Exploring the Potential of a Crowdfunding Program to Achieve Equitable EV Charging Infrastructure

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INTRODUCTION

Transportation is the largest contributor to greenhouse gas (GHG) emissions in the U.S., contributing about 29 percent of total GHG emissions [1-3]. Therefore, transitioning to Electric Vehicles (EVs) can help mitigate air pollution and climate change, as well as decrease dependence on fossil fuels and promote energy independence [4,5]. To make EVs accessible to all Americans for local and long-distance trips, the U.S. government plans to make half of all new vehicles sold in 2030 zero-emissions vehicles, as well as build a network of 500,000 charging stations that are convenient and equitable [6]. With the new Infrastructure Investment and Jobs Act, $7.5 billion has been allocated to EV charging stations and alternative fueling to demonstrate government support for the conversion to EVs. However, significant obstacles still stand in the way of the widespread adoption of EVs, from their high cost to inequitable EV charging stations placement [7]. Although there has been some significant support and growth in the EV charging infrastructure development, the market for EV charging remains uncertain. For example, the top 100 U.S. metropolitan areas are expected to require more than 195,000 non-residential EV charging points by 2025, almost four times what they had at the end of 2017 [8]. A growing trend toward EV adoption will also increase this need. In addition to the increasing need for EV charging infrastructure, research raises the issue of equity. For instance, a study by Roy and Law (2022) demonstrates spatial disparities in EV charging access and recommends considering social equity alongside other criteria when developing these charging stations [9].

There is such a need for equitable infrastructure development that the White House issued Executive Order 13985 and Executive Order 2023 "Further Advancing Racial Equity and Support for Underserved Communities"[10]. The Justice40 Initiative allocates 40% of federal funding to sustainable transportation for underserved communities [11]. There are several challenges associated with building EV charging infrastructure that meets demand and ensures Justice40 compliance. While the Justice 40 initiative aims to direct 40% of federal investments towards disadvantaged communities, since EV ownership is currently concentrated in relatively wealthy areas, installing charging stations alone may not be sufficient to meet the overall demand and fulfill Justice40's goals [12-14]. Placing charging infrastructure solely in affluent neighborhoods may perpetuate existing inequities and limit access for disadvantaged communities. On the other hand, disadvantaged communities often face financial constraints, making it difficult for them to purchase and own EVs. There is therefore a need for a solution that addresses both the current need for EV charging stations and the equitable allocation of federal funding. The purpose of this paper is to propose an EV crowdfunding program aimed at addressing the challenges through meeting EV charging demand and ensuring compliance with Justice40.

In addition, while recent attention has been drawn to equity analysis in transportation projects, studies on EV charging networks development are limited. Several previous studies have examined fairness in accessibility. Access to healthcare [15], EV charging stations [16], parks, and other infrastructure is facilitated by a variety of spatial and temporal accessibility measures [17]. It is important to remember that the equity issue in the EV market consists of two components, namely

(a) the ownership of EVs and (b) the provision of EV charging infrastructure. Since EV adoption is increasing, balancing these two parts is essential. In this regard, the paper discusses how to implement EV crowdfunding program and demonstrate a hypothetical case. Finally, the paper discusses future research directions and the variations of the crowdfunding models.

LITERATURE REVIEW

EV charging station location planning

Due to the availability of newer EV models with greater driving ranges, a variety of models to choose from, more affordable options, and better public incentives, the U.S. is well positioned for increasing its EV adoption rate [18]. Increasing EV adoption calls for public access to EV charging infrastructure that supports both slow and fast charging, which requires major planning to determine locations for the network. As a result, the problem of charging station location has become a research hotspot lately. In most cases, the location determination problem is framed in terms of technical, economic, and user acceptance issues [19]. Technically, since public charging infrastructure uses energy from the grid, it is important to consider the constraints associated with power grid operation and energy storage [20]. Aside from that, since EVs have a different refueling behavior and their batteries can charge while they aren't in use for mobility purposes, it is important to select locations that are suitable for drivers, such as shopping malls, recreation facilities, public parking facilities, and other public spaces. As a result, user acceptance and their needs play a major role in the design of EV charging networks location [19, 21]. Because charging rates and costs vary, more expensive infrastructure should result in higher charging rates for users. In addition to penalizing consumers, a poor choice of EV supply equipment also penalizes operators whose return on investment is better if a charging station is tailored to local needs. Therefore, cost-time-effective location determination solutions become crucial [22, 23].

