Charge: A Peer-to-Peer, Decentralized Network for Electric Vehicle Charging

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Abstract. It's 2035. All car sales made by major brands are for electric vehicles (EVs). All major cities in developed countries have banned petrol and diesel cars, and the trend is showing no signs of slowing down globally. Streets are quieter. The air is cleaner. And it's never been easier to get from A to B. The catalyst? Permissionless, digital charging infrastructure that allows any EV to charge at any charging station with speed and ease, and at a fraction of what it once cost. Range anxiety - the fear of not finding a charging station and running out of charge - is resigned to the mobility history books.

Charging stations are everywhere. Petrol stations are nowhere. Virtually every parking spot, whether owned by the government, a business or your average Joe, is equipped with a charger. People and organizations are freely supplying one another with low cost charge, which is becoming greener and greener by the day. What's more; people are earning a passive income stream by offering charge to other people, having a positive impact on the climate in the process. And they're doing so directly, on a peer-to-peer basis, with no Big Tech firms in the middle to hoover up fees and data.

2035 is green. 2035 is free. 2035 starts now.

1. Introduction

In 2020, the number of EVs grew to almost 11 million globally, an increase of 3 million on the previous year. China hit pole position with 5 million EVs, followed by the USA with 1.77 million and Germany has just over half a million.[1] By 2030, these numbers are expected to skyrocket to 145 million globally.[2] You might not be able to hear it, but the pedal is well and truly on the metal. Are we prepared? Not at all.

Anyone traveling from Berlin to Munich in an EV today has range anxiety, the fear that they won't find a charging station and will subsequently run out of charge. This fear doesn't just come down to a lack of charging stations. There are hundreds of different providers of charging cards and charging contracts in Europe alone. There are also hundreds of different operators of public charging stations. Half a dozen so-called 'roaming providers' try to enable charging cards to work with as many charging points as possible. There is a patchwork of competing and collaborating entities trying to balance profitability with delivering on their core service offering; charging cars. The result is that even though huge investments in new charging stations have and are being made, EV owners still suffer from range anxiety.

This fragmented charging landscape also keeps potential EV drivers out of the market because of how confusing and inefficient the charging process is. Anyone who wants to charge their EV has to use one of a plethora of different charge point providers which all have their own customer database and varying payment methods. What this essentially means is that an EV owner needs to go through the same laborious registration process over and over again whenever they switch providers. This leads to a situation in which users must have multiple data-rich accounts, apps and charging cards - not to mention a lot of time and patience.

What if we didn't have to only rely on a few large corporations to transition the world to e-mobility? What if we could solve the fragmented charging infrastructure issue while enabling anyone, anywhere to contribute and have a tangible impact? And what if we could all earn money by making the world a better place? This is Charge's proposition, in a nutshell.

Charge is the culmination of years of research and development with the leading players and stakeholders in the European EV charging industry. The problems addressed in this paper were highlighted by industry leaders as early as 2018, as was the initial idea to use blockchain technology to address these problems. The ultimate solution, described in limited depth in this paper, is the result of three years of research and development, proof of concepts, consultations and raw trial and error.

2. Charge

Charge's goal is to make EV charging more accessible. The biggest barriers to this right now are the fragmented state of publicly accessible charging infrastructure and that private charging stations are not publicly accessible. Charge aims to solve the fragmentation issue while also making private charging stations available to the public, without having to rely on expensive, centralized platform providers.

[1] Tagesschau, 2021
[2] IEA Global Electric Vehicle Outlook, 2021

Charge allows anyone, anywhere to offer charge to any electric vehicle user - without needing to rely on corporate intermediaries or trusted third parties. But this isn't just about making the existing public and corporate infrastructure more efficient. This is a grassroots movement, and to this end, Charge is enabling private individuals to offer the already existing 6.5 million private charging stations to the public without having to sign up with an expensive centralized platform provider. This is a community owned and Decentralized Autonomous Organization (DAO) governed project. This is the people saying they've had enough of fossil fuels destroying the planet they love, and taking an active role in the transition to a more sustainable future.

