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ELECTRIC VEHICLE GRID INTEGRATION

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INTRODUCTION

The Mobility Open Blockchain Initiative Electric Vehicle Grid Integration Working Group is a global, multi-stakeholder project working to co-design blockchain and distributed ledger technologies standards for connected mobility ecosystems. The project engages stakeholders across OEMs and other mobility industry players, technology solution providers, and both governmental and non-governmental entities. This report is based on numerous discussions, workshops, and research. Opinions expressed herein do not necessarily reflect the views of individual members.

Sincere thanks are extended to those who contributed their unique insights to this report.

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Executive Summary

MOBI's EVGI Standard creates system specs and schemas for Vehicle to Grid (V2G) Integration, Tokenized Carbon Credits (TCC), and Peer to Peer (P2P) energy trading.

The Electric Vehicle Grid Integration (EVGI) Working Group released its first technical specification in Q3, 2020 focused on three core use case areas: Vehicle to Grid Integration (V2G), Tokenized Carbon Credits (TCC), and Peer to Peer (P2P) energy trading applications. The EVGI Standard focuses on creating system specifications and standard data schemas required for applications in each of the above categories. The EVGI Standard is not meant to prescribe one particular application, rather, it ensures that all of the pertinent data attributes and functionalities of each use case are available for organizations to utilize in creating their own applications. In other words, the EVGI Standard is not prescriptive, rather providing a base foundation for a wide range of use cases to be built on top.

Use cases span the energy and mobility value chains and require cross industry collaboration.

The EVGI Working Group's first activity was to collate and evaluate all of the use cases of interest that the Standard was to cover. Those use cases are quite varied, and involve stakeholders of all sizes - drivers, homeowners, businesses, OEMs, utilities, and many others are impacted by the systems and solutions considered by the EVGI Working Group. The diversity of the stakeholders highlights why cross-industry collaboration efforts, like MOBI, are critical for the growth of e-Mobility applications.

This business review document begins with an overview of the current state of affairs with regards to powering electric vehicles, the growth of decentralized renewable energy production, and carbon credit generation/trading. Then, the paper discusses and analyzes a selection of use cases that the Working Group considered in developing the Standard. The analysis is broken down based on each use case's expected time to market, with a short, medium, and long term outlook. Ultimately, this document explains the use cases that the EVGI Working Group focused on and evaluates the expected value they provide; operational efficiencies gained, new revenue opportunities created, and exciting new capabilities and services provided.

Electric Vehicles

It is abundantly clear that auto manufacturers will continue to push their production of electric vehicles, especially battery operated ones.

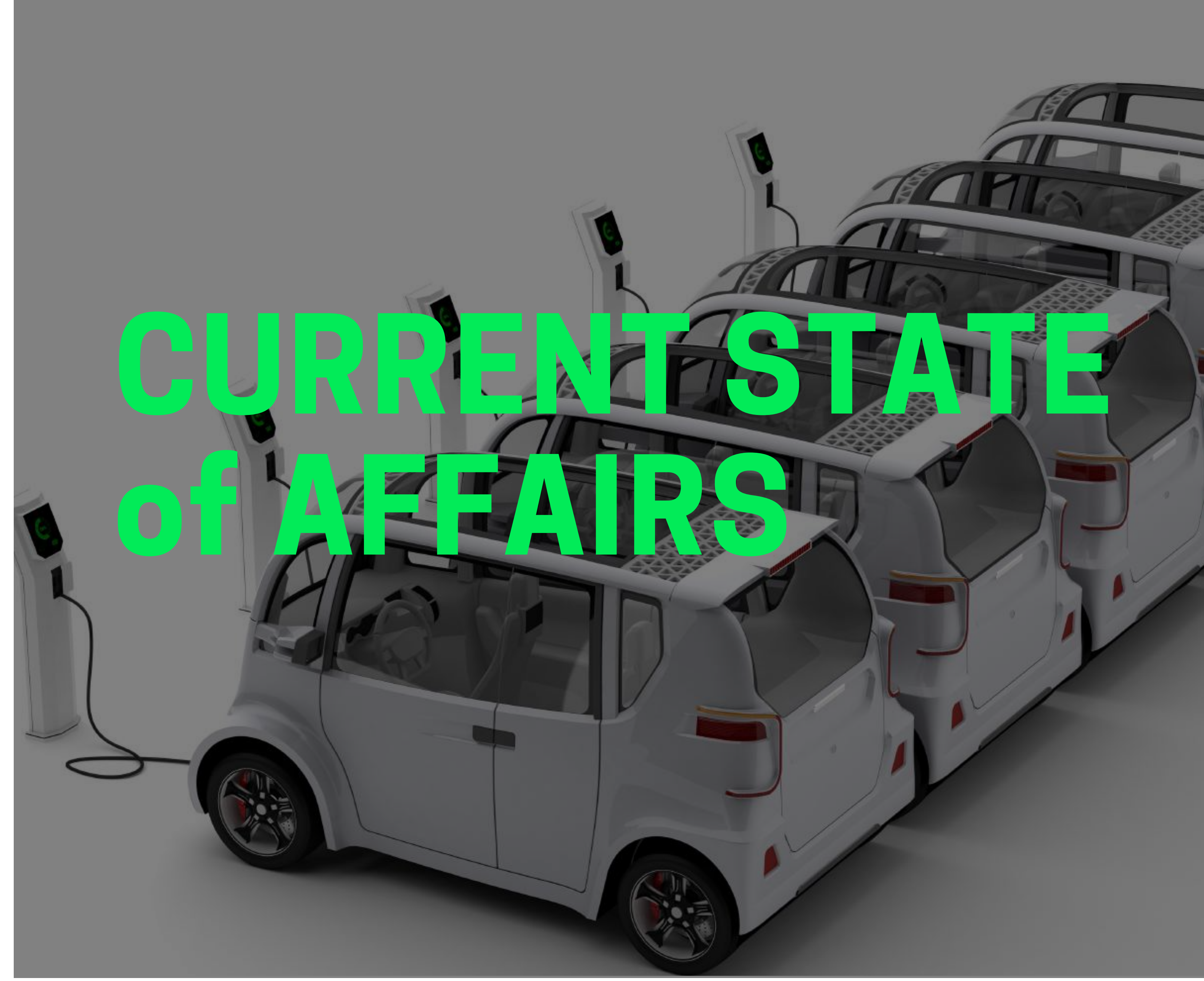
Globally, hybrid and electric vehicles' market share has seen sharp increases over the last thirty years. There are a variety of factors that caused this trend. The looming threat of climate change has prompted strong efforts from both the public and private sectors. In many countries, governments have introduced legislation to provide tax credits, deductions, and exemptions to both consumers and manufacturers of electric vehicles. Further, governments have mandated production of EVs and in some cases committed to fully electric fleets in the next decades.[1] The automotive industry responded in kind, with major automakers strongly ramping up electric vehicle production. Indeed, many governments and automakers have committed to making their entire vehicle offering have an electric or hybrid option, or even moving to an entirely electric fleet. The growth of electric vehicle adoption is very rapid today - US market share in plug-in electric vehicles, for example, nearly doubled between 2017 and 2018 and overall grew 1500% between 2011 and 2018.[2] This trend is projected to continue, with an estimated 27 million electric vehicles on the road globally by 2030, with a CAGR of 21.1%.[3] However, issues like range anxiety and charging availability persist, and if left unaddressed, will strongly hinder that growth.

1. Elijah Shamah, "Colorado Joins California in Requiring Automakers to Sell More Electric Cars," CNBC, August 26,2019, https://www.cnbc.com/2019/08/26/colorado-joins-california-in-requiring-automakers-to-sell-more-evs.html; Michael Coen, "Nine Countries Say They'll Ban Internal Combustion Engines. So far, It's Just Words," Quartz, August 7, 2018, https://qz.com/1341155/nine-countries-say-they-will-ban-internal-combustion-engines-none-have-a-law-to-do-so/

2. "FOTW #1136, June 1, 2020: Plug-in Vehicle Sales Accounted for about 2% of all Light-Duty Vehicle Sales in the United States in 2019," Office of Energy Efficiency and Renewable Energy, accessed January 06, 2021, https://www.energy.gov/eere/vehicles/articles/fotw-1136-june-1-2020-plug-vehicle-sales-accounted-about-2-all-light-duty.

3. "Electric Vehicle Market by Vehicle (Passenger Cars & Commercial Vehicles), Vehicle Class (Mid-priced & Luxury), Propulsion (BEV, PHEV & FCEV), EV Sales (OEMs/Models) Charging Station (Normal & Super) & Region - Global Forecast to 2030," Markets and Markets, accessed June 16, 2020, https://www.marketsandmarkets.com/Market-Reports/electric-vehicle-market-209371461.html.

