Future Archetypes *of* EV Charging

Researching and Developing Archetypes for Investable Infrastructure

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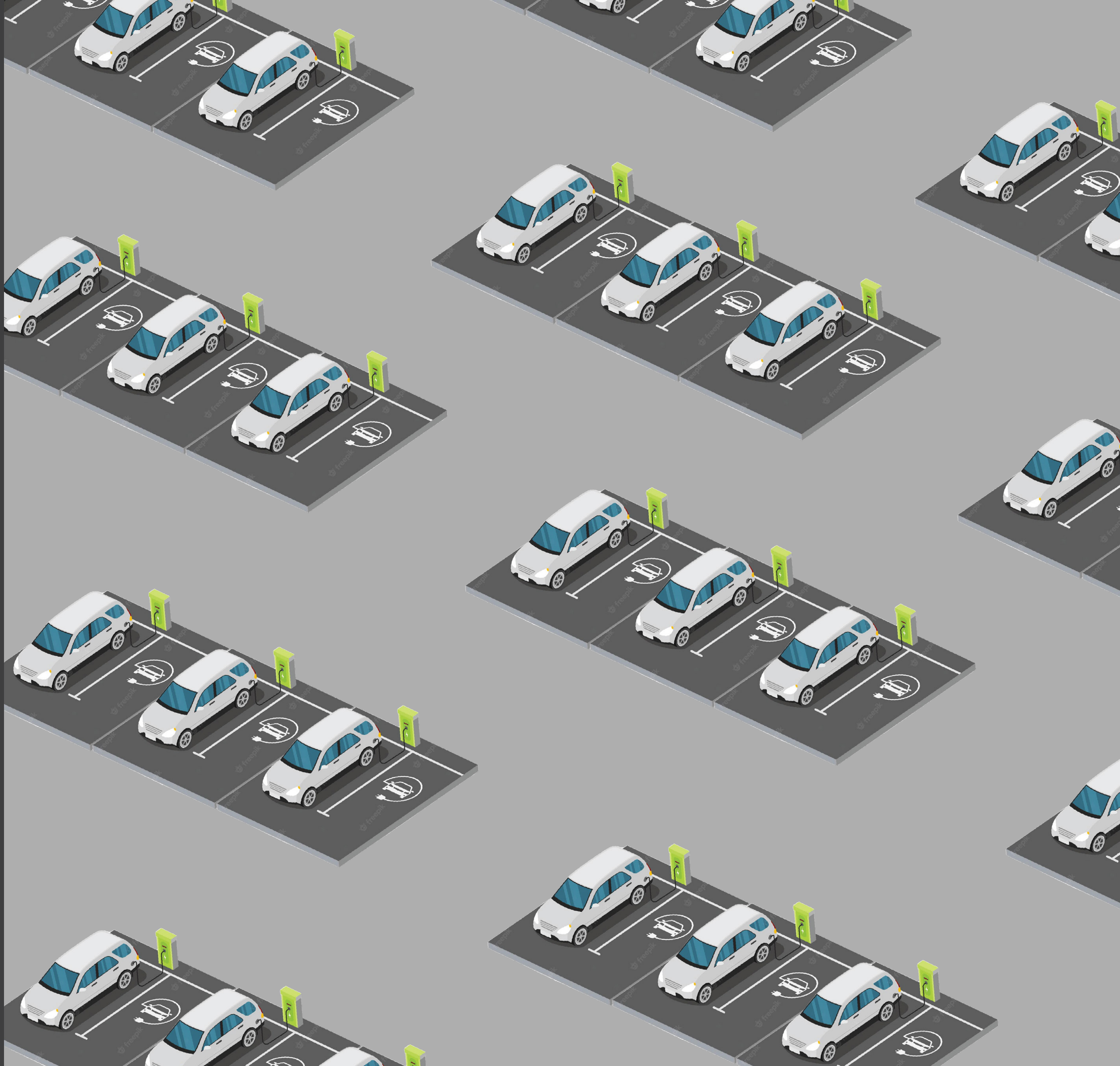

Forward

Sustainable, equitable, and intelligent long-term investable infrastructure

One of the transformative forces in the 21st century is long-term capital investment that is shaping our economy, society, and environment for decades to come. Focusing on how capital is allocated and the decision-making processes happening to drive innovation, we examined how strategic choice-making through design can influence and shape the opportunity space and anticipate the future by imagining different investmnet cases. We explored the potential of EV charging and controlled environment agriculture from the lenses of sustainability, equity, intelligence, and investments. These infrastructures are at the nexus of multiple systems and the way they are shaped will play a major role in responding to complex issues like sustainability and equity faced worldwide.

In this report, we take a Research through Design approach to imaging new archetypes that anticipate the future, embracing these complex issues to operate at the intersection of multi-systems, stakeholders, levels, and intelligence.

Introduction

Long-term capital investment is a transformative force in the 21st century, shaping how we produce, distribute, and consume essential resources. Design is also a transformative force that shapes our experiences, systems, and mindsets. Yet they have traditionally been treated separately, to the detriment of both. To bring them together, we explored the potential of designing investable infrastructure through the lens of capital design.

Creating choices in complex and dynamic spaces requires bringing together multi-systems, stakeholders, levels, and intelligence. While designers are always interested in imagining new possibilities and asking, ‘What if?’ questions. This often requires exploring different options to make choices. Investors, on the other hand, are interested in decision-making. Finding what the right answer is, to be able to make a decision that minimizes risk and maximizes efficiency. While developing these projects, we combined these two perspectives through strategic choice-making to help develop effective, innovative, and investable archetypes through sustainability, equity, and intelligence lenses.

Infrastructure has many definitions. One might think about hard infrastructure like roads, bridges and power generation stations. Or one might consider soft infrastructure, like institutions, relationships and social interactions (Nogueira et al. 2020). The rise of intelligence embedded in everyday infrastructure plays a critical role in shaping and influencing our physical and social world and creating a space of algorithmic materiality that is highly complex. However, an emerging definition blends both aspects with an economic lens: investable infrastructure.

Investable infrastructure, at its simplest, means any fixed asset with a long-term cash flow. This could be an airport or toll road, but it could also include a salmon fishery, mushroom farm, ski hill or network of smart meters - and much more. Through this broad definition, much of our built environment becomes a fair game for design. Yet, to this point, the tools and frameworks for design to engage with investable infrastructure did not exist. The context of investment was important and crucially different from a business context. Notions of risk management, value creation and portfolio strategy all come into play. One of the goals of this class was to experiment and create those tools under the banner of Capital Design.

Capital design posits that design can influence the

Introduction

trillions of dollars in investment from private long-term institutional infrastructure investment through a whole-view model of strategic choice and decision-making that maps strategic design capabilities against capital investment tools across known and unknown domains to assist portfolio construction.

To test this hypothesis in a bounded and controlled environment, the workshop selected two sectors to focus on controlled environment agriculture and electric vehicle charging. Not only have these systems attracted billions of dollars in investment over the last five years, but they also represent the intersection of multiple trends, drivers, systems and forces that will shape our economy, society and environment for decades to come. These forces include the "3Ds" of digitization, decarbonization and decentralization.

Controlled Environment Agriculture (CEA) "uses technology to enable growers to monitor and control a crop's environment to desired conditions", according to the University of Arizona Biosystems Engineering Department. Greenhouses, aquacultures, hydroponic farms, and vertical farms are all examples of CEAs. Moreover, when viewed through an investable infrastructure lens, CEA includes the production of agricultural products, and the post-production supply chain up until consumption or the beginning of the food manufacturing process.

Transportation and mobility are a big infrastructure investment focus and a core lever in global decarbonization. Fundamental shifts in mobility and transport subsectors driven by EV technological maturity, consumer demand/behavior, international government support, auto OEM commitments. Electric Vehicle Charging (EV charging) - similar to CEA - started out as the individual charging stations for electric passenger vehicles. As such, the potential shift from "how do we replicate gas stations for EVs?" to "what should we electrify?" offered significant opportunities for the workshop to design investable infrastructure in novel and productive ways. The class considered many aspects of EV charging, from battery storage, point charging, e-mobility and vehicles-as-a-service, and other innovative uses.

To carry both projects forward, we adopted Research through Design approach to unfold the complexity when looking at everyday infrastructures to embed strategic intent while designing at the nexus of multiple systems, stakeholders, levels, and intelligence. Both projects

Introduction

went through a series of multiple prototyping rounds building off of each other and producing a total of sixteen different prototypes each representing a unique archetype. Each round of prototyping was initiated by a prompt to guide the design process to strategically explore both the opportunity and problem space. After leading the reasoning through a sequence of individual grounded prototypes to create choices, the last round was centered around evaluating the choices that were created and combining them into bundles of features to create unique investable archetypes.

The whole process was carried through multiple frameworks and tools to navigate the complex space of innovation. Asset Mapping, Life Supporting Model, Archetypes, Anti-Oppressive Framework, Narratives, Causal Loops, Action Situations, and Anatomy of Infrastructure were some of the tools that were mainly used to center the archetypes through the lenses of sustainability, equity, and intelligence.

This report is the culmination of a semester's worth of work of masters of design students who have helped establish a new focus for design. We hope readers of this report share our cautious optimism for the future in how design can influence one of the most powerful forces that impact all aspects of our lives.

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Current State

Where are we today when it comes to EV charging and infrastructure?

The electric vehicle market in the US has started growing rapidly. But while the future is unmistakably electric, it is still far away for most people. In 2021, EV's accounted for less than 2% of new vehicle registrations in the U.S. (PWC). And while EV adoption is accelerating, there are still significant obstacles on the road to mass EV adoption across markets and use cases.