In terms of location modeling, a relatively new branch of the literature addresses location determination with flow-based demand, as opposed to classical facility location models. In this approach, due to the limited driving range of EVs, drivers who travel longer distances, usually exceeding their driving range, will have to recharge their batteries. Therefore, recharging demand can be modelled based on origin-destination (OD) of trips [24]. To solve and optimize the charging problem, a variety of heuristics, approximate, and exact methods have been used. While the literature on the technical side of location optimization is extensive, there are other decision variables that contribute to this problem such as technology choice, user demand, local regulations, incentives, operational considerations, and more importantly social equity [19, 23, 24].

Equitable infrastructure development

Engineers' diversity, equity, and inclusion (DEI) studies primarily examine the internal engineering workforce of an organization [25-27], infrastructure siting, design decisions, the impact of individual construction projects [28, 29], or the social costs associated with failures and disruptions [30]. A growing emphasis has been placed on integrating social equity into transportation planning and investment. By ensuring equal access to resources and opportunities for all, regardless of backgrounds, characteristics, or circumstances, equity can be attained. It is crucial to ensure infrastructure equity in order to eliminate social and economic disparities, promote inclusiveness, and contribute to sustainable development. Vertical equity and horizontal equity are the most commonly discussed types of equity in transportation literature. According to a horizontal perspective, equity refers to the distribution of resources and opportunities equally (or "fairly") to individuals and classes considered equally capable and needy [31]. Consequently, horizontal equity involves everyone bearing the same costs, receiving the same benefits, and having the same opportunities. Vertical equity, on the other hand, refers to the distribution of resources among people and groups with differing abilities and needs. Vertical equity eliminates inequalities between socioeconomic groups and individuals by promoting unequal distributions of resources [32].

In the context of EV charging infrastructure, an equitable distribution of public, mobile, and residential types of EV charging infrastructure has been studied [12, 16, 33]. In addition to focusing on inequity in the distribution of EV charging infrastructure, it is imperative to take into consideration the effect of access to EV charging [34]. In studies looking at the relationship between charging infrastructure distribution and socio-demographic data, it was found that population density was not associated with EV charging stations [35, 36], but was correlated with median household income [33, 35–37], age [36], white-identified population [35], and highway presence [35, 38]. While mobile charging stations have gained attention because of their flexibility for public networks, charging networks should be convenient, equitable, and affordable for users, but should also provide providers with a return on investment [39]. As a result, it is imperative to develop innovative approaches to balance the needs of charging infrastructure for EVs with the needs of social equity, such as Justice40 in the U.S.

Crowdfunding

Crowdfunding refers to the practice of raising funds from a large number of individuals or organizations through online platforms to support different types of projects. It operates on the principle of collective financing, where individuals contribute small amounts of money to collectively meet the funding needs of a project [40, 41]. The key benefit of crowdfunding in infrastructure is that it allows project sponsors to access a diverse pool of potential funders, including community members, local businesses, and other interested parties. This opens up new avenues for financing that may not be available through traditional sources such as government grants or bank loans. By tapping into the power of the crowd, project sponsors can generate a sense of ownership and engagement within the community, fostering a greater sense of support and involvement in the project's success [42].

Depending on the funding purpose and investment method, crowdfunding can be classified as donation-based, reward-based, equity-based, or lending-based [43]. Donation-based crowdfunding has been used by non-governmental organizations (NGOs) for more than a decade to raise funds for their missions and projects [44]. Entrepreneurs who are trying to raise money for a campaign often use reward-based crowd funding. Customers-oriented products and services are increasingly sold through reward-based crowdfunding. By matching lenders with borrowers through online platforms, lending-based crowdfunding provides unsecured loans. A crowdfunding platform sets the interest rate, which is typically higher than saving rates and lower than traditional loans. Through an online platform, equity-based crowdfunding allows private businesses to offer securities to the general public for sale [45, 46]. In some classifications, reward-based and donation-based crowdfunding is referred to as “community crowdfunding”, while equity-based and lender-based crowdfunding is referred to as “financial return crowdfunding” or “investment crowdfunding” [47].

In addition to its business applications, crowdfunding has also been applied to civil and infrastructure projects. For example, in light of crowdfunding's success on platforms like Kickstarter, high-tech entrepreneurs are investigating how crowdfunding can be used in civic projects, especially given government budgetary constraints. One example of a crowdfunded civic project that succeeded is The Low Line in New York City, which transformed an abandoned train station into an underground park. In 2012, it raised $150,000 on Kickstarter [48]. Crowdfunding has also been shown to enhance traditional public-private partnership (PPP) delivery models [40, 49]. A number of research studies have shown that crowdfunding can contribute to the delivery of renewable energy projects and a variety of other types of projects as well [45, 50]. As a result, it is worthy of consideration when developing EV charging infrastructure. The purpose of this study is to demonstrate how crowdfunding models and their variations can be used to address current EV charging station needs while complying with Justice40 and equity considerations.