CURRENT STATE of AFFAIRS



Large numbers of electric vehicles in the market means our electrical grid must provide an additional power source to charge those vehicles.

As the use of electric vehicles continues to scale, the electric grid must bear a greater overall load, as well as heavier load fluctuations over time. While the grid's overall capacity is able to shoulder the burden, electric vehicles see much greater use in cities as opposed to rural areas. Within cities, suburban areas will have a much higher concentration of households using electric vehicles as opposed to more urban neighborhoods. All of those electric vehicles follow a similar charging schedule - unplugging to drive to work, and plugging back in when they return home.

Current State of Affairs

Prosumers and P2P Electricity Trading

Due to steady reduction in clean energy costs over the years, small scale prosumers are rapidly increasing. However, they are unable to "sell" their excess production during peak times.

Clean energy production has similarly increased as new energy production technologies achieve greater efficiencies. Solar energy production has boomed, particularly in "small scale" uses like on homes or commercial buildings. Additionally, the ability to generate electricity locally turns consumers into "prosumers", who both consume and produce electricity. Households and businesses are increasingly powering themselves, even to the point of producing excess electricity. During peak production times, these prosumers can produce more electricity than they consume. If consumers have charging infrastructure, then they can sell their excess energy (whether self-produced or not) to EV users by allowing them to charge with their chargers. However, smaller-scale prosumers struggle to charge reasonable prices for their electricity, and their prices are far less than what is charged by large electricity suppliers or large prosumers.

Peer to peer "electricity sharing" systems have the potential to reduce unused electricity generated by the prosumers and also sell them at market price.

P2P systems that can match supply and demand in real time are key to improving this picture[4] — smaller prosumers can access demand for their electricity without bearing the transaction fees of the wholesale market or being forced to negotiate individual PPAs with each buyer. Implementation of these P2P systems would allow natural market forces to drive up the price of renewably generated electricity from small-scale prosumers; higher prices mean a better return on investment for everyday homeowners and bigger incentives for even more households to become energy prosumers. Although it was the growth of prosumer households that spurned development and research for these P2P systems, all households can benefit from their existence. In the case of non-prosumers, allowing P2P charging can reduce costs of infrastructure in the short term and enable new revenue opportunities in the long term.

Carbon Credits

Existing mechanisms for generating, auditing, tracking, and trading carbon credits are inefficient, fragmented, illiquid and prone to fraud.

A variety of instruments exist to reflect the generation of clean energy or reduction of carbon intensity in transportation fuels in the form of tradable certificates. These can take many forms depending on jurisdictions and government requirements. Governments award credits to green-energy-producing companies scaled to the amount of clean energy they produce. Carbon producers are required to procure a minimum number of credits at the end of each year in order to offset their carbon production. Credits are banked and traded widely. However, the marketplace for these credits has strong barriers to entry for small-scale producers - transactions are bilateral and require a large volume of credits per transaction. Without established trading relationships and facilities to generate huge credit volumes, these smaller-scale producers are effectively boxed out of the market. Additionally, the procedure for claiming carbon credits can be onerous and require many manual processes. Auditing carbon credit generation is, therefore, cumbersome, expensive, and often requires third parties, which can be very costly. Carbon credits markets are often very distributed and localized, resulting in liquidity deficiencies. Finally, the information required to register carbon credits is often held by different organizations in disjointed data silos. This increases costs from redundant data collection as well as increases the time required to register.

4. Stephen Hall and Katy Roelich, "Business Model Innovation in Electricity Supply Markets," Energy Policy 92, (March 2016): 286-298, https://doi.org/10.1016/j.enpol.2016.02.019.

WHY BLOCKCHAIN?

Multiple stakeholders are involved in planning and operations of electric vehicle charging facilities. Hence, the data they need also vary, which mostly remains in silos.

As more and more electric vehicles drive on roadways, key stakeholders in the EVGI space (OEMs, utilities, charging equipment providers, etc.) are transacting with each other and grappling with increasing quantities of data as part of these transactions. Charging session events can generate data that capture a rich variety of information - the amount of electricity charged, duration of charge, location, trouble codes in case of equipment failure, and much more. Different stakeholders in the charging session capture different types of data - OEMs only capture data from the vehicles, while utilities only capture data from the grid or their charging stations. Similarly, different stakeholders seek different insights as they relate to their own business' needs. Utilities may be interested in evaluating the average time of day that charging sessions occur in order to best prepare for demand peaks. OEMs may be more interested in measurements of the impact of different charging schedules and usage factors on battery health. Transportation authorities may seek robust geographic maps of electricity demand from EVs in order to determine the best locations for new charging stations. More examples of such stakeholders are provided in Figure 1.

Blockchain allows stakeholders with a tamper-evident ledger to record and share mutually beneficial information.

In order to produce the best insights and accomplish business needs, these players need to be able to access data from each other's silos. These stakeholders can certainly capture value from their own data by extracting pertinent insights, but there is much more opportunity left untapped. When taken together, data captured by each stakeholder can provide much more context on a larger scale. The EVGI Standard provides the necessary framework to deploy core services such as identity, security, or assurance that combine to allow for that information to be collected and made available in an interoperable manner. The standard provides all stakeholders with secure avenues to access more data, allowing them to better understand their equipment, customers, and more. Additionally, the ability to easily and securely share data is critical for monetization of that data - buying or selling data access requires robust access controls for proper security. Blockchain provides a secure avenue for these stakeholders to immutably record and securely expose their collected information to other stakeholders.

Blockchain also provides better security and authentication than traditional PKI and centralized certificates.

Furthermore, to enable cybersecurity and authentication in charging infrastructure, often a Public Key Infrastructure (PKI) is necessary, like the recently announced SAE EV Charging Public Key Infrastructure (PKI) project.[5] Blockchain-based identity management represents a serious alternative to these conventional, often costly PKIs with their centralized certificate authorities (CA). Singla et al.[6] compared blockchain-based approaches with CA-based PKI and concluded that blockchain-based IDs can provide a more robust and better scalable alternative.

5. "SAE International to Launch Industry Driven SAE EV Charging Public Key Infrastructure Project," Alt Energy Mag, May 14, 2020, https://www.altenergymag.com/news/2020/05/14/sae-international-to-launch-industry-driven-sae-ev-charging-public-key-infrastructure-project/33118/.

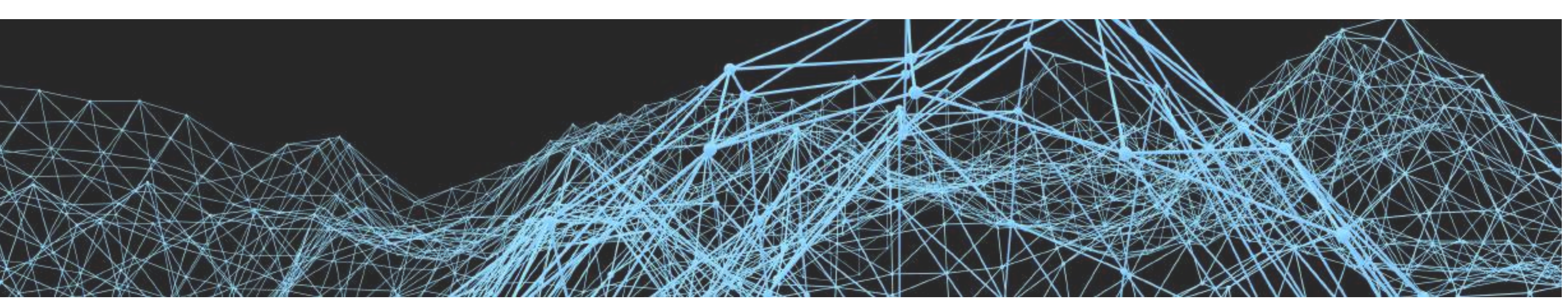
6. Ankush Singla and Elisa Bertino, "Blockchain-Based PKI Solutions for IoT," 2018 IEEE 4th International Conference on Collaboration and Internet Computing (CIC), (2018): 9-15, https://ieeexplore.ieee.org/document/8537812.

Blockchain may allow the stakeholders to share battery life cycle data with other parties and contribute to its re-use of components and minerals.

Transparency of data in an e-mobility ecosystem is also an enabler for a circular economy; a major trend and especially important for the automotive industry, with its complex value chains. Everything produced in future circular economies is optimized for maximum reuse, especially those resources of a scarce, or conflicting nature. Batteries typically contain such resources (for example, cobalt, manganese, etc.) hence their reuse after a “first life” in an EV is highly desired. In order to determine a suitable 2nd or 3rd life use of a battery, it is important to provide as much data as possible on a battery’s condition (e.g., number of passed charging cycles). Blockchain may allow stakeholders to securely share battery data with other parties and enable tracking of battery health across its lifecycle, which directly contributes to its circular (re)use.