EV's of all types, ranging from small recreational vehicles and cars to airport support vehicles and boats face challenges like a lack of public charging infrastructure, slow charging times, high cost of batteries, and costly upgrades to local grid infrastructure. Reliability is a growing issue facing EV drivers, with one study finding that "almost 23% of 657 DC fast chargers in the nation's biggest EV market were nonfunctional". Additional challenges at the system level include significant increases in load on the grid due to mass charging, as well as inequitable distribution of charging infrastructure and associated benefits/costs.

The policy landscape regarding EV infrastructure has shifted significantly in the past few years. At the federal level, the Infrastructure Investment & Jobs Act (enacted in 2021) and the Inflation Reduction Act (enacted in 2022) have major provisions for the funding and support of EV charging across the country. In addition, many states have announced and implemented regulations, purchase requirements, and financial incentives to support the transition to EV's and EV infrastructure. The next decade will see massive growth as these efforts spur new investment in EV infrastructure.

In light of both the challenges and the favorable landscape, there is significant opportunity for investment in new types of EV infrastructure that both generates cash flow and aligns with human values. New archetypes for charging infrastructure also represent an opportunity to take advantage of connected and intelligent systems. These archetypes can re-shape our understanding of not just what it feels like to charge a car, but our relationship with both cars and energy itself.

In this report, our team will present several archetypes for investable infrastructure in EV charging. Each represents a concept and set of features identified and consolidated through multiple rounds of research and prototyping.

Goal

What are we striving for in our research and prototyping?

Our goal can be simply described as "Ubiquitous Charging" through the lens of investable infrastructure. Through our rounds of prototyping and design, we sought to identify features and archetypes that enable a future where EV infrastructure and its many benefits are available to anyone, wherever they live or wherever they choose to travel.

Goal

Three systems goals to guide research and prototyping: Decarbonize, Decentralize, and Digitize.

Decarbonize: Archetypes identified through prototyping research all support a future that has transitioned away from fossil fuels and towards electrified transport and carbon-free electricity generation.

Decentralize: The archetypes emphasize a distributed model of access and ownership to electricity and charging. Rather than focusing on large-scale centralized power generation and charging stations at fixed points, charging +electricity generation (and their associated benefits) are much more accessible to individuals across different levels of geography and socioeconomic status.

Digitize: The archetypes leverage AI and connected technologies to gather, process, and intelligently act on information. The digitized nature of future infrastructure enables relationships with other systems and services that were not previously possible.

Values

What values guided our research and prototyping of different features and archetypes?

Democratization: The archetypes we identify should work towards increasing access to new markets and benefits of electrification and EV charging.

Equity in determining who benefits from new infrastructure investment, and how costs are assessed.

Transparency to end users regarding the use of their data, resources, and time.

Resilience and **Stability** of future grid infrastructure in the face of extreme weather events.

Reframing

Reframing goals and existing archetypes

The current archetype of refueling a conventional car involves a process where the end consumer is either directly interacting with the pump, making a quick trip inside a convenience store while the pumping process completes, or waiting in one's car while someone else pumps gasoline. In all of these scenarios, the exchange of energy in the form of gas takes just a few minutes.

Generally, gasoline obtained for a cheap price in one location cannot be sold at a higher price to generate profit in another place by the consumer (outside of rare instances of illegal resale).

While EV adoption is still in its infancy, the experience is characterized by the driver manually plugging the charger into their car. Generally, charging occurs when parked for extended periods at home, work, or at public chargers near points of interest.

When charging at a fast charger, EV drivers may choose to stay in their vehicles—however, waiting time is still an order of magnitude longer than refueling a gas car (i.e. 30 minutes, instead of 3). In a future that is decentralized, digitized, and decarbonized, there is an opportunity to rethink the archetype of "refueling" or recharging one's car.

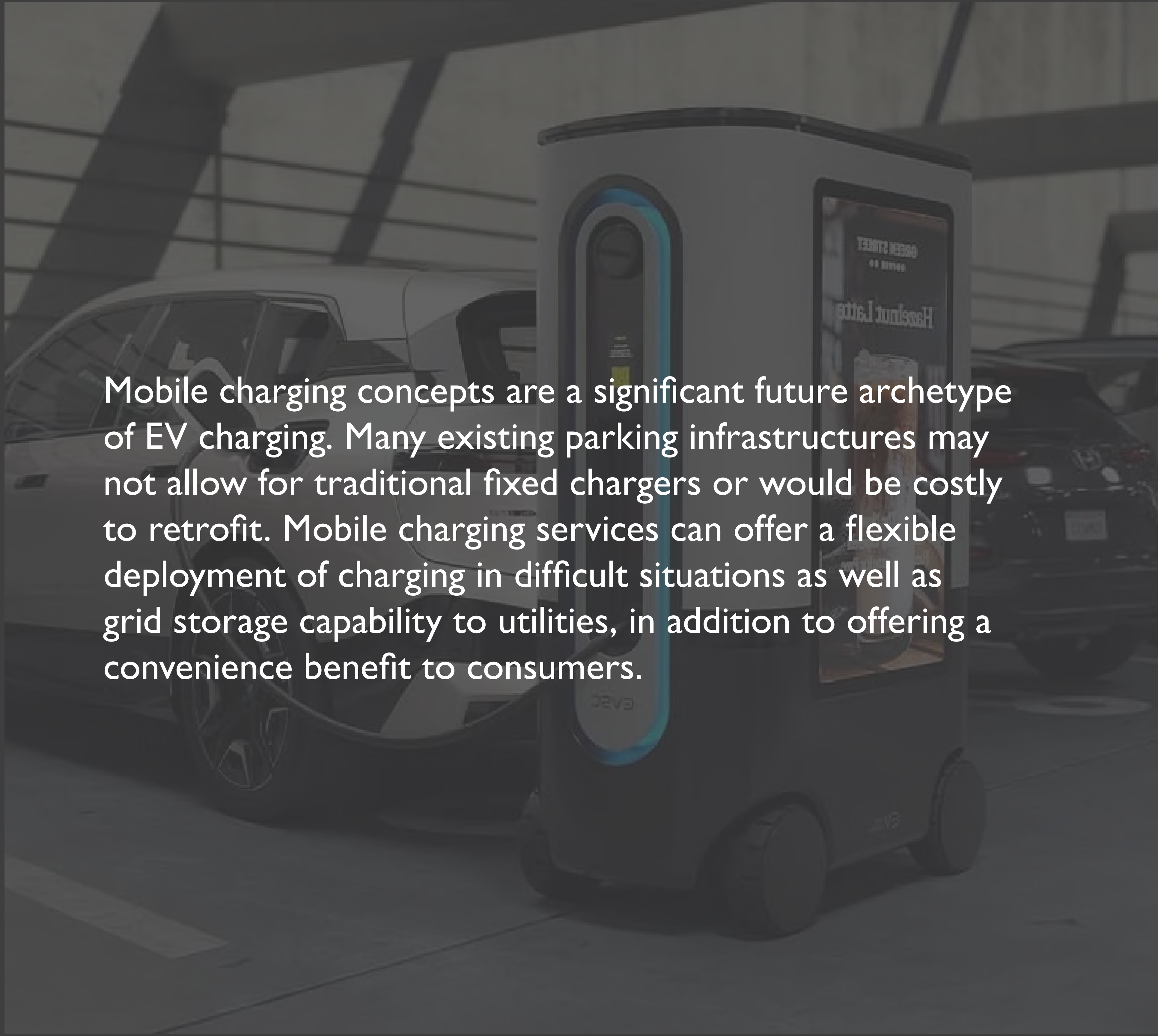
What if the charging process was autonomous, so that no one needed to directly interact with the process?

What if energy generated by low-cost renewable sources at home could be sold back to the grid?

What if intelligent systems could optimize charging at the city-scale so that the grid would never be overloaded?

Mobile EV Charging

Archetype 1



Mobile charging concepts are a significant future archetype of EV charging. Many existing parking infrastructures may not allow for traditional fixed chargers or would be costly to retrofit. Mobile charging services can offer a flexible deployment of charging in difficult situations as well as grid storage capability to utilities, in addition to offering a convenience benefit to consumers.

Mobile Charging

Feature:
Autonomous Operation

EV charging stations will be equipped with autonomous functionalities that don't require human intervention. These functions include networking and communication capabilities with EVs to optimize charging by identifying and supplying as per charging standards or norms for an EV, movement capabilities to be mobile and reduce space use.

