25% discount on the normal public charging rate. (MD PSC, 2019)

Despite the increasing focus on equity, it remains a highly challenging goal to achieve, even with regulated and intentionally designed utility programs. California's experience is particularly instructive. Not only is it the leading state – by far – for EV adoption and for utility investments in electric transportation, it also has incorporated strong equity goals and requirements throughout its EV policy landscape. Despite this, a recent study by Hsu et al., (2020) found that significant disparities remain when it comes to access to chargers. These disparities correlate with belowmedian household incomes, higher proportions of multi-unit housing, and Black and Hispanic race and ethnicity. Hsu et al.'s detailed spatial analysis of charger access overlaid with demographic data found that chargers can be deployed in disadvantaged census tracts yet still fail to provide meaningful access to the underserved residents who live there. One example of this would be a census tract that includes a heavily traveled highway. A charging station operator may install several publicly accessible fast chargers at a location along the highway or nearby to it. As a result, the chargers serve through-traffic but fail to serve those residents of the census tract whose apartments may be several blocks away. This contributes to a self-perpetuating cycle in which residents lack sufficient charging access so they do not drive EVs, which discourages private charging companies from installing chargers, and so on.

5. Discussion

5.1 Deployment

Utilities have a significant role to play to support the deployment of EV chargers. This role includes both third-party incentives and utility owned-and-operated chargers. Though the EV charging market is no longer in its infancy, both the cost and pace of deployment remain two significant barriers that hinder adoption. Despite billions of dollars in funding for research, development, and deployment from the U.S. Department of Energy and other Bipartisan Infrastructure Law-funded programs, there often remains a gap between proven technology and commercial competitiveness at scale. This is where utilities continue to have an important role to play – one that warrants their ratepayers' investment because of the benefits these technologies offer. Indeed, by delivering value to the grid, these investments ultimately return value to ratepayers as well.

Areas of continued market failure most clearly warrant continued utility investment. Even though private charging companies are now investing in EV charging deployment, they are not investing uniformly across customer segments. Examples of underserved segments include low-income communities and the multifamily building sector.

Another area that warrants continued utility investment is on the utility side of the meter. Distribution-side policies such as California's AB 841 approach of considering EV-related upgrades to be part of the usual course of business warrant broader consideration nationwide. As manufacturers are starting to offer more medium- and heavy-duty vehicles, the need for utility-side grid planning and investment will become even more acute; ensuring sufficient grid capacity to support twenty 100 kW fast chargers is a challenge of a much greater magnitude than supporting twenty 7 kW Level 2 chargers.

While utilities should continue to have a role in customer-facing charging programs, it is also important to establish regulatory guiderails. One example where this comes into play is in siting charging stations. Because electric utilities have unique visibility of their planning processes for future distribution grid expansion, upgrades, and interconnections, failure to establish a clear internal firewall between a utility's grid planning team and its charging station deployment team may give it an unfair advantage over private charging companies when it comes to siting.

5.2 Managed Charging

Managing charging will become an ever more important need as EV adoption grows. As noted previously, studies show that unmanaged EV charging will implicate a need for expensive grid upgrades whose costs will ultimately be borne by ratepayers, while managed charging more than pays for itself, ultimately applying downward pressure on rates to benefit all ratepayers.

In theory, the seemingly unlimited potential to connect gigawatts of new renewable energy capacity onto the grid, store it in batteries so it's available when needed, and integrate it all with managed EV charging, paints an almost utopian picture of a transportation sector powered by cheap, clean energy. As Parrish et al. found, however, customer participation rates in dynamic demand response programs have been meager. The industry faces a significant challenge to convert the theoretical promise of demand response into a practical solution at scale. As Parrish, SEPA, and others, have recognized, customer engagement is a critical element for successful outcomes. This need for customer engagement and the relatively meager participation rates thus far suggests a need for more deliberate customer engagement planning and programming, and for associated budgets to pay for it. This need for customer engagement to support managed charging program participation aligns with the need for community participation and empowerment in decision-making processes to support more equitable outcomes.

Regulators are often reluctant to authorize utilities to fund these activities out of the rate base. Indeed, regulators often are of the perspective that this type of program coordination, education, and outreach, is – or perhaps should be – an inherent responsibility of the utility.