MOBI’s EVGI Standard provides a secure framework for identity, data exchange, and access rights.

The remainder of the document focuses on explaining what use cases are covered by the EVGI Standard and why their implementation provides value. With all of the use cases discussed below, blockchain is ultimately providing secure, decentralized systems for identity, data ingestion, and management, and access rights. The sections below go into greater depth use cases in the V2G, P2P, and TCC categories, broken down by the feasibility of their deployment within short (0-5 years), medium (5-10 years) and long (10+ years) time horizons. The graphics below in Figure 2 summarize those use cases, as well as provide examples of key EVGI stakeholders.



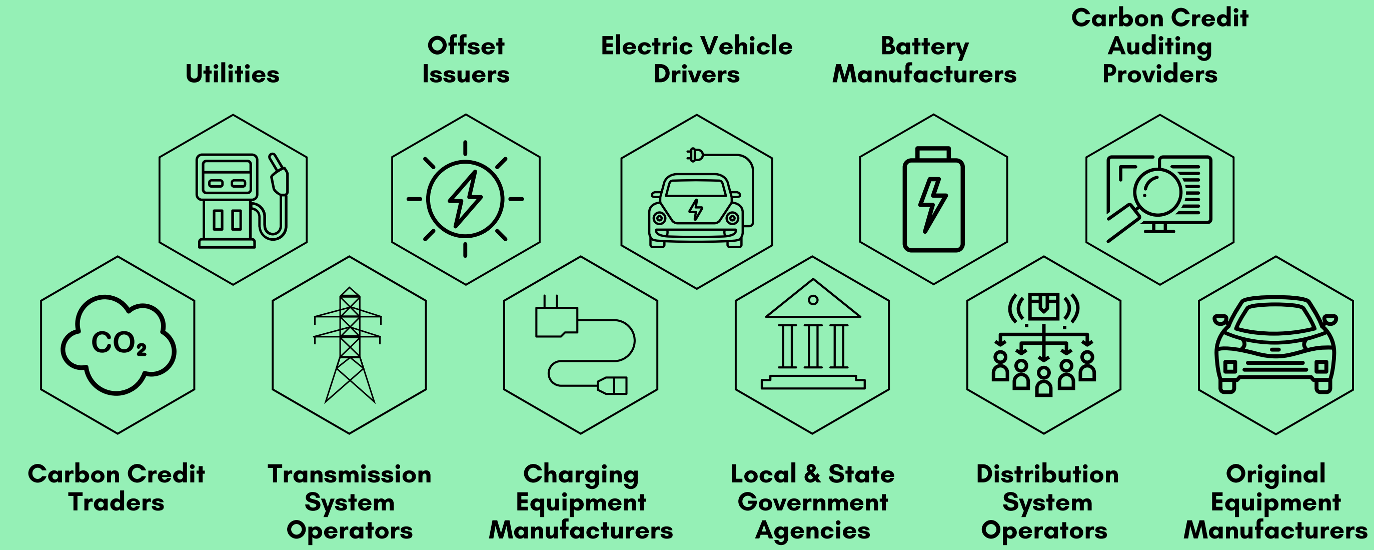


Figure 1 — EVGI Stakeholders

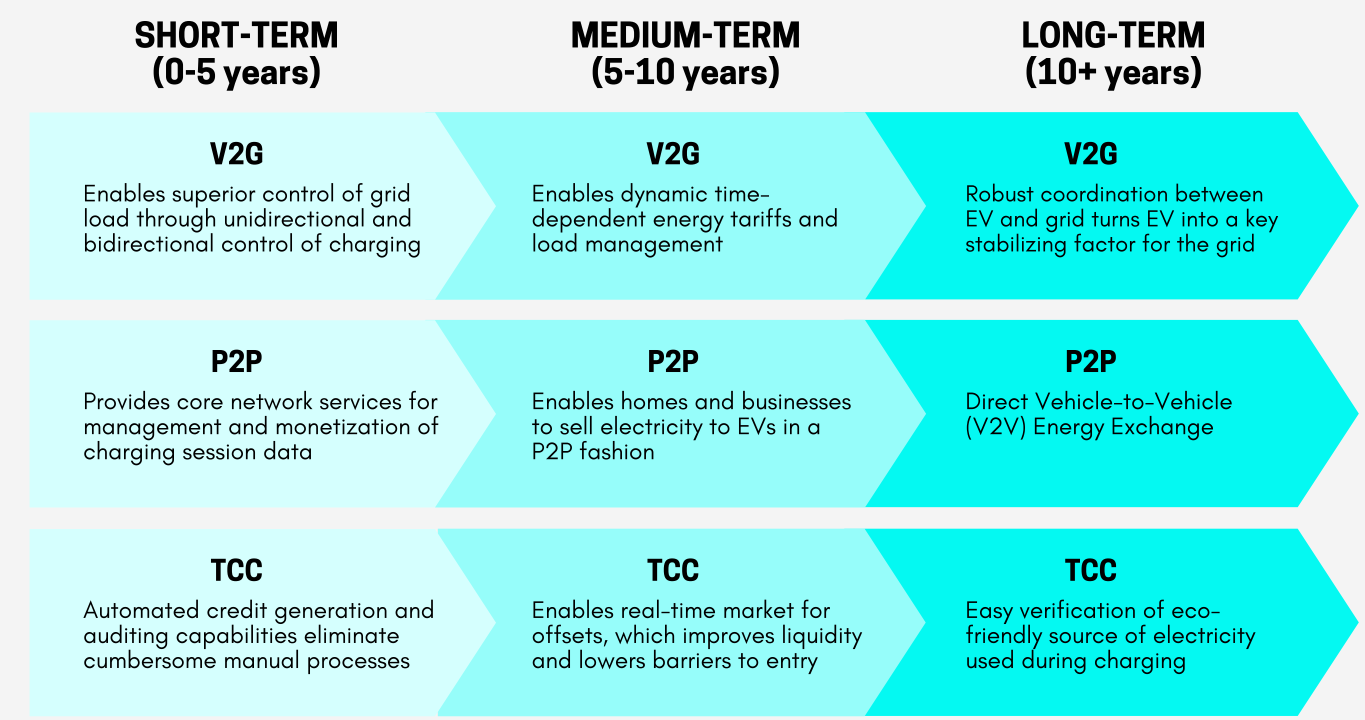


Figure 2 — EVGI Business Value Timeline

VEHICLE-TO-GRID (V2G) USE CASES

The growth of electric vehicles presents an increasing load on the grid. This concentration of demand in highly localized areas presents a challenge for utilities, as it puts a strain on the local infrastructure and increases incidents of costly failures. If a neighborhood has a high percentage of households using electric vehicles, not only will their average electricity demand be higher, but their peak demand as well. Electric vehicle charging follows a relatively predictable time frame. If everyone drives home from work and plugs their car in within a relatively short time, the sudden spike in demand can cause transformers to overload and fail. A single transformer can cost anywhere between USD150k to USD1m to install.[7]

7. Eric Schmidt, "The Impact of Growing Electric Vehicle Adoption on Electric Utility Grids," FleetCarma, August 28, 2017, https://www.fleetcarma.com/impact-growing-electric-vehicle-adoption-electric-utility-grids/

Research has shown that EV pools have the potential to balance the electric grid by putting the electricity stored in batteries back to the grid.

It has been theorized for quite some time that electric vehicles could be used to balance the electric grid by taking the electricity stored in their batteries while they are not in use and putting it back in the grid when local demand is high. An existing business model for energy resource aggregators is to sell pool capacity to grid operators; modern EVs and fleets now allow the mobilization of such capacity. While the hardware is ready, secure data provision is needed to enable efficient controls to manage pool capacity.[8]

It is imperative that for vehicle grid integration to be successful, all the concerned stakeholders must collaborate at systems level.

A 2018 study from the Lawrence Berkeley National Laboratory showed that with just uni-directional EV charging control "California can achieve much of the same benefit of its Storage Mandate for mitigating renewable intermittency, but at a small fraction of the cost. Moreover, EVs provide many times these benefits if two-way charging control becomes widely available. Thus, EVs support the state's renewable integration targets while avoiding much of the tremendous capital investment of stationary storage."[9] Solving this problem by taking advantage of the charging capabilities only just now becoming available in electric vehicles requires innovations in the areas of vehicle to grid (V2G) data gathering, governance, and management, as well as collaboration between cities, smart charging hardware manufacturers, electric grid operators, EV manufacturers, and consumers. All these actors form an ecosystem for e-mobility with numerous business opportunities.