Mobile Charging

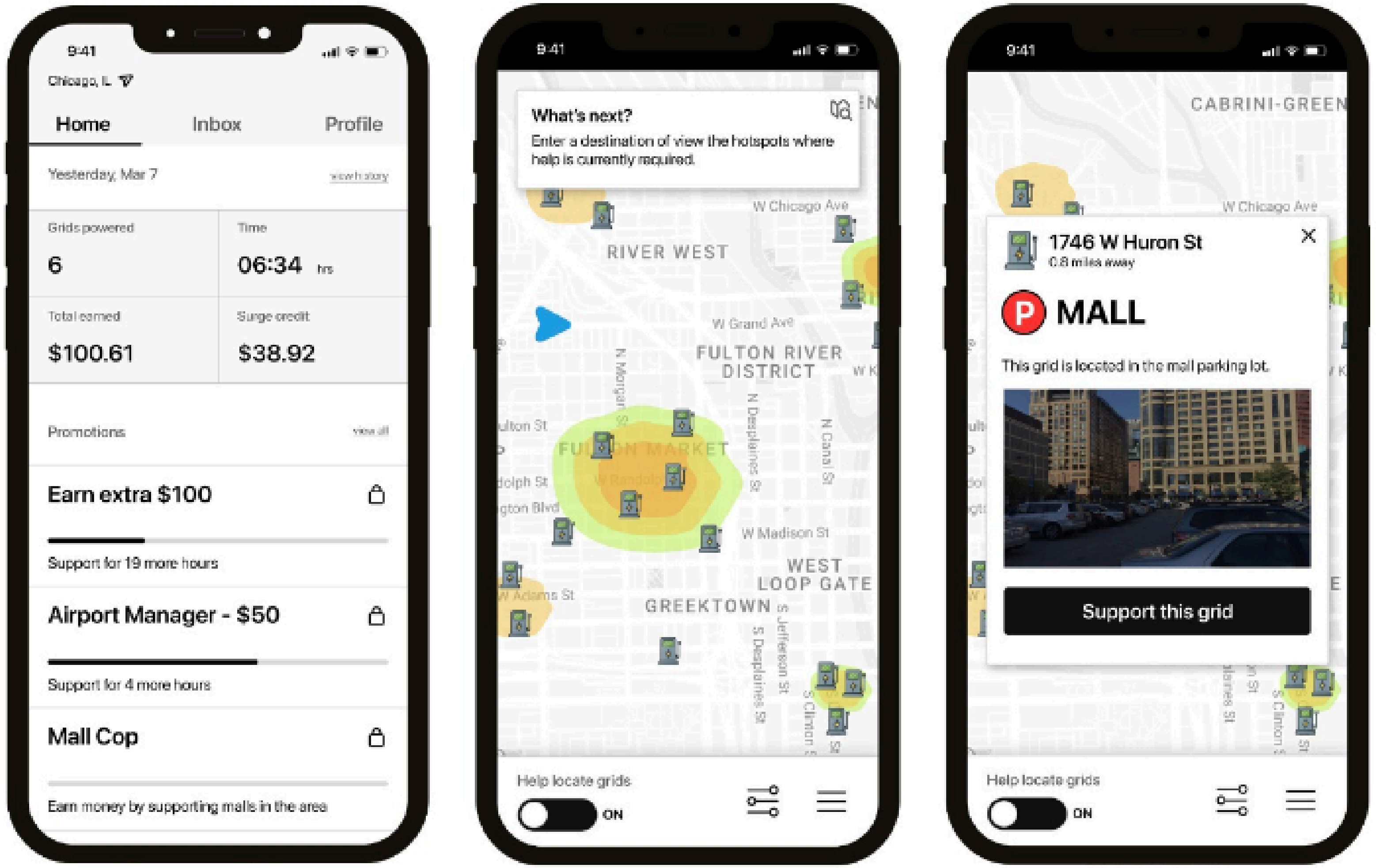
Feature:
Universal Charging Adaptor

The ability to support and accommodate different charging adapters, regardless of EV brand or model. This also means working with varying standards of charging and port types to match additional charging requirements.

Mobile Charging

Feature:
Intelligent Optimization

Intelligent and connected charging allows customers to communicate with their EVs and optimize the charging process based on factors such as battery capacity, energy demand, and charging rates.



Mobile Charging

Partners + Long Term Cash Flow

Building management organizations and managers of large parking garages may make natural partners for a autonomous mobile charging project. These organizations may be unwilling to spend large sums to install and retrofit fixed charging equipment within their infrastructure. A partnership, or recurring subscription with a mobile charging service would be much more attractive for these organizations.

While these images do not depict an autonomous service, the concept could start as a human-operated service before transitioning to full autonomy.

Energy Exchange

Archetype 2

What if EV drivers could use their vehicles as a way to earn credit for supporting grid stability? The feature of bidirectional charging, currently being implemented by various manufacturers, allows fleets of EV’s connected to the grid to act as a unit of grid storage.

Owners could receive compensation for supplying back to the grid during high demand periods, or charge at home using renewable sources and sell back when connected to the grid at a work parking lot.

A service that partners with a big box store, corporate parking garages, or even airport ground support vehicles to implement these features represents an opportunity for long-term cash flow while supporting a new exchange of decarbonized energy.

Energy Exchange

Feature:
Bidirectional Charging / Energy Flow

EV's utilizing chargers in this system can either charge normally, or supply energy back to the grid using special chargers. For this feature, charging infrastructure is installed in collaboration with the local utility.

Energy Exchange

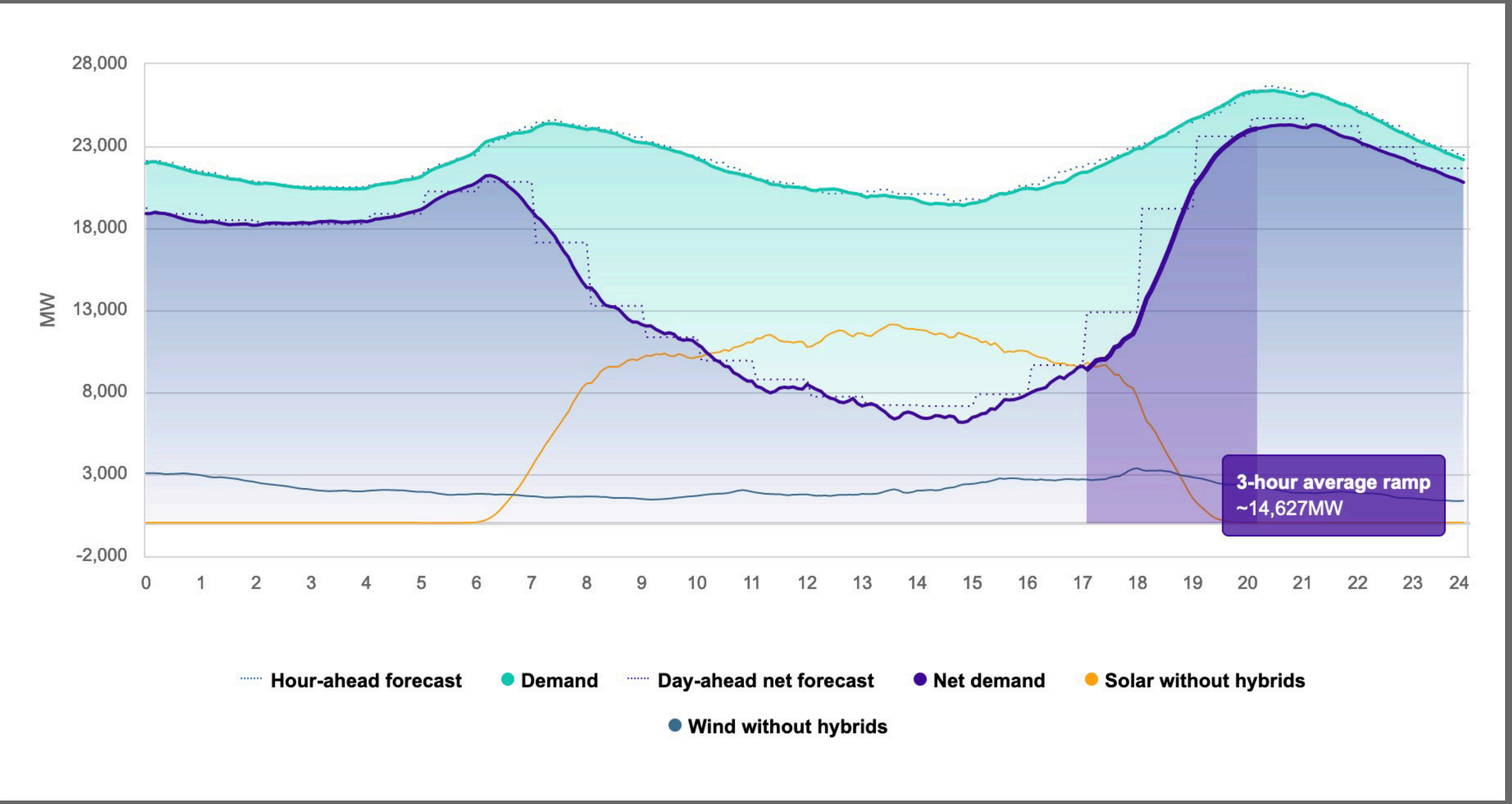
Feature:
Net Metering & Variable Pricing