RESEARCH METHODOLOGY

EV Crowdfunding program design

EV infrastructure crowdfunding represents an innovative and unique approach to promoting equity and inclusion in the construction of charging infrastructure (see Figure 1). In Figure 1, we can see how the crowdfunding approach differs from the traditional public-private partnership approach.

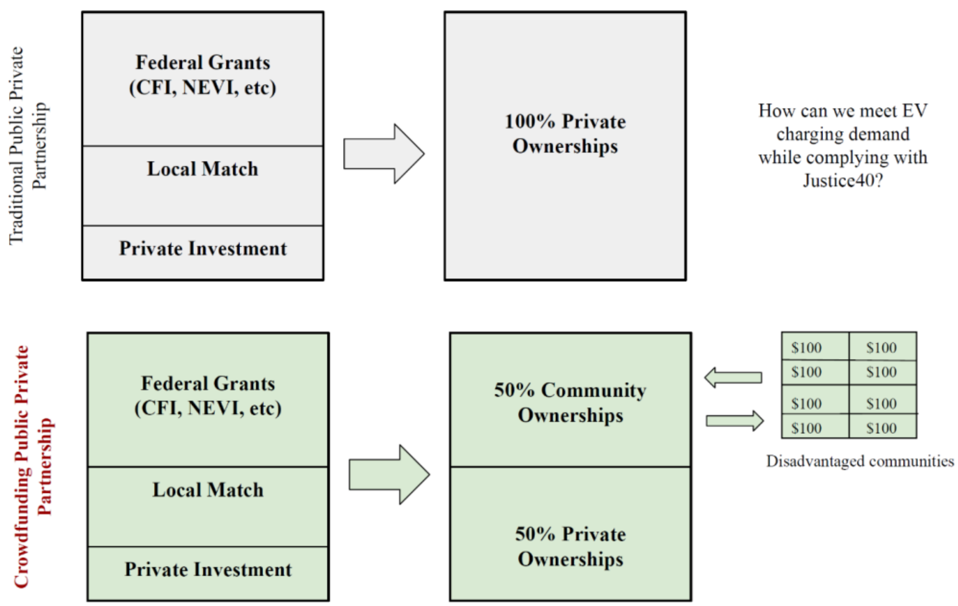

Figure 1. A Framework of the Crowdfunding for EV Infrastructure Pilot Program

Unlike typical crowdfunding in infrastructure projects, this specific crowdfunding program focuses on engaging and empowering the very communities that have been historically underserved. One distinguishing feature of this crowdfunding initiative is the offering of charging station ownership shares to community members at high discounts. By providing ownership opportunities, community members become active stakeholders in the project, aligning their interests with the success and sustainability of the EV infrastructure. This approach not only fosters a sense of ownership and pride but also ensures that the benefits of the charging stations directly flow back to the community.

Furthermore, the discounts offered on ownership shares make participation more accessible and attractive to individuals in disadvantaged communities who may have limited financial resources. This aspect of the crowdfunding initiative helps bridge the affordability gap and encourages community members to invest in clean transportation infrastructure that directly benefits their neighborhoods. By targeting disadvantaged communities, this crowdfunding program addresses the disparities in EV ownership and charging infrastructure access. It creates an avenue for community members to actively participate in the transition to electric mobility and enjoy the benefits of reduced emissions, cleaner air quality, and increased transportation equity.

The following structure is considered in order to implement the proposed EV crowdfunding program. This is a practice-oriented recommendation that includes details on the set-up and reporting of the platform. In addition, we will demonstrate the calculation of this equity based crowdfunding model on a hypothetical EV charging development project. The following steps are recommended for a successful crowdfunding program.