Charge is a DAO operating a decentralized application (dApp) running on a decentralized network, peaq. Charge provides a neutral backbone for authentication and payment between charging stations and EVs to enable the trade of energy for e-mobility in a peer-to-peer manner. Charge leverages Self-Sovereign Machine Identities (SSMIs)[3] for peer-to-peer identification and authentication, and digital currency for peer-to-peer payments and settlement. All business logic is executed in a decentralized and fully automated manner using smart contracts. Charge uses democratic voting mechanisms for decentralized governance.

In the next sections we will explore how centralized systems cause major problems for EV charging, and how Charge's decentralized approach fixes them.

3. Fragmentation

Status Quo | Today's charging infrastructure is highly fragmented due to the large number of centralized charging platforms in the market. These platforms are silos, operated by different companies. Users need to sign up with multiple platforms in order to access the full selection of charging stations. This is due to each platform requiring its own user identity and payment method for authentication and payment purposes. This fragmentation leads to users only having access to a fraction of the available public charging infrastructure and this leads to range anxiety - the fear of not finding a charging station and running out of charge. This is one of the biggest problems in the e-mobility space as it isn't just a worry for existing EV drivers, but keeps a huge number of potential EV drivers driving petrol-powered vehicles instead. In order to have access to the majority of public charging stations, a user needs to administrate a dozen or so charging accounts and cards, leading to a large adoption barrier. A few roaming providers try to solve this problem by trying to aggregate different charging providers. However, this aggregation involves building an additional layer on top rather than solving the issue at the root level and has led to a more costly charging process.

[3] peaq, 2022

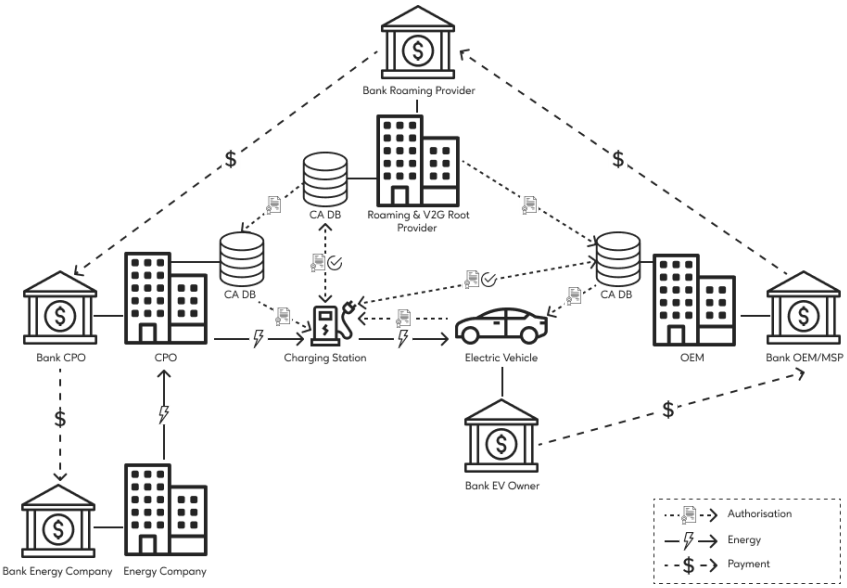

Figure 1. (Leonard Dorlöchter 2021) captures the current, centralized charging process.

Charge | Charge is solving the fragmentation issue. Charge enables individuals and organizations to register charging stations and EVs on a permissionless platform using Self-Sovereign Machine Identities (SSMIs), and equip them with a payment method. Every charging station, EV and user existing on the platform can identify and access charging stations with a single account and payment method. Authentication and payment for a charging session takes place instantly and in a peer-to-peer manner. By providing an open, neutral register for all charging ecosystem participants the Charge dApp is solving the issues of charging infrastructure fragmentation and range anxiety among EV drivers.