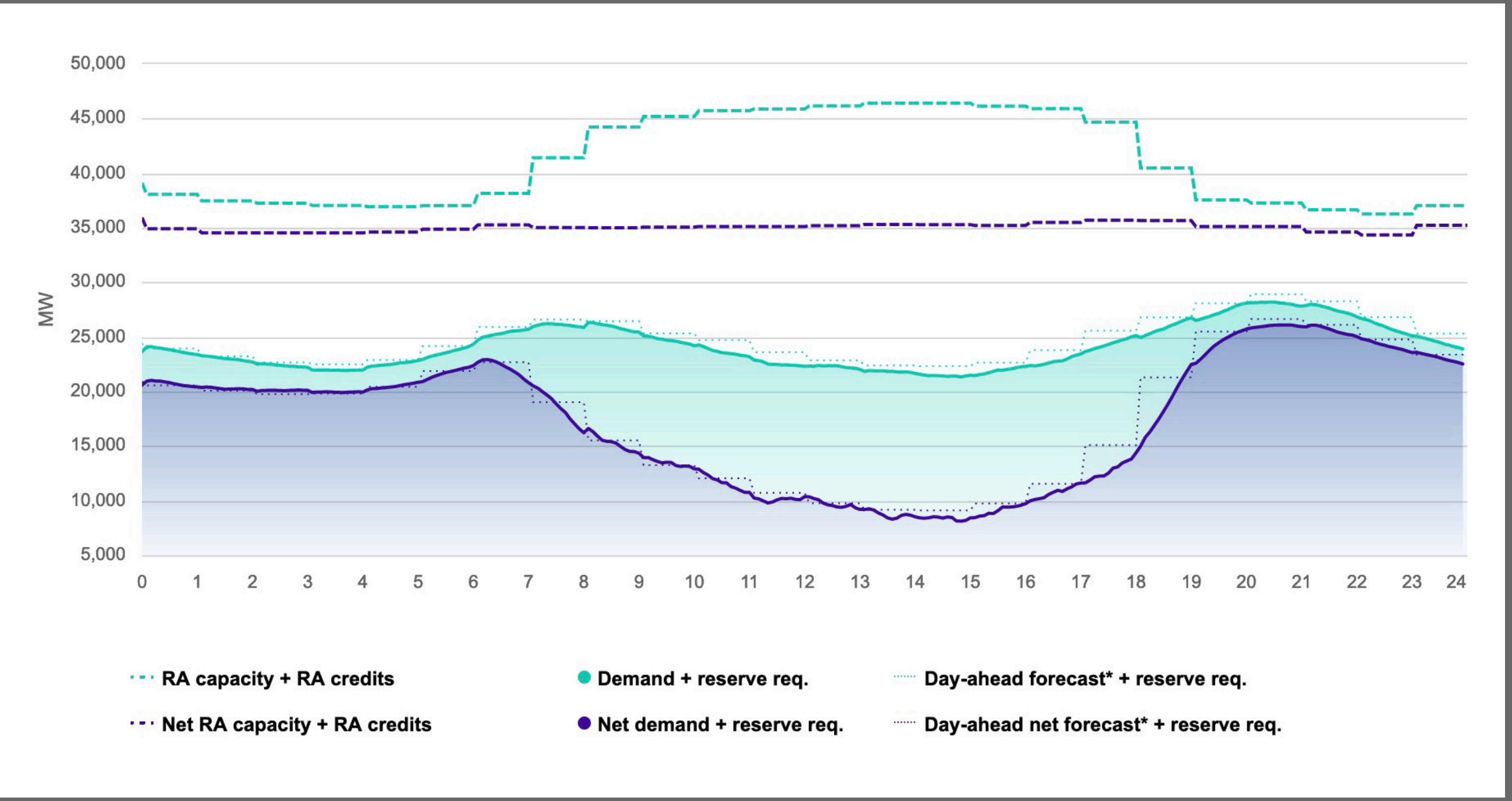
EV owners receive incentives to use renewable sources of energy, supplying excess energy during peak grid demand. This mechanism paired with bidirectional charging enables energy exchange service between stakeholders.

Energy Exchange

Feature:
Intelligent Optimization and Induced Supply + Demand

What if the local utility knows that there will likely be a grid demand emergency later in a particular day? EV's participating in the net metering program could essentially be called up in advance through mass notifications and increased incentives, inducing thousands of drivers to connect their cars and temporarily increasing the supply of energy.





These two charts show California's net demand and resource adequacy/ allocation on May 2nd, 2023. Note the abundance of solar power in the middle of the day, and the peak in demand later in the evening.

Energy Exchange

Partners + Long Term Cash Flow

This service could exist in partnership with businesses, garages, or airports that already have hundreds of parking spaces and would likely be installing many chargers in the near future.

Large parking lots and garages represent exisiting infrastructure that has the function of enabling transportation. By adding bidirectional chargers and connections to the grid, they gain the additional function of balancing the grid and providing stability.

A service that installs, operates, and maintains this infrastructure could partner with big box stores or transportation hubs as well as the local utility to operate a long-term contract. In exchange for regular payments, the service could guarantee a certain number of EV customers.

Equity & Ethics

Determining who benefits, and avoiding dark patterns

Computation, intelligence, connection, and data enable powerful new services and relationships, but also introduce potential for dark patterns. Additionally, the benefits of new charging archetypes are not naturally equitable in their distribution—wealthy areas receive the newest innovations first.

Both archetypes can be implemented equitably and responsibly by accounting for different levels of income as well as location when determining rates for charging payments and credits, using publicly available data on geographical income distribution. Additionally, partnered businesses could be an opportunity to provide additional benefits for SNAP (food stamps) users, for example.

Designing with values will be important to avoid the emergence of dark patterns in the interface; for example, making sure potential negative consequences of participating in the bidirectional charging feaature are communicated clearly.

Contributions

Our thanks to everyone who participated in the many rounds of EV Charging prototyping, as well as those who guided our process and shared their knowledge and experience.

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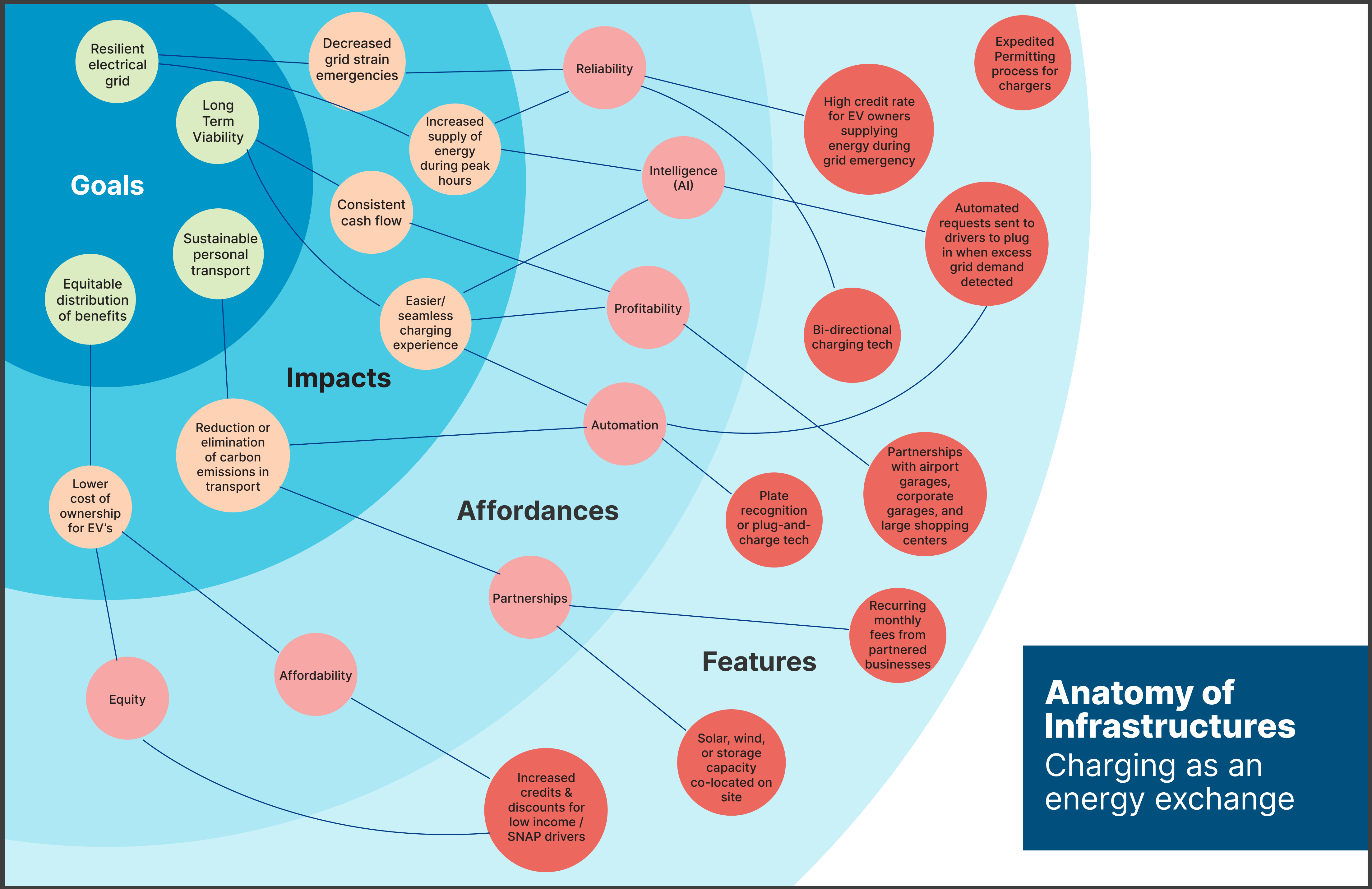
Appendix