- **Needs Assessment and Feasibility Study:** Conduct a thorough needs assessment to identify target disadvantaged communities and assess their readiness and interest in participating in the crowdfunding pilot. Evaluate the feasibility of implementing the program, considering factors such as local regulations, available charging infrastructure, and community support.
- **Program Development:** Develop a comprehensive program framework that outlines the goals, objectives, and guidelines for the crowdfunding pilot. Define the ownership structure, including the discount rates and ownership share options to be offered to community members. Establish clear eligibility criteria and guidelines for community participation in the crowdfunding program. Design an engagement strategy to raise awareness and foster community buy-in, including outreach efforts, community meetings, and educational campaigns.
- **Platform Selection and Setup:** Identify and select a suitable crowdfunding platform that aligns with the goals and requirements of the program. Set up the crowdfunding platform, ensuring it allows for the creation of ownership shares, secure transactions, and transparent reporting. Customize the platform to incorporate program-specific features and branding.
- **Community Engagement and Promotion:** Implement an outreach campaign to inform and engage community members about the crowdfunding program. Organize community meetings, workshops, and webinars to educate participants about the benefits of EV infrastructure and ownership opportunities. Collaborate with local organizations, community leaders, and influencers to promote the crowdfunding initiative.
- **Evaluation and Selection Process:** Develop a transparent and fair evaluation process to review and select community members for ownership shares. Establish criteria for selection, such as residency, financial need, and community involvement. Ensure the selection process is well-documented, impartial, and communicated clearly to participants.
- **Implementation and Monitoring:** Facilitate the installation and operation of charging stations, utilizing the funds raised through the crowdfunding pilot. Regularly monitor and evaluate the progress and impact of the EV infrastructure in disadvantaged communities. Collect feedback from community members and stakeholders to identify areas for improvement and address any challenges.
- **Reporting and Documentation:** Maintain comprehensive records of the crowdfunding program, including financial data, ownership agreements, and community participation. Generate reports on the program's outcomes, highlighting the number of charging stations installed, community involvement, and socioeconomic benefits.

- Scaling and Expansion: Assess the success and lessons learned from the program to determine the potential for scaling up and expanding the initiative to additional communities. Seek partnerships and explore additional funding sources to support the growth and sustainability of the crowdfunding program.

Hypothetical example

The purpose of this section is to demonstrate in a hypothetical example the financing process and benefit calculations for disadvantaged communities that participate in the crowdfunding program for building EV charging networks. In this case, Montgomery County in Maryland will be used as an example. In order to encourage residents and businesses to switch to eco-friendly transportation options, Montgomery County has implemented numerous incentives, infrastructure improvements, and awareness campaigns. As part of its Climate Action Plan [51], Montgomery County has set an ambitious target of reducing carbon emissions by 80 percent by 2027 and 100 percent by 2035. As part of those reductions, the County officials are focusing on the transportation sector, which contributes 42 percent of the county's climate-changing emissions. The numbers and examples used in this section are intended to demonstrate the challenges this county faces in applying for federal funding programs like Charging and Fueling Infrastructure (CFI) discretionary grant program and working with the current trend of electric car usage and ambitious climate goals.