These new charging capabilities will enable several new business cases within this ecosystem, based on the usage of electricity stored in the batteries of EVs and the data about the usage that can now be provided. By utilizing data on past, current, and planned charging activities provided by electric vehicles, our cities, utilities, and consumers will each see benefits.

Fundamental components of such collaboration are digital identities, data management, and governance. Blockchain/DLTs provide digital infrastructure to build these components.

Since the data generated by these business cases is both valuable and sensitive as it involves personal data, a core component of the solution will utilize digital identities and data governance. This maintains trust, privacy, and security of the data, while still making it useful for analysis and decision making. Blockchain and Digital Ledger Technologies (DLTs) inherently provide data trust, privacy, and security, and must be a core component of the solutions.

The EVGI standard has been drafted with modularity and flexibility in mind, to match the broad service landscape in the energy and e-mobility sector. The standard contains key specifications to allow stakeholders the design of interoperable systems for V2G services. In the following section, some of these use cases are analyzed in more detail with regards to their business value and deployment over time.

8. Sid-Ali Amamra and James Marco, "Vehicle-to-Grid Aggregator to Support Power Grid and Reduce Electric Vehicle Charging Cost," IEEE Access, (December 2019): 178528-178538, https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=8930487.

9. Jonathan Coignard, Samveg Saxena, Jeffery Greenblatt, and Dai Wang, "Clean Vehicles as an Enabler for a Clean Electricity Grid," Environmental Research Letters, (May 2018): 1-8, https://iopscience.iop.org/article/10.1088/1748-9326/aabe97/meta.

Vehicle-to-Grid Use Cases

V2G Use Cases — Short-Term

Implementing the EVGI standard for V2G applications can show immediate benefits for all stakeholders involved, from those in the energy sector, to OEMs and consumers. Doing so enables the integration of the EV's battery system and chargers with several layers of grid control systems for managing load through control of charging, both unidirectional and bi-directional. While bi-directional charging hardware is now introduced by numerous OEMs and suppliers (for example, vehicles or chargers need a DC/AC inverter), and a secure V2G charging standard is in the making (ISO 15118-20), a widespread, scalable data ingestion & management layer to make use of the hardware is still missing.

MOBI standards provide a clear framework for vehicles and charging stations to securely disclose various data sets to the network of stakeholders.

Different eMaaS stakeholders, such as energy aggregators, infrastructure providers, OEMs, etc. are interested in different data sets for data analysis and to determine which grid services can be offered. Using the EVGI Standard to make the capabilities of vehicles and charge stations visible on the network will provide exactly the type of data required by these stakeholders. Additionally, it will provide the trust such data requires through the use of a DLT to create an immutable secure record of vehicles, their characteristics, and any transactions (like purchasing or selling electricity) associated with them. When such data is made available, it can be utilized in smart contracts to execute a wide range of business logic.

Utilities will be better able to manage estimated grid loads of locations based on reported routes and charger reservations and actual charger usage. This can be achieved by utilizing V2G network data provided by EVs. Some immediately implementable use-cases are in the growing field of electric trucking, predicting daily grid-wide fluctuations based on EV charging behavior of commuters, and weekday vs. weekend charging transactions of passenger electric vehicles.

In addition, the EVGI Standard will alleviate any concerns around unauthorized use and incorrect payments or billing due to the on-chain tracking of complete charging sessions as well as distributed access control to a network for transactions.

EVGI Standards with common data specification will allow the stakeholders to develop interoperable interfaces across transportation modes, manufacturers, and geographic regions.

Transparency of transactions, and showing them in near real-time will delight consumers and make the day-to-day operations of utilities much more efficient. With the common data specification provided by implementing the EVGI Standard, the development of user interfaces to track V2G transactions, activities across multiple charging services providers will be simple. These user interfaces can be for end-users, utilities, charge point owners, etc., and could be applications available in-vehicle, on mobile devices, via the web, or wherever needed.

Vehicle-to-Grid Use Cases

V2G Use Cases — Medium-Term

The uni-directional coupling of vehicles to the grid (“V1G”) can be seen as an intermediate step towards full-fledged V2G services. V1G implies controlled charging, where a charging session may be interrupted on purpose. This enables several services that grid operators and EV owners both can benefit from. When charging in a certain region is not convenient for the grid (for example, at times of heavy load), charging is interrupted. If the EV owner is willing to accept such minor inconveniences, he or she is compensated by the utility. This would be realized by smart contracts that execute custom energy tariffs with time-dependent pricing or acceptance of switchable load. The EVGI standard provides data on vehicles and battery capacities but also allows to design interfaces for controlled charging, as well as tariff mapping in smart contracts.

In the medium term, uni-directional coupling of vehicles to the grid will benefit the stakeholders.

In addition, utilizing the EVGI standard to implement such a system would be significantly less expensive than upgrading the grid to accommodate the additional load. A study of the grid in Hamburg showed that if 97% of the vehicles in the city are electric, there would be congestion at many of its feeders and that upgrading the grid to alleviate the problem would cost USD 24.5 million. However, if the grid were to use a smart charging system with the electric vehicles, which temporarily omits charging at times of heavy load, the congestion could be prevented for only €2 million.[10]

Facility managers of commercial or municipal buildings have the possibility to install local load control with V1G to optimize charging schedules of several vehicles parked on site.

10. Jeff McMahon, “Electric Vehicle Batteries Could Dwarf the Grid’s Energy Storage Needs,” Forbes, January 29, 2020, https://www.forbes.com/sites/jeffmcmahon/2020/01/29/electric-vehicle-batteries-could-dwarf-the-grids-energy-storage-needs/#315745605929

Bi-directional coupling, which does not include the electric grid involves two prosumers sharing unused electric source with battery acting as a temporary storage and blockchain as a ledger to share transactions between the stakeholders.

Optimization can be done in a way that load peaks of that building are avoided, or to guarantee a fair charging scheme among vehicles. Facility management especially seeks to omit peaks, as they lead to out of scale costs.

Another category of services considered here requires bi-directional charging but does not involve the grid. For example, house owners can transfer excess solar energy into the EV and at the same time use the EV’s battery as a temporary storage system, which reduces the consumption of regular energy coming from the grid. Blockchain can keep track of this self-consumption of electricity and even help with optimizing energy flows between vehicle and home (for example, via a third-party dapp). Blockchain can then be used to share the information in an immutable ledger with utility companies and in P2P electricity sharing schemes. Furthermore, loyalty programs based on blockchain tokens can incentivize the usage of self-generated green energy for mobility. Data attributes in the EVGI standard provides a framework to model such functions and processes.

Vehicle-to-Grid Use Cases

V2G Use Cases — Long-Term

In the long term, bi-directional charging will involve electric grids from which electric vehicles can receive and send power.

In the long term, electric vehicles with bi-directional charging capabilities will be able to receive energy from the grid, and feed it back to the grid, wherever capacity is needed. Hence, such a system could become a key tool for utilities to stabilize the grid. As with the aforementioned V1G services, the EV owner can be transparently compensated based on logics and mechanisms (e.g., special tariffs) encoded in blockchain, enabling visibility, and therefore trust, for all parties. Through data sharing of routing information in EVs, degree of charging infrastructure utilization, and available capacities in a region, utilities and grid operators are better able to predict and manage grid loads. Use-cases of this can be found in electric trucking/logistics and weekday vs. weekend charging behavior. The EVGI Standard provides the specification for data-generating energy peers (e.g., charging stations, utilities) and is a key enabler for V2Network data sharing.

Smart contracts play a special role in long term V2G scenarios, as they may host the aforementioned intelligent energy tariffs. According to a Fraunhofer position paper on smart contracts, the lack of trust between arbitrary actors on the decentralized energy market calls for trustless value exchange based on smart contracts.[11] While there is even potential for smart contract marketplaces to rise, the future will show to which degree smart contracts will be used in typically highly regulated energy markets.

Figure 3 gives an overview of some different key applications that the EVGI Working Group considered in developing the V2G components of the Standard.