Anatomy of Infrastructures

Archetype: Energy Exchange

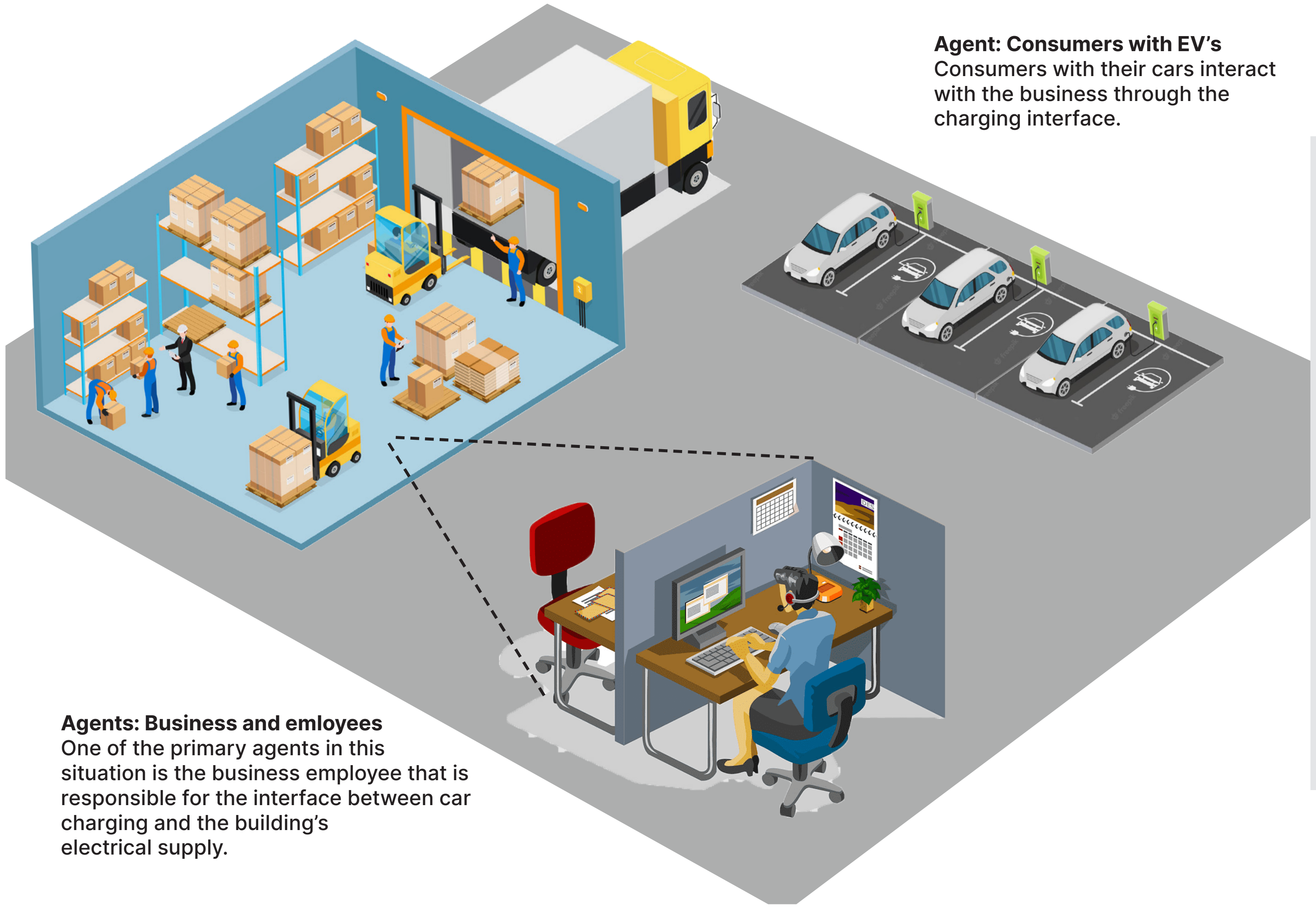
This archetype was explored through the lens of high-level goals, the impacts driving towards those goals, the features that generate the impacts, and what those features afford.



Action Situation

Archetype: Energy Exchange

The archetype was also explored through an action situation, in the context of a business with many parking spots available for bi-directional charging installations.

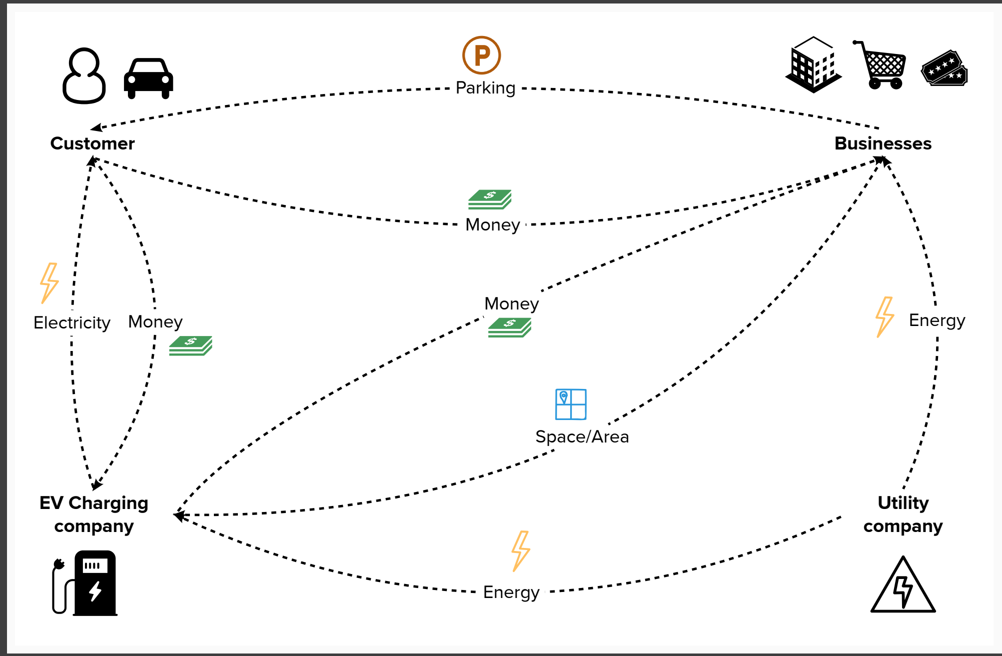


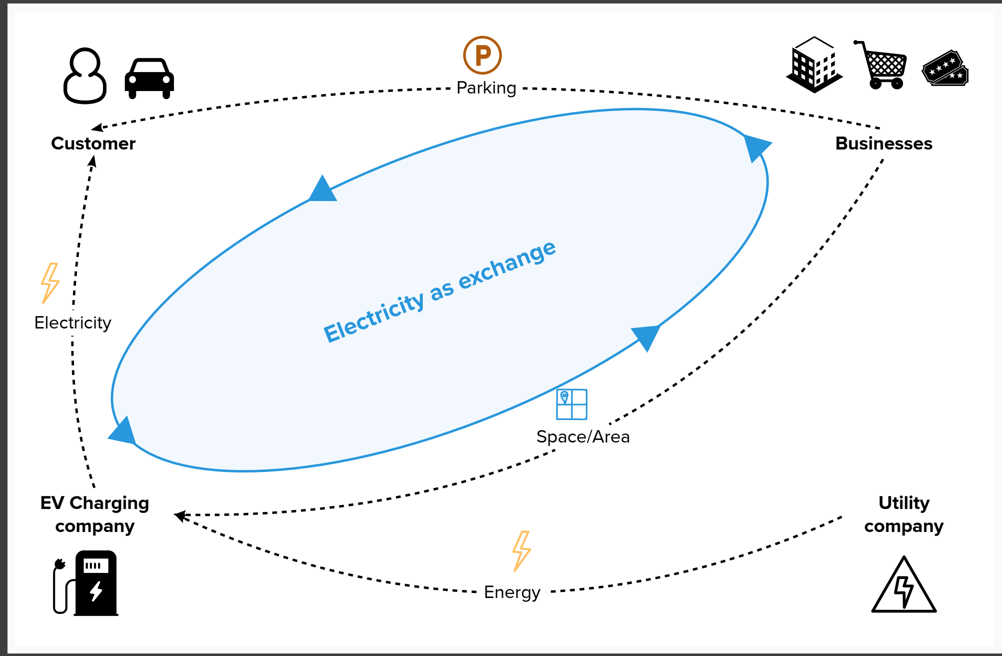
Action Situation 2: Situated in Partnered Business

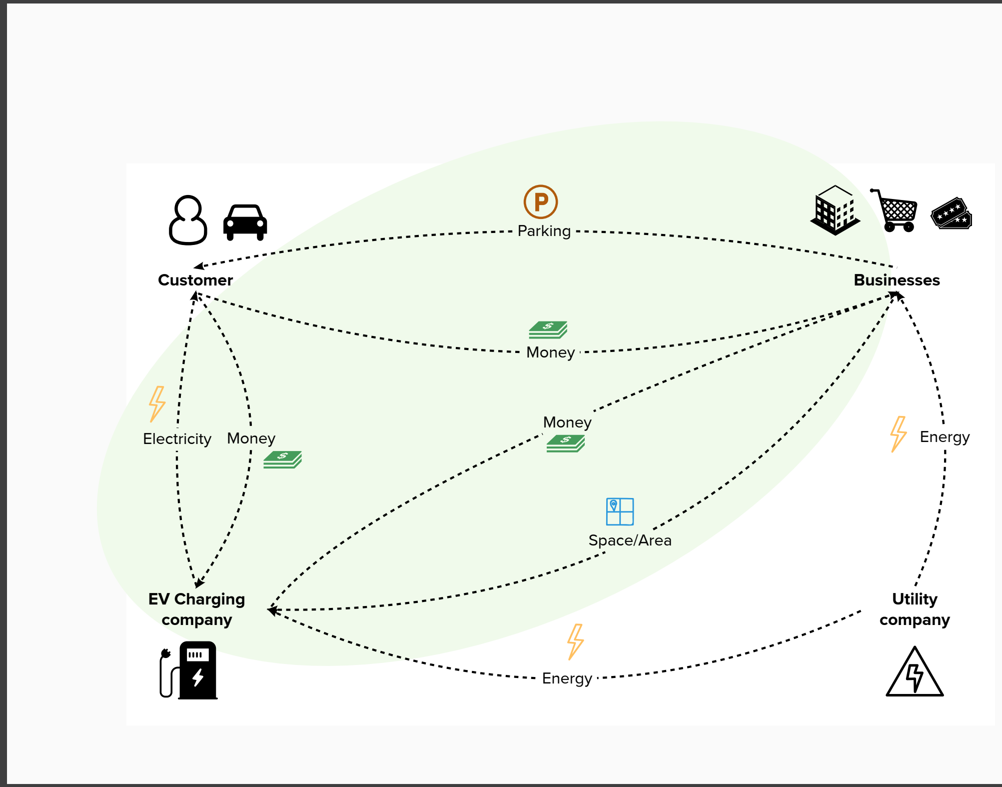
Socio–Ecological–Technical System
The business employee sits in between (and is responsible for) the car charging system and its interface with the building's electrical system. The electric utility company provides electricity and bills the business/charging service in return (or receives energy during periods of high grid demand). Policies set by the utility and regulations at the state level might restrict how much energy the charging service is able to draw from / return to the grid, and how that is paid for. An AI element interacts with the business employee and building systems, taking in data and making recommendations.