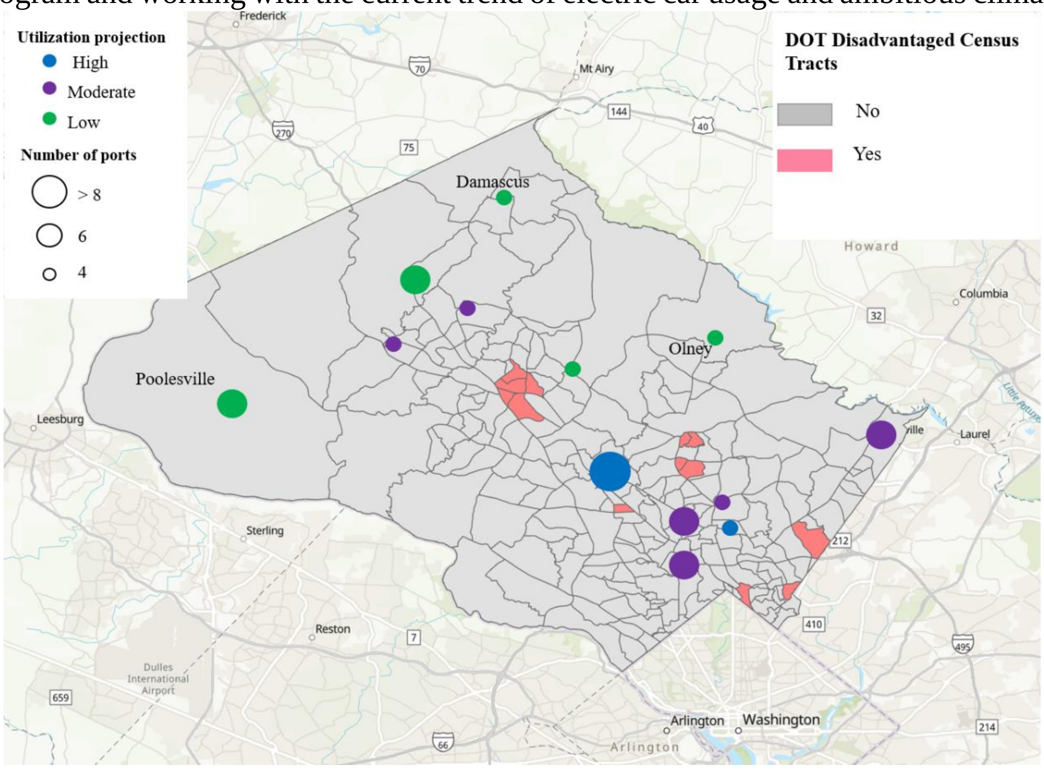

Figure 2. EV charging network locations and disadvantaged communities using ETC tool

As shown in Figure 2, EV charging network placement has been selected based on neighborhood EV registrations and projected utilization rates across the county. Additionally, the figure shows historically disadvantaged communities (HDC) according to US DOT's Equitable Transportation Community (ETC) Explorer. The ETC tool recognizes disadvantaged communities in the following five component areas: transportation insecurity, climate and disaster risk burden, environmental burden, health vulnerability, and social vulnerability. The tool examines the cumulative burden disadvantaged communities face as a result of underinvestment in transportation. Using newly available 2020 Census Tracts data, the tool adds additional indicators reflecting a lack of investment in transportation [52]. All EV network areas do not lie in HDC areas which challenge Justise40 compliance.

For the purpose of illustration, we assume that 40 Level 3 Superchargers (350kW) and 60 Level 2 chargers are installed in the highlighted areas of Figure 2. While other research estimates cost items and revenue of EV charging networks based on usage rate, energy price, and other uncertainties related to this topic [53, 54], we have included cost items and revenue projections based on average data available for EV networks for demonstration purposes. Table 1 provides details on the funds required for this project, which total $10 M.

Table 1- EV charging network cost items

Item	Cost
Level 3 Supercharges -350 kw	40 units
Labor	$1,000,000
Material	$1,000,000
Permit & tax	$20,000
Land	$1,000,000
Level 2 Chargers	60 units
Cost per charger- $5,000	$300,000
Traffic Management	$2,000,000
Design and Construction	$800,000
Public Engagement	$1,000,000
Operation for 5-yr	$2,500,000
Contingency	$380,000
Total	**$10,000,000**

Although the estimates are only for demonstration in this hypothetical example, we have included reasonable estimates. Cost items include the installation of type 3 and type 2 chargers as well as other indirect costs related to the entire project, including design, traffic management, public engagement, and operation. A 10-year lifecycle calculation is used for chargers, and the CFI grant program covers five years of operation costs. In order to implement the EV crowdfunding program and calculate further benefits, the following financing structure is considered. The CFI program requires a minimum 20% matching fund for the project, so the county is considering receiving $8 M from the federal government out of 10 million dollars. The remaining $2 M is composed of $1.5 M from private investors and 500,000$ for HDC ownership on crowdfunding program. For selected HDC communities to participate in the crowdfunding program, 5000 shares with high discount rates are proposed at a $100 price. In the proposed crowdfunding program, a process will be created to review and select community members who apply to own shares, with a maximum limit on the number of shares that can be purchased by a single individual. An equity structure is proposed for the crowdfunding program that would give 50% ownership to the operator and 50% to HDC communities (Figure 1). Accordingly, 50% of net project revenue (after any expenditures on operations and maintenance) will go to the operator and 50% to the owners through the crowdfunding program. Table 2 demonstrate the return on investment according to project revenue and equity structure. In the first five years of the lifecycle of the project, assuming that operating costs are covered by the CFI program, the HDC community will receive $72 per share per year. For the remainder of the project lifecycle, each crowdfunding program share will produce $22 per share annually.