11. Wolfgang Prinz and Axel T. Schulte, "Blockchain und Smart Contracts," Fraunhofer, November 2017, https://www.iml.fraunhofer.de/content/dam/iml/de/documents/OE260/Fraunhofer-Positionspapier_Blockchain-und-Smart-Contracts.pdf

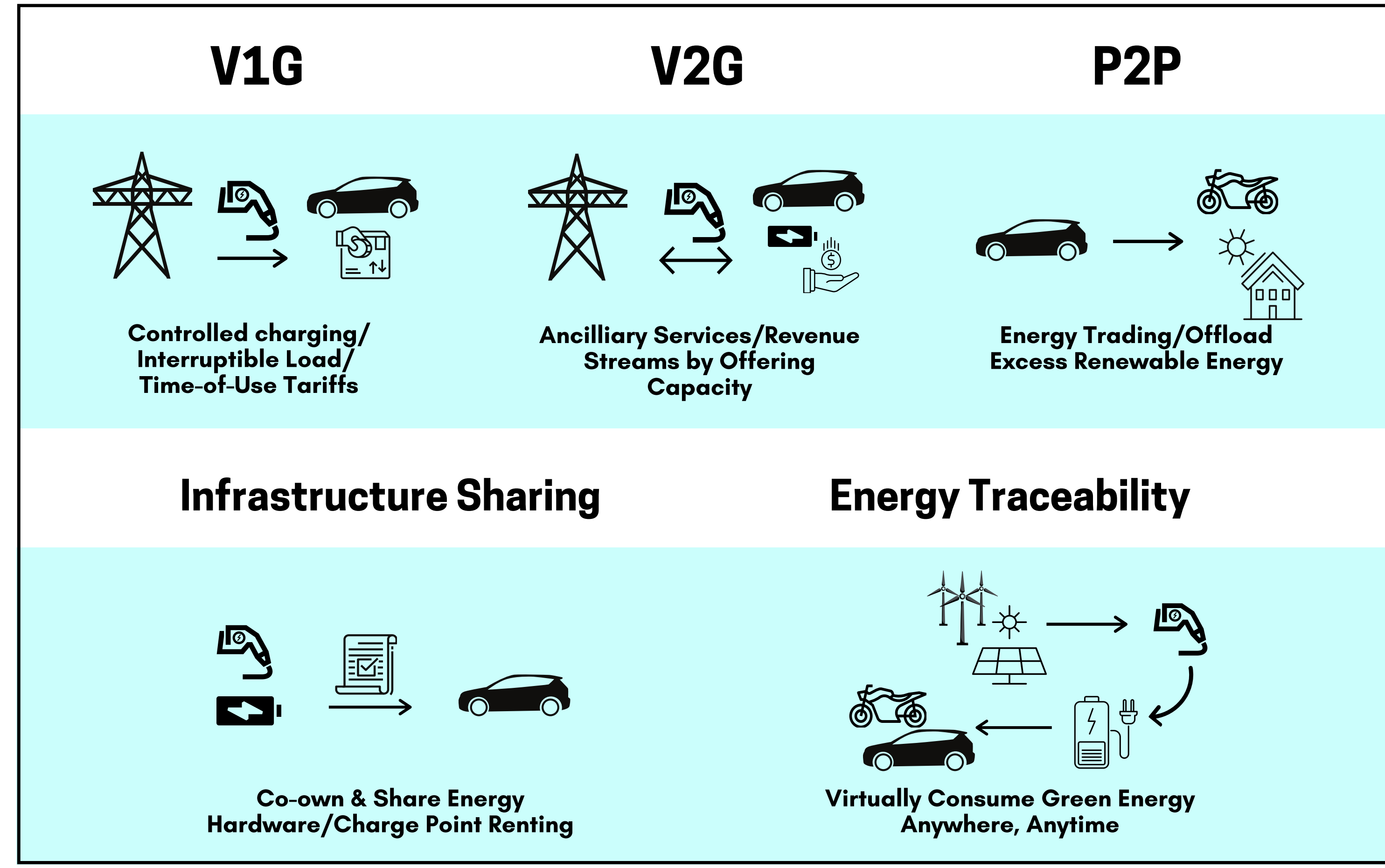


Figure 3 — EVGI Use Cases

PEER-TO-PEER USE CASES

Households and businesses are getting increasingly more equipped for the next peer to peer applications of mobility in the context of electric vehicles. Excess energy is seen as a new revenue opportunity by allowing external peers to use this energy in the form of charging their electric vehicles. Smart home chargers are now able to be shared for public pay per use and short term lease of charging points, creating a sharing economy for EV charging infrastructure. In order to facilitate such electricity transactions, chargers need to become visible and usable for the public. In a distributed system, charger identity will be key to this solution. Today there are no standard ways to process such transactions, track usage, and monitor energy consumption. Blockchain smart contracts and dapps offer a high potential for P2P registering, offering, leasing, and billing of charge points.

Implementing the EVGI Standard provides a variety of benefits for stakeholders of the electric vehicle and charging ecosystem. Electric vehicles, charging stations, and utilities can have a secure identity, communicate with a standard messaging format, and record transactions on a distributed ledger. Such transactions may include charging events, electricity generation reporting, electricity exchange events, etc. These services provide value by enabling secure, decentralized communication and immutable recordkeeping between data-generating energy peers.

Peer-to-Peer Use Cases

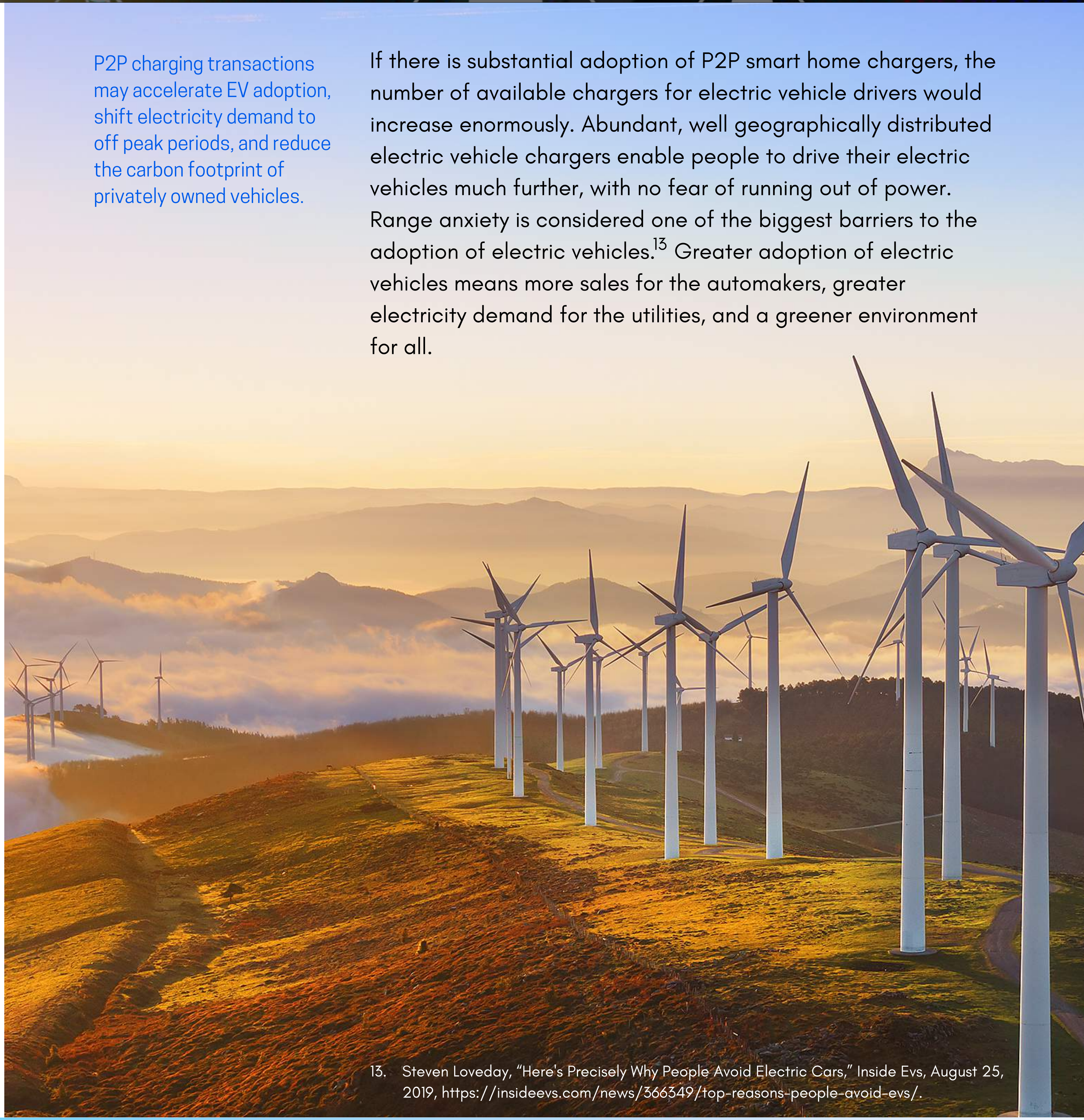
P2P Use Cases — Short and Medium-Term

The EVGI Working Group primarily considered two use case scenarios that fell particularly under the P2P umbrella – electricity pooling and selling, and direct vehicle to vehicle energy exchange. As such, this section combines the Short and Medium term into one subsection to focus on the former use case, while the Long term section focuses on the latter use case.