Stakeholder Relationships

Archetype: Energy Exchange



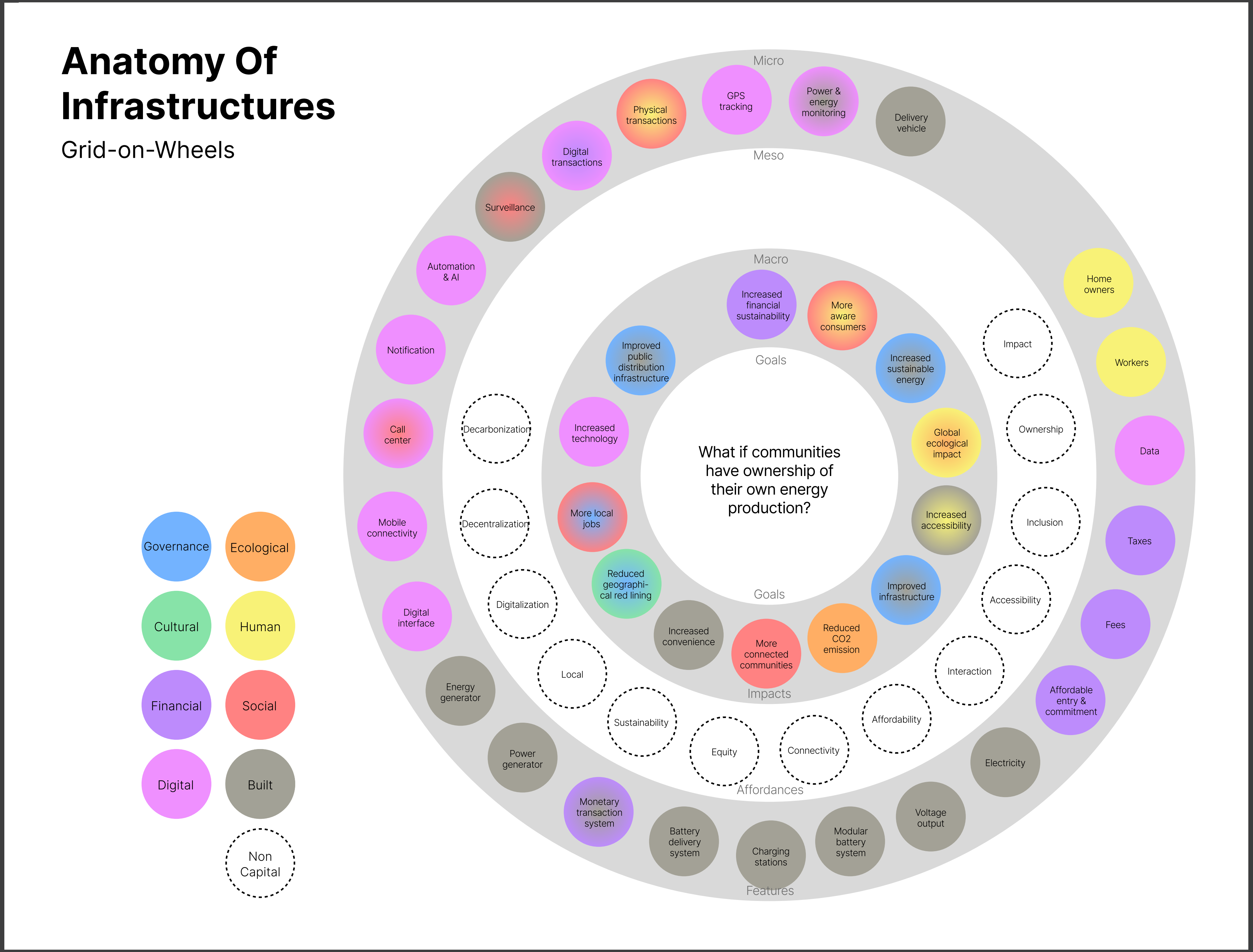




Anatomy of Infrastructures

Archetype: Grid on Wheels

Previous rounds of prototyping also explored a grid-on-wheels archetype through the lens of different levels of infrastructures.



Action Situation

Archetype:
Grid on Wheels

The features of bidirectional charging and geographic distribution of energy were also explored.

Vehicle Energy Distribution

Commercial vehicles (delivery vans) are centralized at a location capable of both charging them, and **distributing their energy back to the grid**.

From here, drivers are assigned routes that take into consideration the energy needs of a bigger grid, and individual households.

Vans and batteries are driven to destinations to better distribute the energy across the grid, and microgrids that are not connected to it.

Business Model Canvas

Archetype: Energy Exchange

This canvas was developed as part of one of the later rounds of prototyping.

ChargeUnity

Last update
Wednesday, 4 January 2023

Mission: To revolutionize EV charging by providing a universally adaptive, autonomous, and optimized solution that facilitates bidirectional energy flow and supports sustainable energy consumption.

Key Partners

- EV manufacturers
- Renewable energy providers
- Grid operators
- Real estate developers
- Local and national government agencies

Key Activities

- Developing and manufacturing universal, autonomous charging stations
- Building and maintaining charging infrastructure in strategic locations
- Collaborating with renewable energy providers and grid operators for net metering arrangements
- Developing a user-friendly mobile app for remote charging management and optimization
- Continuous R&D for improved charging technology and integration with emerging EV models and standards

Key Resources

- Hardware and software engineers for product development
- Strategic partnerships with EV manufacturers, renewable energy providers, and grid operators
- Sales and marketing team to target customer segments
- Expertise in regulatory compliance and industry standards

Value Propositions

1. Value Proposition: ChargeUnity offers a unique EV charging solution that caters to all EV brands and models, supports bidirectional energy flow, and promotes sustainable energy consumption through net metering incentives. Our intelligent charging system streamlines the user experience by optimizing charging based on individual needs while reducing the overall carbon footprint.

Customer Relationships

Building long-term trust and satisfaction by providing excellent service, support, and personalized experiences.

- Personal Assistance
- Self-service
- Community Building
- Customization and Personalization
- Proactive Support
- Loyalty and Rewards Program

Channels

- Direct sales to individual customers and businesses
- Partnerships with EV manufacturers for product bundling
- Online presence through our website and social media platforms
- ChargeUnity mobile app for remote management and charging optimization

Customer Segments

- Individual EV owners
- Fleet operators
- Businesses with EV fleets or employee EV users
- Public and private parking facilities
- Residential communities
- Shopping centers and commercial establishments

Cost Structures

- Research and development
- Manufacturing and supply chain expenses
- Marketing and sales expenses
- Infrastructure deployment and maintenance
- Licensing and regulatory fees

Revenue Streams

- Sales of ChargeUnity charging stations
- Subscription fees for premium features in the ChargeUnity mobile app
- Revenue sharing agreements with renewable energy providers and grid operators
- Energy credits or cashback from bidirectional energy flow