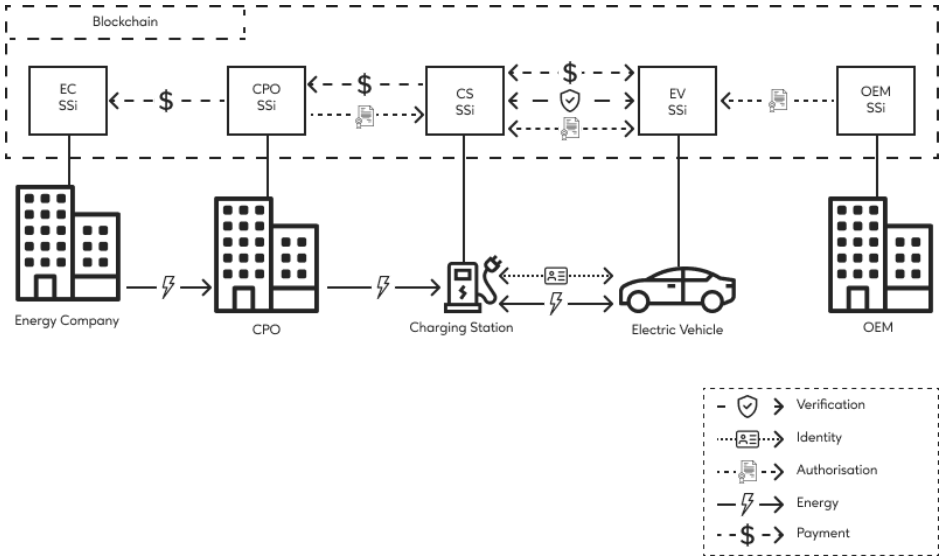

Figure 2. (Leonard Dorlöchter 2021) captures the charging process with Charge.

4. Accessibility

Status Quo | In 2019, China, UK, Norway, Japan, Germany, Netherlands, USA, France and others had 862K publicly accessible charging stations between them, but had 6.5M private charging stations.[4] Only 13.2% of charging stations were publicly accessible. The majority of charging stations are still not publicly accessible. As of today, only so-called public charging stations, meaning charging stations that are publicly accessible like traditional gas stations, are accessible to EV users. Semi-public charging stations and private charging stations are barely listed on centralized charging platforms. Owners of semi-public and private charging stations that want to make them available to others can do so only via centralized charging platforms, where they must pay fees to the middlemen involved.

Charge | Charge enables private and semi-public charging stations to become fully publicly accessible. This is accomplished by allowing owners of charging stations to register and list them on the open, permissionless Charge dApp. Vehicles will be able to leverage SSMIs to authenticate and verify themselves, and not have to pay fees to any centralized middlemen. Furthermore, payment and settlement can be conducted without any trusted third parties involved.

5. Costs

Status Quo | Traditional finance firms involved in the settlement of charging sessions increase the costs for users significantly. Today's settlement of a charging payment involves many middlemen. In order to settle costs between the different stakeholders such as Users, Mobility Service Providers and Charge Point Operators, many manual invoices and bank transfers take place. The entire settlement process can take up to 4 weeks. Roaming platforms, also called clearing houses, also take a cut to conduct the settlement between stakeholders.

Charge | On Charge, settlements are instant. All stakeholders receive their share directly and the process is fully automated using smart contracts. By removing manual processes, legacy financial systems and middlemen from the settlement process, it is estimated that around 40% in ecosystem reconciliation costs can be saved. This decreases the cost of conducting a charging session for all stakeholders in the charging ecosystem, of which the most important are EV users. These cost savings can further accelerate the transition to a more sustainable world.

6. Governance

Status Quo | Today’s charging infrastructure has limited, if any, democratic governance. It consists of individual centralized charging platforms which are owned and governed by a variety of centralized organizations. Investment decisions regarding the development of charging infrastructure are decided on in a centralized manner. Technical standardization processes are performed by centralized standardization organizations and rolled out by the centralized charging platforms individually, leading to long and complicated industry wide implementation cycles.

[4] IEA Global EV Outlook, 2020

Charge | Charge is set up as a DAO to enable decentralized governance by all stakeholders of the charging industry. A DAO is a decentralized organization constructed by transparent rules encoded as smart contracts on the blockchain which are controlled by the DAO's members collectively. It enables stakeholders to vote democratically and transparently on proposals. These proposals can range from investment decisions to standardization decisions which can result in core protocol changes. This is made possible without the centralized influence of any one individual or organization by smart contracts to execute the decisions in an automated fashion based on stakeholder votes.