Homes and small businesses can pool unused electricity or request electricity from other pools. This will allow less load on the main electricity grid.

With a basic set of schemas for communication between electric vehicles, chargers, and the grid, electric vehicles will be able to share data and communicate with chargers, regardless of the manufacturers that built them. With robust P2P systems that can match supply and demand, the possibilities are endless. For example, electric vehicle chargers in homes and small businesses can become publicly available charging stations. Prosumers and non-prosumers alike would be able to provide their electricity to the public and earn revenue that will offset infrastructure costs in the short term and create more profitable business opportunities in the long term. Systems that are able to match local supply and demand will result in better energy prices for consumers and prosumers alike. Furthermore, direct prosumer – consumer energy exchange reduces the load on the grid, which reduces maintenance costs for utilities, as well as reduces transaction costs from avoiding grid fees. With multiple prosumer homes pooling their electricity, they can form microgrids that can achieve enormous cost savings, as they are effectively generating their own power. That cost saving is not only for the homes within the microgrid, but also passed to the EV drivers in the form of cheaper electricity, which also vastly expands the pool of available chargers. There are multiple microgrid communities growing around the world, and this trend is only projected to continue.[12]

12. "Brooklyn Microgrid (BMG) Marketplace," Brooklyn Microgrid, accessed June 16, 2020, https://www.brooklyn.energy/



P2P charging transactions may accelerate EV adoption, shift electricity demand to off peak periods, and reduce the carbon footprint of privately owned vehicles.

If there is substantial adoption of P2P smart home chargers, the number of available chargers for electric vehicle drivers would increase enormously. Abundant, well geographically distributed electric vehicle chargers enable people to drive their electric vehicles much further, with no fear of running out of power. Range anxiety is considered one of the biggest barriers to the adoption of electric vehicles.[13] Greater adoption of electric vehicles means more sales for the automakers, greater electricity demand for the utilities, and a greener environment for all.

13. Steven Loveday, "Here's Precisely Why People Avoid Electric Cars," Inside Evs, August 25, 2019, https://insideevs.com/news/366349/top-reasons-people-avoid-evs/.

Peer-to-Peer Use Cases

P2P Use Cases — Long-Term

Electric vehicles can exchange power with each other when they are parked. Vehicles with excess power because of short commutes can sell the power to vehicles with longer commutes. A scenario when supply and demand is optimized within a small geographical pool of vehicles.

Peer-to-peer smart home chargers certainly represent a major milestone in the decentralization of electricity distribution for EVs. From there, the next clear milestone is the direct exchange of electricity between the EVs themselves. Consider a large random sample of EV drivers in a given city. Drivers will have varying schedules, commute distances, and vehicles. Moreover, vehicles will be parked at different locations in the city, for different lengths of time throughout the day. Drivers with short commute times will find a consistent excess of electricity, while those with much longer commutes may have to stop at a charging station

By enabling EV identification, coordination and settlement, MOBI's EVGI standard provides the foundation of a greener and more efficient mobility economy.

during their trip. Even within a single parking lot, there will be different electric vehicles with different charge levels, and varying degrees of available excess electricity; there is a clear opportunity to match the supply and demand in this situation. Drivers purchasing electricity could achieve enormous cost savings, estimated to reach up to 71%. Drivers that are selling their excess electricity also see the value – they can earn a return on energy.

In order for the above scenario to be achieved, individual steps in the use case workflow requires the ability for EVs to communicate and coordinate– from the authentication between EVs to begin charging sessions, to submitting buy/sell orders for certain quantities of electricity at certain prices, to coordinating the charge session. That coordination is not just bilateral – there must be consensus within that mesh network of EVs that matches buy and sell orders. Collating and recording each buy and sell order on a distributed ledger requires consensus between all participants – so too does a distributed buy and sell order matching process. With blockchain, these EVs can easily and securely identify themselves and each other; secure digital identities are key to enabling the trusted P2P messaging and coordination required by a direct electricity exchange. The EVGI Standard provides a framework for allowing EVs to authenticate each other's identities and validate each other's pertinent data (current charge level, trouble codes, etc.. Direct P2P energy exchange between vehicles will require a strong, robust application layer to implement the order matching engine, buy/sell order submission process, coordination of drivers to execute trades, and much more. But the EVGI Standard is the first key step – providing the core building blocks of these applications so that engineers have the data and core network services they need.

TOKENIZED CARBON CREDITS (TCC) USE CASES

The EVGI Working Group chose to focus narrowly on registering the credits on chain, and to accommodate what is required for them to be registered/exchanged/retired. That can all occur without literally tokenizing them. The EVGI Working Group did not ultimately have the standard require that those credits be tokenized, and the method of tokenization for these credits was left to implementation.

Tokenization of carbon credits has received increasing attention from the mobility industry as a way to introduce efficiencies and new ways in managing carbon credits. Carbon credits are certificates or permits that represent the right to emit fixed volumes, typically one metric ton, of CO2e (carbon dioxide equivalent). The carbon credits are typically able to be transacted in carbon markets, which can take various forms. The term ‘carbon credits’ is used to cover a wide range of programs and incentive schemes including carbon offsets, carbon production permits, renewable energy certificates, guarantees of origin, cap and trade programs, and other green attribute tracking mechanisms. The Low Carbon Fuel Standard (LCFS) program is one such mechanism, and the focus of this standard as the most directly applicable one to the mobility industry.

The LCFS programs utilize market-based incentives to encourage reductions in the carbon intensity of transportation fuels. By setting carbon intensity goals, regulators administering LCFS programs can mandate importers and refiners of carbon-intensive fuels to lessen their environmental impacts by either reducing the carbon intensity of their fuels or purchasing LCFS credits from generators of lower carbon-intensity fuels (i.e. electricity, biofuel, renewable diesel). The program therefore also incentivizes the production of those lower carbon-intensity fuels. The State of California in the United States, for example, was one of the first ones to adopt the LCFS program in 2009 and it has seen many enhancements since then. Many other states and countries, including British Columbia and the UK, have either adopted or are exploring similar programs. California, Oregon, Washington, and British Columbia strategically align policies to reduce greenhouse gases and promote clean energy. “Over time, these LCFS programs will build an integrated West Coast market for low-carbon intensity fuels that will create greater market pull, increased confidence for investors of low carbon alternative fuels, and synergistic implementation and enforcement programs. Other regions including Canada and Brazil are also noticing California’s success and developing LCFS-like performance standards for transportation fuels.”[14]

14. Low Carbon Fuel Standard,” California Air Resources Board, accessed June 16, 2020, https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard.

Fuels generate LCFS credits if they have carbon intensity (CI) lower than the target established by the regulators. Those fuels in the transportation fuel pool with CIs higher than the target generate deficits. A fuel producer with deficits must have enough credits through generation and acquisition to be in annual compliance with the standard. Petroleum importers, refiners, and wholesalers are Regulated Parties (RPs) under the LCFS. The regulator approved alternative fuel producers can opt-in to the program; these participants are also referred to as RPs. When transportation fuels are imported, refined, or sold in California, for example, RPs and opt-in RPs enter the transaction level information into the regulator's central data system for the standard, the LCFS Reporting Tool (LRT). The LRT tracks each transaction of fuel with its corresponding credit or deficit position, and sums for each RP. Credits are retired when used to cover deficits per annual compliance report. LCFS credits do not have a vintage and do not expire. Credit transactions are reported to the LRT, including the transaction price in units of million tonnes (MT) of LCFS credits. Credit owners can only sell or trade their credits with other[16] RP deficit holders. Parties outside the 230 RPs are not allowed to hold LCFS credits.[15]

In Figure 4, for example, shows how the limit of compliance for fuel carbon intensity is getting more strict over time in the state of California. Transportation fuels high in carbon, such as gasoline, sit near the top of the chart, and thus these importers and refiners accrue a credit deficit. Fuels with a lower carbon intensity, like electricity from renewable resources, sit well below the compliance standard and therefore generate a credit surplus. In this way, an exchange marketplace is set up between parties with credit deficits and those with a credit surplus.