Table 2- Return on investment

	Year 1 to 5	Year 6 to 10
Revenue of level 3 charges	$360,000	$360,000
Revenue of level 2 charges	$360,000	$360,000
Total Revenue	$720,000	$720,000
Operation Cost	-	$500,000
Operating Profit	$720,000	$220,000
Dividend to Operator	$360,000	$110,000
Dividend to Crowdfunding	$350,000	$110,000
Return per share	**$72**	**$22**

From the perspective of the HDC community, investment cashflow includes a $100 payment in Year 0, $72 received each year over the first five years of operations, and $22 each year in the subsequent five years. An analysis of this investment shows an internal rate of return (IRR) of 68%, making it an attractive investment for HDC. Although we only include direct revenue resulting from electricity charges in our financial analysis in Table 2, other benefits can be included in a benefit-cost analysis, such as a reduction in carbon dioxide emissions, climate change benefits, and energy security benefits. Furthermore, as EV cars become increasingly popular and in demand for EV charging increases in the future, the revenue is expected to increase over the entire project lifecycle; however, we considered a level revenue stream for our demonstration.

DISCUSSION: CROWDFUNDING PROGRAM VARIATIONS

Many federal funding programs allocate a significant portion of their resources to projects that benefit disadvantaged and underserved communities. Setting criteria that prioritize projects in low-income and historically marginalized areas, such as the ETC Explorer and Climate and Economic Justice Screening (CEJST) Tool, can help direct funding where it is most needed. When it comes to projects like EV charging infrastructure, where demand may be concentrated in wealthier areas, it can indeed be challenging to ensure compliance by providing 40% of benefits to disadvantaged communities. Crowdfunding can be an effective strategy to promote equity and ensure Justice40 goals are met by providing benefits to disadvantaged communities who own the EV charging network, rather than the vehicles. The model emphasizes empowering communities through direct involvement in the charging infrastructure, which fosters a sense of ownership and control over one of the most important elements of sustainable transportation. Despite the fact that this study focused on introducing equity-based crowdfunding to make ownership shares more financially accessible for community members with limited resources to get involved, there may be other variations and strategies to address this issue as well.

Rather than offering shares to individuals, a crowdfunding program could offer community shares, which provide participants in the community investment with non-monetary benefits, instead of financial returns. A number of benefits could be offered, such as priority access to the charging infrastructure, discounts on charging rates, or other incentives that encourage community involvement. Individuals who participate in crowdfunding programs may be offered additional incentives, such as discounts on EV purchases or lease options, to encourage them to adopt EVs in underserved communities.

A synergy can be created between the ownership of EVs and ownership of charging infrastructure. This could be expanded to a rebate program for HDC communities. To promote the adoption of EVs while addressing social and economic disparities, rebates can be offered to disadvantaged communities to help them purchase EVs. There is room to add a donation matching program for HDC communities, which will increase partnership and benefits. Corporations and foundations can partner with community organizations to establish donor-matching programs. By matching every dollar raised through crowdfunding, a partner organization effectively doubles the amount available for the development of EV charging infrastructure.

Finally, EV charging infrastructure projects can be financed with green bonds to attract socially responsible investors. Funds raised from the bond issuance can be used to build and operate charging stations in underserved areas. The advantages of each of these variations can be tailored to meet the specific needs and goals of each community and region. We can maximize community engagement, foster social equity, and accelerate the transition to a sustainable mobility future by exploring and implementing innovative crowdfunding models for EV charging infrastructure.

CONCLUSION

EVs are crucial to combating climate change, reducing greenhouse gas emissions, improving air quality, and achieving a sustainable and environmentally responsible transportation system. In prior studies, it was found that the current distribution of EV charging stations is not equitably distributed across the country, since EV charging stations were not correlated with population density, but rather with median household income, age, and racial background. Further, the current concentration of EV owners in wealthy areas makes it difficult for federal money to support grant programs that develop EV charging networks due to Justice40 constraints. In accordance with Justice40, at least 40% of investment benefits must go to HDC communities. Yet, members of HDC communities that do not own an EV might not benefit from the network if it is only located in their neighborhood. Therefore, to address current demands for EV charging networks and to comply with Justise40, this article proposes an EV crowdfunding program. Through this crowdfunding program, disadvantaged communities can invest in the development of EV charging stations. By offering discounted ownership shares to community members with limited resources, it becomes more financially accessible. In this way, they become active stakeholders in the project and benefit from the charging network financially or otherwise.

A hypothetical example of a crowdfunding program in Montgomery County, Maryland was used to demonstrate the program structure and benefit calculations. In spite of the fact that our findings are limited to our assumptions and revenue calculations, we demonstrate the potential of this crowdfunding program to attract the HDC community to participate and benefit. It is necessary to conduct further research and other efforts in order to develop detailed program setups, community detection techniques, outreach programs, and to implement this crowdfunding program in practice. We have also discussed the potential for innovative approaches such as rebates and donor-matching to improve this crowdfunding program. Further research is needed to explore these methods' effectiveness and attractiveness.

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