7. Stakeholders

Electric Vehicle (EV) Owners	
Status Quo	**With Charge**
● Have range anxiety; they're worried they will run out of charge since they can only charge at a handful of charging stations. ● Need to sign up with several centralized charging platforms and payment methods to charge at different charging stations.	● Charge ends range anxiety; anyone can charge seamlessly at any charging station. ● Only one account and payment method are needed to charge anywhere. ● Rewards can be earned for using a decentralized system, allowing EV owners to pay even less overall.

Private Charging Station Owners	
Status Quo	**With Charge**
● There's no cost-efficient, time-efficient way to offer private charging stations to the public. ● Deterrents, not incentives, exist to the prospect of offering private charging stations publicly.	● Private charging station owners are able to offer their charging stations to the public without any recurring cost. ● New income streams can be created by offering charge to EV users. ● Charging stations are subsidized when purchased on Charge. ● Additional rewards can be earned for using Charge.

Charge Point Operators (CPOs)	
Status Quo	**With Charge**
● CPOs have to rely on centralized roaming platforms to make their charging stations accessible to large user bases. ● They have high Capital expenditure (CAPEX) when installing new charging stations and too little traffic on them. ● They have high settlement costs due to manual and third party settlement for each Mobility Service Provider they cooperate with.	● CPOs can connect to large user bases without using a centralized roaming platform and generate more traffic to their stations. ● Save around 40% in settlement costs by making settlements automated and direct. ● CPOs can create additional income streams from Charge's economic incentive mechanisms.

E-Mobility Service Providers (EMSPs)	
Status Quo	**With Charge**
● EMSPs currently rely on centralized roaming platforms to provide their users with more charging stations. ● They have high settlement costs because of manual and third party settlements for each Charge Point Operator they cooperate with.	● EMSPs can connect to large charging station bases without using a centralized roaming platform, giving their users more options. ● Save around 40% in settlement costs through automated and direct settlement. ● They can offer custom loyalty programs and have a stake in their customers' user journey.

Electric Vehicle Manufacturers (OEMs)	
Status Quo	**With Charge**
● OEM customers suffer from range anxiety due to the fragmented charging infrastructure. This slows adoption of EVs and is the biggest barrier in the way of OEMs reaching their sales targets.	● Charge ends range anxiety for customers by solving range anxiety for EV owners and users, taking down the biggest barrier to EV sales growth for OEMs.

Charging Station Manufacturers	
Status Quo	**With Charge**
● Charging Station Manufacturers are waging price wars with other charging station manufacturers, pitching limited differentiation and therefore limited opportunity to stand out from competitors.	● Charging Station Manufacturers can increase their sales by selling Charge-ready charging stations to the community. ● They can increase the value of their charging stations by providing their customers better monetization opportunities. ● They can participate in the Charge incentive mechanisms and earn from the charging ecosystem as a whole.

Investors	
Status Quo	**With Charge**
● Can only invest in individual businesses in the charging ecosystem but not in the charging ecosystem as a whole.	● Can earn from the entire charging ecosystem and generate instant liquid returns. ● Can actively contribute to the growth of the ecosystem by subsidizing the purchase of charging stations and increase their returns.

8. Conclusion

In this paper we looked at how centralized, closed systems cause major problems for EV charging infrastructure and all the stakeholders in the EV charging ecosystem. By creating a decentralized and permissionless backbone for the entire charging ecosystem, Charge solves the issues of fragmentation, increases the number of charging stations accessible to electric vehicle users, lowers the costs for everyone involved and provides an open, democratic governance system for the charging ecosystem.

The result is a solution to a problem with a solution. E-mobility is a solution to the vital, global spectre of climate change, but for all its positive intentions, e-mobility has so far been stunted by legacy systems. It is a perfect example of new, well-intentioned technology being held in its tracks by traditional approaches, traditional technology, traditional political systems and traditional ways of doing business.

Charge goes beyond these anachronisms and proposes a solution which has the potential to free up and democratize EV charging infrastructure, globally. Charge is a peer-to-peer, grassroots movement. Charge is telling everyone, everywhere, that you can contribute to net zero, that you can do something for your planet, if you want to. You don't need to buy an EV to help transition mobility from fossil fuels to e-mobility. Purchase a charger and you can plug into the global Charge network and help speed up the transition to e-mobility. What's more - you'll be paid for making an impact. This is one of those rare win-win-win scenarios. This is an opportunity for global, positive change, by providing global, permissionless charge. Join us.

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