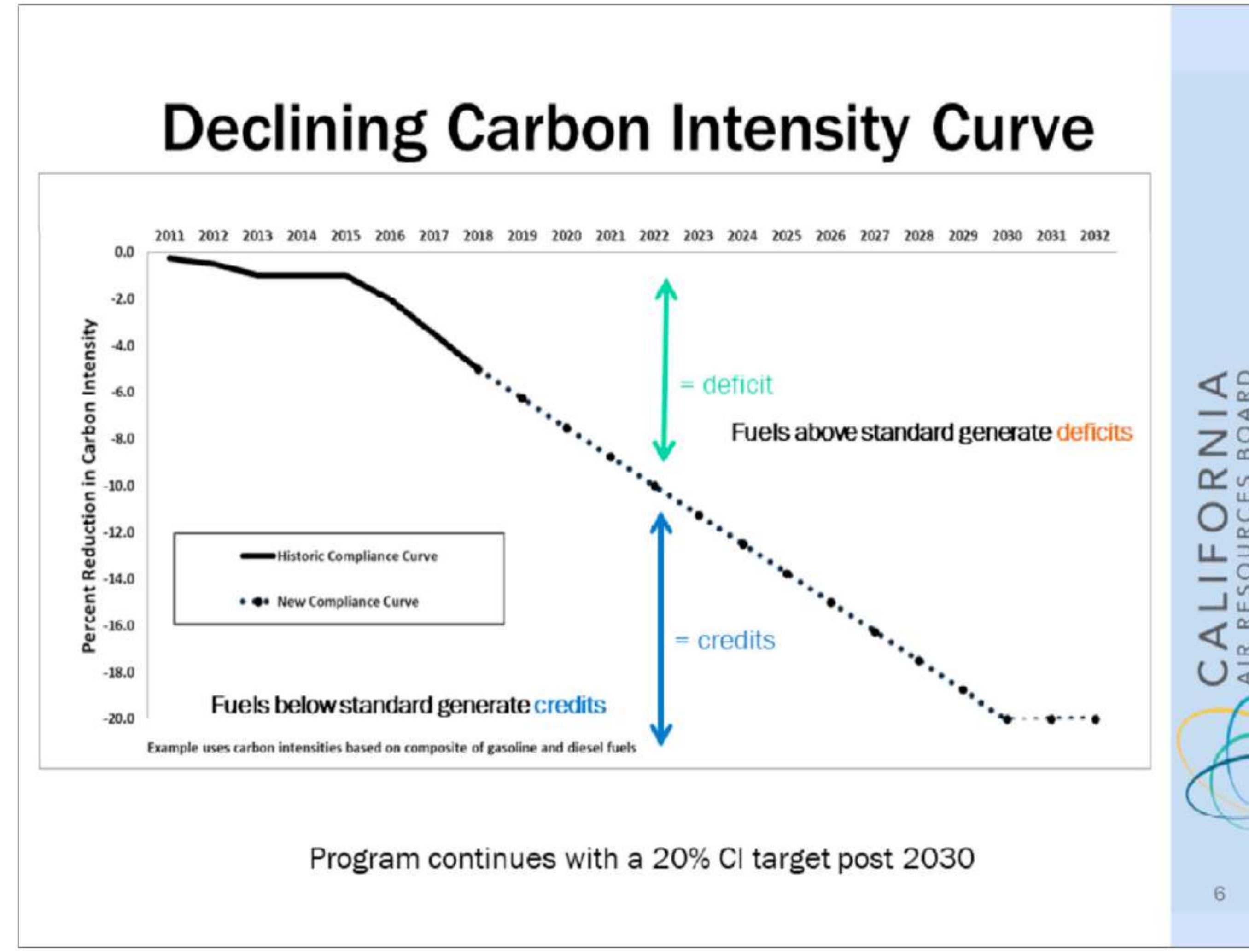


Figure 4 — California Air Resources Board Declining Carbon Intensity Curve.[16]

15. "LCFS 101 - A Beginner's Guide," Stillwater Associates, accessed June 16, 2020, https://stillwaterassociates.com/lcfs-101-a-beginners-guide/?cn-reloaded=1.

16. "LCFS Basics," California Air Resources Board, accessed June 16, 2020, https://ww2.arb.ca.gov/sites/default/files/2020-09/basics-notes.pdf.

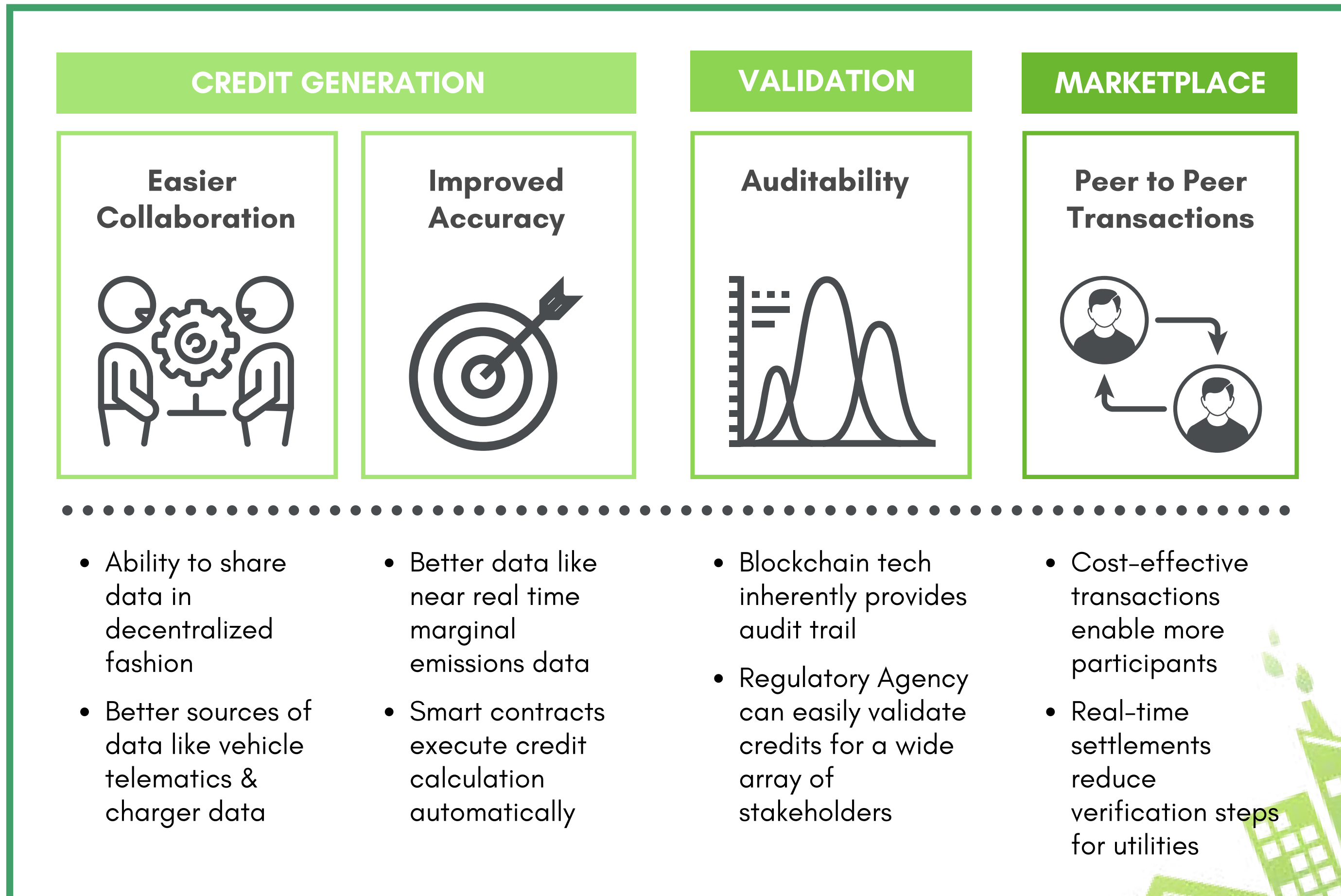


Figure 5 — Major Phases of the LCFS Process

While focused on EVs, the standard could be extended to other fuels and modes of mobility.

There are three major phases of the LCFS credit lifecycle considered in this document as shown in Figure 5 below – 1) credit generation, 2) auditing/validation of credit generation, and 3) credit marketplace. Note: While this document is solely focused on electric vehicles, there are other fuels (ethanol, hydrogen, etc) that this process could be applied to. These other fuels have not been included due to the EVGI Working Group's limited study and investigation into those fuels, but portions of the standard could potentially be utilized for tokenized carbon credits based on those fuels as well.

Tokenized Carbon Credits Use Cases

TCC Use Cases — Short-Term

The EVGI standard can help with the carbon data provenance, integrity, chain of custody, and audit needed for a viable carbon credit framework.