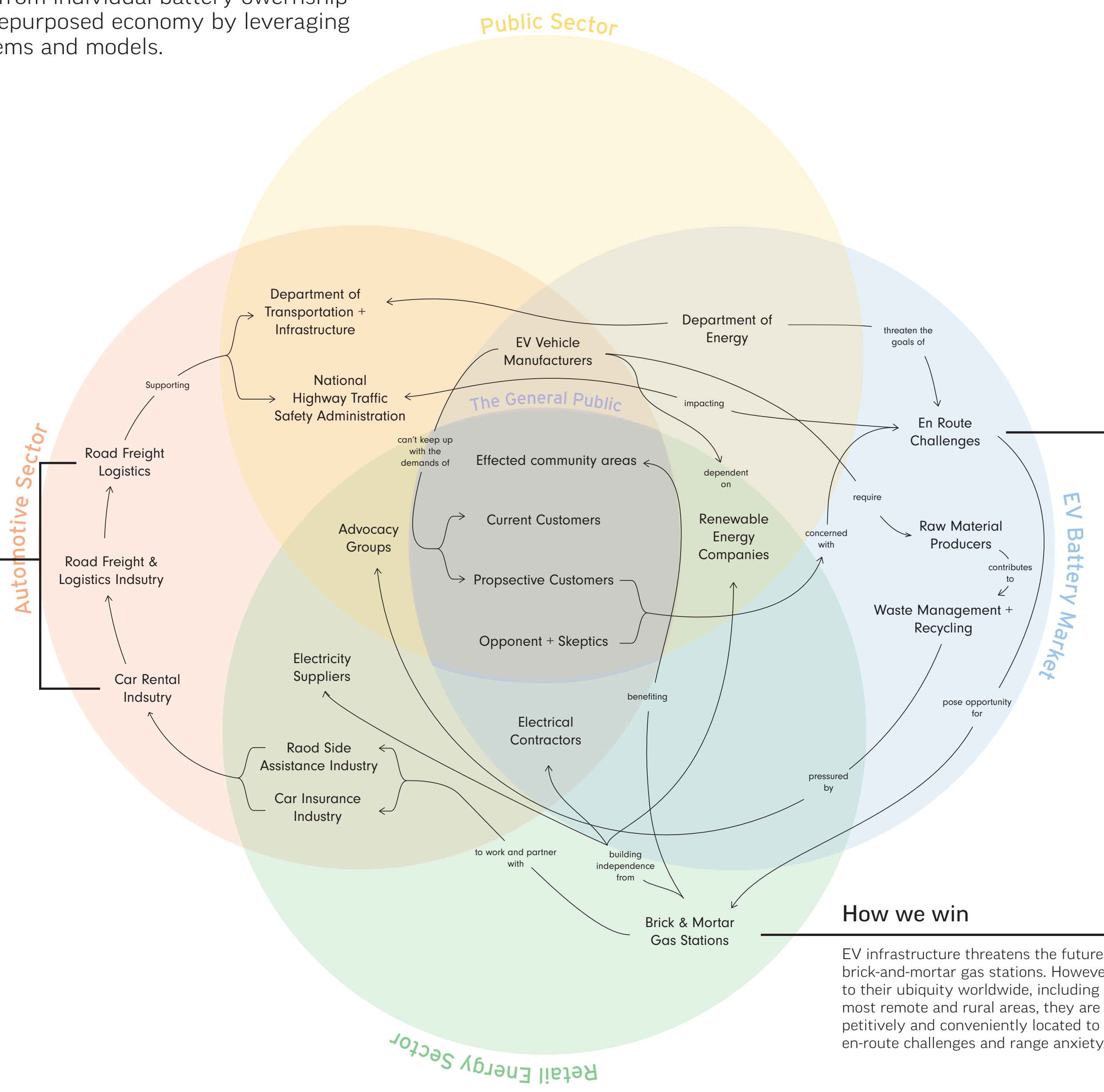
Stakeholders

Archetype: Grid on Wheels

This stakeholder map for the grid-on-wheels archetype was developed during a previous round of prototyping.

Systems
Stakeholders
Networks

Our Guiding Aspiration: Shift EV charging conventions, from individual battery owernship to a shared, repurposed economy by leveraging existing systems and models.



What capabilities we need

Reimagining car insurance and road logistics services by altering, adjusting, or entirely repurposing existing and essential equipment to suit EV needs could reduce or eliminate range anxiety and en route challenges.

Where we play

A barrier and obstacle to the widespread adoption of electric vehicles is range anxiety, the fear that an electric vehicle will not have enough battery charge to reach its destination, leaving its occupants stranded. Once addressed, consumers will have more driving confidence in EVs and charge toward them.

How we win

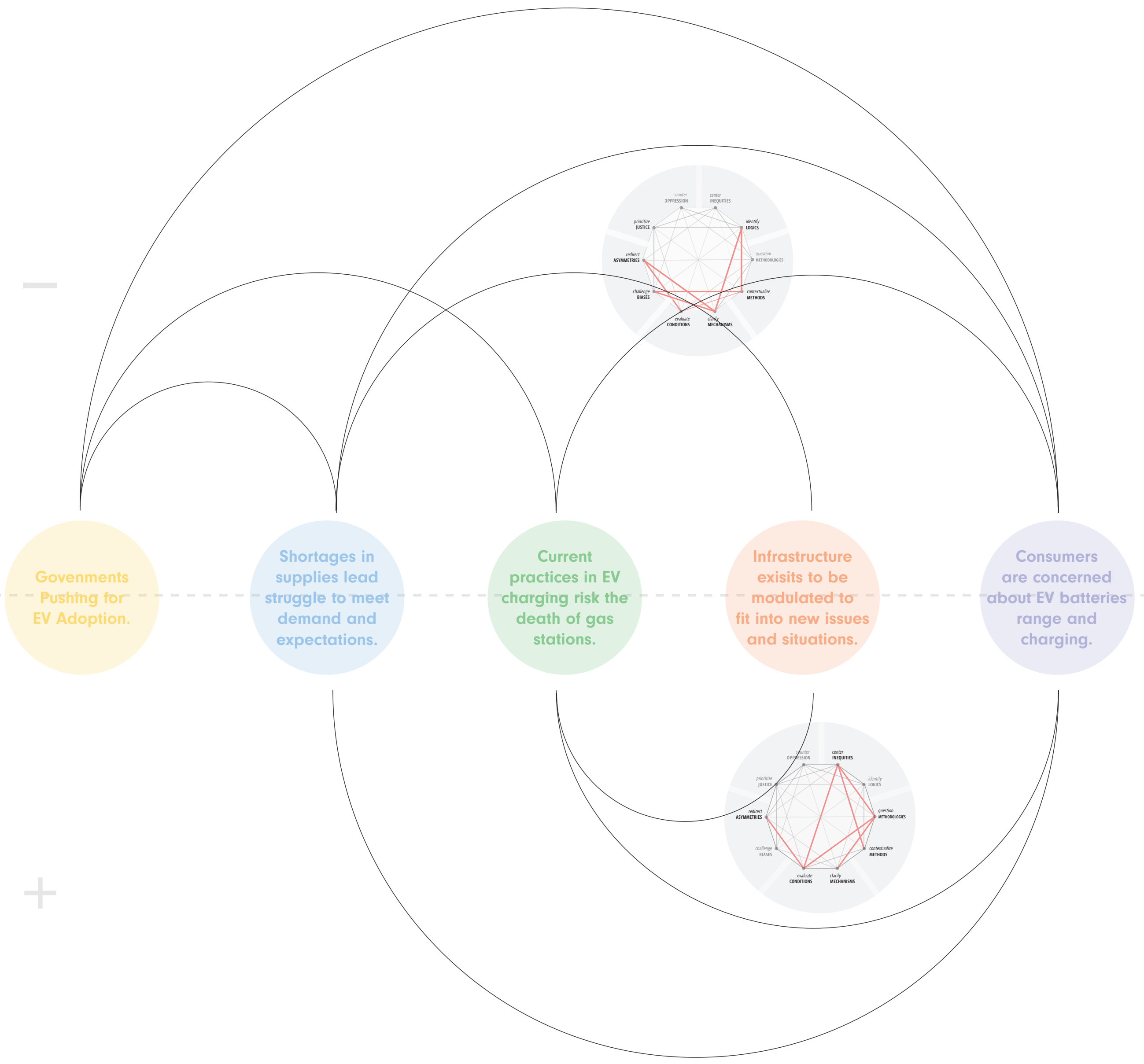
EV infrastructure threatens the future of brick-and-mortar gas stations. However, due to their ubiquity worldwide, including in the most remote and rural areas, they are competitively and conveniently located to solve en-route challenges and range anxiety.

Equity and Causal Loops

Archetype: Grid on Wheels

Causal Loops
Equity Frameworks

Conflicts in goals, agendas, perceptions, and expectations around EV present barriers to adoption, ultimately hindering the implementation of new everyday infrastructures. Aligning human and non-human actors through an equitable lens could address the observed issue and instill confidence in EVs.



Archetype

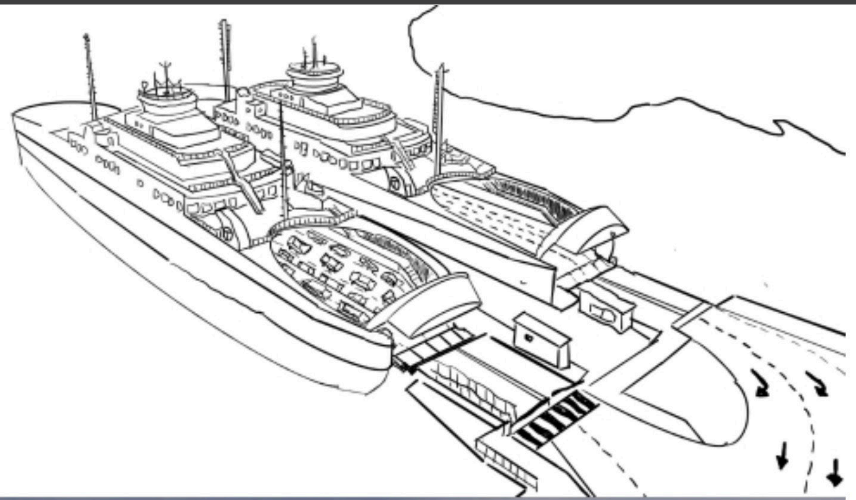
Archetype: Ferry Charging station

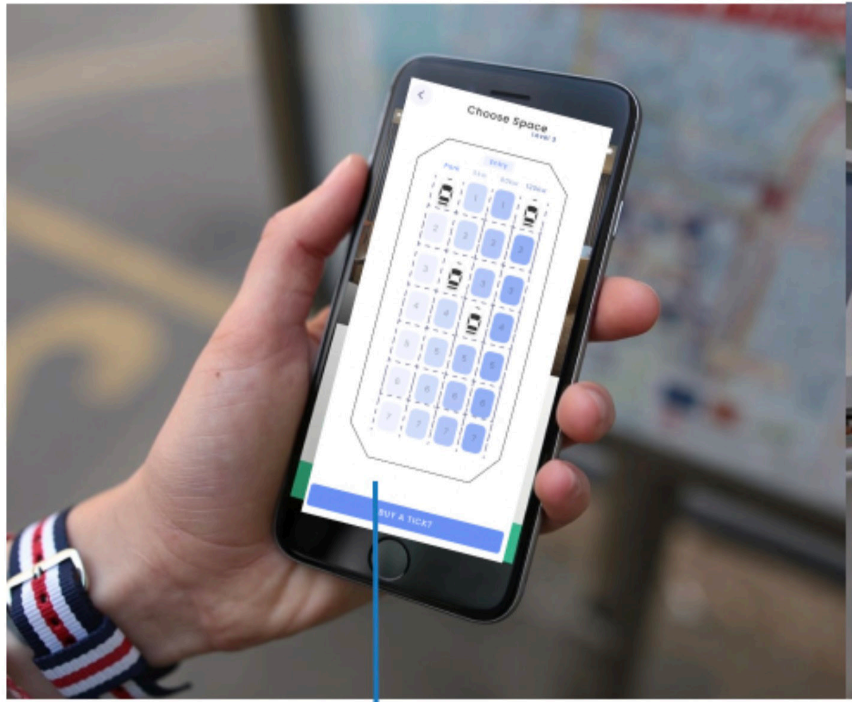
This archetype was developed during round 1.