Related to managed charging is the concept of interoperability. Utilities – both through their program requirements for third-party ownership incentives and through their utility-owned programs – can require open communication protocols and standards. This will help avoid stranded assets, ensure a more seamless experience for drivers and charging providers alike, and enable participation in the marketplace by third-party service providers who can add additional value to the EV charging ecosystem. Additionally, harmonizing and aligning utility program requirements for interoperability with federal standards can help avoid competing sets of standards from one utility to another, or from one state to another, thereby supporting a simpler and more consistent approach nationwide.

5.3 Equity

As noted above, equity remains an elusive outcome in electric transportation, despite significant efforts otherwise. Hsu et al.'s research (2020) reveals that even when regulatory programs require deployment in disadvantaged communities, private charging operators still aim to locate chargers in proximity to existing EV drivers, thereby increasing the likelihood of higher utilization and return on investment. This is eminently understandable, given the profit motive of for-profit companies. The impetus then falls on policymakers, regulators, and utilities to even more intentionally design programs to achieve intended results. One such implication for the deployment of publicly accessible chargers is to require siting them in closer proximity to the multi-family residences and other underserved community members the regulators intend to serve. One first step in achieving this may be to utilize more granular mapping data than census tracts, such as using census block groups instead.

SMUD – Sacramento's municipal utility – has developed a promising approach to enable this type of granular planning and community engagement. Its Community Resource Priorities Map includes multiple layers and serves as an "interactive map [to] help analyze current data to indicate the local areas most likely to be underserved or in distress." (2023)

Another approach to support equity is to incorporate more intentional ground-up inclusion and empowerment in decision-making processes by those most impacted. The Greenlining Institute, a California-based organization dedicated to advancing economic opportunity and empowerment for people of color, has developed one strategy to do this. Its Mobility Equity Framework sets forth a model to "center social equity and community power" in transportation planning. Its pyramid-shaped diagram incorporates the Framework's three broad steps: a community needs assessment, a mobility equity analysis, and community decision-making. (Creger, 2018).

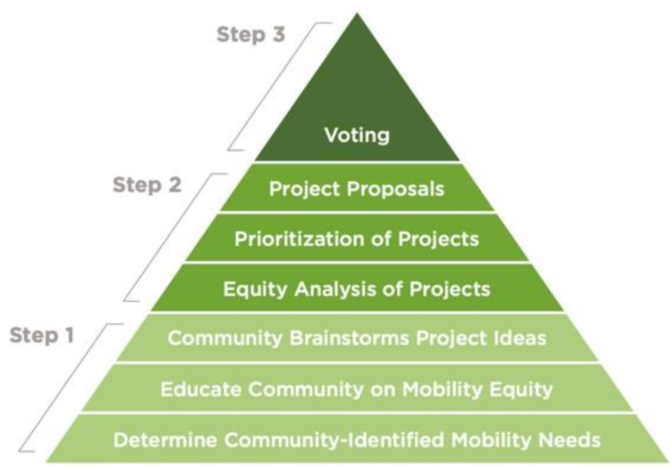

Figure 5: The Greenlining Institute's Mobility Equity Framework (Creger, et al., 2018)

6. Conclusion

Change is a defining characteristic of the EV charging sector today. Any study of the electric utility's role can only be considered within the context of a market landscape characterized by the regular emergence of new companies, technologies, and evermore ambitious clean transportation policy targets. This constantly evolving aspect of the market environment is amplified by two major federal policy developments – the Bipartisan Infrastructure Law of 2021 and the Inflation Reduction Act of 2022. These two laws are expected to incentivize tens of billions of dollars in new public and private investment over the next decade, fundamentally changing the market landscape in ways that are difficult to project.

Given this rapidly changing market environment, with billions of dollars in new funding expected, one might argue that the utility's role should be more limited. The ChargeAhead Partnership, an association comprised of EV charging operators and traditional gas stations and truck stop operators, is one such organization. It advocates for regulated utilities to be prohibited from owning and operating charging stations, instead relying on private businesses and capital. (ChargeAhead Partnership, 2023).

This perspective fails to take into consideration that, although more private dollars and companies are entering the market, the goalposts themselves are moving. It is worth noting that some of the strongest voices against utility ownership are those with a vested interest in limiting such investment, whether they are private charging companies who view utilities as competition encroaching on their market share, or because they sell traditional fuels and see electrification itself as an existential threat to their business model.

Despite this disagreement, there are many areas of common ground. Utility incentives, including ownership in certain circumstances, continue to be warranted to support deployment in disadvantaged communities and for underserved customers. Continued support for managed charging will ensure that EVs remain a positive value proposition for the grid and for its ratepayers. And lastly, intentionality, community engagement, and empowerment are imperative to support an equitable transition.

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