In the short term, the framework laid out in this standard can be used to create blockchain-based applications that will help the credit generation and auditing phases of the LCFS credit lifecycle. Credit generation refers to the process of pulling data related to charging of a specific vehicle and quantifying the numbers of credits based on calculations defined within the LCFS program. These are typically set by the regulatory body overseeing the program.

These applications can help streamline and standardize the collection of data needed to quantify carbon credits while providing an immutable audit trail for data used in the quantification of carbon credits. This will be valuable to both LCFS credit producers and regulators.

Both carbon credit producers and consumers can benefit from the transparency, trust and timeliness enabled by MOBI's EVGI.

Credit producers will benefit from these applications to quantify carbon credits in more real time through standardizing automated pulls of charging data. One challenge for small companies (e.g. independant charging station providers) who are eligible to claim credits is the time and effort needed to collect this data and fill out the relevant forms to submit credits on regular intervals. Additionally, many credit producers struggle to understand how many credits they have accrued at any given time. Utilizing these applications, the credits can be quantified and created in real time.

Auditing of the credits generated is important to avoid any manipulation of the program as a significant amount of money can be accrued. In fact, ~$2.7 billion was transacted in California's LCFS program in 2019. The California Air Resources Board (CARB), for example, notes 5 examples of settlements for incorrect reporting including a payment of $1,365,000 from Tesoro Refining and Marketing LLC, for misreporting volumes in its quarterly and annual LCFS reports.[17] That particular incident did not appear to be due to manipulation as the errors were self-disclosed. Additionally, CARB has noted several account balance adjustments including one in 2017 for 109,226 credits. At today's market prices of ~$200/LCFS credit, today those credits would be worth around ~$21 million. These incidents show that there is a fair amount of money riding on auditing these LCFS submissions.

Existing reporting processes are error prone yet expensive to audit.

For regulators, auditing the credits and deficits produced can be an issue. One area where utilizing the blockchain for auditing carbon credits can be beneficial is in ensuring that records at the meter haven't been falsified. Storing the data from the meter or charger through an immutable ledger, whether the data is stored on-chain or off-chain, can ensure that records aren't manipulated afterward. Additionally, double counting of charge sessions (i.e. 2 entities claiming for the same charge session) can be caught through tracking charge sessions using the ledger.

By standardizing the data collection and reporting process, the standard enables audit, and regulatory oversight.

The framework laid out in the standard could be utilized to create an immutable and auditable ledger of charging data that regulators could audit. The standard outlines a process for registering credits which can then be used in the TCC process. The standard notes certain data fields which would be required or likely desired in a DLT/blockchain based credit generation application. These same data fields and structures will also support implementing auditing capabilities for regulators. Systems created could set permissions for regulators to see all credit activity in real time, while protecting data privacy of individual credit claimants.

17. California Air Resources Board, LCFS Enforcement, accessed June 16, 2020, https://ww3.arb.ca.gov/fuels/lcfs/enforcement/enforcement.htm.

Tokenized Carbon Credits Use Cases

TCC Use Cases — Medium-Term

Transparency around potential counter-party ownership, production and demand for credits, as well as mechanisms for dispute resolution, will be needed for active trading.

In the medium term, DLT/blockchain can be further leveraged to create a more real time marketplace for transacting credits.

Credit marketplaces are important to enable transactions between credit buyers and sellers. Credits can be transacted in many ways, but for sellers with a smaller number of credits, they typically must go through an aggregator or broker because of their limited volumes of credits, which can be costly to these sellers. The current LCFS credit trading process in California takes data from a number of siloed databases, and, since 2018, relies upon a third party to verify and confirm credit transactions. This requirement for third-party verification was added by CARB in 2018 to "ensure data completeness, accuracy, and conformance with the regulation."[18] Regulators run the system, and need to be able to see how many credits each party owns, and have the authority to resolve any disputes arising within the network. The current system relies on complex contracts and manual processes that result in smaller players being excluded from the market; because the barriers to entry and cost of transactions is high enough to prevent parties with only a small number of credits from engaging in the exchange.

Standards for carbon data encourage the development of a liquid market for credits.

Current existing marketplaces are illiquid. A lot of stakeholders have the desire to participate, but cannot due to low volumes of credits and difficulty establishing relationships with a buyer. One challenge for many small credit producers, is the ability to sell their credits. Choices for small credit producers typically only include paying aggregators or brokers large fees to exchange their credits. Waiting to accrue enough credits to transact with deficit producers is often not feasible. A blockchain based marketplace could enable larger deficit producers to purchase multiple small batches of credits while avoiding exorbitant broker fees ranging from 1 to 5% based on volume. A tokenized credits marketplace can enable the exchange of credits between surplus and deficit holders, in near real-time without a bottleneck intermediary. Getting the credits on a DLT/blockchain powered network is the first step to achieve this.

The standard should also improve market efficiency, reduce bid-ask spreads, and minimize middleman friction.

This framework laid out in the standard supports the creation of carbon credit marketplaces by outlining a process for initializing and then finalizing TCC contracts. This process could enable users to compensate each other using the tokenized carbon credits without the direct need for a broker or aggregator.

18. "LCFS Verification," California Air Resources Board, accessed June 16, 2020, https://ww2.arb.ca.gov/lcfs-verification.

Tokenized Carbon Credits Use Cases

TCC Use Cases — Long-Term

A liquid market for mobility carbon credits can be leveraged and extended to other green energy markets to enable additional environmental and social benefits.

In the long term, the tools used to build out the credit generation, audit, and marketplace components of carbon credit and LCFS ecosystems could also be leveraged to expand to other programs or processes. One example is linking together the tracking systems for Guarantees of Origin / Renewable Energy Certificates[19] that track the generation of green energy with the LCFS program, to verify and enable green charging. A clear standard of inputs and outputs for each system would make the process of linking this tracking system infrastructure together significantly less complex. This would include an extension of the infrastructure used to quantify carbon credits. This same infrastructure could also be used to create applications for providing incentives to charge with green energy.

Furthermore, these systems could enable real-time incentivization of green energy charging and usage through users collecting carbon credits as incentives in their wallet. Incentive / token reward for each km traveled with green energy. However, these programs would have to be created by regulators or other entities who would ensure the incentives are aligned and the business case for giving the incentives is properly structured.

19. "Guarantees of Origin (GOs)," ECOHZ, accessed January 5, 2021, https://www.ecohz.com/renewable-energy-solutions/guarantees-of-origin/.

CONCLUSION

For eMobility, the grid, and carbon offset markets, blockchain technology offers a variety of benefits, both in the reduction of costs and in the enablement of new revenue opportunities, for players on all sides of the ecosystem. Though vehicle-to-grid coordination may seem quite different than peer-to-peer electricity trading, the processes that underlie those applications are similar. They have the same needs for core network services - digital identity, permissioning, data exchange, and more. At its core, blockchain provides a trust layer, which perfectly complements the mutual business interests between utilities, charging service providers, property owners, and electric vehicle drivers. Additionally, blockchain enables these parties to create a shared ledger of data, a single source of truth of paramount information to facilitate interactions, a secure and trusted marketplace where transactions can be facilitated without intermediaries through efficient and automatic smart contracts.

While each of these use cases would certainly provide value in and of themselves, the exciting prospect is what happens when all those applications can interact and share data with each other. The value of distributed ledger technologies is directly determined by their network effects. Such scale can only be reached if all the stakeholders are able to build applications that are interoperable from the bottom up. Without standards and coordination, these DLT applications will struggle to reach production. And that delay in their time-to-market comes at an ever-increasing cost. The pain points addressed by these applications are ultimately symptomatic of legacy systems that are struggling to handle larger and more complex workloads. Until new systems are put into place, that friction will only continue to get worse.

The trust layer brought by distributed ledger technologies will have an enormous impact on eMobility. But that impact won't just be felt by the institutional players operating the grids, charging stations, etc., but will affect all the EVGI stakeholders. And those stakeholders are many, at all scales - OEMs, households, and individual drivers are all stakeholders in the EVGI ecosystem. As distributed ledger technologies continue to mature, all stakeholders will receive streamlined workflows, reduced costs, and exciting new capabilities and services. But most importantly, these technologies will be key for our systems to reach the scale demanded by the "all electric future" we're approaching.

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MOBI is a nonprofit industry consortium of many of the world's largest vehicle manufacturers, along with many startups, NGOs, transit agencies, insurers, toll road providers, smart city leaders, and technology companies working to accelerate adoption and promote standards in blockchain, distributed ledgers, and related technologies.

MOBI is creating simple blockchain-based standards to identify vehicles, people, and businesses in order to securely exchange and monetize data, and pay for mobility services, with the goal of making transportation more efficient, affordable, greener, safer, and less congested. MOBI itself is technology and ledger agnostic. For additional information about or joining MOBI, please visit our website.

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