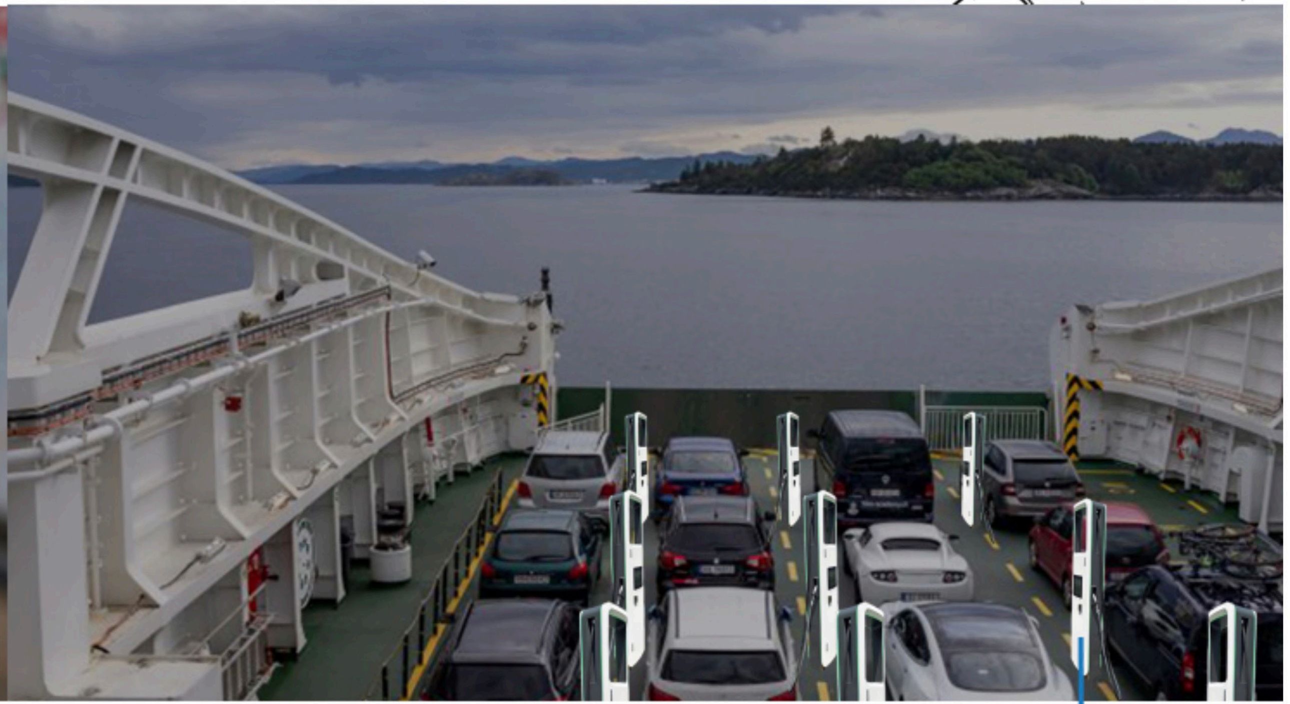
Ferries as EV charging stations

Torghatten's fleet of ferries are all equipped with charging ports, available at each individual parking spot so that it ultimately serves as a charging station. Onboard charging is supported by electricity generation on the ferry itself.

Charging needs can be indicated at the time of buying a ticket both online as well as the ticket counter at the port itself, or even once on the ferry using the app if passengers make a last minute decision. Ports remain inactive unless charging has been requested.



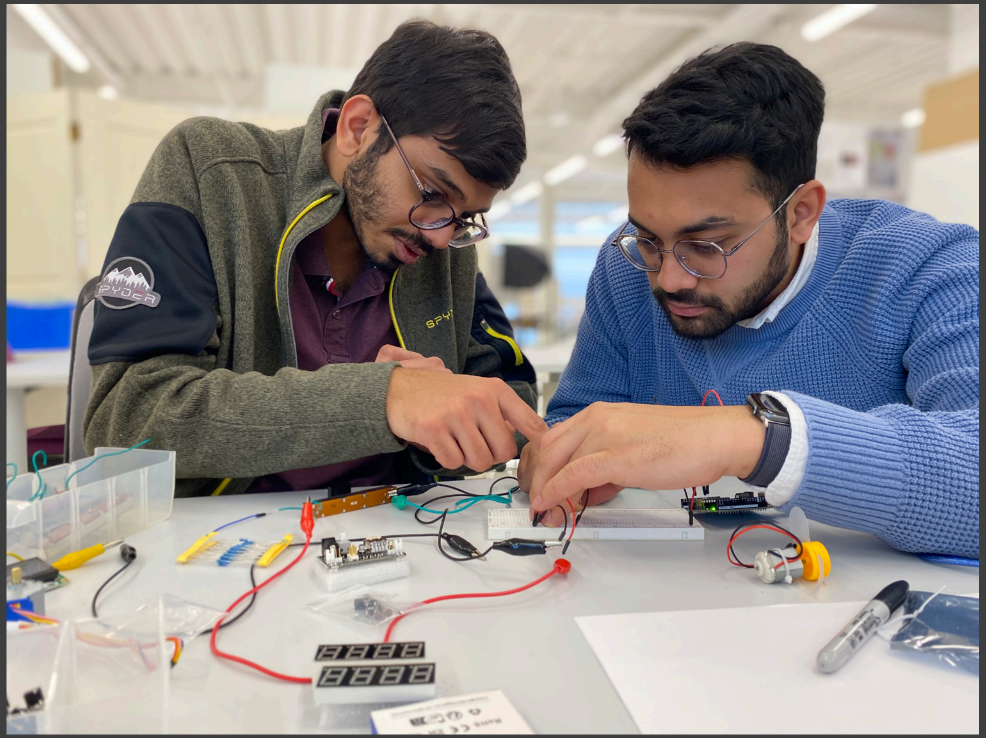


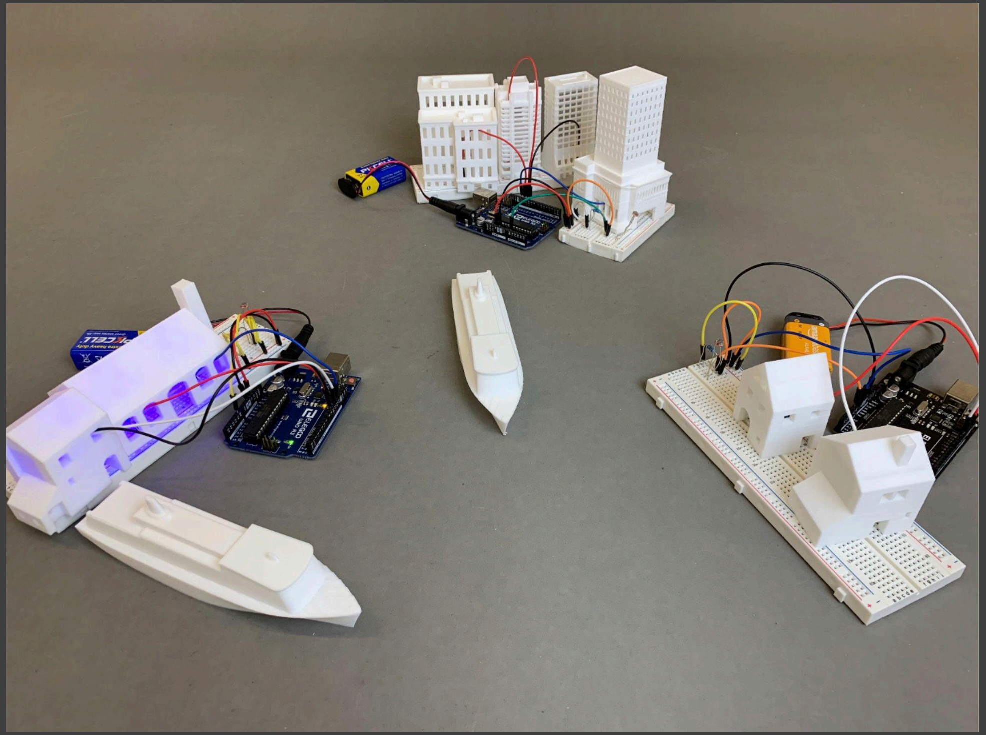


A Torghatten app enabled digital payments, ticket purchasing as well as indicating that a passenger will need to charge while on board.

Each spot on the ferry is equipped with the potential to charge at a Level 2 (5kW), Level 3 (80kW) or Level 4 (120kW) capability. Prices vary by charing level and by charging time.

Prototyping Process





Final Presentation & Prototype